aquatera
environmental services and products

Promoting aquatic renewable energy to increase energy diversity in Peru

Executive Summary

Report to Foreign and Commonwealth Office in Lima

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Glossary

ANA	National Water Authority (Autoridad Nacional del Agua, ANA)
IEC / TC	International Electrotechnical Commission / Technical Committee's
ME – OMC	Marine Energy – Operational Management Committee
SEIN	National Interconnected Electric System (Sistema Eléctrico Interconectado Nacional)
SENAMHI	National Meteorology and Hydrology Service (Servicio Nacional de Meteorología e Hidrología)
DICAPI	General Direction of Captaincies and Coast Guard (Dirección General de Capitanías y Guardacostas, DICAPI)
PROINVERSION	Agency for the Promotion of Private Investment (Agencia de Promoción de le Inversión Privada, PROINVERSION)
ANP	Protected Natural Areas (Areas Naturales Protegidas, ANP)
SERNANP	National Service of Natural Areas Protected by the State (Servicio Nacional de Áreas Naturales Protegidas por el Estado, SERNANP)
ACR	Regional Conservation Areas (Areas de Conservacion Regional, ACR)
ACP	Private Conservation Areas (Areas de Conservacion Privada, ACP)
SINANPE	National System of Natural Areas Protected by the State (Sistema Nacional de Áreas Naturales Protegidas por el Estado, SINANPE)
SEIA	The National Environmental Impact Assessment System, SEIA (Sistema Nacional de Evaluación de Impacto Ambiental)
DGER	National Rural Electrification Office (Direccion General de Electrificación Rural, DGER)
DGE	National Electricity Office (Direccion General de Electricidad, DGE)

DGEE	National Energy Efficiency Office (Direccion General de Eficiencia Energetica, DGEE)
DGAAE	National Energy Environmental Office (Dirección General de Asuntos Ambientales Energéticos, DGAAE)
SENACE	The Environmental Certification Directorate (Servicio Naciona de Certificacion Ambiental para las Inversiones Sostenibles, SENACE)
DGOT	General Direction of Territorial Organisation (Dirección General de Ordenamiento Territorial, DGOT)
ZEE	Economic Ecological Zoning (Zonificación Ecológica Económica, ZEE)
MIZMC	Integrated Management of the Coastal Marine Zone (Manejo integrado de Zona Marino Costeras, MIZMC)
EMEC	The European Marine Energy Centre Ltd, EMEC
PNER	The National Plan for Rural Electrification (Plan Nacional de Electrificacion Rural, PNER)
PRODUCE	Ministry of Production (Ministerio de la Produccion, PRODUCE)
SHP	Smart Hydro Power, SHP
NCRE	Non-Conventional Renewable Energy. In Peru, The Legislative Decree N°1002 considers NCRE biomass, wind, solar, geothermal, tidal and hydropower when the installed capacity does not exceed 20 MW.
IRENA	The International Renewable Energy Agency, IRENA
INEI	National Institute of Statistics and Informatics (Instituto Nacional de Estadistica e Informática, INEI)
OSINERGMIN	Supervisory Agency for Investment in Energy and Mining (Organismo Supervisor de la Inversion en Energia y Mineria, OSINERGMIN)

INDECOPI	National Institute for Defence of Competition and Protection of Intellectual Property (Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual, INDECOPI)
COES	The System Economic Operation Committees (Comite de Operacion Economica del Sistema Interconectado Nacional, COES)
NCCC	National Commission for Climate Change, NCCC
UNFCCC	United Nations Framework Convention on Climate Change, UNFCCC
ENCC	The National Strategy on Climate Change (Estrategia nacional ante el cambio climático, ENCC)
TUPA	Single Text of Administrative Procedures (Texto Unico de Procedimientos Administrativos, TUPA)
NREL	National Renewable Energy Laboratory, NREL
IDB	The Inter-American Development Bank, IDB
TRL	Technology Readiness Level, TRL
NAMA	Renewable Energy Nationally Appropriate Mitigation Actions, NAMA

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EXECUTIVE SUMMARY

ACKNOWLEDGEMENTS

This study was commissioned by The British Embassy in Lima and was developed by Aquatera with support from the European Marine Energy Centre (EMEC)[1], The International Centre for Island Technology (ICIT)[2] and Universidad de Ingeniería & Tecnología in Lima (UTEC)[3].

Special thanks to the Ministry of Energy in Peru (MINEM)[4] who supported the organisations of the workshops and to the individuals and organisations that attended to the workshop and were involved in the consultation process developed through the project. Finally, a special acknowledgement is due to the British Embassy in Lima for financing this project through the UK Foreign and Commonwealth Office Prosperity Fund.

INTRODUCTION

According to the Ministry of Environment of Peru (MINAM)[5], Peru is the third country most vulnerable to the effects of climate change because of the variability of climatic conditions of the region.

Peru's aquatic renewable energy resources (wave, tidal, floating wind, floating solar and river hydrokinetic) could have an important role to play in generating green growth and providing access to energy in rural areas, but experience and understanding of the potential of these new types of renewable energy is limited.

This study combines knowledge of the energy situation in Peru with experience and understanding from more than a decade of aquatic energy activity internationally and specifically from Orkney in the UK. A lot has been achieved in the UK, but many lessons have also been learned. The aim of this project is to use this collective insight to propose steps that can help maximise Peru's aquatic energy potential.

This report aims to promote Peru's aquatic renewable energy potential by combining information on Peru's resources with the identification of specific and achievable steps that government, industry and the R&D community could take to enable and support the development of aquatic renewable energy projects. This project will promote this new industry and develop achievable recommendations tailored to the Peruvian situation through consultation with local stakeholders.

ENERGY IN PERU

In March 2017, the International Renewable Energy Agency (IRENA) presented a landmark report called "Perspectives for the Energy Transition" in collaboration with The International Energy Agency (IEA). The report shows that a dramatic increase in the deployment of renewable energy and implementation of energy efficiency measures in the G20 countries, and also globally, will be required in order to remain within the temperature benchmark necessary to comply with the Paris agreement[6]. That is, holding the increase in the global average temperature to well below 2 C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 C above pre-industrial levels,

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[1] http://www.emec.org.uk/

[2] https://www.hw.ac.uk/schools/energy-geoscience-infrastructure-society/research/icit.htm

[3] http://www.utec.edu.pe/

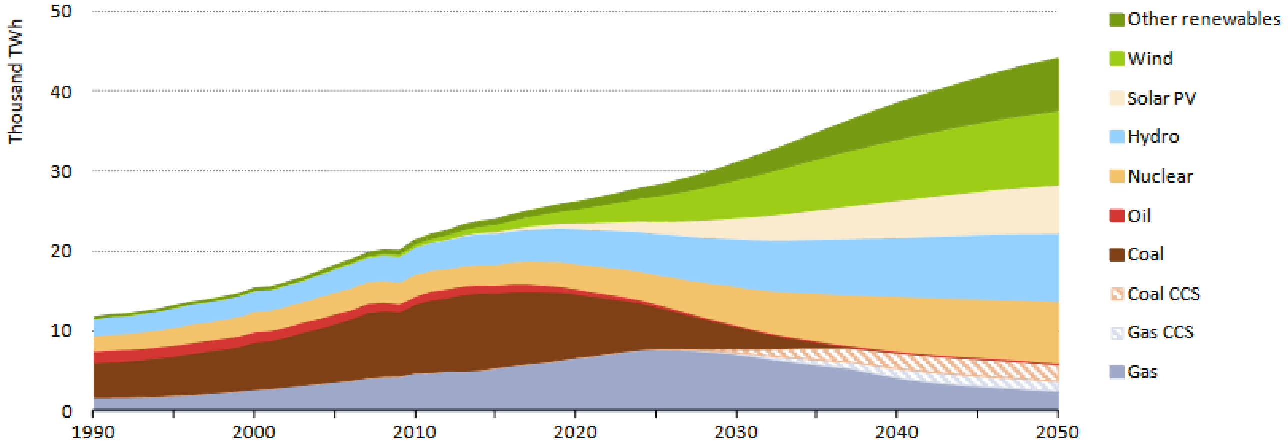
[4] http://www.minem.gob.pe/

[5] http://www.minam.gob.pe/

[6] The 2015 United Nations Climate Change Conference, COP 21 or Paris Agreement is an agreement within the United Nations Framework Convention on Climate Change (UNFCCC) dealing with greenhouse gas emissions mitigation, adaptation and finance starting in the year 2020.

to achieve this temperature goal, Parties aim to reach global peaking of greenhouse gas emissions (GHGs) as soon as possible (Change, n.d.), avoiding the severe impacts of global warming.

Figure 1 Global electricity generation by source in the 66% 2°C Scenario [7]



Note: TWh = terawatt-hours; CCS = carbon capture and storage.

Source: (IRENA, 2017)

As shown in Figure 1, the global electric mix in 2050 is predicted to be radically transformed and will be based on renewables, nuclear and Carbon Capture and Storage (CCS), after a period of elimination of carbon and declining natural gas. The proportion of fossil fuels are expected to decrease from 70% to 30%. Solar photovoltaic and wind energy, both terrestrial and marine are expected to contribute the major portion of the renewable energy generation.

The National Energy Plan 2014 - 2025, developed by MINAM, sets out future growth scenarios which show that final consumption of energy is expected to continue to grow as a function of the development of the internal economy and that a higher proportion of the production of electrical energy will come from hydroelectricity, as well as increasing the contribution of non-conventional renewable sources, estimated to reach 5% by 2021.

However, natural gas is expected to have a large share of final energy consumption and the contribution of NCRE is less than that of fossil fuels and hydroelectricity.

The NUMES[8] study (and others) propose that in 2040 Peru will continue to source more than 70% of the country's primary energy from fossil fuels. This is inconsistent with the requirements to reduce carbon emissions and safeguard finite resources for future generations, so a more sustainable way to help maintain oil and gas reserves that are currently being wasted on electricity generation and to a large extent, fuel would be needed. It is essential that stocks of these 'commodities' are protected for future generations as aquatic renewable energy is a key source for Peru's future.

[7]The International Energy Agency (IEA) and The International Renewable Energy Agency (IRENA) developed one core scenario that would be compatible with limiting the rise in global mean temperature to 2°C by 2100 with a probability of 66%, as a way of contributing to the "well below 2°C" target of the Paris Agreement.

[8] http://www.iadb.org/en/projects/project-description-title,1303.html?id=PE-L1121

AQUATIC RENEWABLE ENERGY POTENTIAL IN PERU

The original scope of this project was to consider marine (wave and tidal) and river hydrokinetic resource potential. However, after consultation with Peruvian stakeholders and evaluation of the available resources, the scope was expanded to consider "aquatic renewable energy resources". The following types of renewable energy resource are considered within this definition:

- Ocean renewable energy resources including (Ocean Thermal Energy Conversion (OTEC), ocean current (thermohaline/deep ocean), salinity gradient, offshore wind, wave energy, tidal energy (tidal range and tidal stream)
- River hydrokinetic energy
- Aquatic solar photovoltaic resource (marine and onshore floating)

After analysing the potential of the previous list of resources in Peru, those with limited potential were discarded. Table 1 shows the potential aquatic resources that have been considered in this study.

Table 1 Overview of aquatic renewable energy resource potential in Peru

Aquatic renewable energy resource	Resource assessment measures	Technology used and Technology Readiness Level (TRL) (IRENA, 2014c)	Relative Peruvian potential
Offshore wind	m/s flow speed or kW/m^2 swept area	Rotary turbines in air flow **TRL = 9 (fully commercial)**	**MEDIUM:** Moderate wind speeds and limited seabed area of suitable depth, but some sites of interest
Wave	kW/m wave front – varies with wave height squared and linearly with wave period	Various device types (e.g. point absorber/flap) and power take-off systems (e.g. hydraulic/mechanical) **TRL = 6 to 8 (full scale demonstrators)**	**HIGH:** Consistently energetic waves along entire Peruvian coast
River hydrokinetic	m/s flow speed or kW/m^2 swept area – typically above 2 m/s required	Rotary turbines operating in pre-existing river flows. Includes Archimedes screws **TRL = 7 to 9 (some now commercial)**	**HIGH:** True potential difficult to determine without more detailed surveys but many sites of interest
Floating solar	kW/m^2 solar radiation over panel area	Solar photovoltaic panels **TRL = 9 (fully commercial)**	**MEDIUM:** Some potential in sheltered waters (also reservoirs - reduces evaporation)

For the aim of this project, Peru has been divided in seven Regions:

1. Pacific North (PN)
2. Pacific Central (PC)
3. Pacific South (PS)
4. Atlantic North (AN)
5. Atlantic Central (AC)
6. Atlantic South (AS)
7. Titicaca (T)

See Map 11.1 showing the seven regions considered for the analysis (Appendix C).

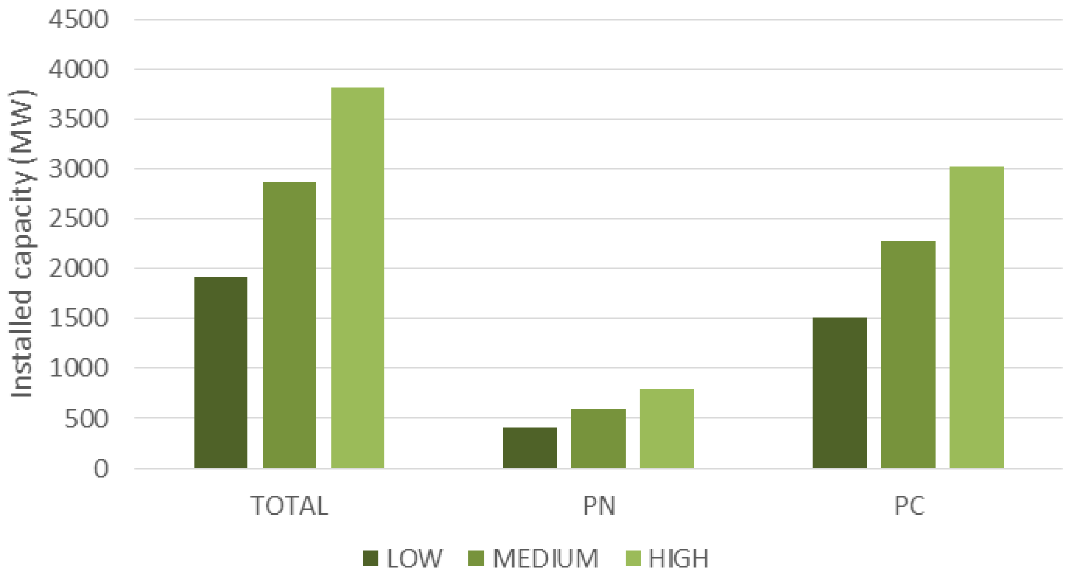
The potential of the aquatic resources selected for the different regions of Peru is indicated below.

Offshore wind potential

The offshore wind industry is growing rapidly internationally and as costs come down, fixed and floating offshore wind systems are becoming more competitive. Peru has a moderate wind resource and a very steeply shelving seabed, but it appears likely that there are specific locations where fixed and floating offshore wind projects could be realised.

Aquatera estimates that the practically extractable Peruvian offshore wind resource may be 2 to 3.5 GW (Figure 2).

Figure 2 Offshore wind resource for Pacific North (PN) and Central (PC)



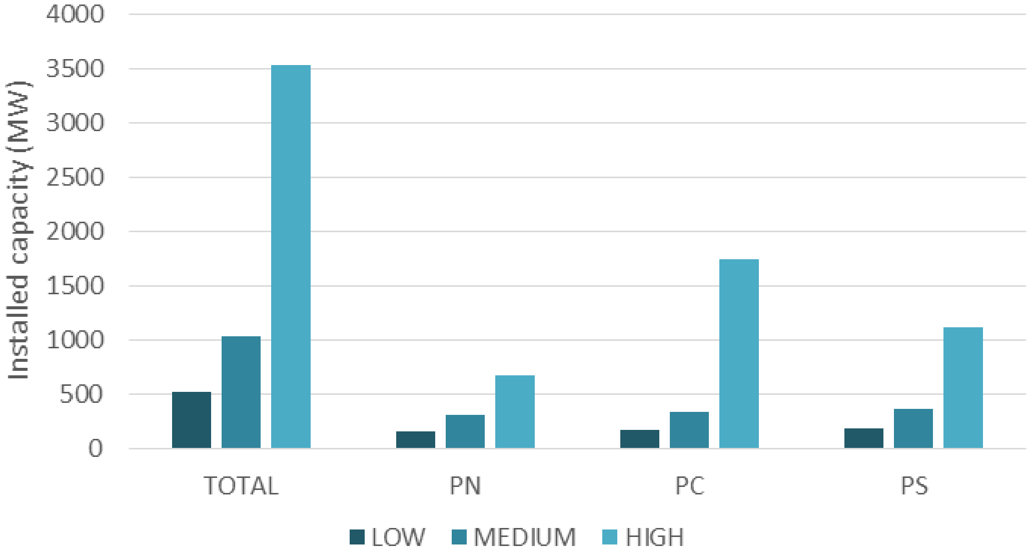
See Map 3.2 showing the onshore and offshore wind potential areas (Appendix C).

In Scotland, Hywind Pilot Park project is the world's first commercial scale floating wind farm (see Case Study 1). The UK is currently a market leader (see Case Study 2) in offshore wind development, with deployment expected to reach 20 - 55 GW by 2050, depending on the UKs broader energy mix and carbon reduction strategy (ETI, 2015). Offshore floating wind development has reached the stage whereby floating design concepts have been tested and demonstrated, and the industry is planning to deploy large scale wind farm projects. The three main markets for offshore floating wind are currently Europe, the US and Japan.

Wave potential

Aquatera estimates that based on conservative assumptions, the total practically extractable wave resource in Peru could be at least 0.5 or 1 GW. With more optimistic assumptions, the total practically extractable wave resource could be as high as 3.5 GW (Figure 3).

Figure 3 Wave energy resource for Pacific North (PN), Central (PC) and South (PS) regions of Peru

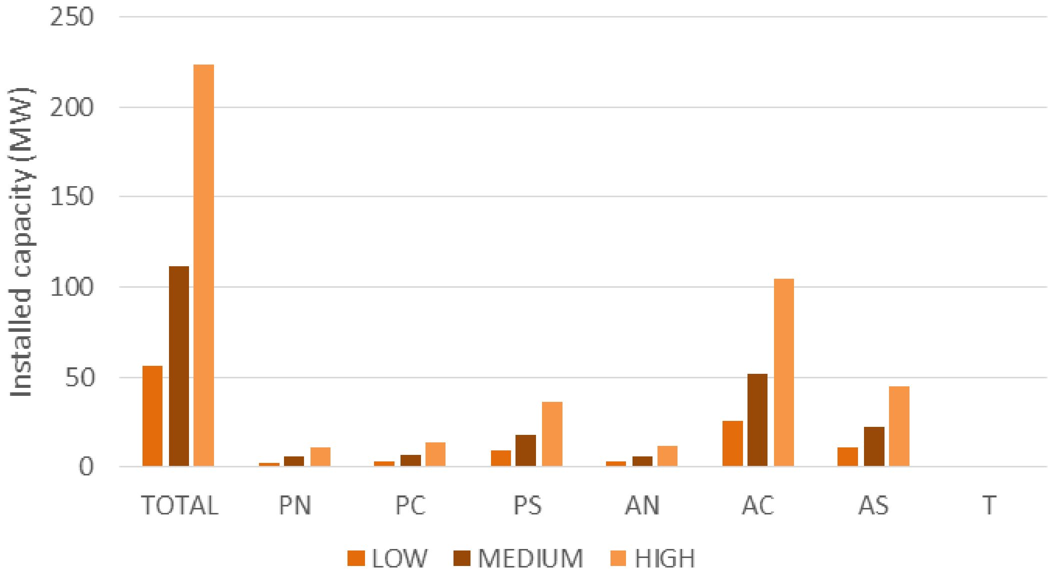


See Map 3.3 showing wave resource in Peru (Appendix C).

River hydrokinetic potential

Aquatera estimates that based on conservative assumptions, the total practically extractable hydrokinetic resource in Peru could be at least 0.1 or 1.5 GW. With more optimistic assumptions, the total practically extractable wave resource could be as high as 2 GW (Figure 4).

Figure 4 River hydrokinetic resource by region



The river hydrokinetic assessment carried out by Aquatera identified three sources of information which have been used in order to characterise the river hydrokinetic conditions in Peru. Information from the Peruvian national water authority provides spot data for current speeds (see Case Study 3), the other is a basic analysis undertaken by project partners from Universidad de Ingeniería & Tecnología in Lima (UTEC) to develop estimates of river section velocity and other metrics and data shown in The Inter-American Development Bank (IDB) report (see Case Study 4). These data sets were used collectively to help establish possible resource-rich sections of rivers. A minimum average current velocity cut off of 2 m/s was assumed for sites to be considered attractive.

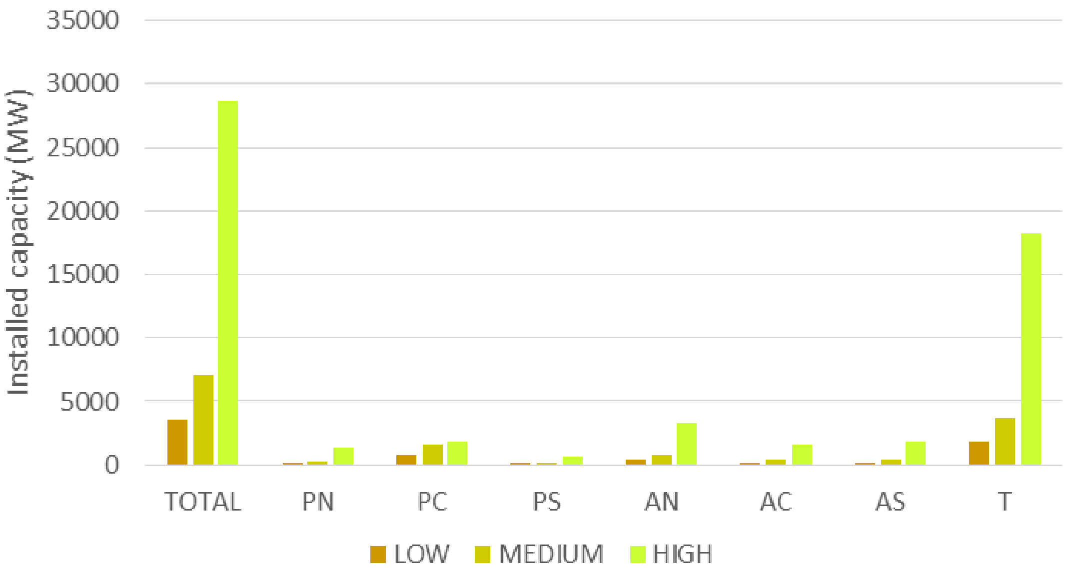
See the average annual precipitation in Map 3.4 and Map 3.5 showing the location of measured river data suitable river hydrokinetic deployments (Appendix C).

In Appendix B the results of the analysis performed in seven basins are shown.

Floating solar potential

Based on relatively conservative assumptions about the areas available for future developments, Aquatera estimates that floating solar could generate more than 5 GW of power (Figure 5). With more optimistic assumptions about the size of projects, the total resource could be much higher, into tens of GWs. Most of this resource is concentrated in Lake Titicaca, which is a sensitive area. More detailed resource assessment could validate these numbers taking into account the scale of project that would be environmentally and socially acceptable but it is clear that the raw potential is very large indeed.

Figure 5 Solar energy resource by region



See Map 3.1 showing the annual average solar energy resource in Peru in kWh/m^2 (Appendix C).

REGULATORY FRAMEWORK

There are two key areas of the regulatory framework regarding aquatic renewable energy:

- Legal or commercial rights to use the seabed/riverbed. In Peru all water area concessions are the responsibility of General Direction of Captaincies and Coast Guard (DICAPI)[9].
- The remaining permits and licences required to develop and work on the site, including planning permission, environmental impact assessments (EIAs), navigational permits, grid connection concessions, etc.

Other aspects of aquatic renewable energy that may require regulation include:

- Marine and river planning
- Energy generation tariffs
- Electrical generation standards
- Health and safety of workers at sea and emergency response provision
- Maritime and river marking and navigation

This chapter focuses on the development of the Peruvian regulatory framework as regards aquatic concessions, aquatic permits and licences, planning and electrical generation standards.

Onshore aquatic energy

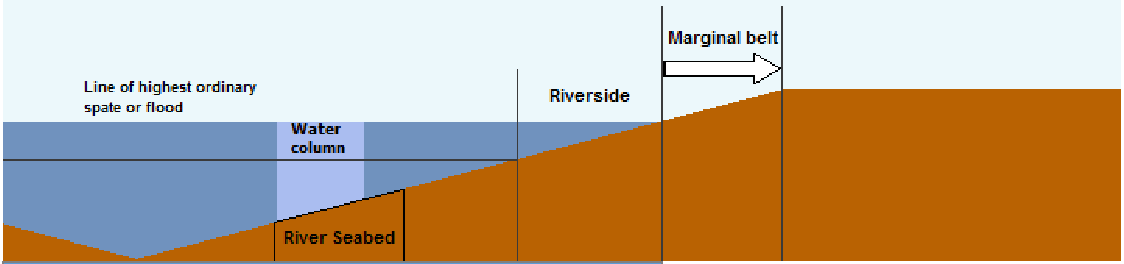
National Water Authority (Autoridad Nacional de Agua, ANA) [10] is responsible for planning, directing and supervising the integrated and multi-sectorial management of water use. Article 4 of the Law N°29.338 regulates the processes of granting rights of use of onshore aquatic areas. It defines that the water administration and its associated properties are exclusively managed by the National Water Authority. Regional and local governments participate through the Water Resources Basin Councils in accordance with their respective laws.

The responsible body for any kind of permit of use or concession in river areas is DICAPI. Aquatic areas susceptible of being affected by right of use granted by DICAPI for defined activities are: maritime domain and inland waters, island areas located in the aquatic environment of Peru and navigable rivers and lakes.

Figure 6 presents some of the main areas of responsibility and permits that may be required to implement a project at a river area in Peru.

[9] http://www.dicapi.mil.pe/
[10] http://www.ana.gob.pe/

Figure 6 Permits and licences for acuatic renewable energy projects in rivers



	Time (days)
Hydrography and Navigation Division	
Dirección de Hidrografía y navegación de la Amazonia	
National Water Authority (ANA)	
Superintendence of National Assets (SBN)	
Environmental Impact Assessment Service	
Ministry of Energy and Mines	
Regional Government	
Local Municipality	
License, permit and authorization to use water for productive purposes	
Approval of temporary use of riviera or marginal belt	
Authorization to use land area	
Temporary authorization water area	
40. Granting of registration certificate for companies related to aquatic activity	10
112. Preliminary approval right use aquatic area	30
113. Granting right of use of aquatic area for fixed installations	30
115. Granting of right of use of aquatic area for floating installations	30
119. Favorable view granting use on islands	30
127. Authorization to use water area in jungle sector	30
123. Authorize construct, modify. And operation of aquatic facilities / supervision of works	
Approval Hydro-oceanographic study - EHO	
Certification of works and nautical signaling	
1. Granting of definitive concession (Directorate of electric concessions)	60
2. Granting of temporary concession (Directorate of electric concessions)	25
13. Establishment of easement (Directorate of electric concessions)	60
7. Granting of authorization of electric projects from 10MW (Directorate of electric concessions)	30
Authorization Granting Electrical Projects 0.5MW-10MW	
Granting of definitive concession for ERNC 0.5MW-10MW	
56. Approval of a semi-integrated environmental impact study (Directorate of Energy Environmental Issues)	78
61. Approval of EIS for rural electrification system covering two or more departments or regions (Directorate of Energy Environmental Issues)	15
Granting of Environmental Certification for rural electrification projects that cover two or more regions; Electrical generation with ERNC and thermoelectric; Electric transmission; And Electrical distribution greater than or equal to 30 MW.	
Approval Detailed Environmental Impact Studies EIA-d (National Environmental Certification Service for Sustainable Investments)	
Granting of Environmental Certification to construction projects	
4.1.1 Certificate of urban planning and building parameters	5
4.1.2 Preliminary draft in consultation	8
4.1.3-9 Building License	25

Source: Aquatera

Note: Side number of permits relates to exact reference number for each institution TUPA.

The Peruvian Government has created a new temporal Multi-Sectorial Working Group in charge of generating technical information to guide the implementation of the Multiyear Sectoral Strategic Plan of the Environment 2017 - 2021.

Scotland has developed a first draft strategy of the future of energy of Scotland that could be a guideline for the multi-sectorial working group and support the development of Peru’s climate change plan (
Case Study 5).

Offshore aquatic energy

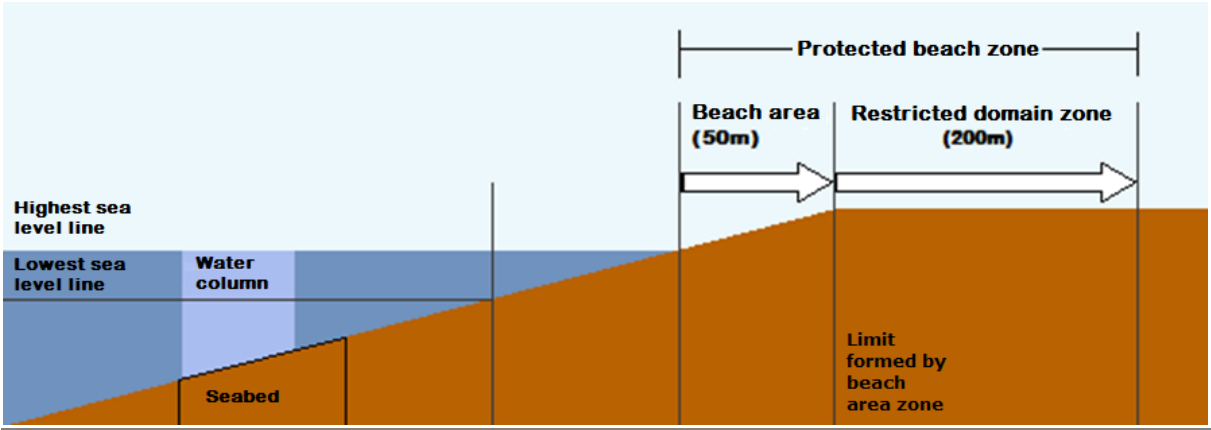
DICAPI is responsible for marine concessions and administration of water areas including sea, interior waters, island areas, rivers and navigable lakes (ref. first article of the Legislative Decree N°1147).

The protected beach zone is designated as an area for public infrastructure works and public services. The responsibility for granting concessions in this area resides with the Agency for the Promotion of Private Investment (PROINVERSION)[11] in accordance with the Legislative Decree No. 839, Supreme Decree No. 059-96-PCM, Supreme Decree No. 060-96-PCM and other complementary and related rules.

Law No. 26620 establishes that DICAPI is responsible for monitoring and controlling activities in the 50 meter strip of beach area, but this operational responsibility is separate (although overlapping) with PROINVERSION's competence to grant concessions. Figure 7 presents some of the main areas of responsibility and permits that may be required to implement an aquatic energy project in Peru.

[11] http://www.proinversion.gob.pe

Figure 7 Permits and licences for acuatic renewable energy projects in the sea



Offshore generator	Cable route	Nearshore generator	Shoreline Generator/ Cable or pipline route	Onshore Generator/ Substation/ Offices etc.

Permit / institution	Time (days)
Captaincy and Coast Guard General Division (DICAPI)	
Hydrography and Navigation Division	
Superintendence of National Assets (SBN)	
Environmental Impact Assessment Service	
Ministry of Energy and Mines	
Regional Government	
Local municipality	
118. Favorable opinion for adjudication on land of the coastal strip of the sea	30
Authorization to use land area	
Temporary authorization water area	
40. Granting of registration certificate for companies related to aquatic activity	10
112. Preliminary approval right use aquatic area	30
113. Granting right of use of aquatic area for fixed installations	30
115. Granting of right of use of aquatic area for floating installations	30
119. Favorable view granting use on islands	30
127. Authorization to use water area in jungle sector	30
123. Authorize construct, modify and operation of aquatic facilities / supervision of works	30
Authorization of installation of nautical signals	
Approval Hydro-oceanographic study - EHO	
Certification of works and nautical signaling	
1. Granting of definitive concession (Directorate of electric concessions)	60
2. Granting of temporary concession (Directorate of electric concessions)	25
13. Establishment of easement (Directorate of electric concessions)	60
7. Granting of authorization of electric projects from 10MW (Directorate of electric concessions)	30
Authorization Granting Electrical Projects 0.5MW-10MW	
Granting of definitive concession for ERNC 0.5MW-10MW	
56. Approval of a semi-integrated environmental impact study (Directorate of Energy Environmental Issues)	78
61. Approval of EIS for rural electrification system covering two or more departments or regions (Directorate of Energy Environmental Issues)	15
Granting of Environmental Certification for rural electrification projects that cover two or more regions; Electrical generation with ERNC and thermoelectric; Electric transmission; And Electrical distribution greater than or equal to 30 MW.	
Approval Detailed Environmental Impact Studies EIA-d (National Environmental Certification Service for Sustainable Investments)	
Granting of Environmental Certification to construction projects	
4.1.1 Certificate of urban planning and building parameters	5
4.1.2 Preliminary draft in consultation	8
4.1.3-9 Building License	25

Source: Aquatera

Note: Right hand side number of permits relates to exact reference number for each institution TUPA

See Map 4.2 showing the Maritime territory of Peru (Appendix C).

There are a significant number of national and international policies, strategies, action plans and regulations related to climate change and the development of renewable energies that have been created in the United Kingdom.

In Scotland, changes have been made to planning and licensing regime over the past decade in order to deal with new uses of the marine environment (see Case Study 6 and Case Study 8). Case Study 9 shows how the UK has developed its regulatory framework for offshore wind.

Protected areas

In Peru, protected areas are grouped under the name Protected Natural Areas (ANP) and are established in accordance with the Law on Natural Protected Areas (Law No. 26834 and its Regulations published by Supreme Decree No. 038-2001-AG).

Protected areas in Peru are classified in three groups according to whom manages them:

- ANPs protected areas administered by the National System of Natural Areas Protected by the State (SINANPE);
- Regional Conservation Areas (RACs), managed by Regional Governments;
- Private Conservation Areas (ACPs), managed by individuals.

These areas are defined in different categories. There are several options for protected natural area categories whose protection objectives vary gradually. Depending on their legal status, purpose and permitted uses, there are areas of direct use and areas of indirect use.

- Areas of direct use: allow the use of natural resources, primarily by local populations, under the guidelines of a Management Plan approved and supervised by the competent national authority.
- Areas of indirect use: extraction of natural resources or modification of the natural environment are not allowed. These areas only allow non-manipulative scientific research and tourist, recreational, educational and cultural activities under duly regulated conditions.

Table 2 Potential conflicts for aquatic deployments

Type of potential conflict with project location	Compatibility with onshore and offshore aquatic energy project
Overlapping of concessions	Permissible with consent of existing concession holder
Protected Areas	Category
National Park	Indirect
Protected forest	Direct
Wildlife refugee	Direct
National sanctuary	Indirect
Communal and National reserve	Direct
Landscape reserve	Direct
Historic reserve	Indirect
Hunting zone	Direct
Reserved zone	Area in transition
Regional conservation area	Direct

In addition to the above, Peru also has Private Conservation Areas (ACP) that are regulated in a different way. ACPs are defined by SERNANP by volunteer request of owners of the property. The ACPs have two types of zoning, Multiple Use Zone (ZUM) and Limited Use Zone (ZUL).

See Map 4.3 and map 4.4 showing the natural land protected areas and ecosystems in Peru (Appendix C).

More than 3,000 indigenous territories have been identified in the Amazonian biome. These areas represent 35% of the Amazon. Together with indigenous territories and protected areas, 49.4% of the biome is under some type of management and protection.

See Map 4.5 showing the indigenous land and ethnic groups (Appendix C).

Electrical concessions

For the application for definitive concessions or authorisations it is necessary to submit a document of Concession or Authorisation in accordance with articles 25 and 38 of the Law to the General Electricity Directorate (DGE) of the Ministry. The application will be sent to the General Directorate of Environmental Affairs (DGAA) for its opinion, evaluation and conformity. Likewise, in the case of projects whose installed capacity is greater than 500 KW and less than 10 MW, both the authorisation for the electric generation and the definitive concessions for generation with renewable energy resources is granted by Regional Governments.

Environmental permits

The Environmental Certification Directorate (SENACE)[12] and the competent authorities, composed of ministries, regional and local governments, conduct the process of environmental impact assessment, through the categorisation, review and approval of environmental studies.

The Electric Concessions Law No. 25844, indicates that the concession holders with generation, transmission and distribution infrastructure must comply with Peru's laws and norms relating to conservation of the environment. The Regulation on Environmental Protection in Electrical Activities, approved by Supreme Decree No. 029-94-EM, specifies that the authority responsible for issuing general and specific guidelines for environmental protection policy is the Directorate General for Energy Environmental Affairs (DGAAE) in coordination with the General of Electricity (DGE), both from MINEM.

Scotland has endeavoured to apply such principles to its regulatory process with some success. A review of the potential impacts of wave and tidal renewable energy developments on Scotland's marine environment (see Case Study 10) has been developed to identify what is known about the impacts of wave and tidal energy devices in the marine environment, and gather and present additional knowledge and data to provide information and guide decision making on potential development of key areas for renewable energy.

The Scottish Government has sought to manage the environmental risks of marine energy projects without placing unnecessary restrictions on developers. See Case Study 11 as an example of how to manage the environmental risks of marine energy projects.

[12] https://www.senace.gob.pe/

Spatial Planning

In 2016, the General Directorate of Land Management has provided technical assistance and follow-up to the different processes of Economic Ecological Zoning (Spanish acronym ZEE) that have been developed at national level and have resulted in 13 regional governments having ZEE processes approved and 2 regional governments having completed ZEEs.

The ZEE becomes a technical and guiding instrument for the sustainable use of a territory and its natural resources. It is, therefore, an instrument to understand the geographic and environmental basis on which social and political action is based, as well as economic and productive projects. The ZEE provides systematised and geographically localised information on the capacity, fragility and potential of the territory and its natural resources.

Micro-ZEE processes in development are Economic Ecological Zoning processes carried out at the district level. To date, 21 districts in the regions of Piura, Ayacucho, Cusco, Arequipa, Puno, Madre de Dios, Apurímac and Huancavelica have been developing their ZEE processes at the micro level and have basic information for decision making and management of their territory.

Law No. 29338 - Law on Water Resources and its Regulations approved by Supreme Decree No. 001-2010-AG, creates the National System of Water Resources Management, composed of a set of institutions with the objective of coordinating and ensuring integrated and multi-sectorial management, sustainable use, conservation, efficient use and increase of water resources.

The Water Resources Law also creates the Basin Water Resources Councils with the objective of involving it in the planning and coordination of the sustainable use of water resources in their respective areas.

Peru does not have a marine planning system but a pilot model has been proposed in Piura and Ica to analyse the process and to discuss the support for the initiative according to the interests of different partners, their roles and possible contributions along with the synergies that could be established with other initiatives. MINAM is working now on an integrated management system of marine coasts using marine spatial planning as a key tool for its development.

The existing regulation R.J. N° 202-2010-ANA, in Annex 1 (Coastal-Marine Classification) refers to a list of "31 seas" located in different zones off the Peruvian coast, classifying them as "Category 4: Conservation of the Aquatic Environment".

The General Direction of Territorial Organisation (Dirección General de Ordenamiento Territorial, DGOT) has promoted actions and developed inputs and instruments for the implementation of Integrated Management of the Coastal Marine Zone (MIZMC) in the Country since 2011. In addition, ANA has launched a study called "Classification of the Marine-Coastal Water Body" which is further discussed in the paragraph below.

The Scottish Government has developed a full-colour marine atlas about Scotland's seas to provide in-depth information about different aspects of Scotland's seas, an overall assessment of the current condition of the seas and consideration of future priorities (see Case Study 12). The Marine (Scotland) Act in 2010 introduced a new statutory marine planning system to allow better management of the competing demands on marine resources (see Case Study 13).

Scotland has made strenuous efforts to streamline the process of securing commercial rights to the seabed for marine energy developers from which many lessons can be learned. One of the mechanisms adopted in the UK to accelerate the growth of its marine energy industry was the introduction in 2009 of commercial seabed leases, giving marine energy technology and project developer's medium-term security over future leasing options for areas of the seabed. Case Study 14 shows some of the key lessons learned from the leasing process in the UK. Peru could use these Case Studies as a reference system to develop their marine spatial planning process.

INFRASTRUCTURE AND SUPPLY CHAIN

As with any emerging industrial sector, the development of a successful and economically viable onshore and offshore aquatic energy industry will be fundamentally linked to the availability and capacity of the necessary infrastructure and a suitable supply chain.

Electricity grid

In Peru, generation is provided by a mixture of 40 private and state owned companies, with the top five contributing 65 percent of the total capacity, as shown in the table and graph below.

The central zone of Peru is where most of the thermal systems of generation are concentrated. The central zone of Peru has become an electrical subsystem that is clearly an exporter to the north and south of the country. The concentration of electric generation systems in the central zone of Peru generates a certain vulnerability in the Peruvian electrical system. However, with the entry into operation of new hydroelectric plants and renewable facilities in the north and south of the SEIN[13] there has been a reduction of the vulnerability along with the decrease of congestion of the system thanks to the implementation of new transmission lines of 500 kV.

Electricity generating companies compete to supply power to electricity distribution companies, while there is a spot market for energy transfers between generating companies. Generators also compete with distributors to supply energy to large consumers, these are users with an annual demand exceeding 1 MW. On the other hand, in Peru's energy transmission system, there is a participation of 12 companies, where the 5 main companies are responsible for almost 93% of the supply (MINEM, 2016).

Grid capacity and international connectivity

Peru's electricity sector is currently facing an oversupply due to the rapid expansion of natural gas power generation. Current peak demand at the SEIN is approximately 35 percent lower than installed capacity[14], although electricity demand grew 8.8 percent between 2014 and 2015 and grew 7.1 percent from last year in September 2016 (MINEM, 2016).

The SEIN currently has a real electric power transmission highway along the Peruvian coast. The entry into operation and connection to the SEIN of several lines of transmission of 500 kV and the construction of new hydroelectric plants and renewable plants in the north and south of Peru have reduced the restrictions that the network suffered previously. The new 500 kV electric transmission lines electrically connect the regions of Piura and Monquegua across the Peruvian coast from north to south, in turn new connections are expected in the south of Peru contributing to a greater level of reliability to the electricity supply.

The Peruvian electricity transmission system in 500 kV and 220 kV will continue to be strengthened in accordance with the Transmission Plan 2015 - 2024. COES updates the Transmission Plan every two years to determine new infrastructure requirements for the SEIN. The Plan identifies points of saturation and congestion and projects of reinforcement or new construction of transmission lines are proposed.

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[13] http://www.coes.org.pe/portal/

[14] Total capacity (MW): 9,686 Maximum demand (MW) 6,244 (MINAM, 2015b)

In June 2016, a draft law on the export of trans-boundary electric energy was sent as a matter of urgency to commercialise the excess supply in the framework of the Andean Community of Nations (CAN) and the Union of South American Nations (UNASUR). Also participating in the initiative is the Andean Electrical Integration System (SINEA) which is complementary to CAN.

Up to 2025, energy integration projects will be strengthened with Ecuador, Brazil, Chile, Colombia, and Bolivia (under negotiations). These interconnections will have similar characteristics, but the existing infrastructure and/or planned infrastructure makes some links more feasible and profitable in the short-term than others, and this marks the priorities for Peru. Currently, progress has been made with the design of a 500 kV link to Ecuador, in addition to the emergency link of 220 kV. The new link will allow a permanent exchange of surpluses in each country at market prices (MINEM, 2014).

Cadena de suministro

There are often specific requirements for aquatic renewable energy projects, determined by the characteristics of the devices (eg size, weight and geometry) and the environment where the project is implemented. Peru has a great maritime trajectory and a considerable coastal and river infrastructure, which has the potential to support the emerging sector of aquatic renewable energies. The maritime and industrial infrastructure required to manufacture, install and maintain marine energy devices is similar to other marine industries and includes ports (with operation and maintenance capability).

Peru has river and coastal ports, as well as buoy locations for mooring vessels suitable for promoting aquatic renewable energy facilities in the country, there are also several shipyards that could allow integration into the aquatic renewable energy supply chain.

The aquatic renewable energy sectors work closely, in functional terms, with other maritime markets such as those serving commercial fishing, merchant shipping, cable laying and marine recreation activities. As far as related ground sectors are concerned, there are close links to the electricity sector in general, to manufacturing and other ground engineering services as well as to a wide range of support services and expertise that this sector requires as any other commercial sector.

This means that many of the basic elements necessary to supply aquatic renewable energy to the market are already likely to exist in Peru. The key is to make sure they are available to emerging aquatic renewable energy sectors, that the costs are appropriate and that the quality of the services and equipment supplied meets the demands of the end user.

Supply chain key parameters include:

- Governance
- Local/regional development
- Technology manufacture
- Project planning and development
- Project construction and installation
- Project operation
- Decommissioning
- Marine support services
- Other/supporting tasks

See Maps 11.3, 11.7, 11.11, 11.15, 11.19, 11.23, 11.27 showing the infrastructure available for the development of the aquatic energy industry in Peru (Appendix C).

The marine energy industry in Scotland has benefited from the availability of an extensive existing network of maritime infrastructure, support vessels and a skilled workforce that has built up around the North Sea oil and gas industry. As a reference, see the Scottish Marine Infrastructure Plan in Case Study 16 and the capabilities of the supply chain in Orkney and the UK (Case Study 17 and Case Study 18).

Ocean profiles and bathymetry of the north, central and south coast Peru are key for strategic deploments.

See Maps 6.1, 6.2, 6.3 showing the bathymetry of the Peruvian coast for aquatic energy deployments (Appendix

RESEARCH, DEVELOPMENT AND INNOVATION

Research, development and innovation (RD&I) are the catalysts of any emerging industry and an integral part of progress from the early stages of technology testing to the realisation of an economically viable, commercial scale industry.

Fundamental to this approach is the belief that Peru as a country and South America as a region are going to be important to the future development of a successful aquatic technology industry and perhaps even more importantly that these water technologies can be an important and critical component of the transition to a more energy secure and less carbon dependent energy economy. With these factors as a background, a new renewable energy centre could embrace the different regional opportunities and character found in Peru.

There are key areas of aquatic technologies research for Peru that could be implemented through a Centre of Excellence or independently, the priority ones are described below.

Technology cost reduction and adaptation for Peruvian conditions

In Europe and a few other developed countries, aquatic technologies have made significant progress over the last decade, with the deployment of a significant number of wave, tidal and river prototypes at sea and in rivers but also floating solar and wind as a proven technology are taking a lead position internationally. However Peru has different local conditions, different barriers and advantages which need to be identified for technologies to be deployed and drive the aquatic renewable industry forward.

Some of the lines of research identified under the adaptation of technologies and cost reduction are showed in Table 3.

Table 3 RD&I technology cost reduction and adaptation for Peruvian conditions

Aquatic energy technology development	
1.1	Establishment of protocols, third party verification & quality systems
1.2	Design and adaptation of aquatic renewable devices
1.3	New materials and components for aquatic renewable devices
1.4	Energy delivery and storage components & systems for off-grid applications
1.5	Advanced tools for aquatic technology development
1.6	Demonstration of technologies

Case Study 19 presents some of the areas identified for aquatic energy cost reductions and initiatives for developing R&D related to cost reductions.

Resource assessment and site selection to minimise cost of energy

The first steps towards understanding Peru´s marine renewable energy, river hydrokinetic, floating solar and offshore wind resources should be taken to identify the most promising sites and to develop these into successful projects. The baseline conditions at these sites also need to be better understood for the design/adaptation of appropriate aquatic renewable devices (see Table 4). Coastal and river planning is a new challenge for local authorities but tools and methods developed internationally could support the process.

Table 4 RD&I resource assessment and site selection to minimise cost of energy

Resource and site aquatic energy development	
2.1	Evaluation, measurement and analysis of baseline conditions
2.2	Improved resource analysis
2.3	Development of a site selection tool
2.4	Strategic environmental assessment
2.5	Aquatic energy atlas and marine spatial planning
2.6	Proportionate environmental management methods

Sector development

When the technology reaches an implementation stage, the infrastructure in Peru must be able to support its integration. To ensure readiness, there must be testing and demonstration areas to reassure investors. If the electrical grid, port facilities, or installation and maintenance techniques are not adequate, there will be a lag before the aquatic energy technologies can be utilised.

Some of the R&D lines identified for the aquatic sector development in Peru are showed in Table 5.

Table 5 RD&I sector development

Sector development	
3.1	Aquatic renewable markets and investment models
3.2	Installation and maintenance technologies and methods
3.3	Port and industrial capacity reinforcement
3.4	Electrical grid capacity and integration study
3.5	Testing sites and demonstration zones (see Case Study 21)

The EU already supports offshore aquatic energy development through its programme Blue Growth which is the long-term strategy to support sustainable growth in the marine and maritime sectors as a whole. The EU envisage the development of this offshore emerging sectors to help to achieve EU renewable energy and greenhouse gas reduction targets, but it could fuel economic growth through innovation and create new, high-quality jobs (see Case Study 34).

The EU Ocean Energy Strategic Roadmap is another example of the support that some aquatic technologies are receiving in the EU. The Strategy reflects the common vision of the ocean energy sector, identifies a path forwards, building on European leadership in ocean energy, and developing technologies and projects that can meet a significant amount of Europe's power demand over the next 35 years (see Case Study 35).

Knowledge transfer and dissemination

The need for sharing knowledge between research institutions and between research institutions and industry has become increasingly evident in recent years. Perhaps the most pertinent rationale for establishing a renewable R&D centre in Peru is that it will become an integral part of the global network of institutions researching and developing aquatic renewable energy and can take part in global knowledge transfer.

Knowledge transfer and dissemination in Peru has the following key action lines (see Table 6)

Table 6 RD&I Knowledge transfer and dissemination

Knowledge transfer and dissemination	
4.1	Education and training (Case Study 22, Case Study 23 and Case Study 24)
4.2	Projects and technology register
4.3	Intellectual property bank and market place
4.5	Regulation and policy support
4.6	Regional industrial capacity
4.7	Health, safety and risk
4.8	Dissemination programme

Funding programs to support research in aquatic energy deployments is key for the sector in Peru to move forwards. See Case Study 20 as an example of funding provision for some offshore aquatic technologies.

SOCIO-ECONOMIC AND ENVIRONMENTAL IMPACTS

To achieve sustainable development, countries will need a diverse energy mix and countries such as Peru with an extensive coastline and large riverine systems have the potential to provide a large portion of this energy from aquatic technologies – a market which is going to continue to grow in the coming years and decades. This presents huge cultural, economic and social opportunities for Peru.

The likely social, cultural heritage and economic impacts of aquatic renewable technologies are provided in Table 7. A general indication of some of the potential impacts of the various technologies are outlined, however the level of impact may vary widely depending upon the scale of the project, its location, the technology type and the social, cultural heritage or economic sensitivities of the site. The table of potential impacts below is not exhaustive and there will be other impacts that are device and project specific. Further research at a site-specific level would be needed to develop a comprehensive set of impacts and to validate levels of significance.

Table 7 Potential cultural heritage, social and economic impacts of aquatic renewable technologies

Issue	Aquatic renewable technologies potential impact and explanation	Source
Heritage		
Geology	Very localised disturbance from cable trenching, if required and anchoring operations.	Aquatera experience
Species	There is potential for direct negative effects upon species from devices, although impacts at the population level are likely to be limited. Exclusion of trawl fishing could help stocks of marine species.	Aquatera experience
Habitats	Potential for direct negative effects on habitats from devices. Can be mitigated by micrositing of devices.	Aquatera experience
Landscapes	Surface piercing technologies or components may impact on the landscape which could detract from the amenity value of an area and impact negatively on local residents and/or tourists. Importance will depend upon site specific sensitivities and experiential value of the area to receptors.	Aquatera experience
Culture	Potential for disturbance to other existing sea users such as fisheries if not managed appropriately.	Aquatera experience
History	Little scope for direct disturbance to historical artefacts, some potential to influence the setting of coastal protected areas. Through careful siting of developments impacts can be mitigated.	Aquatera experience
Social		
Population	Effects likely to be positive, population in Orkney has increased by 10% over 10 years, in part due to renewables jobs.	Aquatera in-house data
Demographics	Development of these technologies create challenging jobs for younger people and are often located far away from large population centres, thus improving demographics in rural areas.	Aquatera experience
Facilities	Little change expected until workforce is sizable, i.e. greater than 200 people.	Aquatera experience
Culture	These technologies form international global businesses which can lead to international links for host/nearby communities.	Aquatera experience
Employment	Local employment can take place and certain operational support jobs will be long-term. Service providers may get experience and expertise that they can then apply to other markets.	Aquatera experience
Economic		
Overall activity	Development of these technologies can lead to significant supply chain activity in the local area, creating business opportunities and employment.	Aquatera experience
Other sea users	There is potential for disruption to fishing and shipping activities from cable laying and from the testing and deployment of these technologies, particularly when large arrays are concerned.	EMEC and Aquatera direct experience
Infrastructure	There can be competition for berthing space in small ports until purpose built facilities are available.	EMEC and Aquatera direct experience
Energy	Deployment of these technologies adds to the diversity of energy supply.	

Potential environmental impacts of each aquatic renewable technology are provided in Table 8 to Table 13. Again, this list is not exhaustive and there will be other impacts that are device and project specific. Further research at a site-specific level would be needed to develop a comprehensive set of impacts and determine levels of significance.

Table 8 Potential environmental impacts of wave energy

Issue	Wave potential impact and explanation	Source
Physical		
Sea conditions	Wave devices take their highest proportion of energy out of moderate waves. Key processes are often shaped by storm conditions, when devices tend to shed energy. Therefore there is little likelihood of marked effects.	Direct observations internationally
Seabed	No measurements made, but modelling has suggested some build-up of sediments in the wave shadow of an array, albeit not to a pronounced level.	Oregon Wave Energy Trust studies
Energy flux	Generally low sensitivity in ecosystem to reduced energy flux. A few species are adapted to extreme energy, e.g. *Fucus disticus* in Orkney. Plankton succession could be changed in significant wave shadow areas if stratification starts earlier in season.	ICIT studies
Noise	Devices designed not to emit noise (extract energy) and many operate very quietly, wave noise and vessel noise are the dominant sources.	Direct observations in Orkney
Seascape	Exposed coastal areas can represent wilderness type areas, often with little human influence. Such areas may merit protection from near shore wave energy development. Importance will depend upon site specific sensitivities and experiential value of the area to receptors.	Aquatera 2005 & 2007. Resource assessments
Coastal processes	Along rocky shores there is little potential for change. Even on sandy coasts most change occurs during storm events which remain little changed by most wave energy devices.	Analysis of extracted energy spectrum
Ecological		
Plankton	No direct effects anticipated. Possible that a distinctive wave shadow could alter water column mixing dynamics and thereby change the succession of species in the influenced area. This would have to be at very large scale, >10 km^2 shadow area before it could be significant.	Aquatera experience
Benthos	Direct affects from the placement of anchor and mooring systems, also from cable laying and burial. Scale of negative impact would be confined to the area where anchors come into contact with the benthos. Devices create obstacles to bottom trawling which help to protect seabed communities.	EIAs completed to date, video monitoring of moorings at EMEC sites
Fish	Most likely effect is attraction and aggregation around the structure (device plus moorings) creating a 'reef effect'. Concerns raised about the migration of conservation designated species e.g. salmon, but no evidence to support this. Devices will create obstacles to trawl fishing which will help to protect local fish stocks.	EIAs completed to date
Marine mammals	Potential interactions with wave devices are benign. Some concerns about entrapment (within device chambers) in densely populated areas.	EMEC monitoring data
Sea birds	There is potential for some species to use the devices as roosting platforms.	EMEC and other bird monitoring data

Table 9 Potential environmental impacts of offshore floating wind energy

Issue	Floating wind potential impact and explanation	Source
Physical		
Sea conditions	Floating wind devices consist of semi-submersible platforms or spar-buoys with wind turbines attached. These would be unlikely to significantly affect sea conditions.	EIAs completed to date
Seabed	Changes in sediment dynamics generating scour and/or siltation around anchors could potentially impact on seabed habitats, albeit not to a pronounced level.	EIAs completed to date
Energy flux	Would not be significantly affected by floating wind devices.	EIAs completed to date
Noise	Main concern regarding noise is from piling operations which are temporary. Floating wind devices likely to avoid use of piles due to being situated in deeper water.	Floating wind EIAs
Seascape	Possibility for impacts on seascape. Importance will depend upon coastal character type and experiential value of the area to receptors. Floating wind turbines have the advantage that they can be placed further offshore (compared to pile driven turbines) which means the impact on seascape can be reduced.	Aquatera experience
Coastal processes	Devices situated far offshore and are widely spaced so there is very little scope for impacts on coastal processes.	Aquatera experience
Ecological		
Plankton	No impacts anticipated.	Aquatera experience
Benthos	Installation of device anchors would result in disturbance to the seabed either through direct loss of benthic habitat or from sediment plumes which can block the respiratory systems or feeding appendages of benthic organisms.	EIAs completed to date
Fish	Exclusion of trawlers would provide a positive impact and floating wind farm structures would provide artificial refuges for fish.	EIAs completed to date
Marine mammals	Possibility for very large marine mammals (e.g. right whales) to become entangled in mooring lines however studies suggest this is unlikely to be an issue for medium to smaller sized marine mammals (Benjamins, et al., 2014). This should be considered during siting and project design activities.	Scottish Natural Heritage study
Sea birds	Potential for collision between turbine blades and birds. Some nature conservation bodies (e.g. Royal Society for the Protection of Birds (RSPB)[15]) have highlighted that floating wind farms represent less of a risk to bird species than fixed substructure wind farms as they can be sited further offshore away from breeding bird populations. However, birds on migratory routes may be put at increased risk.	RSPB comment and EIAs completed to date

[15] http://www.rspb.org.uk/

Table 10 Potential environmental impacts of offshore floating solar energy

Issue	Floating solar potential impact and explanation	Source
Physical		
Sea conditions	Areas such as sheltered bays and coves with calm sea conditions only likely to be suitable for floating solar deployment where sea conditions are unlikely to be affected by its deployment.	Aquatera experience
Seabed	No measurements made, but unlikely to directly affect the seabed other than where moorings come into direct contact with it.	Aquatera experience
Energy flux	No change in energy flux anticipated.	Aquatera experience
Noise	Noise would be emitted from inverters, but would not be anticipated to result in significant impacts.	Aquatera experience
Seascape	Possibility for impacts on seascape. Importance will depend upon coastal character type and experiential value of the area to receptors. Floating solar likely to be deployed close to shore which could increase the impact on the seascape.	Aquatera experience
Coastal processes	A very slight dissipation of wave energy is possible due to the buoyancy of floating solar platforms, however there is little scope for impacts on coastal processes. Although possible that erosion of reservoir embankments will be prevented through a reduction in wave action.	Aquatera experience
Ecological		
Plankton	Floating solar would block sunlight from reaching the sea surface and thus would limit the growth of phytoplankton in deployment areas which could have an impact upon the food chain. Conversely this could result in a positive impact through reducing algal blooms and thus improving water quality, particularly in sheltered embayments where water circulation may be limited.	EIAs completed to date
Benthos	Direct effects from the placement of anchor and mooring systems, also from cable laying and burial. Scale of negative impact would likely be small. Furthermore, devices create obstacles to bottom trawling which help to protect seabed communities.	EIAs completed to date
Fish	Most likely effect is attraction and aggregation around the structure (devices plus moorings) creating a 'reef effect'. As with wave and tidal possible concern about the migration of conservation designated species e.g. salmon, but no evidence to support this. Devices will create obstacles to trawl fishing which will help to protect local fish stocks.	EIAs completed to date
Marine mammals	Floating solar arrays could create artificial barriers for surface breathing animals and could hold some entrapment and entanglement risks. Site selection would need to consider the risk of wildlife interactions avoiding important and sensitive areas of deployments to reduce hazards.	Aquatera experience
Sea birds	Possible loss of feeding grounds for sea birds, however impacts likely to be similar to wave devices and effects not significant. Potential for birds to use the infrastructure as roosting platforms.	Aquatera experience

Table 11 Potential environmental impacts of river hydrokinetic energy

Issue	River hydrokinetic potential impact and explanation	Source
Physical		
River processes/ energy flux	The introduction of river hydrokinetic devices has potential to affect river morphology and the ecosystem it supports. Pre- and post-installation monitoring of flow conditions is required to quantify impacts on river processes and energy flux.	Aquatera experience
Noise	Devices designed to operate at low noise levels. Ambient noise in rivers increases as turbine noise increases. No sudden changes in noise levels from devices, i.e. turbines start and stop spinning gradually. Largest source of noise is from vessels.	Aquatera experience
Visual impact	Not an issue for riverbed mounted devices, however potential for surface piercing devices to cause visual impact. Importance will depend upon site specific sensitivities and experiential value of the area to receptors.	Aquatera experience
Ecological		
River benthos	Varies with technology type (floating or bottom-mounted) but installation of either of these types of devices would result in disturbance to the benthos either through direct loss of benthic habitat or from sediment plumes which can block the respiratory systems or feeding appendages of benthic organisms.	Aquatera experience
Fish	There is potential for collision between river hydrokinetic turbine blades and fish which has potential to result in mortality. Also potential for large arrays to block the migration routes of e.g. salmon. No instances of mortality from collision have been recorded. Potential for devices to act as fish aggregation devices which could result in a positive impact.	Collision risk modelling and monitoring of an operational river hydrokinetic turbine
Mammals	As with fish, collision risk is the main concern. Monitoring around arrays of devices is needed to provide certainty. Highly dependent on the species present at the site. There is also potential for barrier effects.	Aquatera experience
Birds	Potential for collision between turbine blades and diving birds. Modelling and environmental monitoring to date indicates that, in general, the likelihood of a blade strike is low. However, monitoring around arrays of devices is needed to provide certainty.	EIAs completed, video & acoustic monitoring & collision risk modelling

Table 12 Potential environmental impacts of inland floating wind energy

Issue	Inland floating wind potential impact and explanation	Source
Physical		
Lake/reservoir conditions	The introduction of floating wind devices would not be expected to significantly affect the lake or reservoir conditions.	Aquatera experience
Noise	Dependent upon the sensitivity of the species present to noise impacts. The biggest source of noise would be through piling.	Aquatera experience
Visual impact	Less likely to be an issue if situated on hydroelectric based reservoirs, as opposed to natural lakes. Importance will depend upon site specific sensitivities and experiential value of the area to receptors.	Aquatera experience
Ecological		
Lake/reservoir Benthos	Installation of device anchors would result in disturbance to the benthos either through direct loss of benthic habitat or from sediment plumes which can block the respiratory systems or feeding appendages of benthic organisms. Less likely to be an issue in hydroelectric reservoirs as these tend to have limited biodiversity.	Aquatera experience
Fish	Most likely effect is attraction and aggregation around the structure (devices plus moorings) creating a 'reef effect'. In lakes devices will create obstacles to trawl fishing which will help to protect local fish stocks.	Aquatera experience
Birds	Potential for collision between turbine blades and birds, similar to that of an onshore wind farm. Would depend on the particular sensitivities of bird species and habitats at the site.	Aquatera experience

Table 13 Potential environmental impacts of inland floating solar energy

Issue	Floating solar potential impact and explanation	Source
Physical		
Lake/reservoir conditions	The introduction of floating solar devices would not be expected to significantly affect the lake or reservoir conditions.	Aquatera experience
Noise	Noise would be emitted from inverters, but would not be anticipated to result in significant impacts on species.	Aquatera experience
Visual impact	Less likely to be an issue if situated on hydroelectric based reservoirs, as opposed to natural lakes. Importance will depend upon site specific sensitivities and experiential value of the area to receptors.	Aquatera experience
Ecological		
Benthos	Installation of device anchors would result in slight disturbance to the benthos either through direct loss of benthic habitat or from sediment plumes which can block the respiratory systems or feeding appendages of benthic organisms. Less likely to be an issue in hydroelectric reservoirs as these tend to have limited biodiversity.	Aquatera experience
Fish	Most likely effect is attraction and aggregation around the structure (devices plus moorings) creating a 'reef effect'. In lakes devices will create obstacles to trawl fishing which will help to protect local fish stocks.	EIAs completed to date
Birds	As long as the ecological quality of the water is maintained and areas important for birds avoided or impacts appropriately mitigated this is not anticipated to be an issue.	Aquatera experience

Case Study 15 shows the regional guidance for offshore wind, tidal and wave energy which considers environmental, technical and socio-economic and planning issues.

FINANCE

Currently there is little in the way of support for aquatic renewable energy in Peru. For example, no subsidies have been introduced to support aquatic renewable energy technologies in Peru and there are no funding mechanisms in place for developers to conduct RD&I projects in Peru, also there are no facilities for the testing of prototypes or full-scale models located across the coastline.

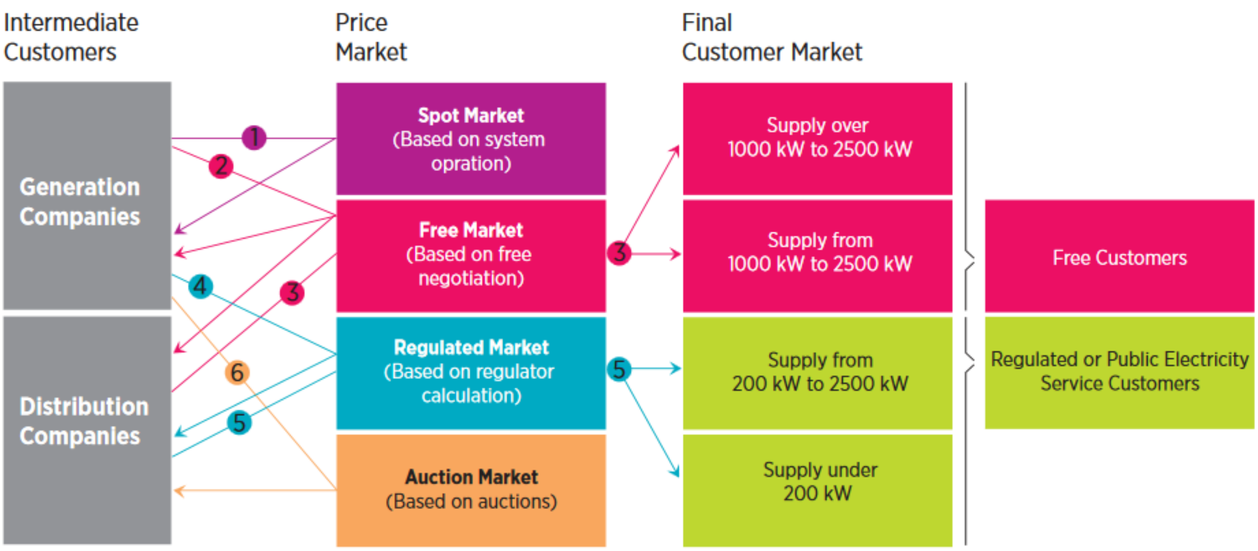
Aquatic renewable energy can compete directly with other forms of generation but early technologies such as wave will require support – both capital grants and possibly revenue support - for technology development (research and development) and for the first offshore aquatic energy farms until such time as the technology cost has reduced to a level where it is competitive with other forms of energy. Investment in aquatic renewable energy technology and projects is not isolated, an investment into the supply chain and host communities to create jobs and long-term economic growth, energy security, reducing poverty etc. is crucial.

Markets for aquatic power in Peru

The Peruvian electricity market consists of four units:

- Spot market - is operated and controlled by the Committee for the Economic Operation of the National Interconnected System (COES) that determines the conditions and prices for spot energy transactions.
- Free market - applies to transactions between generation and distribution companies as well as distribution to final customers - maximum power demand from a free customer is 200 kW. Where users have maximum power demand of 200 kW - 2.5 MW, they can choose between the free or regulated market.
- Regulated market - generating companies negotiate and sign contracts with distribution companies at a given price ceiling set by OSINERGMIN. Distribution companies can then sell electricity to customers with power demand of under 2.5 MW at rates and conditions existing in the regulated market.
- Auction market - accessible to generation companies selling electricity awarded to distribution companies in the auctions.

Figure 8 Electricity market in Peru



Source: (IRENA, 2014c)

Figure 8 displays the interaction between the four submarkets.

Following the reform of the electricity sector in 2006, auctions were adopted in Peru as the preferred mechanism for introducing cost-effective electricity rates to users. The country is therefore already familiar with auction processes. It has perfected it for large hydropower and combined cycle natural gas power plants, and has also introduced this mechanism for renewable energy with the aim to promote biomass, wind, solar and small hydro (IRENA, 2014c).

Direct supply to industrial clients

There are many coastal and inland industries in Peru that could be supplied directly with power generated from aquatic power devices, for example. Many ports, mining export terminals, desalination and water pumping or treatment plants, mariculture and aquaculture, fish flour factories etc. have their own generators on site and there is the potential for aquatic renewable energy to replace or reduce conventional generation for these clients.

Such projects could take the form of bilateral contracts at non-regulated prices, but others could involve industrial clients not connected to the grid or who own the power generation equipment themselves.

Isolated and remote communities

In Peru, 85% of the population is connected to the national power grid, the National Interconnected System (SEIN), with the remainder connected to 'isolated' systems or remaining unconnected to any form of grid electricity. Therefore a significant proportion of the rural population of Peru are paying high prices for their electricity as a result of accessing power provided by diesel generators. There is an opportunity for aquatic renewable energy to supply power to isolated communities in Peru and indeed for these projects to be community owned; bringing jobs, investment, and improvements in infrastructure, greater access to clean water and reducing extreme poverty.

Remote and low demand energy are also a possible market for aquatic renewable energy technologies. Terrestrial solar is already widely used for this purpose where grid connection is not possible. Possible uses for aquatic technologies include power for data buoys.

Current support mechanisms in Peru

Whilst there are many financial mechanisms available around the world for supporting renewable energy projects, there are certain key attributes to a 'good' financial mechanism.

Case Study 25 and Case Study 26 shows financial incentives for some aquatic technologies in the UK. One crucial element of a government sponsored incentive scheme is that of surety and in particular the requirement that the investor/developer must have confidence that an incentive mechanism once awarded will not later be arbitrarily revoked. Furthermore, properly designed incentive schemes should optimally reduce the barriers for small scale projects including introduction of reliable means and the timing of the disbursement of funding. Key to the long-term success of a project is ensuring that the proper analysis and steps are taken throughout the project at the project conceptual and development phases and in the project finance phase.

There are several tools to encourage the adoption of hydrokinetics of rivers and other renewable energy sources in Peru. While the underlying physics and engineering principles can be consistent across projects, the financial situation can vary greatly. The tools described below have different degrees of relevance depending on the scale of the projects in question. At one extreme, large-scale commercial projects, carried out by multinational corporations, can be 100 megawatts of capacity, making a strategic contribution to the national energy supply. At the other extreme, a small non-profit community organisation may aspire to install a device of a few kilowatts. It is unlikely that a single financial support structure would be appropriate for both scenarios

Support mechanisms can be considered in three broad categories:

- Market support - Measures which seek to improve market conditions (enhanced prices or price stability for electricity).
- Cost reduction support - Measures which reduce costs of development or provide access to finance.
- Project support - capacity building, advice, pump priming and administrative support.

Currently, the unit costs of most aquatic technologies is higher than other forms of renewable power generation. This is understandable when considering the relatively early stage of development of these technologies and that the level of deployment currently seen across the globe is not very high albeit growing rapidly annually.

The auctions that have already taken place in Peru were particularly influenced by the projected continuing price reduction in wind and solar technologies. In the near future it will not be possible for some aquatic power generation technologies to match these. If for example, wave power generation is going to play a significant role in the future power generation in Peru then a level of support or incentive will be required prior to the Levelised Cost of Energy (LCOE) achieving a more competitive level.

In the report produced by the Carbon Trust, 'Future of Marine Energy' (Carbon Trust, 2006) data and conclusions are presented to discuss the trends and projections in the cost of renewables in the marine environment. The report identifies the importance of these technologies being cost competitive with other renewable energy generation technologies (i.e. onshore wind, solar, etc.). The best means of accomplishing this, as highlighted within the report, will be through economies of scale. Deploying multiple devices will reduce costs associated with construction, deployment, maintenance and decommissioning. It is also acknowledged that the value of learning is still very high in these emerging fields. The experience gained from deploying every additional device will benefit the deployment of the next. The other highlighted area holding the potential for cost reduction is within the conceptual and detailed design phase, where component design can be optimised either prior to fabricating or through prototype testing.

In order to support these projected areas of cost reduction development strategies should lay out steps to achieve these in an appropriate order and time-scale. For example:

- Supporting RD&I projects that have the capacity to develop technologies appropriate for Peru's marine environment prior to fabrication, as well as supporting the deployment of scaled devices to promote iterative design development prior to full-scale fabrication.
- Evaluate the capacity across Peru's coastline for large scale multi-device array deployment that will then support capacities of scale.
- Support mechanisms for promoting knowledge sharing to minimise independent developers covering the same areas independently where it would be in the interest to share experiences, where not commercially sensitive.

Inland aquatic renewable energy deployments may take place in areas where the grid infrastructure is already in place, for example developing a floating solar project in the water reserve of a hydro plant where most of the infrastructure needed is in place may already become competitive with conventional solar plants.

The river hydrokinetic resource is be distributed across inland rivers and waterways, which will also be dispersed throughout regions of little to no grid connection. Establishing off-grid solutions will maximise the level of deployment possible throughout the country; which could also provide power to additional markets such as desalination and fisheries.

Case Study 27 shows The Applecross micro hydro project, located in the northwest Highlands of Scotland involving a community where hundreds of individuals invested in the scheme to raise almost £800 k. It is valuable as a case study in highlighting a number of project development issues.

NICHE MARKETS

Whilst the ultimate goal for aquatic technologies is to provide mass produced energy such as grid supplied electricity there are a number of potential obstacles and barriers that need be overcome before that can happen. The fundamental factor is the cost of energy produced from aquatic sources. The energy produced needs to be price competitive in energy markets. Mass energy markets, particularly those supported by grid supplied electricity, are often the cheapest energy markets.

The problem for aquatic energy to date has been that in many situations it is not the cheapest form of energy supply. The recent depression in oil prices has meant that energy from oil and gas has become cheaper. The maturity and great expansion in onshore wind, offshore wind and onshore solar energy has brought those technologies towards prices comparable with traditional energy supplies. Newer aquatic energy technologies such as wave, RHK and floating solar are generally less mature and with the added costs of operating in and on water often are more expensive than onshore alternatives. However, over large and diverse geographical energy markets there may in fact be opportunities where local aquatic based energy supplies are technically and from a cost point of view competitive or even advantageous. For each of the markets discussed below it is important to understand what the driver is to move these sectors towards renewable energy sources:

- Price – the current alternative for some remote communities/uses may currently be diesel generators in which case aquatic renewable energy may be able to provide cheaper energy.
- Remote or off-grid solutions (communities which currently do not have a source of electricity) - aquatic renewable energy may be able to provide access to energy where otherwise none would exist otherwise.
- Decarbonisation – for some energy uses the driver may be to decarbonise their energy supply.

For example, opportunities for aquatic energy may exist where:

- An isolated village, town or city in the middle of a jungle type habitat with extreme pressure on available land.
- Existing hydro energy infrastructure can be added to by extra aquatic based generation capacity.
- Remote and low demand energy uses lie next to usable aquatic resources (data buoys etc.).
- Cheaper energy could be provided for remote communities.
- A premium price may be paid by a customer for using renewable energy from aquatic sources (e.g. luxury coastal hotels).

These types of markets are often referred to as niche energy markets. They tend to be smaller and more isolated than mass energy markets, but they may provide a better price for supplied energy and they may move towards new technology solutions faster than mass energy markets.

Within Peru there are various niche energy markets that aquatic energy may be suitable for. Taking into account the distribution of activity, the scale of activity and the availability and price of existing energy supplies the following niche markets have been taken forward as the primary focus of this study:

Fisheries, aquaculture and mariculture industry

Within the fisheries sector there are two major sources of energy use, the use of fuel by fishing vessels and the energy used for onshore fish processing. The use of diesel and marine oils for vessel propulsion is not considered further here although the conversion of fishing vessels to alternative less carbon rich, or even carbon free fuels is a major area for future carbon management. Rather the focus is upon the fish processing activities which include freezing fish, canning fish and the production of fishmeal and fish oil.

Peru is a major producer of fishmeal and fish oil (FMFO). The Peruvian FMFO sector produces in average (2006 - 2015) 1.183 million tonnes of fishmeal and 230,000 tonnes of fish oil per year, which represent 24% and 23% of the global production, respectively.

The modern steam plants consume both heavy fuel and natural gas when available. Both residual and traditional plants mainly use heavy fuel as their energy source. There are a total of around 170 fishmeal plants operating in Peru, which correspond to a total processing capacity of around 9,300 t/hr. These plants are located all along the Peruvian coast, with concentrations close to the main fishing harbours of the largest coastal cities (Chimbote, Chancay, El Callao and Pisco).

Generic energy consumption for the processing of 1 ton of raw fish for processed human consumption is estimated to be 1,760 MJ of heat and 33 kWh of electricity, a total of around 510 kWh (Pierre Freon, 2017), whereas fishmeal production requires 268 kWh of electricity per ton of feed produced (Avadí, et al., 2012).

The fish catch for human consumption is typically in the region of millions of tonnes as is the catch for fishmeal processing. Applying these energy demands to the annual production levels (assume 3 million tonnes each) gives an estimated energy demand of around 2,400 GWh for the fisheries sector in Peru.

The aqua/mariculture industry is a potential market for aquatic renewable energies due to the location of the production units besides or in water bodies and its high consumption of energy. In Peru, most of the energy required for fish farms is currently produced by local diesel generators. In remoter areas the transportation and storage costs for diesel can become very high. It would therefore be expected there may be a premium price available for aquatic energy provision at the remoter sites. The scale of production may also be a significant factor, smaller scale subsistence type fish farms may not have a strong existing demand for energy, whilst larger facilities may have processes and fish husbandry activities that do require and use more energy. It is the combination of larger and remoter sites that may hold most short-term opportunities.

See Map 10.1 showing the distribution of these aquaculture and mariculture locations and their scale (Appendix C).

Mining and quarrying

According to a report from the MINEM published in 2016, the total energy consumption of the mining sector in 2013 was 16,765 GWh (about 8% of the total energy consumption in Peru), out of which 10,927 GWh were electricity (over 28% of the national electricity consumption). The mining sector is a prime target for aquatic energy supplies because of its economic scale, the high value of the products produced and the ever increasing demand for smarter more sustainable production systems.

See Maps 10.2 and 10.3 showing the major existing mining projects and potential mining sites (Appendix C).

Vessels

River and maritime transportation is another opportunity for systems powered by renewable energies. Different technologies exist and are currently in use in several countries. For example, these can use electricity directly as a fuel, as in batteries, or use it to produce a new product such as hydrogen (via an electrolyser). Hybrid systems are also partially powered by electric systems.

Batteries

Electrical power has been powering and assisting ship propulsion for many years. However, this has nearly always been sourced from on-board diesel generators providing exactly the power at that moment to meet manoeuvring requirements. As additional technologies continue to develop they become a feasible contribution into the propulsion system either reducing the amount of diesel required, through efficiency maximisation; or removing the requirement completely, through the use of alternative energy storage mediums.

Electrical battery driven systems refer to the sole use of electrical propulsion powered by energy held within on board battery banks. Different kinds of batteries exist: lead-acid, nickel-cadmium, nickel-metal hybrid, lithium-ion, zinc-air, sodium-sulphur, sodium-nickel chloride. Lithium-ion are the kind of batteries used the most in transportation as they have the highest energy density (200 - 400 Wh/L) and a longer life, constituting a perfect opportunity for renewable energies, but there are very few working examples of this technology to date.

Some examples of full electric vessels:

- Medium scale: Norled's *Ampere* passenger (and vehicle) ferry in Norway using two lithium-ion batteries (Case Study 28).
- Small scale: JiriJiri project in Colombia offering an efficient and sustainable means of transportation for children to go to school, see Figure below.

Figure 9 Training with electrical boat motor, JiriJiri project

Hydrogen

Hydrogen can be produced biologically (e.g. through anaerobic digestion) or by electrolysis, the latter consists in running electric current in a solution (e.g. water) to separate the molecules of fluid and free hydrogen ions. Hydrogen can be used in the liquid or gaseous form to power directly a transportation system or to produce electricity via fuel cells.

There are several examples of the production and use of hydrogen (see Case Study 29 and Case Study 30). The Technology Roadmap developed by IRENA (Case Study 31) covers the use of hydrogen as an energy storage medium, and fuel cells as a means of power production across a number of sectors.

Electric-driven hybrids

Electric hybrids combine an internal combustion engine with a battery and electric motor. This combination offers the range and refuelling capabilities of a conventional vessel, while providing improved fuel economy and lower emissions. This system also offers the backup capability if the batteries run out of charge. Plug-in hybrid electric systems are similar to traditional hybrids but are also equipped with larger, more advanced batteries that allows the vessel to be plugged in and recharged in addition to refuelling with diesel.

Electric hybrids are powered by an internal combustion engine or other power sources that can be run on conventional or alternative fuel and an electric motor that uses energy stored in a battery. Hybrid electric vessels combine the benefits of high fuel economy and low emissions with the power and range of conventional vessels. There are a number of examples of this type of system and they are readily available on the market.

Example of electric hybrid vessel:

- Medium scale: Two hybrid electric ferries run by Caledonian MacBrayne operate on the west coast of Scotland.

Rural electrification

Peru has achieved a coefficient of electrification of 93.3% at national level and 78% in rural areas in 2015 but there is a large disparity issue between urban areas mainly along the coast and the more rural areas such as the Amazon and Andes. It is generally assumed at present that grid connection is the primary or first approach to electricity supply. This judgement is usually made due to the continuity and security of supply which is usually delivered through a grid mechanism. However, in a country such as Peru there can be technical, economic and bureaucratic hurdles to overcome to enable further grid connection to be made.

The first alternative strategy adopted by MINEM has been to prioritise the use of solar energy as a secondary technological option to rural electrification. This is achieved through the implementation of photovoltaic systems for domestic or communal use in geographic areas with suitable solar potential, such as in the Andean highlands and Amazonas jungle areas.

DGER in recent years has increased the number of projects based on photovoltaic solar energy, primarily driven to meet basic energy needs in isolated, rural and border areas, using domestic solar panels and community scale projects to provide electricity to homes, communal premises and public institutions, as appropriate.

Currently MINEM has a massive solar panel program providing 500,000 solar panels to rural communities (MINEM, 2014). Floating solar onshore and offshore would open a new scenario for remote communities struggling with land issues.

Finally, floating wind energy is the third option and its application is being evaluated for the purpose of rural electrification in areas preferably located in the intermediate valleys and near the coast.

As an alternative solution for rural electrification small hydropower is often used. Case Study 32 shows some of the challenges faced in the development of micro hydro projects in Scotland. In Peru, this solution is mainly used in areas located in the Andes on both the eastern and western slopes where there are adequate water resources and waterfalls. River hydrokinetic technologies could also provide electricity and water supply to remote communities in other areas of Peru as is shown in Case Study 33.

See Map 4.1 showing the population density of Peru (Appendix C).

Desalination

One of the most obvious sector combinations is wave power coupled with desalination because, in most cases, the two main components of wave energy and sea water are available in abundance and at the same location.

The advantages of using wave energy can be achieved by pressurising sea water directly in the hydraulic power take-off used in many wave energy converters. This avoids the conversion of the energy from hydraulic to electrical and then back to hydraulic, eliminating the need for a hydraulic turbine/motor, an electrical generator, an electrical motor and a hydraulic pump (Folley, et al., 2008).

The current wave-powered desalination technologies are based on modifications of wave energy technologies designed for electricity production. Therefore, they are typically relatively large with unit capacities in the range of 500 – 5,000 m^3/day. Thus, the primary target of wave-powered desalination plants is municipal-scale water production. The co-generation of fresh water and electricity by wave power is also being actively developed. While smaller desalination units (less than 500 m^3/day) are technically feasible, the development effort for the smaller capacity units is modest at present. A number of past and present wave power concepts have proposed the production of desalinated water, including:

- Carnegie Corporation Ltd – CETO desalination technology.
- Aquamarine Power Ltd - Oyster desalination technology.
- Oceanlinx Ltd – OWC desalination technology.
- McCabe Wave Pump.
- Atmocean.

All of these technologies are/were based on the direct pressurisation of sea water (avoiding the generation of electricity) that is then fed into a reverse osmosis desalination plant to produce fresh water (PRODES, 2010).

REGIONAL ASSESSMENTS

For each of the four aquatic renewable energies considered, assessments of resource potential, technical conditions, enabling infrastructure and market availability/value were undertaken. This initial analysis suggested that compared to other countries, Peru has excellent solar energy resources, moderate river hydrokinetic resources, moderate but attractive wave energy resources and rather limited offshore wind potential.

Based upon the methodology outlined above regional assessments of potentially exploitable resource areas were established using Aquatera's in-house RADMAPP geographical information system. The different potential development areas were subsequently evaluated to determine what percentage of the identified area could be expected to be developed and with what density and operational efficiency under the hypothesis of a baseline scenario. These factors were applied to the potential development area for each specific technology class. In turn, an additional analysis was conducted to establish the high and low capacity scenarios, the two extremes of the baseline scenario.

See Map 11.1 showing the regions analysed in this section (Appendix C).

Medium capacity (base case) scenario

The results of this base case analysis suggest that the potential for floating solar deployments on coastal lagoons and large lakes and reservoirs lying in grid connected areas is very large. In terms of overall energy supply, the most productive resource/technology sector is floating solar which accounts for around 69% of the predicted installed capacity and some 64% of the predicted power output in this scenario. The next most productive resource/technology area could be offshore wind if developments were shown to be possible in the moderate winds and relatively deep waters found off the coast of Peru. Wave energy may be the next most productive area once these technologies are commercialised. Although river hydrokinetic technology area is estimated to have the lowest installed capacity this estimate is minimised since only candidate rivers have been analysed rather than all rivers. Nevertheless, there is still significant capacity predicted and this technology is already being installed now. In addition whilst these river hydrokinetic projects may be small they can also be important for specific communities that have few other options for energy and especially renewables generation. In this medium capacity scenario, aquatic renewable energy could contribute the equivalent of around 50% of Peru’s current electricity demand by 2037.

High capacity scenario

The application of the high capacity assumptions lead to tripling the installed capacity and the annual generation estimates compared to the base case. The largest increase in capacity and power output is predicted to arise in the floating solar area, with four fold increases envisaged. There are lesser, three fold, but still significant increases in the offshore wave area and lesser, doubling, increases in terms of river hydrokinetic and offshore wind. Such a high yield scenario would provide the equivalent of around 200% of Peru’s present electricity output.

Low capacity scenario

By contrast the application of the low capacity assumptions would reduce the estimated capacity and generated power by half from 22,000 GWh to 11,000 GWh as shown in Table 14. Nevertheless, even under this low capacity scenario the capacity and output could still make a major contribution to Peru’s growing energy needs. The predicted levels of output would be equivalent to around 20% of Peru’s current electricity production.

Table 14 Estimates of total potential installed capacity and annual power generation by 2037

Resource	Development area by region (km² or km)							
	Scenarios	Total available resource area (km² or km)	Development potential	Practical area	Capacity per unit area (MW/km² or MW/km)	Installed capacity (MW)	Capacity factor (%)	Energy output (GWh)
Grid connected large scale floating solar (km²)	Low	4,724	1 – 5	54	50 - 100	3,109	15 - 25	6,040
	Medium	4,724	1 – 10	62	100	6,218	15 - 25	12,080
	High	4,724	5 – 10	245	100	24,450	15 - 25	51,735
Off-grid and micro-grid floating solar (km²)	Low	2,498	1	25	2 – 50	388	15	506
	Medium	2,498	1	25	5-100	794	15	1,036
	High	2,498	2 – 5	71	5-100	3,699	15	4,827
Grid connected river hydrokinetic (km)	Low	529	10	53	1	53	60	276
	Medium	529	10	53	2	106	60	552
	High	529	10	53	4	212	60	1,105
Off-grid and micro-grid river hydrokinetic (km)	Low	30	10	3	1	3	50	13
	Medium	30	10	3	2	6	50	26
	High	30	10	3	4	12	50	52
Offshore wave (km²)	Low	894	5	45	10	447	40	1,556
	Medium	894	10	89	10	894	40	3,111
	High	894	10	338	12	3,384	40	9,610
Coastal wave (km²)	Low	148	5	7	10	74	20	129
	Medium	148	10	15	10	148	20	258
	High	2,638	10	15	10	148	20	258
Floating wind (6 - 7 m/s) (km²)	Low	7,652	5	383	5	1,913	20	3,329
	Medium	7,652	8	574	5	2,870	20	4,993
	High	7,652	10	765	5	3,826	20	6,657
Overall total	**Low**	**16,475**		**569**		**5,987**		**11,848**
	Medium	**16,475**		**821**		**11,035**		**22,055**
	High	**18,965**		**1,490**		**35,730**		**74,243**

The results show that the greatest resource areas are to be found at sea in the Pacific North and Central regions and in inland lakes and reservoirs in the Atlantic North and Titicaca regions. The exploitable resource areas identified in the Pacific South, Atlantic Central and Atlantic South are still significant but noticeably lower.

See Maps showing Aquatic Resources: 11.2 Pacific North, 11.6 Pacific Central, 11.10 Pacific South, 11.14 Atlantic North, 11.18 Atlantic Central, and 11.22 Atlantic South

See Maps showing Infrastructure and Supply Chain: 11.3 Pacific North, 11.7 Pacific Central, 11.11 Pacific South, 11.15 Atlantic North, 11.19 Atlantic Central, and 11.23 Atlantic South

See Maps showing Niche Markets: 11.4 Pacific North, 11.8 Pacific Central, 11.12 Pacific South, 11.16 Atlantic North, 11.20 Atlantic Central, and 11.24 Atlantic South

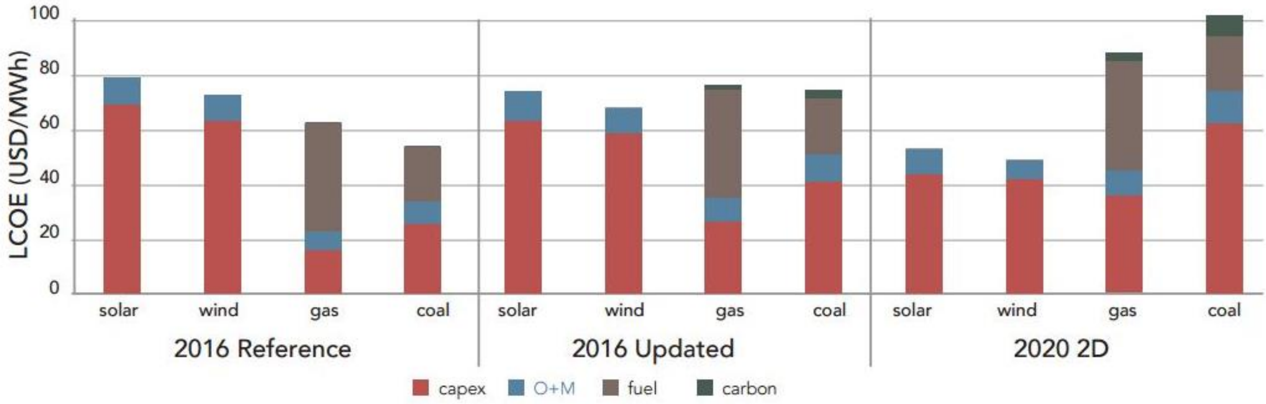
See Maps showing Development Potential: 11.5 Pacific North, 11.9 Pacific Central, 11.13 Pacific South, 11.17 Atlantic North, 11.21 Atlantic Central, and 11.25 Atlantic South

POSSIBLE GROWTH SCENARIOS

The potential role of aquatic renewable energy

The National Energy Plan 2014 - 2025 of Peru (Plan Energetico Nacional 2014 - 2025, (MINEM, 2014)) requires that expected increases in final energy consumption be met with national rather than imported energy resources, and at competitive cost. In the short-term it is expected that most of this demand will be satisfied with natural gas, requiring further construction and modernisation of gas pipelines, refineries and other infrastructure. However, given the additional needs and commitments to tackle climate change, extend rural electrification, reduce local pollution, electrify transportation systems and meet the UN Sustainable Development Goals it is likely that renewable energies will need to play an increasingly important part in Peru's energy mix. This likelihood is further increased by the fact that the costs of electricity from renewables such as solar and wind have fallen dramatically in recent years, as more and more GWs of capacity have been built internationally. For example, Figure 10 shows that solar and wind can be cost competitive with coal and gas now, and that by 2020, even very low hydrocarbon prices would not tip the advantage back to fossil fuels.

Figure 10 Comparison of LCOE results across all scenarios



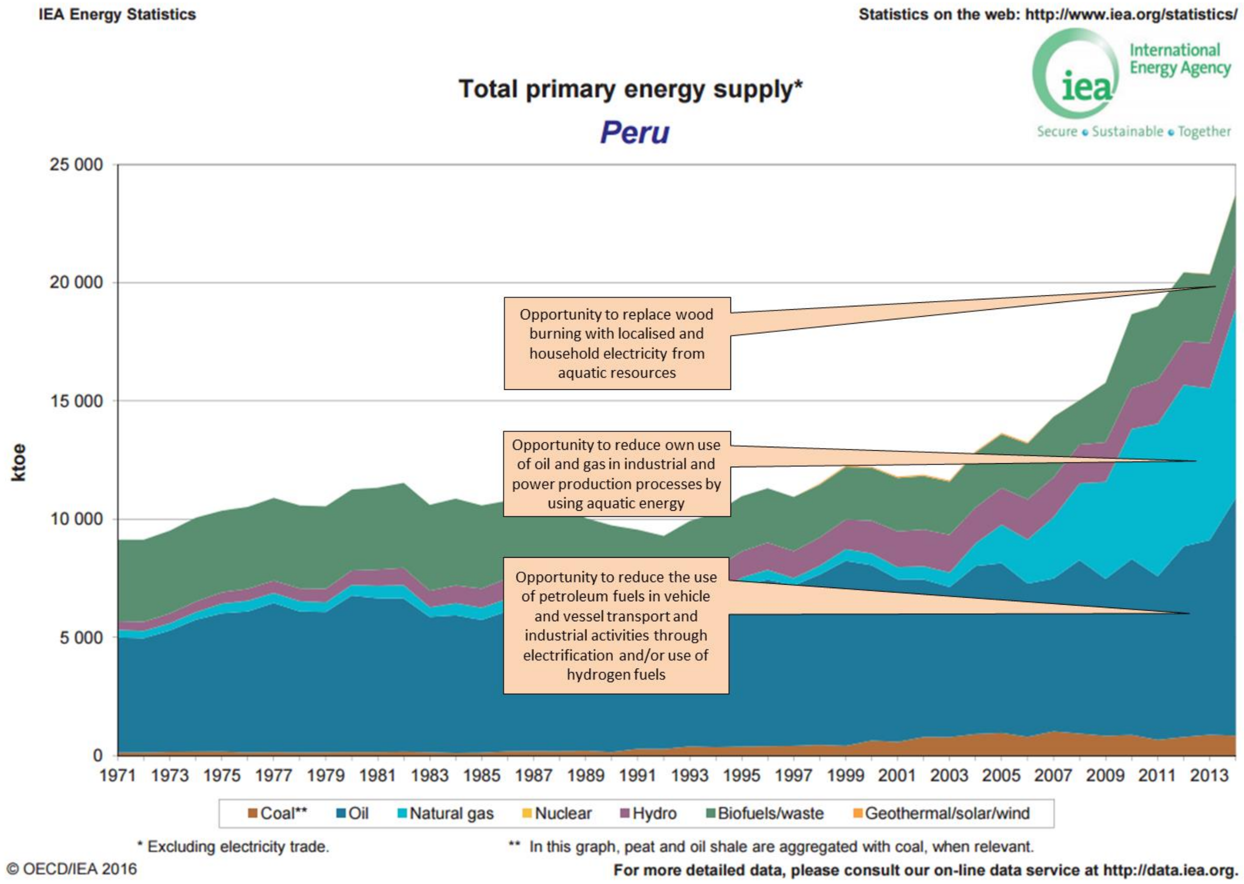
Source: (Carbon Tracker, 2016)

COP 21, the Paris climate change agreement reached in December 2015, provides further momentum for the move towards renewable, carbon free sources of energy. Although this change will not happen overnight it is also clear that any reliance on gas or indeed other carbon based energy sources will now at best be transitional towards a more sustainable energy system.

The key question to be answered in this study is whether aquatic energy resources can be expected to contribute to the decarbonisation of the energy supply in Peru? If so, then the next questions are where, by how much and when? The following analysis first considered whether aquatic energy could make a contribution to the existing energy mix in Peru and then goes on to consider how that contribution would be aligned with other contributions to the overall energy mix through to 2037.

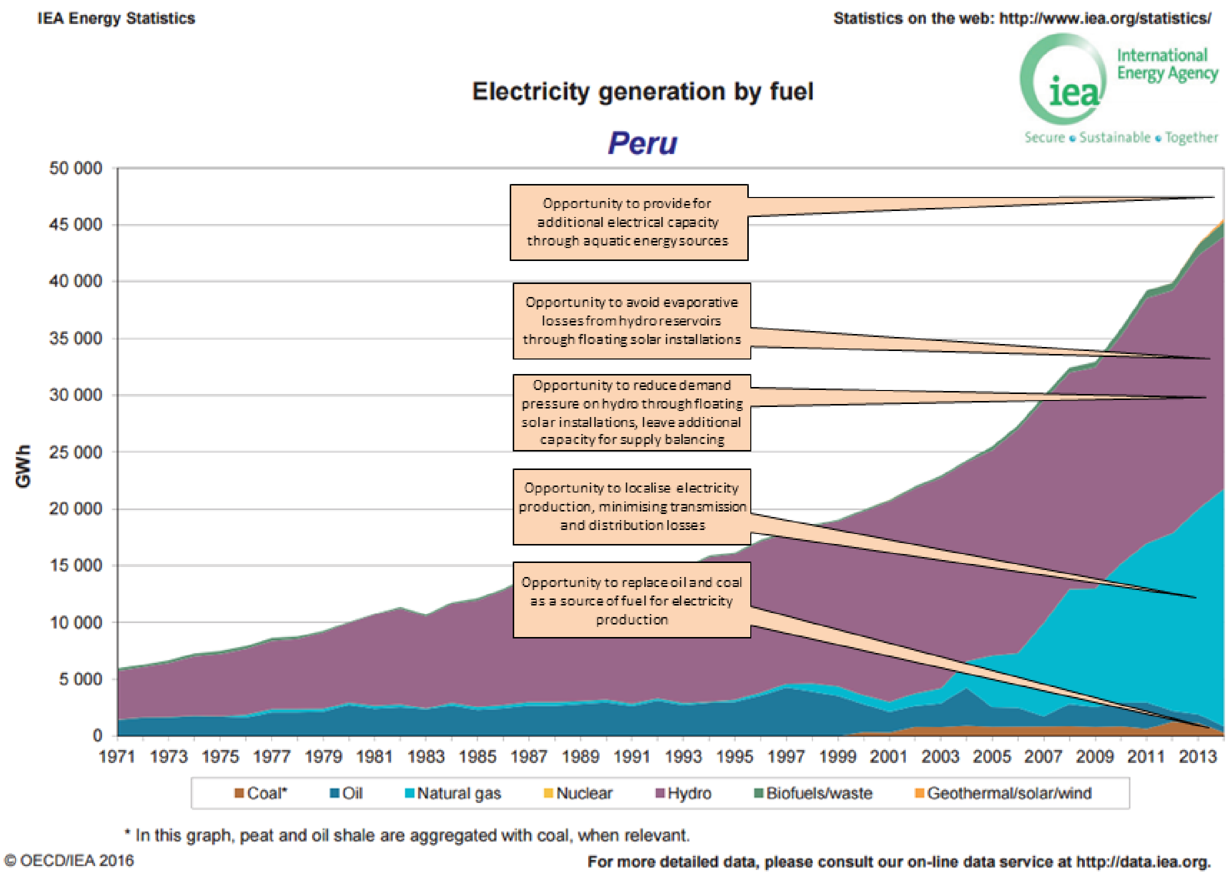
The previous regional resource assessment chapter of this report showed the widespread availability of aquatic energy and also the particular geographical hot spots where key resources may lie. Here the existing energy supply pattern is considered and the contributions which could be made by aquatic energy are highlighted for both the total energy scenario (see Figure 11) and also the electrical supply scenario (see Figure 12).

Figure 11 Aquatic energy opportunities for energy supply in Peru (total energy supply)



Revised from (IEA, 2017)

Figure 12 Aquatic energy opportunities for electricity generation in Peru (electricity supply)



Revised from (IEA, 2017)

It can be seen from Figure 11 and Figure 12 that aquatic technologies have the potential to support different industries, communities, and regions in various ways.

Floating and fixed wind

Offshore wind is one of the most developed aquatic technologies to be evaluated. In Peru there are possible deployment area but these are mostly at depths suitable for floating wind technology rather than founded wind technologies. However, the level of wind resources indicated for the offshore waters of Peru are at the low end of what is generally considered viable for cost effective offshore wind production. It is therefore uncertain whether a business model can be made for offshore wind in Peru at prevailing market prices. Should any such wind capacity be possible to develop, the energy markets that it could serve would be similar to those associated with wave technology, namely:

- Desalination of seawater to provide industrial freshwater and/or drinking water supplies.
- Replacement of gas and oil for domestic and industrial energy supply.
- Replacement of petrol and diesel for vehicle and vessel transport.
- Contributing to the phasing out of coal based power generation for electricity supply.
- Contributing to the improved management and use of hydro resources by reducing demand and offer opportunities for pump storage solutions.

Wave energy

Generation of energy from waves is still an emerging technology, but the prize of achieving viable energy generation from this source could be major on a global scale and has particular opportunities for Peru where its Pacific coast is exposed to one of the most dynamic and regular wave regimes in the world. The waves along the Peru coast are not as large as those in Chile, nor those in the north off Alaska and British Columbia. The wave regime is however significant and very regular.

Peru could therefore offer some opportunities for early technology deployment given the rather benign wave regime, but the main challenge is the market rates for energy along the coast which tend to be rather low due to the available grid supply infrastructure. The regularity of any generated energy may however hold some additional value for an integrated low carbon energy system.

The particular roles that wave energy could provide within the overall energy supply and energy management mix includes:

- Desalination of seawater to provide industrial freshwater and/or drinking water supplies.
- Replacement of gas and oil for domestic and industrial energy supply.
- Replacement of petrol and diesel for vehicle and vessel transport.
- Contributing to the phasing out of coal based power generation for electricity supply.
- Contributing to the improved management and use of hydro resources by reducing demand and offering opportunities for pump storage solutions.

It is important to note that wave energy generation is not as well developed as wind, hydrokinetic or solar power generation. Consequently, if Peru is to pursue wave energy as part of the short-term energy mix the country may have to play a role in the early development and demonstration of this sector. If the early adopted role was taken up there may be additional opportunities arising from the development of this technology sector, conceivably with a range of engineering and manufacturing opportunities as well as future local deployment market opportunities and wider export potential. Such a proactive role is however not essential for Peru and a more pragmatic strategy of providing opportunities for the deployment of proven technologies may well be a better fit with the overall industrial and economic strategy for Peru at this time.

It would be relevant to engage with the wave energy sector as it advances so that suitable demo and project opportunities are available as the technology matures. This will ensure that Peru can benefit from the significant advances being made in the sector internationally.

Case Study 36 shows the experience of Atmocean testing their technology in Ilo (Peru).

River hydrokinetic

River hydrokinetic energy is the most complex of the energy resources to estimate given the wide variation in site conditions, the strong seasonal cycles in possible output and the lack of available data about seasonal river flow conditions at different sites. However, with the right set of local conditions river hydrokinetic could be an almost continuous source of energy, although the rate of output may still vary with current strength through the year. The problem at present is the lack of site specific data and the related fact that it is virtually impossible to generalise and model conditions effectively without site specific data.

From an impact and operational viability point of view there are several benefits of river hydrokinetic technology that do not exist by comparison with alternative and large scale hydro power schemes. For example, while theoretically river hydrokinetic is more expensive to build per MW than larger hydro schemes, the river hydrokinetic approach may allow for more sustainable, lower-impact projects by limiting the amount of land required for reservoirs and by maintaining the natural flow of the river and allowing the river to remain unobstructed for navigation and transport. In such a country such as Peru with very important biodiversity as well as energy resources, such lower impact approaches may be particularly useful and may attract some backing from the national or the regional governments.

The role that river hydrokinetic energy could provide within the overall energy supply and energy management mix includes:

- Replacement of wood burning in remote and rural areas.
- Replacement of direct use of gas and oil for domestic, public and industrial use through grid connected or off-grid electricity supply.
- Replacement of fuel oils for road transport and water transport, through electrification and/or the use of alternative fuels such as hydrogen.
- Provision of local new or additional off-grid, micro-grid energy sources.
- Better management in the use of hydro resources by providing a source or energy for creating new or additional pump storage capacity.

Floating solar energy

The regional analysis of floating solar potential showed that there were opportunities for this form of energy production in a number of settings. These settings include deployment of natural lakes and relict river meanders, on man-made water supply and hydropower reservoirs, on coastal lagoons, on sheltered coastal embayment's and in the lee of coastal islands. Finally such technology could also possibly be deployed on rafts in larger river systems and flood areas. The spatial spread of these sites reaches across all parts of Peru, with some potential in each study region but the greatest potential capacity and the most productive area in terms of solar radiance would be in the Titicaca region and specifically associated with Lake Titicaca itself. The development of a small proportion of the lake, at an optimised location or set of locations could provide the largest single source of aquatic energy in Peru. There are however many other smaller scale locations which may have particular local importance and for many off-grid communities in the high Andes or Amazon jungle the adoption of floating solar solutions may provide the only low impact source of energy available to them Such deployments may however be at the kilowatt (kW) rather than the megawatt (MW) scale.

One factor that needs to be considered with regards to any floating solar deployments is the periodicity and variability of the generated energy. Obviously there will be a strong daytime/night-time cycle of energy output but there will also be variability due to the position of the sun during the daytime, any shading from trees, buildings or surrounding land, the amount of cloud cover and possibly the amount of reflected energy arising from any nearby free water surface. These will lead to site by site variation and may also lead to a requirement for some kind of back-up energy supply or for a form of energy storage to be incorporated into the overall energy system. Such integrated and balanced total energy supplies based around solar are now becoming more widely established. Especially as energy storage prices as well as solar generation prices are reducing drastically.

The role that floating solar energy could provide within the overall energy supply and energy management mix includes:

- Replacement of wood burning in remote and rural areas.
- Replacement of direct use of gas and oil for domestic, public and industrial use through grid connected or off-grid electricity supply.
- Replacement of fuel oils for road transport and water transport, through electrification and/or the use of alternative fuels such as hydrogen.
- Provision of local new or additional on-grid, micro-grid or off-grid electricity supply.
- Reduction in evaporation losses of water from reservoirs and lakes.
- Better management in the use of hydro resources by providing an alternative daytime supply of energy and potentially by providing a source or energy for creating new or additional pump storage capacity.

STRATEGIC OVERVIEW

The diversity of Peru's geography with major inland water bodies and its extensive coastline present the country with an exciting opportunity to play an active role in the development and commercial-scale utilisation of aquatic energy, with potential benefits far beyond the increased energy generating capacity. The use of aquatic renewable energy systems can also provide additional benefits such as employment opportunities, industrial capacity building, wealth creation and improved infrastructure.

The strategies adopted to exploit the various aquatic energy opportunities can be extremely varied and disparate between the various technology types. The types of strategies include:

- Pioneer strategy – being the first to encourage, develop and deploy technology.
- Enabler strategy – provide all the support needed to attract innovative technologies early in the deployment cycle.
- Early adopter strategy – provide opportunities for the early deployment of newly established technology.
- Commercial application strategy – let aquatic technologies compete against existing generation systems without additional support.
- Niche market strategy – use aquatic energy for specialised situations where alternatives are difficult to deploy and the market price for energy is relatively high.
- Mass market strategy – use aquatic energy to supply large scale grid connected electricity at market competitive rates.
- No development strategy – do not develop aquatic energy for a specific situation and focus upon other energy sources instead.

The decision needs to be made as to which of these strategies can best be applied to any of the resource categories and the various regional contexts analysed in this study. It may be for example that a particular technology makes more sense as a priority in one region or another. It may also be that a specific technology becomes a priority because of the critical mass that can be achieved across a number of regions. Alternatively the timescales for technology adoption and related infrastructure developments such as expanding electricity transmission networks, improving road access, bridge and port building etc may all influence the viability and make up of energy provision. The very specific location of large energy demand sites such as for mining with nearby resource potential may also be a key driver.

Underpinning all of this strategic and project specific decision making will be the life cycle cost of the energy produced. As was shown earlier it is anticipated that certain forms of onshore renewables will become cheaper than traditional hydrocarbons in the open market over the next few years. Some of the aquatic technologies, namely floating solar and offshore wind are also considered likely to reach price parity with carbon based energy sources in the near future, where resources are suitable. Small scale, river hydrokinetic may also soon approach price competitiveness in remoter off-grid situations. It may take longer for wave energy to reach a price competitive point.

Whilst it is not absolutely certain that aquatic energy has a key strategic role to play in Peru's future energy mix it is believed that this study has shown that there could be a significant clean energy dividend from adopting appropriate aquatic energy solutions. Furthermore some of these solutions are rather well aligned with the geographical, infrastructure, social, ecological and economic settings within which such energy supply needs to be made. If Peru did adopt some or all of the aquatic energy opportunities that it has it would not be alone in that endeavour. Other countries and wider economic groupings such as South East Asia's ASEAN and the European Union (EU) are also considering the adoption and prioritisation of aquatic energy within their overall energy mix.

Possible energy sector growth estimates

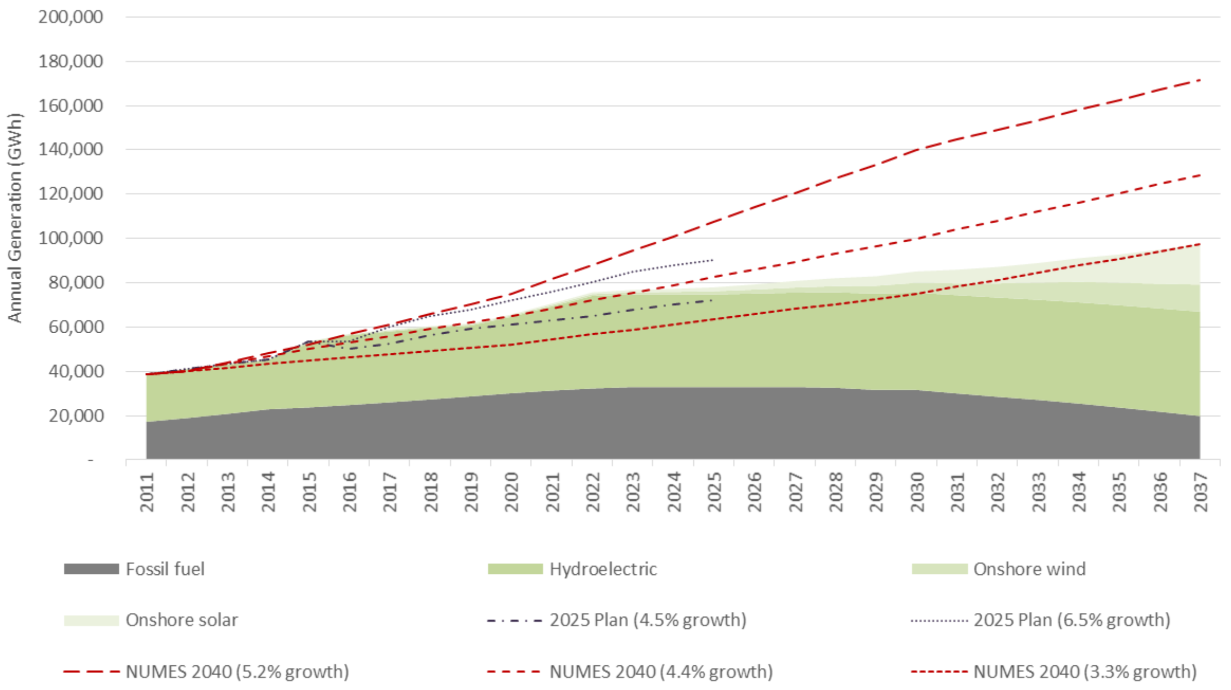
It is very difficult to accurately forecast what the future level and structure of the energy market in Peru may be and also the possible contribution that aquatic renewable energy technologies may be able to make to that energy demand and mix. In Peru the political climate and regulatory regime may support or hinder developments, technological advances may make some technologies more competitive and others obsolete. The future cost of wave energy is particularly uncertain, but even more established technologies such as floating solar and offshore wind are vulnerable to disruptive new technologies and changes in commodity prices.

Peru's National Energy Plan for the period 2014 to 2025 considers annual average economic growth of between 4.5% and 6.5%. Between 2013 and 2025 primary energy use was expected to rise from around 700 peta joules (PJ), to somewhere between 1,300 and 1,800 PJ depending on the economic growth rate and extent of energy efficiency measures deployed. This study estimates that total electricity generation in Peru may grow from its current level of around 60,000 GWh/yr to around 72,500 GWh or 90,500 GWh/yr by 2025 (Figure 13).

A 2012 study considering a sustainable energy mix and strategic environmental impact assessment (*Elaboracion de la Nueva Matriz Energetica Sostenible y Evaluacion Ambiental Estrategica, NUMES*) considered the future evolution of Peru's energy sector over the period 2011 to 2040. This study considered three different economic growth rates of 3.3%, 4.4% and 5.2% and suggested that primary energy use in Peru could grow relatively linearly from 700 PJ in 2013 to just under 1,800 PJ in 2040. Figure 13 shows how the longer term forecasts for electricity generation in the NUMES report (CENERGIA, 2012) compare to the estimates in Peru's 2025 plan.

Historic generation data and the forecasts from these reports were used to develop a base case for the growth of onshore fossil fuel and renewable electricity generation in Peru, considering ongoing growth in onshore renewables and a reduction in fossil fuel generation from the mid-2020s onwards. As Villacorta (Villacorta, 2016) has highlighted, the NUMES study (and others) propose that in 2040 Peru will continue to source more than 70% of the country's primary energy from fossil fuels. This is inconsistent with the requirements to reduce carbon emissions and safeguard finite resources for future generations, so a more sustainable base case has been assumed here (Figure 13). In any case for this report, the purpose of this base case is simply to provide a benchmark against which the growth of aquatic renewables can be compared.

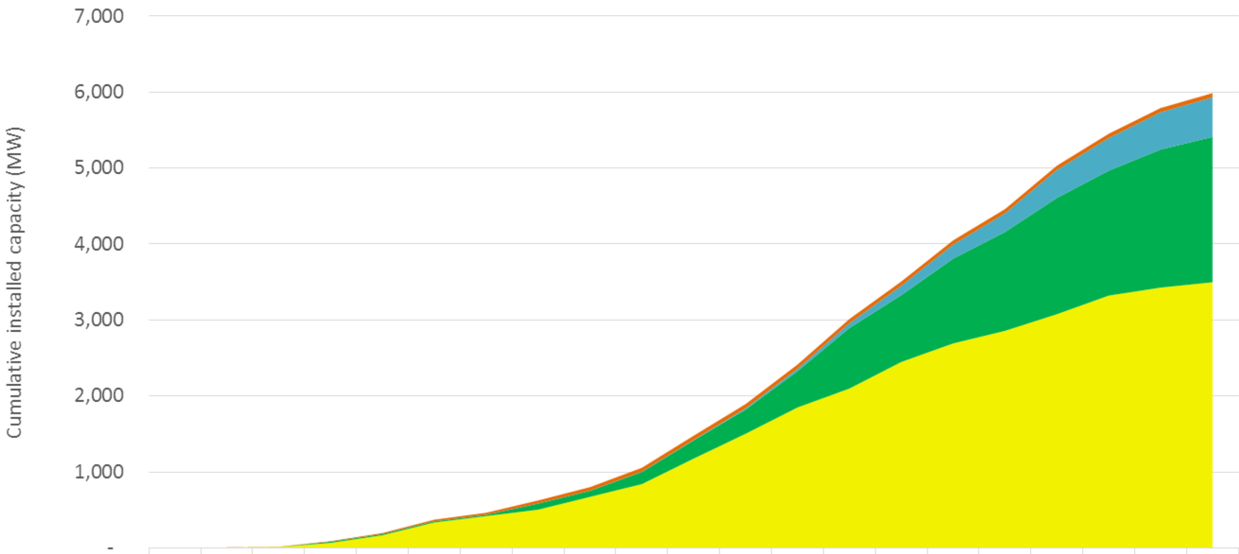
Figure 13 Assumed base case for onshore power generation in Peru and forecasts



The details of the outputs from this spatial resource evaluation are shown in the tables in the regional assessment section of this report. Having calculated a LOW, MED and HIGH development area for each type of aquatic renewable energy for each region of Peru, the number of projects that it would be feasible and realistic to install on a yearly basis was considered and used to calculate feasible growth rates for each type of aquatic renewable energy to achieve the LOW, MED and HIGH targets within a twenty year timescale (by 2037).

Figure 14 shows the national growth rates estimates for the most pessimistic (LOW) case. Note that the different subdivisions by installation location (e.g. river, coastal or lake/reservoir based) are not shown: the figures are for the total cumulative installed capacity for each technology type.

Figure 14 Growth estimates for installed capacity of different aquatic renewables (LOW case)



	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
River hydrokinetic	-	2	3	7	13	20	26	39	46	53	56	56	56	56	56	56	56	56	56	56	56
Wave energy	-	-	-	-	-	1	1	2	2	3	6	15	31	61	123	184	245	368	429	490	521
Offshore wind	-	-	-	16	16	16	16	80	80	159	239	319	478	797	880	1,116	1,301	1,530	1,645	1,817	1,913
Floating solar	-	7	13	67	168	336	420	504	672	841	1,177	1,504	1,849	2,098	2,448	2,693	2,858	3,077	3,322	3,427	3,497

In all of the cases considered, floating solar is expected to have the most potential both in the short and long-term. This is principally because of a) the high technology readiness of solar photovoltaic panels and b) the large areas of water surface that are available for development. Offshore wind energy potential is limited by the relatively modest wind speeds in Peru and the lack of coastal areas with suitable shallow seabeds for fixed turbine installations. However, as floating offshore wind turbines optimised for deeper waters and lower wind speeds are developed, it is conceivable that multi-GW offshore wind projects could be realised in the 2030s. Hundreds of MWs of wave energy capacity could be deployed along the Peruvian coast once these technologies are commercialised. The potential for river hydrokinetic projects is small compared to other aquatic renewable energy technologies, but river hydrokinetic turbines are now commercially available and for specific communities with fast flowing river currents, such projects can be very attractive.

For each of the three scenarios, estimates of annual generation were made by considering the capacity factors listed below. It is important to note that actual capacity factors will depend on the technology used and the installation site. The following capacity factors for a range of onshore and aquatic technology options are not definitive but are listed here to clarify the assumptions that the growth estimates are based on:

- Fossil fuel: 35%
- Onshore renewables:
  - Hydroelectric: 70%
  - Onshore wind: 20%
  - Onshore solar 25%
- Aquatic renewables:
  - Large scale floating solar: 25%
  - Off-grid and micro-grid floating solar 15%
  - Offshore wind (floating and founded): 15%

- Offshore wave energy: 40%
- Coast wave energy: 20%
- River hydrokinetic: 60%

Note: annual generation = installed capacity x number of hours in a year x capacity factor

Figure 15 shows the annual generation figures for the pessimistic (LOW) growth scenario combined with the base case for electricity generation from conventional fossil fuel and onshore renewable power plants. In this combined scenario, aquatic renewable energy would be responsible for 2% of power generation in 2025, growing to 12% in 2037. The contribution from aquatic renewable energy and the assumed base case for conventional generation would result in just over 111,000 GW of power generation in the year 2037, of which 14,000 GW could come from aquatic renewables.

Figure 15 Pessimistic (LOW) growth scenario for aquatic renewable generation

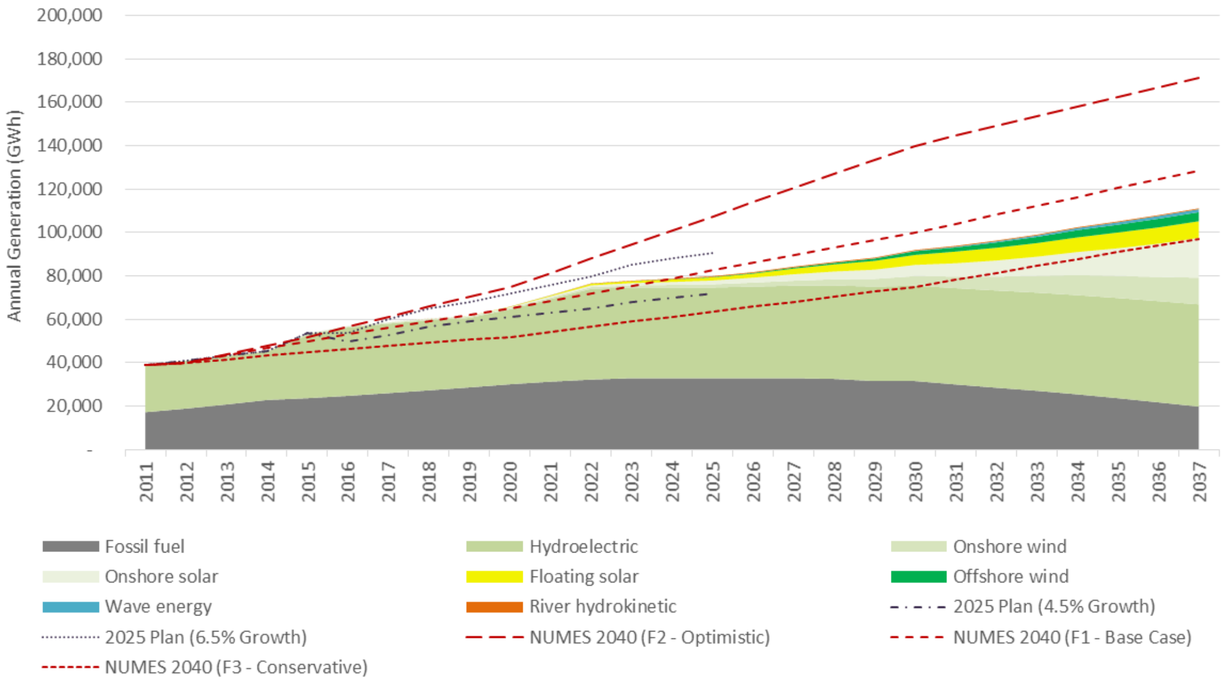
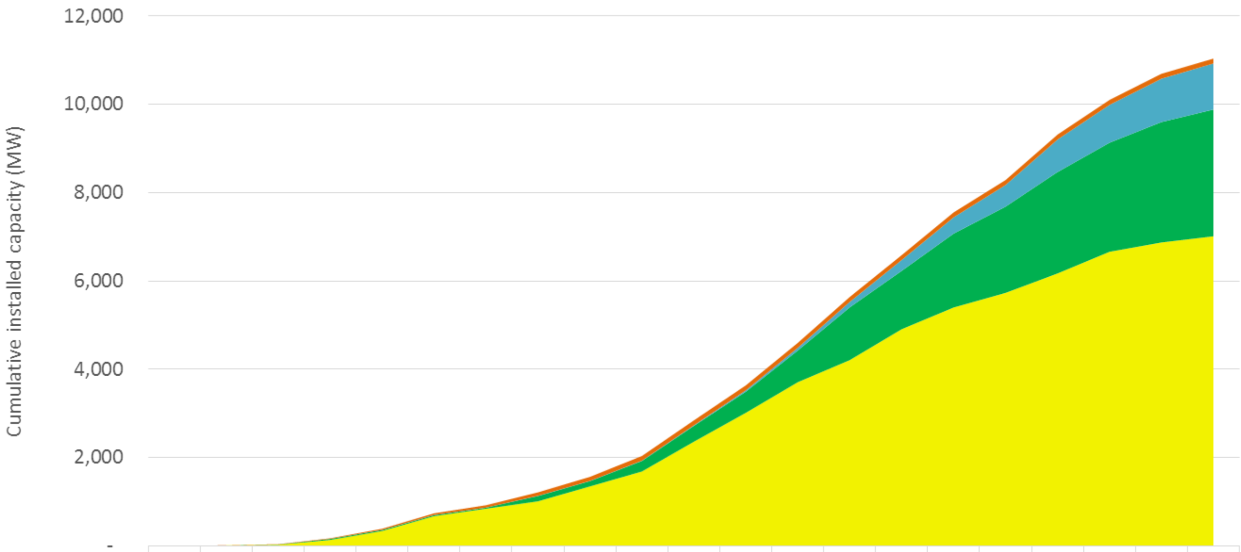


Figure 16 shows the growth estimates for installed capacity of different aquatic renewables under the mid-range (MED) case. In this case, offshore wind and wave energy pilot projects are supported within the next few years to promote stronger growth of these technologies. River hydrokinetic development is also stronger, and the total installed floating solar capacity is double that considered in the pessimistic case: 7 GW by 2037.

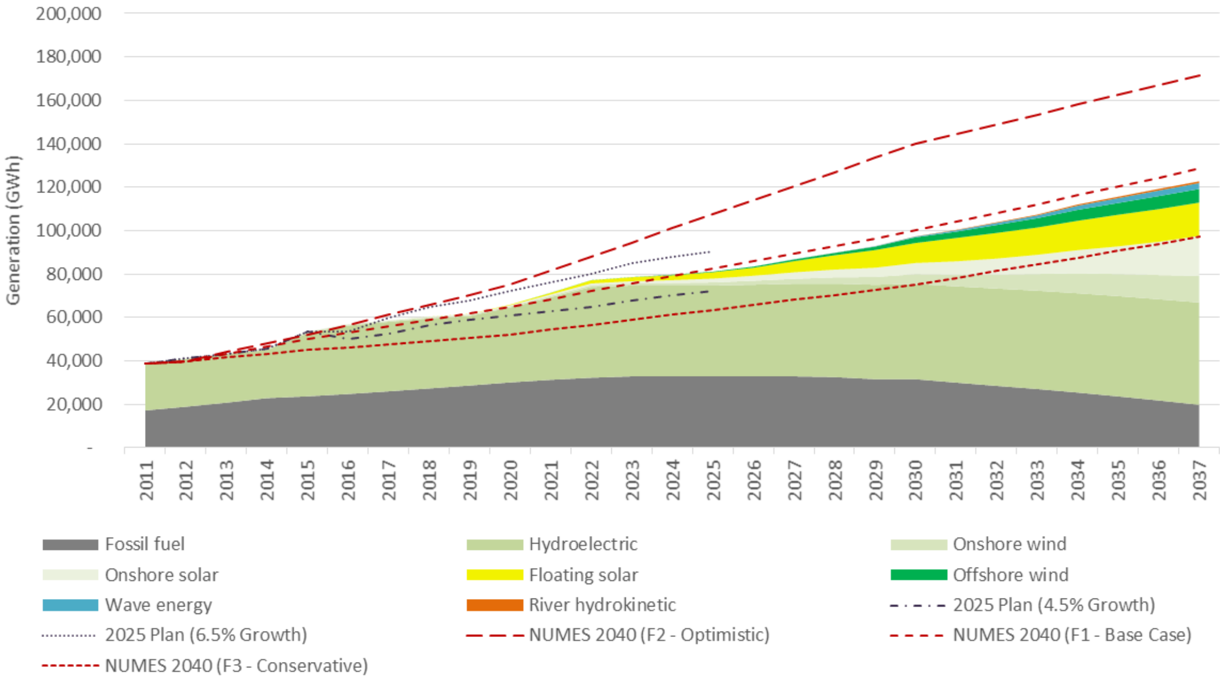
Figure 16 Growth estimates for installed capacity of different aquatic renewables (MED case)



	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
River hydrokinetic	-	3	7	13	26	39	53	79	92	105	112	112	112	112	112	112	112	112	112	112	112
Wave energy	-	-	1	1	2	2	2	4	4	6	12	31	61	123	245	368	490	736	858	981	1,042
Offshore wind	-		6	24	24	24	24	120	120	239	359	478	717	1,196	1,320	1,674	1,951	2,296	2,468	2,726	2,870
Floating solar	-	13	27	135	337	674	843	1,011	1,348	1,685	2,360	3,015	3,708	4,207	4,908	5,399	5,731	6,170	6,661	6,871	7,012

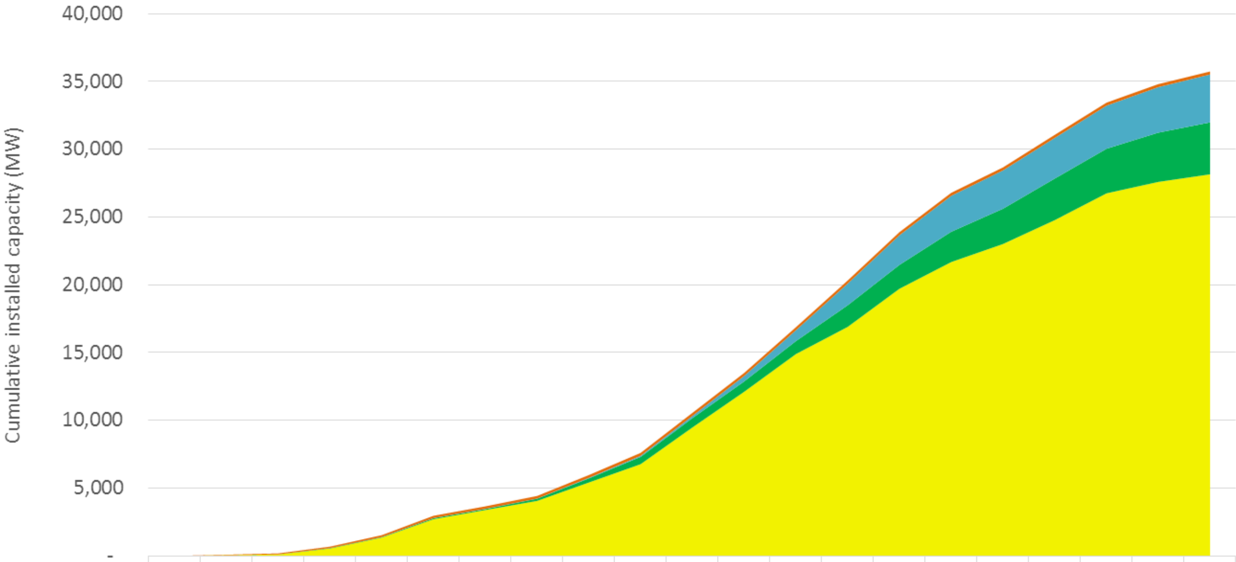
In this mid-range growth scenario, aquatic renewable energy could be responsible for 4% of power generation in 2025 and 20% in 2037. Total power generation would be 123,000 GW by 2037, of which 25,000 GW could come from aquatic renewables (Figure 17).

Figure 17 Mid-range (MED) growth scenario for aquatic renewable generation in Peru



In the most optimistic (HIGH) growth scenario, immediate massive investments would be made to maximise the utilisation of available resources and this would be continued across the 20 year timescale to achieve the maximum possible contribution from aquatic renewables. The annual installations required to meet this scenario would be technically challenging to deliver but this example serves to underline the scale of the resources available, with multiple gigawatts of wave, offshore wind and floating solar theoretically achievable (Figure 18).

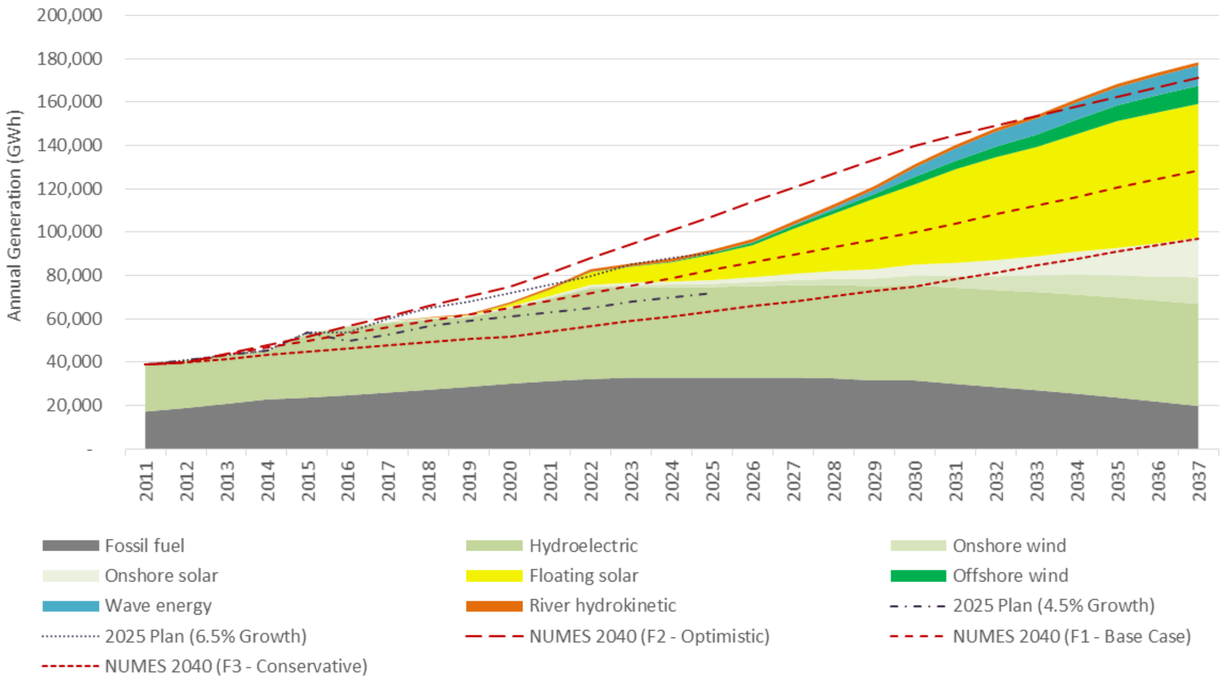
Figure 18 Growth estimates for installed capacity of different aquatic renewables (HIGH case)



	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
River hydrokinetic	-	36	72	107	139	168	179	190	201	212	224	224	224	224	224	224	224	224	224	224	224
Wave energy	-	-	1	1	6	6	12	12	40	80	160	400	800	1,600	2,190	2,649	2,826	3,002	3,179	3,355	3,532
Offshore wind	-		6	32	32	77	77	159	306	536	689	765	957	1,594	1,760	2,232	2,602	3,061	3,290	3,635	3,826
Floating solar	-	54	108	541	1,353	2,707	3,383	4,060	5,413	6,767	9,473	12,10	14,88	16,88	19,70	21,67	23,00	24,77	26,74	27,58	28,14

Coincidentally, this maximum estimate for aquatic renewable energy potential (which is based on spatial assessments of available resource areas) is roughly the same magnitude as the uncertainty in the NUMES forecasts for total electrical demand (Figure 19). In this most optimistic growth scenario, aquatic renewable energy could be responsible for 15% of power generation in 2025 and 45% in 2037. Total power generation by 2037 in this case would be 178,000 GW, of which 81,000 GW would come from aquatic renewables (Figure 19).

Figure 19 Optimistic (HIGH) growth scenario aquatic renewable generation in Peru



Non-electrical energy

Electricity use accounts for only around 20% of Peru's primary energy use, with transport (powered by diesel, motor gasoline/petrol and natural gas) accounting for 42%. To put this another way, if all transportation in Peru were electrified today, the electrical demand in Peru would triple. Some forms of transport (such as air travel) are more challenging to electrify and the cost of some systems remains a barrier but the possibility of terrestrial and particularly municipal transport to go fully electric is increasingly likely.

Although the production of natural gas in Peru is increasing, reserves are dwindling and crude oil production has been declining since the 1980s. Peru's dependence on imported fossil fuels is a weak link in the country's economy (Villacorta, 2016). A massive expansion of renewable energy capacity along with electrification of transport, energy efficiency measures and intelligent control of energy demand would improve Peru's energy independence as well as tackling climate change and creating sustainable economic development.

In conclusion, floating solar has the greatest growth potential due to its competitive cost and the large development areas available (although the local acceptability of projects on Lake Titicaca remains to be seen). There is some fixed offshore wind potential in Peru but this is limited by the fact that the waters offshore of the Peruvian coast become very deep very quickly, and fixed offshore wind turbines have only been installed to date in waters of maximum 40 to 60 m water depth. There is a much larger potential for floating offshore wind deployments in Peru and in the future, lower cost deep water mooring systems and turbines optimised for lower wind speeds may allow these areas to be developed. Peru's wave energy potential is also significant but competitive wave energy technologies have yet to be developed and are not expected before the mid-2020s. River hydrokinetic turbines are now becoming available commercially and there are many attractive sites in Peru but nationwide the total number of MWs which could be developed is less than for floating solar or wind.

Long-term forecasting of aquatic renewable energy developments in Peru is difficult given the uncertainties around economic growth, availability and cost of resources as well as unexpected future technological advances. The growth estimates presented are based on a basic evaluation of available resource areas and should be validated with further more detailed resource assessment work. Nonetheless, the conclusions are striking: the most optimistic estimate for floating solar resource exceeds 60,000 GWh/yr: equivalent to all of the electricity generated in Peru in 2016. Offshore wind and wave resources are also significant, at more than 8,000 GWh/yr (or 14% of 2016 electricity generation) each. The river hydrokinetic resource is lower (1,500 GWh/yr) but still significant and river hydrokinetic projects could be immediately attractive propositions, particularly in remote jungle areas. To date most attention has been focused on the potential for onshore renewables, but it is clear that the growth potential of aquatic renewable energy in Peru is very large indeed.

Alignment with UN sustainable development goals

In concluding on the prospects for aquatic energy developments in Peru and the contribution that they could make to the sustainable development of the country it is perhaps most appropriate to use the United Nations Sustainable Development Goals which were ratified in Peru in 2015. This set of goals provides a globally agreed framework of objectives that all countries, including Peru, have agreed to pursue and promote. The following analysis, presented in Table 15 outlines how aquatic energy could make a contribution to achieving this agreed set of sustainable development goals. It is notable that comment has been made against each of the 17 goal topics, indicating the way in which energy supply and demand pervade all aspects of our lives as individual citizens and as communities and countries.

It can be seen from the comments provided that there are an overwhelming set of benefits to be had from aquatic energy if it can be delivered cost effectively into the overall energy mix. There are a few areas where careful planning and stewardship are necessary to avoid or reduce possible impacts but there are also critically important and unique benefits that can arise especially with regards to providing appropriate energy solutions for the culturally sensitive and habitat fragile communities of the Amazon basin and the high Andes.

Table 15 An analysis of the contribution and issues associated with aquatic energy in relation to the United Nations Sustainable Development Goals

Goal	Brief outline of goal	Possible implications regards aquatic energy
Goal 1	End poverty in all its forms everywhere	Aquatic energy may add new forms of energy supply in areas where energy supplies are not plentiful or they are not accessible to local people. These new supplies may enable local producers to add value to the crops and other items that local communities produce. However, there will be a need to make sure that energy prices arising from aquatic energy solutions do not add to poverty burden.
Goal 2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Aquatic energy may enable better quality and storage of food at cooler temperatures, through faster drying etc. This may help improve food safety, reduce waste from rotten food and extend storage times. This in turn may lead to enhanced profitability for existing food production processes, better food security and also encourage new types of food to be produced locally, especially in currently off-grid or capacity constrained areas.
Goal 3	Ensure healthy lives and promote well-being for all at all ages	The availability of electrical energy in currently off-grid communities may help to enable better communications and health care support through cooling of medicines, providing better temperature control in hospital beds and households and providing clean lighting and cooking options in dwellings.
Goal 4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	Aquatic energy can be part of a training package that enables sustainable engineering and energy supply and demand to be used as a subject for training in remote and undeveloped communities in the Andes and in the Amazonian jungle.
Goal 5	Achieve gender equality and empower all women and girls	The availability of energy in currently off-grid communities may help to offer women more roles within a given lifestyle. Furthermore, the vast majority of jobs within the

Goal	Brief outline of goal	Possible implications regards aquatic energy
		actual supply of energy from aquatic sources can be equally well fulfilled by women as men (*It can be noted that over 50% of the work for this project was undertaken by women, including the project management and stakeholder engagement role*).
Goal 6	Ensure availability and sustainable management of water and sanitation for all	Aquatic energy can help preserve managed water resources themselves for irrigation and direct water supply, rather than having to be used for energy generation. The introduction of pump storage type systems where the uplift of water is powered by aquatic energy may also help to better sustain water reserves. The availability of new localised aquatic energy supplies in currently off-grid or constrained capacity areas may enable further development of appropriate water purification and foul water management techniques.
Goal 7	Ensure access to affordable, reliable, sustainable and modern energy for all	This is at the core of the benefits that could arise from the development of aquatic energy. If suitably priced projects can be developed at local and national scales then much of Peru's increasing demand for energy as a result of rural electrification and wider social, industrial and economic development can be met by a suite of sustainable aquatic energy options.
Goal 8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	The fact that aquatic energy resources can extend the spread of exploitable energy resources into currently off-grid and capacity constrained areas will help spread the potential benefits of development to previously unsupported communities where that is desired and viewed as being beneficial. The availability of considerable aquatic energy resources near to Peru's existing centres of economic development and particularly the city of Lima can also help to make further development of the established urban and industrial centres sustainable in terms of energy demand. The development of aquatic energy will in itself also lead to new work opportunities, often in areas where alternative employment options are currently rather limited. Case Study 37 shows the benefits that the marine energy sector has provided to the Orkney islands.
Goal 9	Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation	The adoption of aquatic energy as a key energy source would help to extend Peru's energy and associated infrastructure into currently unconnected areas. However, where needed and appropriate aquatic energy can provide island or isolated infrastructure nodes that avoid the impacts associated with connecting between such nodes. This can, for example, be used to preserve the integrity of the jungle in the Amazonian basin and similarly fragile cultural and habitat features in other areas such as the high Andes.
Goal 10	Reduce inequality within and among countries	The distribution of aquatic energy resources is different from the distribution of other renewables and existing fossil fuel sources of energy. This means that the benefits arising from the availability of and generation of energy can be more widely spread and shared through the development of aquatic energy. Some of the resources identified may also enable connected energy supply through the grid to nearby countries. Alternatively the adoption of off-grid solutions based upon aquatic energy that are developed and proven in Peru may be exported to neighbouring countries with similar issues and indeed globally.

Goal	Brief outline of goal	Possible implications regards aquatic energy
Goal 11	Make cities and human settlements inclusive, safe, resilient and sustainable	There are a number of cities within Peru where the availability of secure and reliable energy resources will be key to their ongoing development. Many of these lie along Peru's coastal plain and these cities include Lima itself, which already has huge energy demands that will increase markedly in coming years and decades. Aquatic energy can be an important part of the portfolio of measures that will be needed to make such near coastal developments possible. There are also a number of smaller more isolated cities through the highlands of Peru and into the Amazonian jungle where the availability of energy will also be critical. This study has indicated that aquatic energy may be absolutely key to supporting development in these areas, particularly the off-grid cities such as Iquitos.
Goal 12	Ensure sustainable consumption and production patterns	The renewables nature of the aquatic energy resources considered in this study could help to make Peru's overall energy system more sustainable and will help to meet or exceed the COP 21 commitments made by Peru. They could also help to deliver island energy solutions which could provide more appropriate options for development in communities within sensitive and fragile cultural and habitat areas.
Goal 13	Take urgent action to combat climate change and its impacts	As a renewables source of energy aquatic energy could provide a major contribution to Peru's future electricity supply. Aquatic energy is also believed to have enough resource capacity to also contribute to Peru's conversion of non-electrical energy to renewable sources.
Goal 14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development	Aquatic energy resources available in Peru include wave, offshore wind and floating solar resources which it is believed can be developed without harming Peru's maritime natural and wildlife resources. It is also believed that this development can be achieved without harming Peru's important fisheries and coastal aquaculture sectors. In fact there could be added benefits from making these sectors more sustainable for the future through providing renewable energy options for processing of fish and aquaculture products and from providing alternative low-carbon/carbon-free fuels for the fishing vessels themselves.
Goal 15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	Aquatic energy options for energy generation provide an alternative to fossil fuels with a very low land based footprint. They still need to take account of the ecosystems that they are based in and will need careful planning and stewardship to ensure that sites are chosen well and that installation and operation of technologies are undertaken responsibly. Importantly in riverine situations aquatic technologies can be delivered to site and installed without any or minimal land based access requirement. This may be particularly beneficial in sensitive jungle habitats.
Goal 16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	Aquatic energy may in particular provide for low intensity development opportunities in culturally and habitat sensitive communities of the Amazon basin. This may facilitate the introduction of beneficial social and economic developments without the need for unnecessary linking infrastructure and the associated threats and challenges that such links bring.
Goal 17	Strengthen the means of implementation and revitalise the global partnership for sustainable development	The adoption of Peru's aquatic energy resources as a key part of Peru's future development would provide a strong leadership signal from Peru to the wider world that it was committed to transforming its carbon footprint, but doing so in a manner which was appropriate for the uniquely jungle and mountainous environments that characterise so much of Peru's territory.

According to the projections of MINEM (MINEM, 2014), it is indicated that in the year 2025 natural gas will grow to 35% of total final energy consumption. In this way, a clear commitment is made to the massive use of natural gas to satisfy the energy demand in the different sectors of the Peruvian economy.

The international energy model for the next three and a half decades in the IRENA report (IEA, 2017) is clearly different from the current one. Fossil fuels will continue to have a market share, but their share will be one third of the current, with a further decline in the use of coal, while the average fossil fuels will be about 45% of current demand. While natural gas can serve as a bridge to greater use of renewable energy, its role should be limited to fully decarbonising.

Today, new renewable energy plants are being built around the world that generate electricity at a lower cost than fossil fuel power plants. Decarbonisation can fuel systemic economic growth and create more employment in renewable energies by opening up a wide range of possibilities with aquatic renewable energies. The energy transition needs to go beyond the electricity sector and reach other sectors as indicated above. Electric transport, for example, must become the type of transport that prevails in Peru in three or four decades.

In Peru, political efforts to create an enabling framework that facilitates the energy transition and allows the redesign of energy markets are fundamental. There are a number of actions that can help create space to move in this direction, such as pricing carbon or incorporating a number of renewable energy projects in the country for different markets.

KEY RECOMMENDATIONS

The report is supported by a number of case study examples provided within text boxes in Appendix A. Also, through this report, various recommendations are made based on the information that has been presented and the results of the consultation, all the recommendations are showed in the following table.

Recommendations and analysis are developed based on the timescales shown below.

Figure 20 Timescales referred to this report

Recommendation		Possible action holder(s)		Timescale
		Onshore	Offshore	
Aquatic renewable energy potential in Peru				
1	**Development of Regional and National Renewable Energy Plans considering aquatic renewable resources**, integrating renewable energy policy with wider economic and regional development policies and considering novel energy uses (e.g. ice production/electric vehicles). Article 11 of Legislative Decree 1002 already indicates that Peru will develop National and Regional Renewable Energy Plans – it is important that aquatic renewable energy resources are explicitly considered within these.	MINEM, Regional Governments		Short-term
2	**Definition of the future role of aquatic renewable energy in Peru.** The Peruvian Government and Peruvian research organisations continue to develop a better understanding of Peru´s renewable energy resources. It is hoped that this will continue with a focus on aquatic	MINEM, MINAM, ANA, SENAMHI, Regional	MINEM, MINAM, IMARPE, Regional Governments	Short-term

Recommendation		Possible action holder(s) Onshore	Possible action holder(s) Offshore	Timescale
	renewable resources (wave, tidal, river hydrokinetic as well as floating solar and offshore wind). In order to define roles for these technologies in the different regions of Peru it is important to understand local energy demand (now and in the future) and to have an improved understanding of the distribution of these renewable energy resources (now and in the future with a changing climate) – see Recommendation 3.	Governments		
3	**Characterisation of aquatic renewable energy resources.** Different approaches to resource characterisation are required depending on the scale and nature of the resource as well as the development stage and roll-out potential of the different technologies which could harness these resources. Wave Detailed national wave energy resource modelling and mapping validated with field measurements would allow the Peruvian resource to be quantified with more confidence than at present, so that the most attractive development areas can be identified. Run-of-river hydrokinetic National or regional modelling validated and supported by measurements of existing river current speeds in specific locations would help quantify the available resource and select the most promising sites. Offshore wind Offshore measurements at sites of interest would confirm whether existing models are accurate. These can be expensive and are typically done specifically for commercial projects, but some research-led work may be feasible. Floating solar The solar resource is relatively well understood but where local weather conditions may impact (e.g. coastal fog), basic measurements could be useful. As well as the characterisation of the available resource in pure energy terms (e.g. kW/m wave front, m/s wind or current speed), the site with the most energetic resource may not necessarily be the most economic to develop. It is important to consider other factors such as permitting, installation and operation in order to understand the costs of power production in different areas.	MINEM,DHN, ANA, SENAMI	MINEM, DHN, Imarpe	Short-term
4	**Development of links with existing renewable energy forums and publication of annual industry status update(s).** Peru's renewable energy associations (and any future organisations involved specifically on aquatic renewable developments) could have an important role to play in raising awareness about the potential in Peru and in promoting and supporting developments. The International Energy Association (IEA) and the Ocean Energy Systems (OES) networks both publish annual industry updates which Peru could feed in to. The Peruvian Government could consider becoming a signed-up member of OES.	CENERGIA, Camara Peruana de Energias Renovables		Short-term

Recommendation		Possible action holder(s)		Timescale
		Onshore	Offshore	
5	**Mapping suitable aquatic renewable technologies for Peru.** Peruvian organisations, universities and/or the proposed national renewable energy centre may wish to consider some of the aquatic energy technology roadmapping work that has been carried out by international organisations (such as IRENA, the UK Energy Research Council, Edinburgh University and Wave Energy Scotland) to consider which technologies might be most suitable for Peru and to map out where Peruvian organisations would be best placed to contribute.	Peruvian Universities, CENERGIA, Camara Peruana de Energias Renovables		Short-term
Regulatory framework, strategic priorities				
6	**Development of the regulatory framework for aquatic renewable energy deployments**. Ministries and government organisations relevant to these emerging sectors have an important role to play in devising integrated policy instruments to manage Peru's aquatic renewable resources for sustainable economic development. At present, aquatic renewable energy is rarely explicitly mentioned in Peruvian legislation.	MINAM, MINEM, ANA, DICAPI, SENACE DHN, SENAMI, SBN	MINAM, MINEM, ANA, DICAPI, SENACE, DHN, Pro inversión, SBN	Short-term
7	**Development of aquatic renewable energy policies.** There is potential for Peruvian legislative experts to learn from international offshore aquatic renewable energy experience. A technical working group (Grupo Tecnicos de Trabajo, GTTE) could be set up by COMUMA for this purpose and bring together representatives from different government departments and develop cross-departmental recommendations.	COMUMA		Short-term
8	**Streamlining of permits and concessions for aquatic renewable energy deployments.** DICAPI and ANA may be the best-placed organisations to consider what the most workable approaches to permitting and consenting marine and run-of-river energy projects in Peru may be. Existing systems have been adequate for deployments by Smart Hydro Power (river hydrokinetic) and Atmocean (wave) in Peru but for larger and more numerous developments it may be beneficial for DICAPI and ANA to consider international experiences.	DICAPI in coordination with ANA	DICAPI	Short-term
9	**Creation of a "one-stop-shop" (ventanilla única) for permitting and licenses for aquatic renewable energy projects.** It could be beneficial to have a one-stop-shop for permits and licenses needed for aquatic renewable energy developments. This could make the process simpler for project developers, create a team of specialist staff and give MINEM and other relevant bodies an overview of projects in development worldwide.	ANA, SENACE, DICAPI, MINEM.	SENACE, DICAPI, MINEM	Medium-term
10	**Creation of guidelines for permitting aquatic renewable projects.** Permits are crucial aspects of the legal framework which allow local and national government to define development. It would be of great benefit to produce a manual for permitting and concessions for aquatic renewable energy deployments to reduce uncertainty associated with these projects.	ANA, SENACE, DICAPI, MINEM.	SENACE, DICAPI, MINEM	Short-term

Recommendation		Possible action holder(s)		Timescale
		Onshore	Offshore	
11	**Peruvian organisations to consider incorporating aquatic renewable energy developments in its corresponding TUPAs**	ANA, MINEM Marina de Guerra del Perú (DICAPI, DHN)	MINEM, Marina de Guerra del Perú (DICAPI, DHN)	Short-term
12	**Training for staff handling aquatic renewable energy permits and concessions.** A lack of familiarity with (or understanding of) new types of energy project can lead to unnecessary delays in getting projects approved. The responsible agencies for handling permits and concessions may wish to consider training key staff in the evaluation of aquatic renewable energy projects. This can transfer and adapt knowledge from industry experience internationally to the Peruvian situation.	MINEM, MINAM, DICAPI,ANA SENACE, Regional Governments	MINEM MINAM, DICAPI, SENACE, Regional Governments	Medium-term
13	**Include aquatic renewable energy deployments in DGOT- MIZMC training and capacity building for regional governments.** The Direccion General de Ordenamiento Territorial (DGOT) may wish to include aquatic renewable energies in their activities related to Integrated Management of the Coastal Marine Zone (MIZMC) and Ecological and Economic Zoning (ZEE) as part of capacity building for regional governments and the formation of local coordination committees. Local committee staff could also be amongst those trained to evaluate these projects.	MINAM (DGOT), Regional Governments		Medium-term
14	**National, regional and local consultation and coordination to support the development of a leasing process** (to award commercial development rights for aquatic renewable energy projects). It is best to consult and coordinate with local people, industry and relevant departments of national, regional and local government organisations before any strategic release of areas for aquatic energy developments. National, regional and local planning can capture requirements, issues and obligations (be they political, technical, environmental or social) and thereby encourage optimised developments which are acceptable to the local community and suit their needs, whilst creating economic development and new sources of power generation for the wider country. Once the most attractive zones have been identified, developments can be accelerated by establishing less complex permitting procedures in these areas and/or providing support or incentives to project developers. Experience gained in these priority development zones (which may be large or small) can then support further developments elsewhere. The proposed atlas (see Recommendation 15) could support this consultation process.	MINAM, MINEM Marina de Guerra del Peru (DICAPI, DHN), Regional Government, SENACE, SBN, Pro inversión	ANA, MINAM, MINEM, Marina de Guerra del Peru (DICAPI, DHN), Imarpe, Regional Government, Proinversion,SBN, SENACE	Short-term
15	**Potential national aquatic renewable energy resource atlas for Peru.** MINEM may wish to consider compiling a national renewable energy atlas for Peru. Possible locations for priority development zones are best identified through mapping of environmental considerations, energy resource and infrastructure capacities amongst other factors in Peru´s coastal, lagoons, rivers and offshore environments.	MINEM, SENAMHI, ANA	MINEM, DGH	Short-term

Recommendation		Possible action holder(s)		Timescale
		Onshore	Offshore	
16	**Including aquatic renewable deployments in the "Greenhouse Multi-Sectorial Working GTM".** This temporary working group is in charge of generating technical information to guide the implementation of planned and determined contributions submitted to the United Nations Conference on Climate Change (UNFCCC) – ref. SUPREME RESOLUTION No. 005-2016-MINAM. MINAM, through the General Directorate for Climate Change, Desertification and Water Resources, assumes a Technical Secretariat role and could help ensure that aquatic renewable technologies are considered in future Peruvian roadmaps and/or action plans including those targeted at energy markets such as transport, mining, water pumping, desalinisation and off-grid supply alongside grid electricity.	MINAM	MINAM	Short-term
17	**Including aquatic renewable technologies in NAMA Energy.** The Peruvian Government has already established NAMA Energy targets whereby in the year 2021 renewable energy is to represent at least 40% of total national energy use. Article 3 of Decree 1002 mentions that non-conventional energy resources is understood to include biomass, wind, solar, geothermal and tidal and hydropower, when the installed capacity does not exceed 20 MW. It would be beneficial for NAMA Energy to explicitly consider the role other types of non-conventional aquatic renewable technologies (such as wave, river hydrokinetic, floating solar and offshore wind) can play in reducing fossil fuel dependence and greenhouse gas emissions. NAMA Energy could also help these industries by providing support to overcome institutional challenges and by facilitating projects/programmes implementing policies and regulations for non-conventional aquatic renewable technologies.	MINEM, MINAM	MINEM, MINAM	Short-term
18	**Develop aquatic renewable energy spatial planning.** It would be beneficial to develop a national and/or regional spatial plan for emerging technologies in accordance with the local environmental, economic, main water body uses, social development targets and context through Committees and including MIZMC in the case of marine projects.	MINEM, Marina de Guerra del Peru (DICAPI, DHN), MINAM (DGOT) Regional Government, PRODUCE, ANA	MINEM, Marina de Guerra del Peru (DICAPI, DHN), MINAM (DGOT) Regional Government, PRODUCE	Short-term
19	**Development of water basins planning including energy uses in Peru.** Elaboration of watershed zoning studies to understand the development capacity of aquatic renewable energies and their possible economic, environmental and social impact.	ANA, MINAGRI	-	Medium-term
20	**Peru becomes an observer country within the Technical Committee (TC) 114.** The commercial potential of the technologies rests in demonstrating reliability of performance and an acceptable cost of energy. Standards and guidelines are therefore fundamental to the successful development of this nascent industry. In order to facilitate the application of international standards Peru could become an observer country within the International Electrotechnical Commission (IEC) - Technical Committee (TC) 114.	MINEM	MINEM	Long-term

Recommendation		Possible action holder(s) Onshore	Offshore	Timescale
21	**Key standards for wave energy projects in Peru.** There are a number of standards (which would help to demonstrate reliability of performance and cost of energy) that could be applied in technology and project development for wave energy projects: • 62600-2 Design requirements • 2600-10 Assessment of mooring systems • 62600-30 Electrical power quality • 62600-31 Acoustic characterisation • 62600-100 Wave power performance assessment • 62600-101 Wave energy resource assessment • 62600-202 Scale testing	MINEM	MINEM	Long-term
22	**Pilot projects**. Peru could develop pilot projects on testing aquatic renewable energy technologies undertaken at specific sites analysed as suitable.	MINEM, Regional Governments and Produce	MINEM, Regional Governments and Produce	Long-term
23	**Including aquatic renewable technologies in the National renewable auctions launched by OSINERGMIN.** At present, renewable energy tenders in Peru consider biomass, solar, wind and hydro. It would be beneficial to include aquatic renewable technologies within these tenders and/or to consider differential arrangements for emerging technologies.	MINEM, OSINERGMIN	MINEM, OSINERGMIN	Short-term
Infrastructure				
24	**Electrical grid (SEIN) capacity studies considering increased contributions from aquatic renewable energy sources**. COES has already commissioned a study considering increased generation from wind and solar in the Peruvian electricity network. Similar studies considering future contributions from aquatic renewable energy technologies could support planning to ensure that the grid can cope with future developments. These studies could then feed into the Transmission Plan 2015 - 2024 that COES updates every two years to determine new infrastructure requirements for the SEIN.	COES	COES	Medium-term
25	**Feasibility studies for incorporating river hydrokinetic and floating solar into existing hydroelectric infrastructures.** MINEM or another relevant body could consider funding or partially funding feasibility studies into the potential for downstream river hydrokinetic and floating solar to be incorporated into existing hydroelectric infrastructure.	MINEM	MINEM	Medium-term
26	**Energy storage and grid system management feasibility studies**. Peru could undertake a feasibility study into energy storage and system management mechanisms that could be introduced into the national grid network as well as micro-grid locations.	MINEM, COES, OSINERGMIN	MINEM, COES, OSINERGMIN	Long-term
Supply chain				
27	**Aquatic renewable energy infrastructure, logistics and services studies**. Capacity studies and strategic development plans can improve understanding of potential capacity gaps and stimulate growth in local supply chains. These would ideally consider the specific types of	Regional Governments, Port Works Bureau	Regional Governments, Port Works Bureau	Medium-term

Recommendation		Possible action holder(s)		Timescale
		Onshore	Offshore	
	development likely in Peru whilst exchanging knowledge and experience with the international marine energy community.			
28	**Identification and resolution of skills gaps for the aquatic renewable technologies.** Peru may wish to identify areas where supply chain training is required and include these training requirements in their programs. The results of Recommendation 27 could support this task.	MINEM, SNI, Regional Governments	MINEM, SNI, Regional Governments	Medium-term
29	**Guidelines for aquatic renewable energy deployments**. Peru could use as a references the five guidelines developed by Wave Energy Scotland (WES) about compliance, handling, supply chain installation and operations and maintenance (O&M) http://www.waveenergyscotland.co.uk/	MINEM, SNI, Regional Governments	MINEM, SNI, Regional Governments	Long-term
30	**Aquatic renewable energy courses, training and research links.** Universities may want to consider links with national and international institutions active in these sectors in order to, in the longer term have the capacity to fulfil these training requirements in Peru.	Peruvian Universities	Peruvian Universities	Medium-term
Research, development and innovation				
31	**Further investigation into niche markets R&D for aquatic renewable technologies.** As well as the potential for aquatic renewable energy technologies to provide grid electricity, the application of these power generating systems to off-grid communities, aquaculture, mining operations and vessels/transport (power for ferries and ship) should be considered. This is a relatively underdeveloped area where there is the potential for Peru to become a leader in specific market niches. A stepped approach could be followed whereby a short-term focus on isolated niche markets (with very high existing energy costs) is followed by the development of larger scale niche projects where energy costs are somewhat higher than in the electricity grid, before projects then become competitive with grid electricity.	MINEM, PRODUCE, Universities	MINEM, PRODUCE, Universities	Medium-term
32	**Centre of Excellence for renewable energies (or specifically for aquatic renewable technologies) and R&D funding.** A national renewable energy R&D centre involving state agencies, private companies and universities could drive forward technology innovation and integration in Peru. This centre – or an associated funding agency – could also be empowered to finance renewable (or specifically aquatic renewable) R&D projects.	MINEM CONCYTEC, PRODUCE Regional Governments	MINEM CONCYTEC, PRODUCE Regional Governments	Short-term
33	**Include coastal and offshore aquatic renewable energy in the scope of IMARPE's Directorate of Oceanographic Research and Climate Change** (DGIOCC). DGIOCC could include marine renewable energy in their scientific research on the oceanographic, physical, chemical, biological and geological processes and conditions of the Peruvian marine space.		IMARPE	Medium-term
34	**Consideration of aquatic renewable energy resources by SENAMHI and ANA.** SENAMHI and ANA may wish to consider explicitly including the promotion or facilitation of river hydrokinetic, floating solar and wind projects within their remit.	SENAMHI, ANA		Medium-term

	Recommendation	Possible action holder(s)		Timescale
		Onshore	Offshore	
Socio-environmental conditions				
35	Peru could join **OES Annex IV** 16 and the **Offshore Renewables Joint Industry Programme (ORJIP)** 17 for Ocean Energy		MINAM, MINEM, SENACE, IMARPE	Short-term
36	**Risk-based environmental impact assessment.** Environmental Impact Assessments (EIAs) should be informed by risk based assessment which is linked to international experience. Risk based assessment considering lessons learned internationally can address the most relevant environmental considerations and not the whole spectrum of possibilities, which in many cases may have already been established as of little or no concern. Given the pace of change in these sectors, it may be beneficial to periodically develop, review and update a guide for environmental impact assessment of these projects.	MINAM, MINEM, SENACE	MINAM, MINEM, SENACE	Short-term
37	**Consideration of the wider impacts/benefits of aquatic renewable energy projects in EIAs.** MINAM may wish to consider developing criteria to formally take into account wider impacts/benefits from aquatic renewable energy projects in the EIA process. This could include for example the environmental benefits (e.g. habitat creation, pollution reduction and climate change mitigation) and socio-economic advantages which often accompany these energy projects.	MINAM, SENACE	MINAM, SENACE	Medium-term
38	**Database of environmental information gathered for project approvals.** The creation of an easily accessible database of environmental data from project permit applications could help prioritise (and reduce the risk of duplicating) environmental monitoring and research. At the same time such a database could provide a basis for governments, agencies, technology developers, project developers and energy customers to make strategic and site-specific decisions about aquatic renewable energy projects.	ANA, SENACE, DHN	IMARPE, DHN	Long-term
39	**Strategic Environmental Assessment (SEA).** A comprehensive national assessment of environmental issues and constraints for aquatic renewable energy projects can help support the appropriate development of policy and regulation. This will also feed into site selection prioritisation and project development options. This was strategically important in the advancement of the Scottish industry and could be replicated in Peru where appropriate. A SEA will highlight the various environmental factors that influence what sites are developed and can consider possible technology constraints and benefits. The aims of this would be to: Assess the impacts of aquatic renewable energy project developments on Peru´s environment at the national level. Identify which environmental risks are of most concern or require further research to understand. Support the identification of priority development zones and an eventual commercial leasing round. Consider the impacts of industrial scale aquatic renewable projects development and identify the areas where projects can take place with	MINAM, MINEM (DGAA), SENACE, ANA	MINAM, MINEM (DGAA), Imarpe, SENACE	Short-term

[16] https://tethys.pnnl.gov/about-annex-iv

[17] http://www.orjip.org.uk/index.html

Recommendation		Possible action holder(s)		Timescale
		Onshore	Offshore	
	minimum environmental risk. *Note: Environmental impacts can be reduced not only by choice of site but also by choice of technology, timing of construction works, selection of supporting infrastructure, etc.* A SEA can examine plausible alternative development scenarios including zero deployment, in order that meaningful comparisons can be made between the impacts of existing activities and potential marine energy deployments. Regional Governments could also consider commissioning their own regional SEAs. A SEA and a marine spatial plan (MSP) can support and inform each other in an iterative way as they are developed (see recommendation **Error! Reference source not found.**).			
40	**Regional environmental monitoring & evaluation of aquatic renewable energy impacts, and dissemination.** Monitoring and evaluation of aquatic renewable energy projects can also help inform future consenting processes.	ANA, SENACE, Regional Governments	SENACE, Imarpe, Regional Governments	Long-term
41	**A socio-environmental feasibility study of the potential for potential floating solar inland areas identified in the regional assessment chapter** (e.g. Lake Titicaca). It would be useful to complete, to identify any barriers to development early on and develop proposals which would be environmentally benign and acceptable to local people.	ANA, SENACE, Regional Governments	-	Medium-term
Finance				
42	**Aquatic renewable energy R&D financing.** Article 12 "Promotion of Research and Development of Electric Generation Projects with renewables" of Decree Law 1002/2008 indicates that financial funds will come from various finance resources and international cooperation. It would be useful to clarify which directorates within MINEM could help coordinate and prioritise renewable energy research and development. Aquatic renewable energy resources should be included as key renewable resources for Peru and funding should be prioritised in the country for pilot projects and R&D.	MINEM	MINEM	Short-term
43	**Financial support for emerging renewable energy technologies in national R&D funding programme (CONCYTEC).** COCYTEC has a national programme called "National Transverse Environmental Science and Technology Program 2016 - 2021" related to renewable energy. Alternative energy and renewable energy are two priority areas for this fund however emerging renewable energy technologies are not differentiated from commercial technologies. CONCYTEC may wish to consider marine and river hydrokinetic as emerging technologies that could benefit from more R&D support to move forwards in Peru (compared to more commercial technologies such as solar and wind).	CONCYTEC	CONCYTEC	Short-term
44	**Support for emerging renewable energy pilot projects in Peru (Innovate Peru).** The National Innovation Program for Competitiveness and Productivity (Innovate Perú) of the Ministry of Production is a program that seeks to increase business productivity by strengthening the players of the innovation ecosystem (companies,	Innovate Peru	Innovate Peru	Ongoing

Recommendation		Possible action holder(s) Onshore	Offshore	Timescale
	entrepreneurs and support entities) and facilitate the interrelationship between them. Innovate Peru has already supported aquatic renewable energy pilot projects in Peru and may wish to consider aquatic renewables for further support.			
45	**Financial support for off-grid pilot projects.** MINEM and PRODUCE may wish to consider developing financial support instruments to support the development of small-scale, off-grid aquatic renewable energy projects for niche markets such as rural electrification or ice production for fisheries. This could include feasibility studies, pilot projects and related research. These types of project can be implemented at relatively low capital cost, so a focus on projects of this scale is a cost effective (and relatively low-risk) way to introduce emerging technologies and new ways to use conventional renewables in Peru.	MINEM, PRODUCE, Regional Governments	MINEM, PRODUCE, Regional Governments	Medium-term
46	**New financial support instrument for aquatic renewable energy pilot projects**. The Peruvian Government may wish to consider introducing an auction or invitation to bid for a block of aquatic energy projects in the medium-term in order to support the first precommercial farms of aquatic renewable devices in Peru.	MINEM, PRODUCE, Regional Governments	MINEM, PRODUCE, Regional Governments	Medium-term
Niche markets				
47	**Research and pilot projects for niche aquatic renewable energy markets.** The aquatic renewable energy industry could collaborate local organisations for researching and developing pilot and/or demonstration projects using technologies appropriate to niche energy markets such as rural electrification/off-grid communities, ice production for fisheries, water pumping for the mining industry, offshore platforms, desalination, etc.	PRODUCE, MINEM, Regional Governments	PRODUCE, MINEM, Regional Governments	Short-term
48	**Specific sector demand assessment.** Undertake sector specific demand assessments in terms of the amounts of energy, types of energy, patterns of use and value of energy required over future time.	PRODUCE, MINEM, Regional Governments	PRODUCE, MINEM, Regional Governments	Medium-term
49	**Demonstration projects using aquatic renewable energy systems.** Demonstration projects could be developed using aquatic renewable energy systems (for example to power river boats or electric vehicles).	MINEM, CONCYTEC	MINEM, CONCYTEC	Medium-term

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APPENDICES

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APPENDIX A CASE STUDIES

Key

OW Offshore wind **W&T** Wave and Tidal **RHK** River Hydrokinetic

Case Study 1 (OW) Offshore floating wind technology in (Scotland)

The Hywind Scotland Pilot Park project is the world's first commercial scale floating wind farm. It is located approximately 25 kilometres off the coast of Peterhead in north east Scotland, in waters known as Buchan Deep. Hywind Scotland Limited (HSL) was incorporated in 2013 with the single purpose of developing and operating the Hywind Scotland Pilot Park. The project is co-owned by Statoil ASA (75%) and Masdar (25%). This offshore wind farm is unique from other UK developments, which have wind turbine bases fixed to the seabed. Proof of concept has been achieved from operation of a 2.3 MW prototype of Statoil's Hywind floating Wind Turbine Generator (WTG) spar buoy concept which has been in operation since 2009, at the Marine Energy Test Centre (floating) site in Karmoy, Norway.

The Hywind Scotland pilot wind farm has the capacity to generate up to 30 megawatts (MW) of power from five Wind Turbine Generators (WTGs). Siemens supplied five 6 MW SWT-6.0-154 machines which were assembled along with the floating spar foundations at the port of Stord in Norway.

The floating concept utilised a traditional spar buoy structure, which enables the turbines to be deployed at water depths of between 100 and 700 metres. The technology involved uses a 78 metre tall underwater ballast with a three mooring line attachment to the seabed (using suction anchors) to keep the turbines upright.

The project was granted exclusivity rights for the seabed by The Crown Estate in November 2013, and received consent from the Scottish Government in the form of a Marine Licence in November 2015. Offshore construction started in 2017, with the first floating spar buoy/WTG being transported from the Norwegian port of Stord on 19 July and arriving at Buchan Deep on 25 July. By the middle of August 2017 all five turbines had been towed into position, ready to be hooked up to the undersea cables by the anchor handling tug Normand Prosper. The wind farm is planned to be operational by the end of 2017.

The onshore infrastructure requirements for the Project were small in scale and consisted of an underground cable and switchgear yard located between the cable landfall and the existing Peterhead Grange Scottish and Southern Energy (SSE) Substation where the project will be connected to the electrical distribution network.

This project highlights the viability of offshore wind in high wave resource climates and deep water areas where conditions are unsuitable for the build-out of fixed-bottom offshore wind farms. It allows for access to higher wind resources and provides flexibility in the siting of projects in order to avoid environmental and technical sensitivities.

Figure 21 Artists impression of the Hywind Scotland Pilot Park

Case Study 2 (OW) Offshore wind floating wind technology status (UK)

The major driver for the development of offshore floating wind concepts is to unlock deep water sites close to shore which pose a challenge to fixed-bottom offshore technology and to improve upon offshore winds Levelised Cost of Energy (in simple terms, LCOE can be seen as the lifetime cost of the project, per unit of energy generated). It is known that, in water depths of less than 30 m fixed-bottom foundations provide the lowest cost solution, however, in water depths over 50m floating foundations provide the lowest cost solution. Large scale deployment in any country is dependent upon a mix of both offshore floating and offshore fixed-bottom wind technology. Floating wind in suitable sites, coupled with ongoing technology and supply chain innovations could deliver a Levelised Cost Of Energy (LCOE) of less than £85/MWh by mid-2020, with further cost reductions (Energy Technologies Institute, 2015). In comparison, fixed-bottom offshore wind costs have fallen sharply through the adoption of larger turbines, increased competition and lower cost of capital. Projects reached a Final Investment Decision (FID) in 2015/16 with an average Levelised Cost of Energy (LCOE) of GBP 97/MWh, compared to GBP 142/MWh in 2010/11 (Offshore Renewable Energy Catapult).

Over 30 concepts are currently under development for offshore floating wind. There are three dominant typologies for offshore floating wind concepts:

- Spar buoy (examples include; Hywind by Statoil, Sway by Sway, Advanced Spar by Japan Marine United)
- Semi-submersible platform (examples include; WindFloat by Principle Power, Dampening Pool by IDEOL, SeaReed by DCNS)
- Tension Leg Platform (TLP) (examples include; PelaStar by Glosten, Blue H TLP by Blue H Group, Eco TLP by DBD Systems, GICON-SOF by GICON)

Two other variations on typology exist:

- Multi-turbine floating platform (examples include; Hexicon and WindSea)
- Hybrid wind/wave floating devices (examples include; Poseidon P80 Floating Power Plant and SKWID by MODEC)

The floating wind concept which has the highest technology readiness is the Hywind spar buoy, with a prototype in operation since 2009. The semi-submersible floating platform concept is close behind, with the WindFloat full scale demonstration platform in operation since 2011. The Tension Leg Platform (TLP) concept is yet to be deployed as a large scale prototype. Due to abundant offshore wind resource, government incentives and regulatory support framework, the UK has recently started to position itself as a market leader in floating wind, with companies moving to install within Scottish waters. Scottish Government has consented one offshore floating wind farm - Statoil's Hywind project - at Buchan Deep off Peterhead.

Case Study 3 (RHK) Reference document Evaluation of Twelve Hydrographic Basins in Peru (ANA, 2016)

This report provides useful information on the current state of twelve Peruvian river basins showing a significant advance in the knowledge of the twelve river basins in the following aspects:

- It quantifies in detail the water resources in the 12 watersheds (see figure below - River basins considered in ANA study) studied both spatially (hydrological sub-basin scale), and temporally (49 years of calculation of natural water supply).
- Establishes a systematised and highly reliable methodology for the calculation of water contributions to the basins.

- Provides knowledge about the water operation of each basin, based on a flexible and upgradable management model that offers the following results:

  - Monthly sub-basin water balances
  - Reliability of existing water demands
  - Analysis and evaluation of possible future scenarios
  - Objective support for decision-making.

Figure 22 River basins considered in ANA study

Case Study 4 (RHK) Reference document 'Preliminary Analysis of Potential for River Hydrokinetic Energy Technologies in the Amazon River'. Inter-American Development Bank IDB, November 2015

This report performs an analysis of the ORE-HYBAM[18] database from The Observation Service SO HYBAM (formerly Environmental Research Observatory) "Geodynamical, hydrological and biogeochemical control of erosion/alteration and material transport in the Amazon, Orinoco and Congo basins" which has been in operation since 2003. The study identifies a total of 54 sites with data that can be analysed for river hydrokinetic purposes.

From this group, 20 sites were identified as having geomorphological and hydrological characteristics potentially suitable for a future river hydrokinetic initiative (other sites beyond this initial screening and outside the scope of this report exist), 8 of these sites are then chosen for in-depth analysis – 4 of which are in Peru.

The methodology used to conduct this high level analysis was as follows:

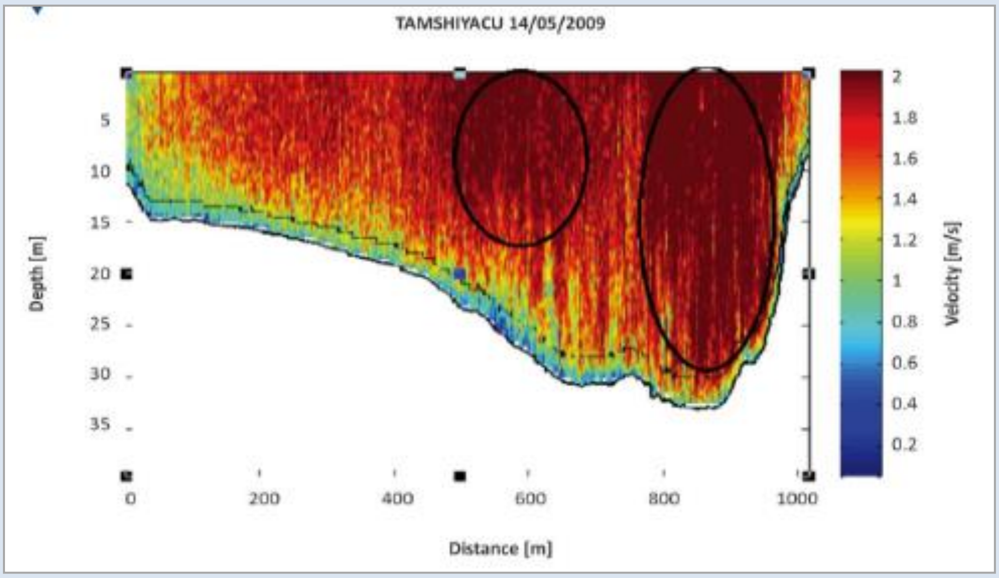
- Historical discharge measurement data was combined with Acoustic Doppler Current Profiler (ADCP) imagery in order to estimate river current velocity and therefore overall energy availability and theoretical energy capture of RHK systems at the selected sites
- Data was extracted from each ADCP measurement image, relating to river current velocities, depths, and the variation of these factors throughout the annual hydrological cycle
- For each ADCP file analysed, two areas from each section were selected: those containing faster water velocities and those with slower water velocities. The root mean cubed was taken over each area for each measurement and plotted against the mean discharge. The relationship between discharge and water speed was calculated for each area.

Of these 20 sites, several did not possess sufficient data for further study. Of the 20 sites, 8 sites were chosen that had the necessary availability and quality of data to perform a first analysis. These sites are distributed as follows: Brazil (3), Peru (4) and Ecuador (1) resulting in eight case studies.

In Peru, the data from 6 gauges was analysed. However, the analysis of the number of days when discharge conditions produced current velocities greater than 2m/s discarded several stations. At each site, the ADCP images were used to indicate the regions with velocities greater than 2m/s. An initial relationship between discharge and percentage of velocity greater than 2m/s was also analysed using a 95% confidence bound. For that initial basic analysis The Tamshiyacu, San Regis, Bellavista and Borja stations were considered with good potential for hydrokinetic deployments. See an example below for Tamshiyacu station.

[18] http://www.ore-hybam.org/

Figure 23 Results for Tamshiyacu station



The report contains evaluations of water discharge and velocity data from a range of Peruvian rivers and provides a basis for sites with high potential to be identified. The report concludes that there are likely to be many locations throughout the Amazon basin with favourable conditions for utility scale hydrokinetic projects which would experience capacity factors in the range of 50% - 80%.

Case Study 5 The future of energy in Scotland (2017) (Scotland)

A new draft strategy outlines targets for 50% of Scotland's energy use to be sourced from renewable sources by 2030. This includes heating, transport and electricity. The strategy also outlines a vision for the coming decades with the use of interconnected power systems that help tackle energy poverty in Scotland. As part of this, £50 million has been allocated in order to fund 13 projects that can demonstrate technologies utilising new renewable technologies to provide power, heat and/or transport.
http://news.gov.scot/news/the-future-of-energy-in-scotland

Case Study 6 (OW and W&T) Marine energy development in the UK

The reasons behind the continued acceleration of the marine energy sector in Scotland are two fold; firstly, Scotland has an excellent geographical position on the edge of the Atlantic Ocean – with 10 per cent of Europe's wave and 25 per cent of its tidal resource. Secondly, and of equal importance – a decade ago the Scottish Government made a very clear commitment to develop a marine energy industry in Scotland. Since then, the Government has worked closely with industry to put in place the crucial policy measures to enable this new industry to become established and grow. Scotland has a long history in marine energy. In the early 1970's (at a time of high oil prices following the OPEC price shock) Professor Stephen Salter of Edinburgh University made a prototype wave energy device known as the Salter Duck. The discovery of oil in the North Sea, however, put a halt to the UK's marine energy research programme until it was resurrected decades later with the installation of the 500 kW Limpet device on the island of Islay in 2000. However, the significant growth of Scotland's marine energy sector over the past decade can for the most part be attributed to the establishment of EMEC in Orkney in 2003, and the publication of the Scottish Government's Marine Energy Group Road Map in 2004 (see Case Study 7). The Marine Energy Group brought together government, academia and industry to understand the challenges and opportunities of marine energy and to present clear recommendations on what measures should be put in place. These recommendations were taken on board and formed the foundation for the industry we now see emerging today. The work undertaken by technology developers at EMEC has enabled Scotland to prove that marine energy technology works, whilst the Marine Energy Group Road Map and other road mapping exercises have helped to put in place the policies and processes to enable the development of a marine energy market. The crucial lesson for the development of a marine energy industry is that all policy measures must be developed in parallel: A partial or uncoordinated set of policy measures is unlikely to provide the political and industrial drivers required to progress the development of a successful marine energy industry. For instance, a well-structured consenting and licencing system will not secure the development of a marine energy industry where there is no ready access to grid infrastructure or alternatively, access to grid will not bring success if there is not a sufficient tariff to attract investment.

Case Study 7 (W&T) Marine energy strategy (Scotland)

A report published in 2004 by the Marine Energy Group (MEG) of Scotland´s Forum for Renewable Energy Development (FREDS) asserted that by 2020, 10% of Scotland's electricity could come from marine renewable sources and highlighted the opportunity for 1,300 MW of marine energy capacity to be installed in Scottish waters with the creation of 7,000 jobs and the potential for Scottish-based marine energy companies to become major suppliers of international energy export markets (FREDS/MEG, 2004). This document formed the foundations of the Scottish Government´s developing strategy for marine energy. A roadmap (FREDS/MEG, 2009) and action plan (FREDS/MEG, 2012) have since been developed by the marine energy group as a way of monitoring progress against these ambitions, and updating the specific recommendations. MEG was an invited group which the Scottish Government has has now formed on 3 occasions. Each group has been shaped to best meet the challenges of the time as they were understood. In the early years this group comprised technology inventors and academics, now it needs a wider more representative basis as the issues become more complex and integrated across the supply chain, government and society in general. This group has also had strong links to Scottish Renewables (SR), a trade body that has wide civic, academic and commercial membership. Both MEG and SR have sought to examine the wider picture and deliver broad based solutions appropriate, as far as practical, to all. The establishment of a group of specialist advisors with whom the government can informally explore options has worked well. Based partly on the findings of the MEG research, the Scottish Government is supporting marine renewable energy sources to contribute significantly towards achieving Scotland's target of generating 100% of the country´s electricity from renewables by 2020.

Case Study 8 (OW and W&T) Regulatory framework (Scotland)

The most important developments for the marine energy sector include:

- Establishment of a 'one-stop shop' for marine licensing (a single point of contact within the government for all licences and permits) and associated streamlining of the consents and licences required for projects in the marine environment.
- Development of bespoke industry guidance and adaptive management policies for offshore aquatic energy.
- Strategic, nationally-coordinated data gathering and environmental monitoring.
- A Strategic Environmental Assessment (SEA) for offshore renewables which identified areas of the country with lesser or greater potential for significant environmental impacts.
- Marine planning, in particular the identification and designation of specific areas as priority development zones for offshore energy.
- Commercial rights (leases) have been awarded to marine energy project developers by The Crown Estate prior to the award of permits and concessions (see case study below), giving developers more security before they begin the permitting process.

Case Study 9 (OW) Offshore Wind Regulatory Framework in the UK - the planning process

Within the UK's energy policy, offshore wind is considered part of the "energy mix", i.e. the various sources which make up the whole of the UK's energy. The deployment of offshore wind needs to take place in full accordance with rigorous environmental and planning procedures, while at the same time ensuring the UK is able to decarbonise its energy sector.

The expansion of the UK's offshore wind industry has been accompanied by changes in consenting regimes and the introduction of legislation designed to facilitate the development of what are known as Nationally Significant Infrastructure Projects. The Planning Act 2008 introduced a new consenting regime for offshore wind farms over 100 megawatts, whereby the entire planning process for a project is overseen by one body, with the intention of streamlining the consenting process to enable Nationally Significant Infrastructure Projects to progress to determination more efficiently.

The regulator of marine projects varies within which country of the UK a project is based. These are as follows:

- Scotland – Marine Scotland Licensing Operations Team (MS-LOT);
- England – Marine Management Organisation (MMO);
- Wales – Natural Resource Wales (NRW); and
- Northern Ireland – Department of Agriculture, Environment and Rural Affairs (DAERA-NI).

The regulations which need to be taken to into account when developing an offshore wind project in Scottish waters are provided below. The same regulations or slight variations of these would be also need to be adhered to in each of the other UK countries.

- Section 36 of the Electricity Act 1989;
- Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2000, as amended;
- The Marine (Scotland) Act 2010;
- The Town and Country Planning (Scotland) Act 1997; and
- Conservation (Natural Habitats, &c.) regulations 1994.

The above regulations are those transposed from European law into national law. In addition to these there are also local council policies and regulations that will need to be adhered to when developing an offshore wind project.

Case Study 10 (W&T) Potential impacts of wave and tidal (Scotland)

A review of the potential impacts of wave and tidal renewable energy developments on Scotland's marine environment has been commissioned by Marine Scotland.

http://www.gov.scot/Resource/0050/00507385.pdf

Case Study 11 (W&T) Survey, deploy and monitor policy (Scotland)

A Survey, Deploy and Monitor Policy (Scottish Government, 2012) was adopted to provide an efficient risk-based "adaptive management" approach for evaluating the potential environmental impacts of wave and tidal energy developments, based on:

- Environmental sensitivity - whether the site is near or in a designated environmental site

- Scale of development - number of devices or total installed capacity
- Device (or Technology) risk classification, based on factors such as noise generation, pollution risk, entanglement/collision which vary between concepts

This policy started life as "deploy and monitor", but concerns from ecological advisors led to the survey provision being added. This has proved costly and controversial for the development community who feel that excessive surveying requirements have been imposed on the sector for early stage developments. In particular there has been an expectation of two years of bird and mammals surveying without a clear risk-founded basis for such work. In addition there has been a weak feedback loop between the operational experiences of the past 10 years of marine energy operations and the development of baseline survey and monitoring requirements. This has arisen partly due to development companies failing to monitor enough or publish the results of their observations, and also because of government failing to support monitoring and baseline studies targeted on a risk-basis. Instead funds have been spent gathering wider strategic data which is not directly relevant to the specific potential impacts of wave and tidal energy projects. Scotland´s adaptive management approach has yet to be fully implemented and there is active discussion ongoing about how it can be improved. Likely improvements could include:

- Defining requirements for limited monitoring of all deployments and publishing of results
- More focussed baseline data gathering within site boundaries at particularly active times of year
- Better dissemination of information about experiences to date

See: http://www.gov.scot/Topics/marine/Licensing/marine/Applications/SDM

Case Study 12 (OW & W&T) Marine Scotland Interactive (MSI) (Scotland)

Marine Scotland Interactive (MSI) is an interactive tool designed to assist in the development of the National Marine Plan. The tool allows users to view different types of information and where appropriate, links have been provided to the related parts of Scotland's Marine Atlas where the information is discussed in more detail.
See: http://www.scotland.gov.uk/Topics/marine/education/atlas

Case Study 13 (OW & W&T) Marine planning (Scotland)

In 2016 the final Pilot Plan was released by the Scottish Government. The Plan sets out an integrated planning policy framework to guide marine development, activities and management decisions, whilst ensuring the quality of the marine environment is protected. The Plan acknowledges that the marine environment is used for a wide variety of different purposes for which it aims to set out a coherent strategic vision, objectives and policies to further the achievement of sustainable development.

Sustainable growth of marine renewable energy and the potential for co-existence with other marine users is a key objective of the plan. This could mean using renewables in combination with other sectors or sharing space, where health and safety requirements permit, with other marine users. The plan option areas represent the strategic development zones in which commercial scale projects should be sited although it is not expected that the whole of each plan option area will be fully developed. Options are considered the preferred strategic locations for the sustainable development of offshore wind and marine renewables. These plan option areas are large areas which would be unlikely to be able to be fully developed by developers and so there are options for sharing and co-location with other industries e.g. aquaculture.

The Pentland Firth and Orkney Waters (PFOW) area has some of the best marine renewable energy resources in the UK and could help support Scotland's ambitious energy targets. The industry is at an early stage of development, but an increase in growth of this sector may result in a big change in the use of the marine environment in this area. This potential growth may impact on other marine users and marine planning aims to guide development to areas of least constraint. Early consultation with other marine users and consideration of shared use will help mitigate adverse impacts.

Case Study 14 (OW and W&T) Leasing (UK)

The commercial seabed leasing process is managed by The Crown Estate (TCE), a public body which manages seabed, and other terrestrial assets. The Crown Estate owns and manages the territorial seabed in England, Wales and Northern Ireland (Crown Estate Scotland took over management of the territorial seabed in Scottish waters in 2017). The Crown Estate issues leases, for commercial fees, to those who wish to make use of the seabed. As well as managing leasing of the seabed out to 12 nautical miles, TCE also holds rights to offshore renewable energy and carbon and gas storage out to 200 nm from the shore.

Offshore Wind

The leasing of seabed areas was done in rounds, beginning with Round 1 in December 2000 which involved leasing of the seabed for commercial development of some of the first ever offshore wind farms. Typically, the areas selected were small in scale and close to shore and projects tended to have no more than 30 turbines, and overall capacities no greater than 100 MW. There are now 13 Round 1 projects fully operational with a generating capacity of 1.2 GW.

Round 2 started in July 2003 and focussed on areas such as the Thames Estuary, Liverpool Bay and the Greater Wash, with some areas outside the 12 nm territorial waters limit. These wind farms are larger in scale and generally further from the shore than Round 1 projects. In 2010 The Crown Estate extended the geographical areas of four Round 1 and Round 2 sites. In total there are some 33 Round 1, Round 2 and extensions projects with a total projected output of 8.5 GW.

The UK Offshore Energy Strategic Environmental Assessment (SEA), published in January 2009, identified up to 33 GW of potential offshore wind capacity in UK waters. This formed the basis of the Round 3 offshore wind programme. Nine offshore wind farm zones of varying sizes were identified within UK waters to deliver the capacity identified in the SEA. Renewable energy developers were asked to bid for exclusive rights to develop offshore wind farms within the zones. The successful development partners for each zone were announced in January 2010, of which eight are currently under active development.

Lessons learned throughout the offshore wind leasing round process have been applied to the W&T leasing rounds with the hope of stimulating development in the industry.

Pentland Firth and Orkney Waters Leasing Round Context (W&T)

In 2009 following calls from the Scottish Government for an acceleration of marine energy development, The Crown Estate held a commercial leasing round for marine energy in an area defined as the Pentland Firth and Orkney Waters Strategic Area (PFOW). The subsequent lease application process attracted some 41 initial applications, of which 15 were invited to a final round of submissions and negotiations. In the end, seven organisations signed agreements with The Crown Estate for lease options covering 10 individual project proposals. The lease options initially agreed amounted to around 1,200 MW of installed capacity. Due to the late withdrawal of a candidate developer from a prime tidal site, a further mini leasing round was held for the Inner Sound within the Pentland Firth. This resulted in a 400 MW lease option being awarded, giving a total of eight developers, 11 projects and 1,600 MW of capacity. The successful applicants included a number of UK electric utility companies and technology companies.

Where different companies may end up competing for the same sea space, and other factors associated with the application are acceptable, negotiations are encouraged to take place to investigate win/win solutions which will allow both applicants to proceed. Applications for small scale demonstration projects as part of the larger leasing process are encouraged but time limited.

The award of leases/lease options is linked to an agreed development schedule to avoid speculation. If this schedule slips then appropriate sanctions are required – this could mean annulling the lease or for example reducing the installed capacity of the lease award by a percentage for every period (e.g. year) of delay. Other key performance factors should also be defined and associated with rewards or sanctions. These may include project safety, level of local content, pattern of energy supply, cost of energy, etc.

The scale of any lease awards needs to reflect the status of the sectors, particularly with regards to technology readiness and the demonstrable experience of the applicants. Projects of up to 10 MW are likely to provide a prudent first step – no wave or tidal projects of this scale have yet been deployed. The largest offshore wind project currently under active development in the UK is the London Array (630MW).

Although one of the stated aims of the Pentland Firth and Orkney Waters Leasing Round leasing process was to avoid a premature "grab" for seabed areas, the eventual approach taken has failed to achieve this. Large areas have been allocated to a few companies, and expansive buffer zones have been created around existing lease option areas which have yet to be developed. Holding secure use rights of the seabed has however enabled two of the successful applicants to adopt a twin track approach of developing their technology and seeking all the necessary consents and permits required, so that they have sites available for commercial use by the time their technology has matured. The publicity around this commercial leasing round has also clearly helped put the UK marine energy industry in the lead internationally.

Pilot Pentland Firth & Orkney Waters - Marine Spatial Plan - Strategic Environmental Assessment - Post Adoption Statement (March 2016)
http://www.gov.scot/Resource/0049/00496909.pdf

Current W&T Leasing Process
Recently, in order to complement the UK's test and demonstration facilities and to accommodate the nascent nature of the W&T industry, TCE, now offer development rights for small scale wave projects of up to 3 MW and tidal current projects of up to 30 MW, with applications able to be made at any time, until further notice. Crown Estate Scotland has taken a similar approach, however, also offers leases for wave projects of up to 30 MW. This update by TCE and Crown Estate Scotland recognises current government policy, industry progression and market conditions.

Case Study 15 (OW and W&T) Regional Locational Guidance (RLG) for planning of offshore renewable developments (Scotland)

RGLs were published for wave, tidal and offshore wind. Within the documents, guidance considers environmental, technical and socio-economic and planning issues.

Draft Wave Regional Locational Guidance:

http://data.marine.gov.scot/dataset/draft-wave-regional-locational-guidance

Draft Tidal Regional Locational Guidance:

http://data.marine.gov.scot/dataset/draft-tidal-regional-locational-guidance

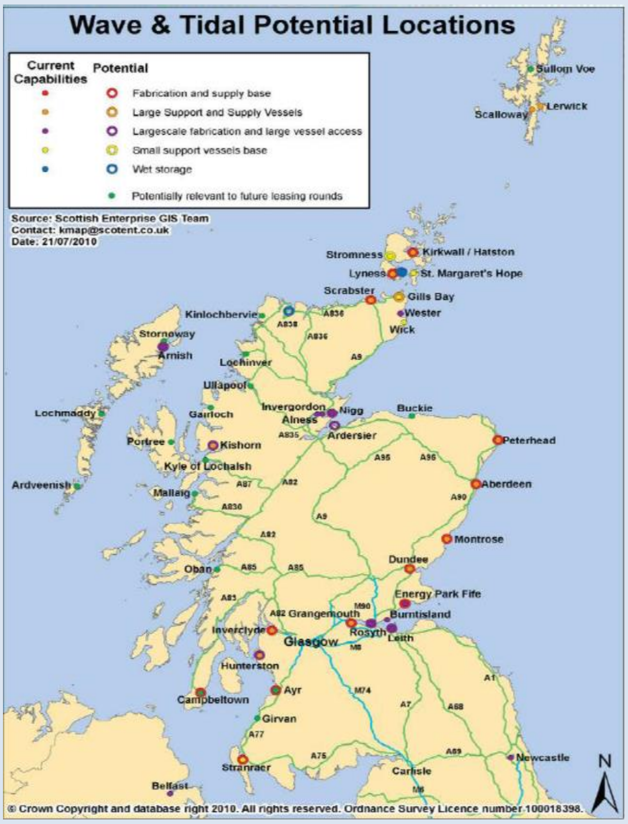
Draft Offshore Wind Regional Locational Guidance:

http://data.marine.gov.scot/dataset/draft-offshore-wind-regional-locational-guidance

Case Study 16 (W&T) Marine energy infrastructure planning (Scotland)

Early decision making resulted in EMEC being established in Orkney, a maritime community with existing ports, electricity grid, support vessels and offshore expertise. This has meant that early technology prototype and full scale testing have not been significantly hindered by a lack of supply chain capacity. However, as the level of activity associated with technology testing and the build-out of the first demonstration sites and commercial-scale arrays increases, infrastructure and supply chain capacity is emerging as a key concern. The Scottish Government - through its economic development providers (Scottish Enterprise (SE) and Highland and Islands Enterprise (HIE) - commissioned a report to develop a National Renewables Infrastructure Plan (N-RIP) which was completed in 2010. The purpose was to develop an investment strategy for port and infrastructure developments that would complement and enhance the renewable industry within Scotland. The motivation for developing this infrastructure stemmed from Scotland´s desire to become a European base for construction and assembly of wind turbines and marine devices (SE/HIE, 2010).

Figure 24 Evaluation of port capacity to support the marine energy industry



Case Study 17 (W&T) Orkney Vessel Trials Project (Scotland)

The project aimed to provide evidence for cost reductions through assessing over 60 vessel operations, which involved 20 local organisations and over 120 individuals. The six areas of investiagtion were:

- Dynamic loading
- Gantry barge positioning and device deployment
- Clump weight friction
- ROV operations
- Response to man overboard situations in tidal currents
- Dynamics of buoy submergence

It was found that device deployment costs could be reduced by 70 - 80% in comparison to conventional utilisation of DP vessels. The method used to determine the capacity of the local supply chain was found to be applicable locally, nationally and globally.

http://www.aquatera.co.uk/blog_post.asp?ID_Press=1

Case Study 18 (OW and W&T) The UK's marine energy supply chain development

One of the key challenges identified in Renewable UK's report 'Marine Energy in the UK: State of the Industry Report 2012' was "developing a UK supply chain with the necessary skills and capacity to deliver rapid growth in the sector and to capture the socio-economic benefits of the industry in the long-term". The most recent available figure suggests that there are currently over 1,000 full-time equivalent jobs in the UK offshore aquatic sector. Future estimates predict that 7,000 direct jobs (FREDS/MEG, 2004) could be created in Scotland within the marine energy industry, related to 1.3 GW of deployment. Renewable UK's report on Employment and Skills in the UK Wind & Marine Industries (2011) reported that in the wave and tidal energy sector, 37% of employers reported that they had experienced difficulty in filling vacancies over the previous 12 months. These vacancies in the wave and tidal energy sector were mainly in specialist skills such as hydrodynamic modelling, aerodynamic mechanical engineering, hydrographic surveying, environmental consultancy, subsea design, ornithology and ecology. These skills may be transferable from other industries but often encouragement is needed to get workers to change industry. Peru is likely to face similar challenges once the aquatic energy activity begins to increase.

Case Study 19 (W&T) Marine energy cost reduction (UK)

The following areas were identified in the Future Marine Energy Report (Trust, 2006) as having the most potential for marine energy cost reduction:

- Device components – Research into lowering costs and improving performance of specific components in existing marine energy devices.
- Installation, operation and maintenance – Developing strategies to enable marine energy devices to be installed, operated and maintained at a lower cost.
- Next generation concepts – Developing new device concepts that could significantly lower the costs of marine energy compared with other front runners. Subsequently, the £3.5m UK Marine Energy Accelerator (MEA) programme was launched to explore cost reduction in marine energy (Trust, 2011).

Focusing on the three areas identified above, this project describes the potential for cost reduction as follows: Energy from wave and tidal energy converters will become more affordable as the number of devices manufactured increases – so-called 'learning by doing'. For energy devices this equates to cost of energy (in p/kWh) dropping by a fixed rate for each doubling of cumulative annual output (in kWh per year). This can be plotted on an experience curve or as a 'learning rate'. Technology innovation can increase the rate of cost reduction – steepening the learning curve – or start the curve at a lower level. The report describes how the cost of energy from marine energy devices can be reduced through two distinct, but often overlapping, effects:

From reductions in the six cost components identified as the constituent parts of the cost of energy (Figure 23), which reduces capital or O&M spend per kWh of output; and,

From improvements in device performance, which increase the number of kWh per unit of capital and operating spend. Efficiency improvements increase the output of the device while operating, while reliability improvements increase the time spent generating electricity.

Wave Energy Scotland (WES)

Wave Energy Scotland was set up in 2014 by request of the Scottish Government to aid Scotland in remaining to be at the forefront of wave energy convertor development. The £10 million annual budget is used selectively to support developers to tackle key technological issues hindering the furthering progress of the industry. It is hoped this will result in the production of more reliable technologies and reduce end costs. To date, WES has awarding over £15 million to 51 projects, across 129 organisations, spread across five different countries.

http://www.hie.co.uk/growth-sectors/energy/wave-energy-scotland/

Marine Energy Component Analysis - (July 2016)

The Offshore Renewable Energy Catapult (ORE Catapult) and the European Marine Energy Centre (EMEC), are working together, and pooling their first-hand testing experience to tackle a key technology challenge facing the marine energy industry; component failures and their impact on device reliability and survivability.

https://ore.catapult.org.uk/wp-content/uploads/2016/08/PN78-SRT-001-Rev-0-Case-Study.pdf

Case Study 20 (W&T) Sector enabling funds (USA and the UK)

Sector enabling funds (Oregon, USA) Oregon has perhaps had the most diversely based funding programme for marine energy. Funds have gone into enabling studies and industry support in addition to direct technology support. It is notable that the Oregon Wave Energy Trust (OWET) is predominantly made up of supply chain service providers. This has perhaps broadened the funding priorities. Such a focus on enabling can make sense - given the lack of a support tariff in the USA and low energy costs, the economic case for technology deployment is less strong than in other parts of the world. In addition Oregon has been more successful in identifying many of the strategic barriers and opportunities that face the wave sector, before major development takes place, than other geographical areas.

Sector enabling funds (Scotland, UK) Enabling funds have also been made available in the Pentland Firth Orkney Waters (PFOW) area by The Crown Estate, recycling some of the income taken from lease fees and including additional finance from The Crown Estate, the Scottish Government and specialist government bodies. Whilst a considerable amount of money has been spent, the focus of the studies has often missed the key priorities that could have best "enabled" the specific projects targeted or the sector in general. In some cases, decisions to support studies were made without sufficient consideration of local knowledge/experience or input from the broader supply chain. Consequently some key, and relatively simple, questions remain unanswered whilst there is a considerable of amount of expensively gathered information that may prove to have little value to the future of marine energy.

Much of these funds have been used effectively in projects which have helped to reduce uncertainty and provide valuable data to help address a number of issues in the marine energy industry, for example, inter-array cable installation methods for tidal energy projects. However, in some cases, decisions to support studies were made without sufficient consideration of local knowledge/experience or input from the broader supply chain. Consequently, some key questions remain unanswered whilst there is a considerable amount of expensively gathered information that may prove to have limited value to the future of marine energy.

It is important therefore that an appropriate foundation of relevant expertise, experience and understanding informs the allocation of future strategic funding programmes. This will ensure that research studies which provide the greatest benefit to the development of the industry, are selected. One UK initiative which aims to address this is the Offshore Renewables Joint Industry Partnership (ORJIP) which identifies and prioritises key strategic environmental research programmes which will help reduce consenting risk for wave and tidal developments.

Case Study 21 (W&T) Marine Energy Centres (the UK, South America and USA)

Marine Energy Centres in the UK

There are three UK test sites which cover the various stages in wave/tidal energy device development, these are described below.

Offshore Renewable Energy Catapult (CATAPULT) - opened in 2002 at Blyth in the north west of England, NAREC carries out scale testing of marine renewable devices and sub-systems. Its facilities include: 1. 3 Dry Docks – the largest of which is 75 m long, 25 m wide and 8 m deep; 2. Wave Flume - A simulated wave environment for the testing of prototype wave energy generation devices sited within a converted dry dock facility; 3. Nautilus - A 3 MW drive train test stand for tidal energy generators which allows certification activities, reliability and performance appraisal of new devices through accelerated lifetime testing at significantly lower cost and risk in comparison to sea testing; 4. Tidal Testing Facility – The Tees Barrage Tidal Turbine Test Facility, located in Stockton, was opened in 2007.

EMEC (European Marine Energy Centre) – facilitating wave and tidal prototype development, EMEC is based in Orkney within the Pentland Firth and Orkney Waters marine energy park. It was established in 2003 and has expanded and diversified its testing facilities, attracting wave and tidal energy developers from around the globe. EMEC is the first and only centre of its kind in the world to provide developers of both wave and tidal with accredited open-sea testing facilities. To date it has had the largest number of marine renewable device deployments within its wave and tidal test sites. The centre has been the focus of a large amount of developer attention and global interest and as such has also attracted a large media focus. The success of the centre has also encouraged the local supply chain to build up and is increasingly the focus for research and education. EMEC also operates scale (nursery) test sites where smaller scale devices (or those at an earlier stage in their development) can gain real sea experience but in more benign conditions than those experienced at the full-scale wave and tidal test sites.

Wave Hub – carrying out the demonstration and proving of arrays, Wave Hub is a grid-connected offshore facility in south west England for the large scale testing of technologies. It consists of an electrical hub on the seabed 16 kilometres off the north coast of Cornwall in south west England to which wave energy devices can be connected. The project holds a 25-year lease for eight square kilometres of sea and has four separate berths, each with a capacity of 4 – 5 MW.

Marine Energy Centres in Latin America

Marine Energy Research & Innovation Centre (MERIC) Chile, the interdisciplinary research developed at MERIC allows understanding of the ecosystem dynamics related to the extraction of marine renewable energy, as well as how to adapt the current technologies to the extreme conditions of Chile.

At the same time, MERIC examines the international experience related to procedures, regulations and public policies that could be adapted to the Chilean context ensuring an appropriate management of social and environmental impacts of marine renewable energy projects, caring for the communities and their interests, and working on models and protocols to support the decision making process.

CEMIE-Oceano (Mexico), the Mexican centre for innovation in Marine Renewable Energy integrates the combined effort of 46 higher education institutes, research centres and national companies, as well as 4 foreign institutions. CEMIE is starting to be organised internally to start developing its activities.

RHK Energy Centres in Alaska

The Alaska Center for Energy and Power (ACEP) is based within the Institute of Northern Engineering of the University of Alaska. ACEP is focused on addressing energy cost and supply issues for remote and 'islanded' grids in Alaska. ACEP hosts the Alaska Hydrokinetic Energy Research Center (AHERC) which is a dedicated research and test facility for river hydrokinetic as well as wave energy technology. AHERC has worked with a number of river hydrokinetic technology developers in deployments in Alaska and has also conducted research on topics such as yield estimation, device performance and also debris characterisation and mitigation.

River Hydrokinetic Centres Alakan entre for Energy and Power (ACEP), test site facilities

Case Study 22 (W&T) Academic aquatic energy courses in the UK

A number of institutions are offering courses specifically aimed at aquatic renewables, some of these are listed below.

UK Institutions offering courses on aquatic energy

Institution	School	Course
Heriot-Watt University	School of Energy, Geoscience, Infrastructure and Society (EGIS)	Marine Renewable Energy
University of Strathclyde	Naval Architecture and Marine Engineering	Sustainable Engineering (Offshore Renewable Energy)
Robert Gordon University	School of Engineering	Offshore Renewables MSc
University of Exeter	Renewable Energy	Offshore Renewable Energy
Cranfield University	School of Applied Sciences	Offshore and Ocean Technology with studies in Offshore Renewable Energy
Plymouth University	School of Biological and Marine Sciences	Marine Renewable Energy
Bangor University	School of Ocean Sciences	Marine Renewable Energy
University of Leeds	School of Electronic and Electrical Engineering	Electrical Engineering and Renewable Energy Systems
University of Edinburgh	School of Engineering	Marine Energy
University of Manchester	School of Electrical and Electronic Engineering	Renewable Energy and Clean Technology

Case Study 23 (W&T) Marine Renewable Energy Knowledge Exchange Programme (UK)

NERC funded the Marine Renewable Energy Knowledge Exchange Programme (MREKEP) to catalyse the development of partnerships between the academic research base and industry, as well as regulators and policymakers, to accelerate the uptake of research to inform the sector:
http://www.nerc.ac.uk/innovation/activities/infrastructure/offshore/
Crown Estate Wave & Tidal Knowledge Network: http://www.waveandtidalknowledgenetwork.com/

Case Study 24 (OW and W&T) Low carbon employee training (Scotland)

In 2010 the Scottish Government announced an initiative to support employers who wish to develop their employees' skills in low carbon technologies. The 650 new places, to be delivered through Skills Development Scotland, are being funded with the support of the European Social Fund. The fund will enable employers to train employees in low carbon technologies as part of the Scottish Government's drive to maximise the economic benefits of greener business.

Case Study 25 (W&T) Financial support for marine energy projects (Europe)

The European Ocean Energy Association has highlighted the need to encourage private sector investment through: revenue support in the early year's allied to soft loans, co-investment and public guarantees, in order to de-risk project finance. It is no coincidence that most commercial marine energy technology development is centred on the UK, where the latest proposed UK tariff is £305 per MWh for projects commencing by 2017. Substantial financial support is also available in France and is closely linked to projects resulting in direct industrial activity within that country. Nova Scotia in Canada has recently set an initial tariff of 575 USD per MWh for test devices at the Fundy Ocean Research Centre for Energy. It should also be noted that the total cost to date of the world-leading Renewable Obligation in Scotland has been less than 75,000 USD (because of the relatively low amount of power produced to date) yet this measure has been instrumental in bringing record-breaking numbers of marine energy companies to Scotland and the UK.

Funding Ocean Renewable Energy through Strategic European Action (FORESEA) aims to provide financial support to developers of wave and tidal technologies through covering the costs associated with deploying scaled technologies among the test centres supported by the Ocean Energy Europe group, which includes:

- European Marine Energy Centre (EMEC), UK
- SmartBay: Galway, Ireland
- SEM-REV: Nantes, France
- Tidal Testing Centre, Netherlands

Testing of pre-commercial technologies can add significant costs to the development of turbines. It is hoped that removing this large portion of the associated cost that private investors will be more willing to invest in the technology's development. In essence this will remove a portion of the risk involved in open sea testing. The project will run until 2019 with a total budget of €10.75 million.
http://www.nweurope.eu/projects/project-search/funding-ocean-renewable-energy-through-strategic-european-action/

Case Study 26 (OW and W&T) Offshore wind investment and financial incentives (UK)

Investment risk into offshore renewables needs to be minimised by a stable regulatory framework. Offshore wind operates under a Levy Control Framework. Historically, this was Renewable Obligation Certificates (ROCs), however a new system is now in place, Contract for Difference (CFD). A CFD is a private law contract between a low carbon electricity generator and the Low Carbon Contracts Company (LCCC), a government-owned company. A generator party to a CFD is paid the difference between the 'strike price' – a price for electricity reflecting the cost of investing in a particular low carbon technology – and the 'reference price'– a measure of the average market price for electricity in the GB market.

The Chancellor of the UK released the budget for 2017, announcing that the Levy Control Framework will be replaced by a new set of control measures to be set out later in the year. It is expected that projects being considered today, will not be covered by the Levy Control Framework in 2020. As discussed, investment risk into offshore renewables needs to be minimised by a stable regulatory framework. Financial investment decisions can be made by project development companies and green investment banks when governments provide confidence in the form of a stable regulatory framework and financial investment incentives for the build of large scale offshore wind projects. This would be the first step for offshore wind to develop within Peru.

Case Study 27 (RHK) A grid-connected community project at Applecross, north west Highlands (Scotland)

An initial desktop survey of the area in 2009 identified eight rivers and burns as suitable for a micro hydro scheme. It was confirmed however, that the potential export capacity to the grid was limited to 90 kW. The most appropriate single site was therefore selected at Allt Breugach and a 90 kW connection was purchased. A rental agreement was agreed with the landowner at 10% gross income after year 9 – a level considered higher than average compared to other similar community energy projects. These factors produced an estimated income to the community of £30k per annum.

In order to maximise the community benefits 'Applecross Community Company Ltd' investigated ways to use surplus electricity generated. A feasibility study of 'hydro to heat' received an £18k grant from Local Energy Scotland. The heating scheme was proposed as it would help reduce fuel poverty (defined as where an individual household spends 10% or more of income on energy) and generate a higher financial return to the community. Modelling was conducted to estimate the amount of both electricity and heat generated, the amount of energy which could not be utilised by either, and the amount of backup heat required when hydro power was unavailable. A financial analyses was undertaken including the income streams from the sale of electricity to the building occupants, FIT payments and the sale of electricity to the grid.

During this project phase the Distribution Network Operator (DNO) announced a reduced revision to the grid export capacity of only 50 kW. Simple paybacks were calculated based on three scenarios: the 50 kW capacity, a 90 kW capacity being available in 2022, and a delayed 90kW connection being available in 2027. The results showed all of the scenarios produced a long-term financial benefit but that the installation of a 90 kW turbine was the most appropriate in all cases – being sufficient to meet the available demand and with little unused generation. The thermal storage scheme enhances the utilisation of electricity but not sufficiently to be financially favourable. It would however be favoured over hydro-only if funding can be secured.

Such community hydro schemes yield a return to investors but also a community benefit which is generally allocated to local good causes. The 2015 Government review of FITs and subsequent policy shift on renewables has dramatically reduced the Feed In Tariff and alongside the removal of tax incentives the model for Community Benefit Companies has recently become much less favourable in the UK.

Case Study 28 Electric ferry (Norway)

The MF Ampere is the world's first full-electric battery powered car and passenger ferry. It operates along a 20 minute, 5.6 km, crossing among the Norwegian Fjords 34 times a day. At the end of each crossing the vessel recharges for 10 minutes before departing again. Large 410 kWh onshore battery banks positioned next to each of the docking points provide the capacity for large rates of power, without putting excessive strain on the local grid. http://corvusenergy.com/tag/mf-ampere/

Case Study 29 Hydrogen production (Scotland, UK)

Enabling funds have also been made available in the Surf 'n' Turf project in Orkney, Scotland, which has been commissioned in order to utilise a higher portion of the potential renewable energy available in Orkney. Since the level of power generation is significantly greater than the demand, the grid is subject to turbines being turned down/off when the grid is full. By increasing the level of electrical demand, it is hoped that turbines will be generating power, and income, more often. The project hopes to use a hydrogen electrolyser when the turbines would otherwise be turned off. This hydrogen will be then used elsewhere on the island to further reduce carbon emissions through the use of a fuel cell providing electricity

http://www.surfnturf.org.uk/

Case Study 30 Hydrogen boat (UK)

Since 2010, the city of Bristol, UK, has been operating a hydrogen fuel cell powered boat within the harbour of the city. This boat provides transport and private hires for the city. The 12 passenger boat is powered by a 12 kW fuel cell, fuelled entirely by hydrogen
http://www.bristolhydrogenboats.co.uk/index.html

Case Study 31 Hydrogen and Fuel Cell Technology Roadmap IRENA

In 2015, the International Energy Agency (IEA) published a hydrogen and fuel cell technology roadmap. The roadmap covers the use of hydrogen as an energy storage medium, and fuel cells as a means of power production across a number of sectors. As part of this roadmap, topics included:

- The steps that were seen as key for the development of these technologies over the next ten years were outlined.
- The current status and performance of the industry, and comparisons with other energy storage mediums.
- Efficiencies of hydrogen production processes and storage.
- Vision for 2050, including transport, industry, buildings, other transformations and power generation.
- Economics of generation and power production.
- The industries hydrogen can be introduced into.

https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapHydrogenandFuelCells.pdf

Case Study 32 (RHK) Delivering Micro Generation projects in remote and challenging conditions: The Scottish Experience

The Highlands and Islands of Scotland have a rugged terrain with a topography and climate which lends itself to exploiting hydro power. Whilst large and medium scale hydro generation involves the construction of imposing impoundment dams, micro hydro generation diverts a portion of the flow through a low head system and after generation returns the water to the river. In Scotland the potential for further large or medium scale generation is now accepted as limited, however the micro market has significant potential with particular relevance to remote areas, individual households, rural business and community groups. This potential is contained within some of the most scenic and unique landscapes in the world and developments must be carried out sympathetically and in line with licensing and environmental protection requirements.

Companies working in the microgeneration market can become recognised as approved installers under the Microgeneration Certification Scheme (MCS) which is linked to eligibility for grid-connected FITS for PV and wind systems less than 50 kW. In the UK micro hydro (less than 50 kW) is accredited through the Renewable Order Obligation (ROO-FIT) and covers capacity up to 5 MW.

Off-grid solutions can provide a stable electrical power supply by the use of innovative power management and energy storage systems (courtesy: Proterra Energy Ltd.)

One Highlands-based company working in this environment is Proterra Ltd [19] who specialise in the design, installation and maintenance of micro schemes, typically up to 100 kW.

The company has gained considerable experience working in remote, often off-grid and logistically challenging areas and within a strict legislative climate. Internationally, the company recognises the potential to translate this experience to developing parts of the world where mains electricity is not regularly available. The company are developing a range of products such as a Mobile Hydro System capable of delivering up to 3 kW, and also Power Management, Load Prioritisation Systems and Intelligent Storage Solutions for off-grid schemes in order to maximise the productivity of the power produced.

Proterra is an example of a Scottish company who are developing links in South America and have already worked in Chile in partnership with local organisations to provide an in-country base working to support the development of Renewable Energy Systems to remote communities. The joint project is looking at promoting Sustainable Clean Energy Solutions with Proterra providing support on hydro elements.

Case Study 33 (RHK) Smart Hydro Power (SHP), RHK in Bellavista (Peru)

SHP[20] installed a project in a rural community of Loreto called Bellavista SHP consisting of 2 hydrokinetic turbines of 5 KW each, 8 solar panels of 250V, batteries and a diesel generator as a backup.

Electrification: after the electrification, all of the 32 households in Bellavista have access to the installed mini grid. Inside each house, a light bulb and an electric socket as well as a circuit breaker have been installed. There is electricity four hours every night from 6pm to 10pm. Further, public lighting has been installed throughout the village centre, allowing for social gatherings and making walking in the area safer (dangerous animals can be spotted).

Potable water: SHP installed a water treatment system in Bellavista. The treatment unit consists of an electric pump, automatically filling the reservoir of a water tower, from where the water passes through multiple filter units. The

[19] www.proterra-energy.com

[20] http://www.smart-hydro.de/

outcome is potable water of a publically accessible faucet.

Cooling: both a large fridge and an ice machine have been installed in the village's communal house for public use.

Job and capacity building: electricity and potable water combined with cooling deliver the potential for several jobs. A first job has been created; a local woman is producing lemonade with the potable water, cooling it and selling it both to villagers and to people travelling on the river.

A team of three people has been capacitated and is maintaining the power plant as well as the water treatment system. These people are being paid with part of the monthly electricity payments.

Figure 25 SHP turbine, Peru

Case Study 34 Blue Growth Strategy (Europe)

Blue Growth is the long-term strategy to support sustainable growth in the marine and maritime sectors as a whole in Europe. The Blue Growth Strategy considers five high potential sectors for sustainable jobs and growth, such as: aquaculture, coastal tourism, marine biotechnology, ocean energy and seabed mining. Particularly, for ocean energy the vision of the Blue Growth Strategy is to bring Member States, the industry and the Commission together to work in a collaborative manner to accelerate the development of the sector. There are a number of actions established by the Commission that envision the future position of the Ocean Energy sector in Europe. In terms of deployed capacity the UK can be regarded as relatively advanced with 9.33 MW of installed wave and tidal stream energy capacity, the greatest of any OES member state. Progress towards UK Blue Growth research and development targets is largely enabled by a number of key R&D institutions including the Energy Technologies Institute (ETI), Innovate UK and The Offshore Renewable Energy Catapult.

http://ec.europa.eu/maritimeaffairs/policy/blue_growth_en

Case Study 35 (W&T) EU Ocean Energy Strategic Roadmap (2016) (Europe)

The Ocean Energy Strategic Roadmap was published in November 2016 and was commissioned by the European Commission Directorate-General in collaboration with the Ocean Energy Forum (OEF). OEF's ambition is to bring together stakeholders to understand problems facing the industry and collectively produce solutions.

https://webgate.ec.europa.eu/maritimeforum/sites/maritimeforum/files/OceanEnergyForum_Roadmap_Online_Version_08Nov2016.pdf

Case Study 36 (W&T) Atmocean deployment (Peru, Ilo)

From the two tests that Atmocean[21] conducted in Ilo in 2015 the company invested in the Peruvian market covering operations ranging from lodging, food, transport of materials, pier fees, marine operations, import fees, local building supplies, local construction. In regards to employment, Atmocean contributed to the direct employment of more than 60 people that worked on the project during testing with 120 others that were indirectly positively affected in the south of Peru. For each commercial system, Atmocean believes they could build 80% of the equipment in Perú. Operations would generate some 20 - 30 full time jobs for each project and a few hundred part time construction jobs created in the build out phase.

Figure 26 Atmocean deployment in Ilo (Atmocean)

Case Study 37 Creating jobs on the periphery (Orkney, UK)

Company formation numbers in Orkney have seen a dramatic increase over the past few years (Duport Associates Ltd, 2012). The report also shows a significant rise in net company growth when comparing 2009 and 2012, suggesting that the past three years have seen the region's economy grow and strengthen. The economy of these relatively isolated islands has long been rooted in agriculture, thanks to extremely fertile soil and a rich farming heritage. However, Orkney is also becoming a leader in renewable energy, particularly wind, wave and tidal power. Naming data included in the Duport report suggests that new companies are forming in this industry, with "wind", "power" and "renewables" all appearing amongst the top ten most popular words used in new company names between June 2011 and June 2012. One single wave energy developer, Aquamarine Power (now liquidated), has spent more than £5 million directly in this peripheral community and has employed more than 50 local businesses. There are currently 14 technology developers actively engaged in Orkney. One study (Aquamarine Power, 2009) estimates that a 200 MW wave farm in Orkney would create £38.3 million gross value added (GVA) to the Orkney economy and would create 1,305 job years, equating to an average of 52 additional jobs each year in Orkney over the 26 year lifetime of the project. It is estimated that there has been upwards of £300 million of investment to date in Orkney as a result of marine renewables projects and supporting infrastructure. This investment has supported upwards of 200 jobs, in a number of different sectors related to marine renewables, including:

- Environmental consulting & consents.
- Offshore operations & surveying.
- Electrical engineering.
- Hydrodynamic modelling.

These investment levels and job numbers have been achieved during the research, development and testing of marine renewables devices, so these numbers can be expected to increase substantially when/if large scale projects

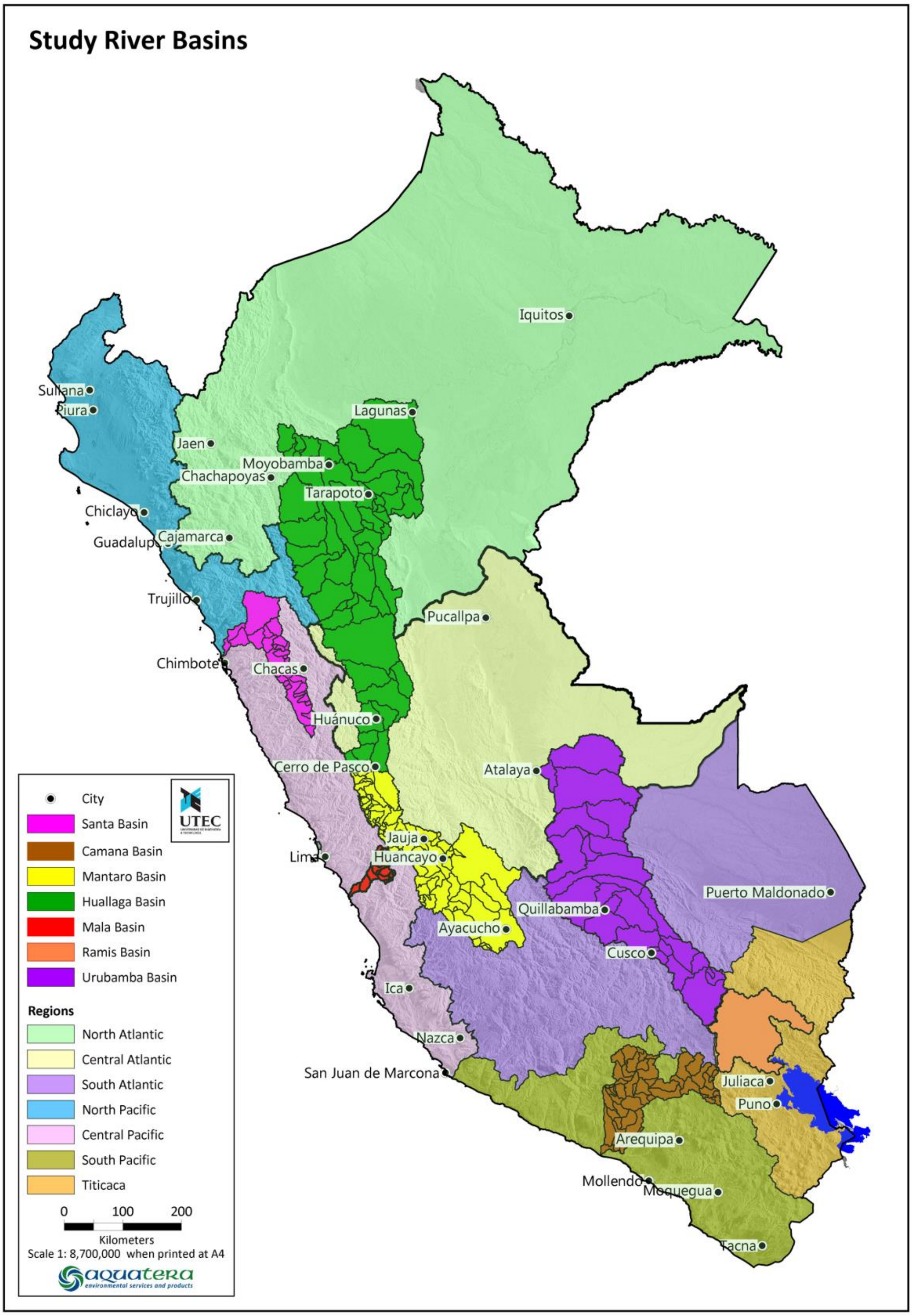
[21] https://atmocean.com/

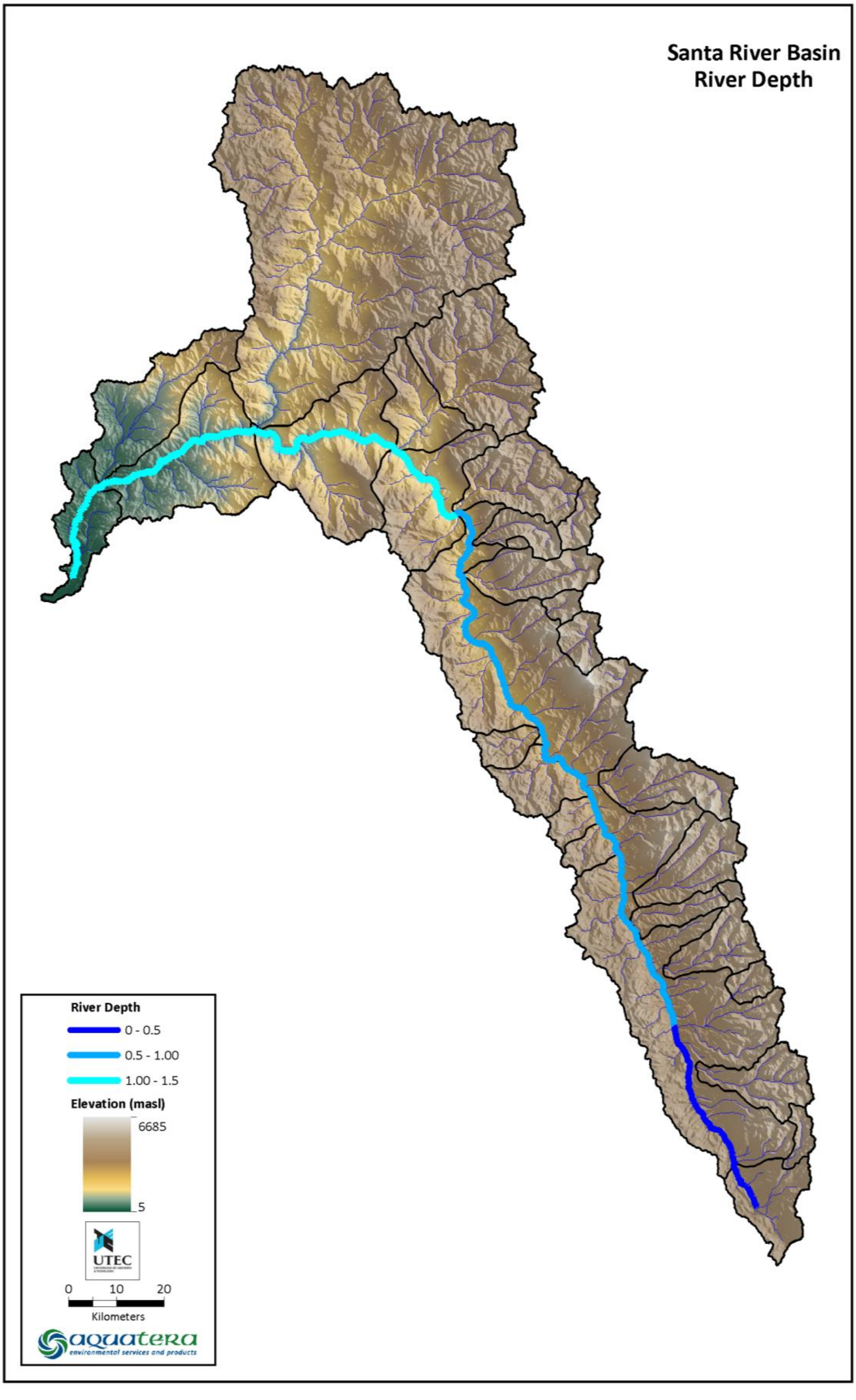
(e.g. Brims Tidal Array[22]) go ahead. A large amount of investment and temporary jobs would be created during the construction of these large scale projects, with smaller, but still significant (due to the existing jobs market within Orkney) jobs and investment being created during the operation and maintenance of such projects.

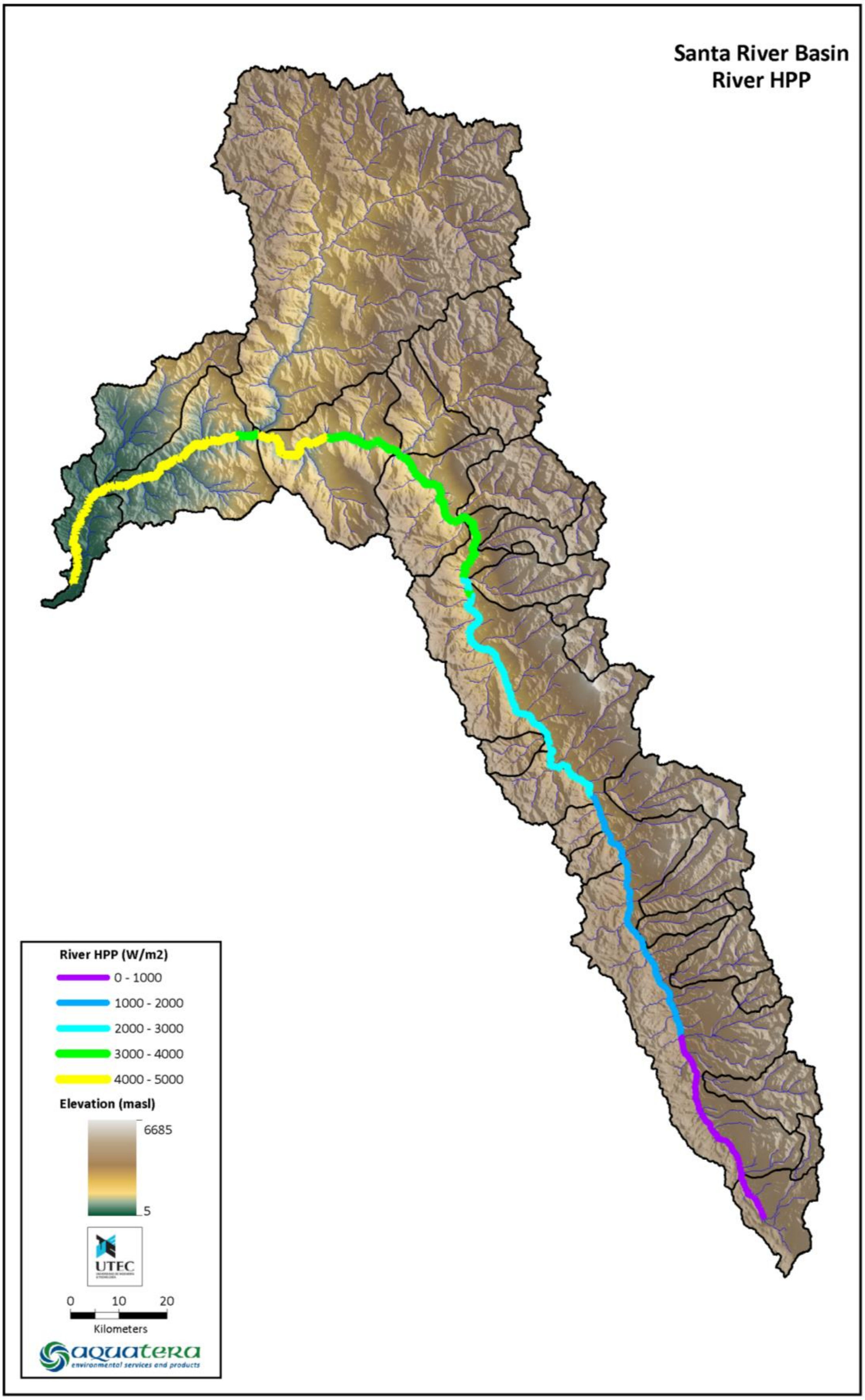
In 2012 there was a total of 70 new businesses registered in Orkney. This was a record year for Orkney. However, since 2012 this has reduced to 57 new businesses in 2013 and 53 new businesses in 2014. As of the most recent data to be published by Duport Ltd, Orkney had seen 18 new organisations registered between January and March of 2015. In regards to naming trends, 'Energy' remains in the top 10 amongst new company names each recorded year; where 'Wind' and 'Renewables' changes in use and popularity. With regards to the number of business that have closed, this grew between 2012 and 2014; from 21 in 2012; to 27 in 2013; and up to 50 in 2014. In the first quarter of the 2015 (again the most recent data) 8 companies have closed; this was up from 7 during the same quarter in 2014.

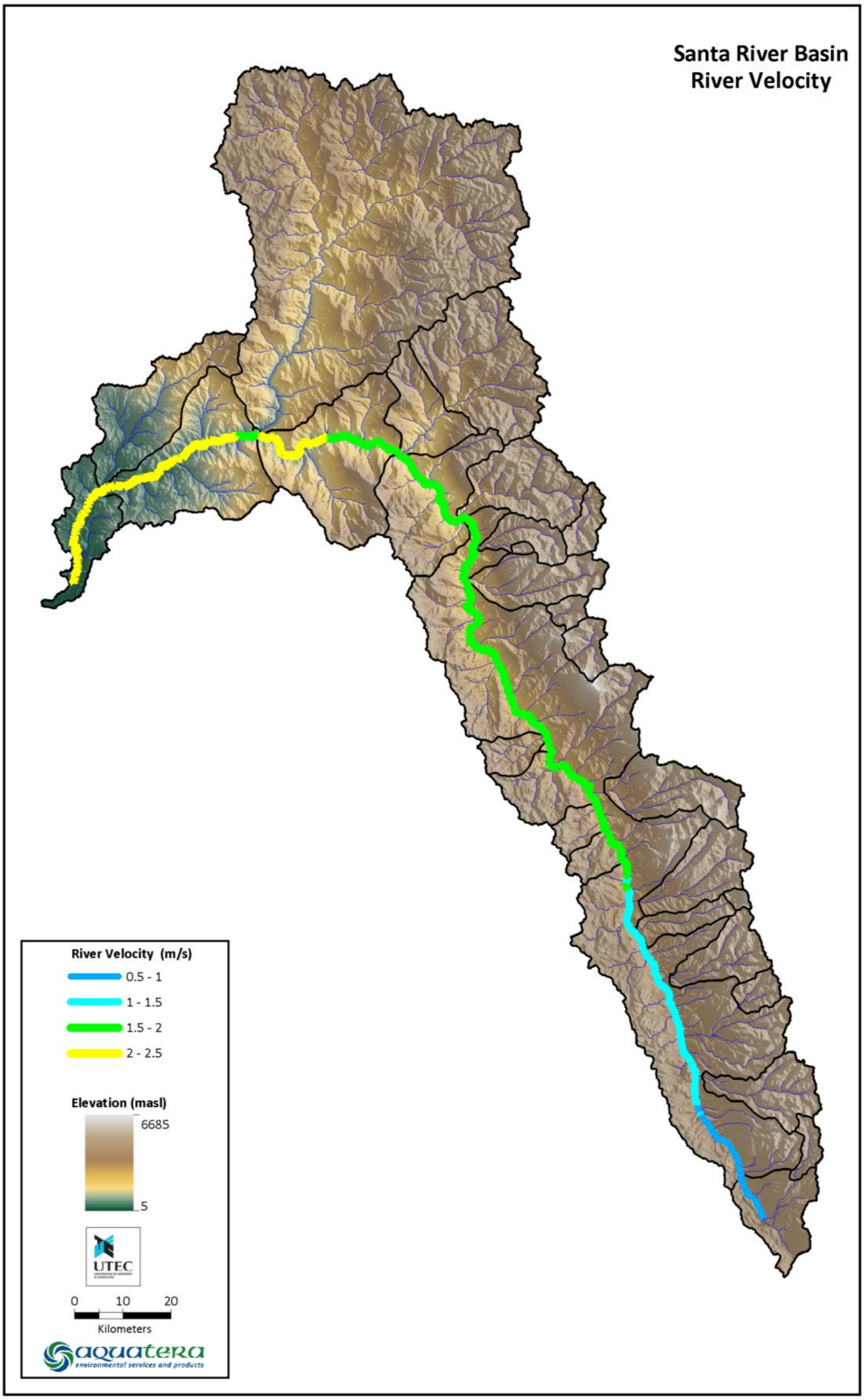
[22] https://tethys.pnnl.gov/annex-iv-sites/brims-tidal-array

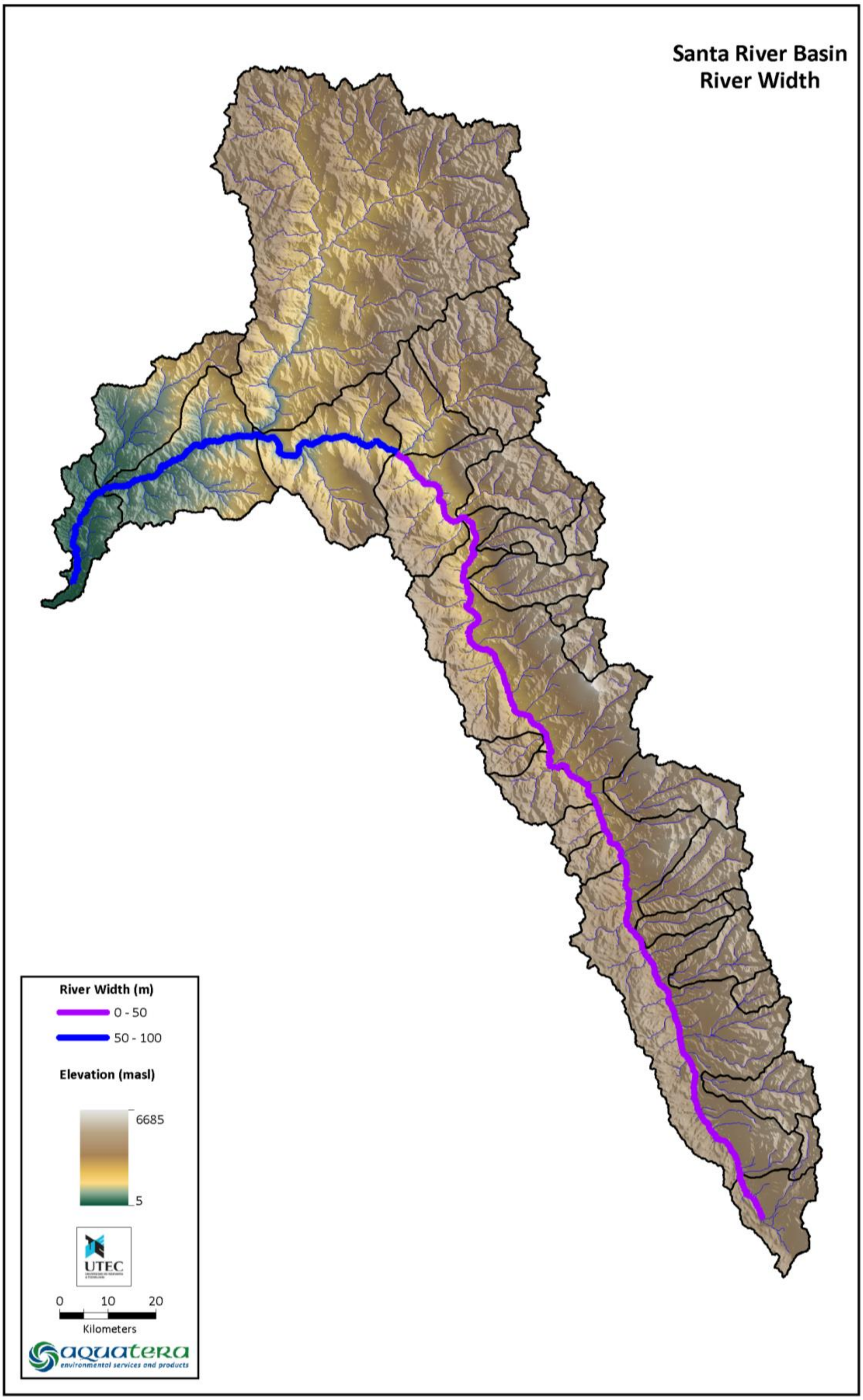
APPENDIX B RIVER HYDROKINETIC RESOURCE ANALYSIS OF 7 BASINS

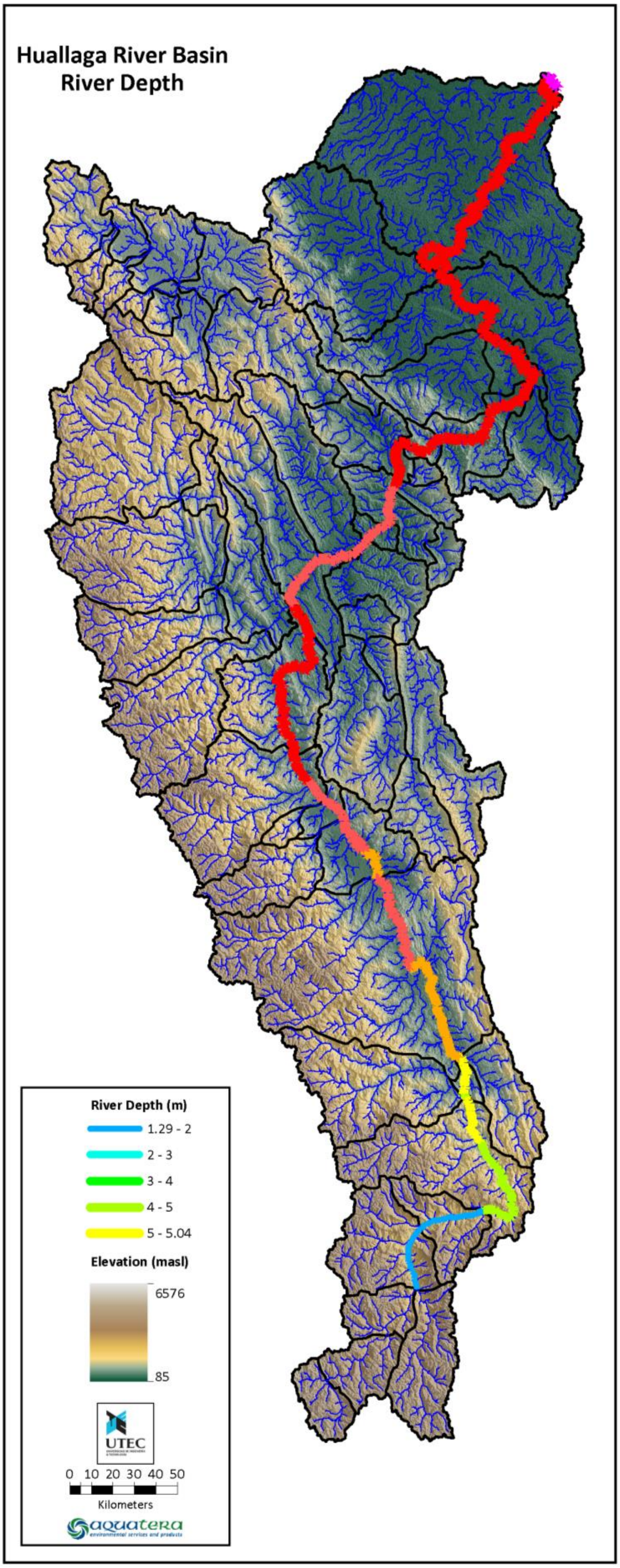


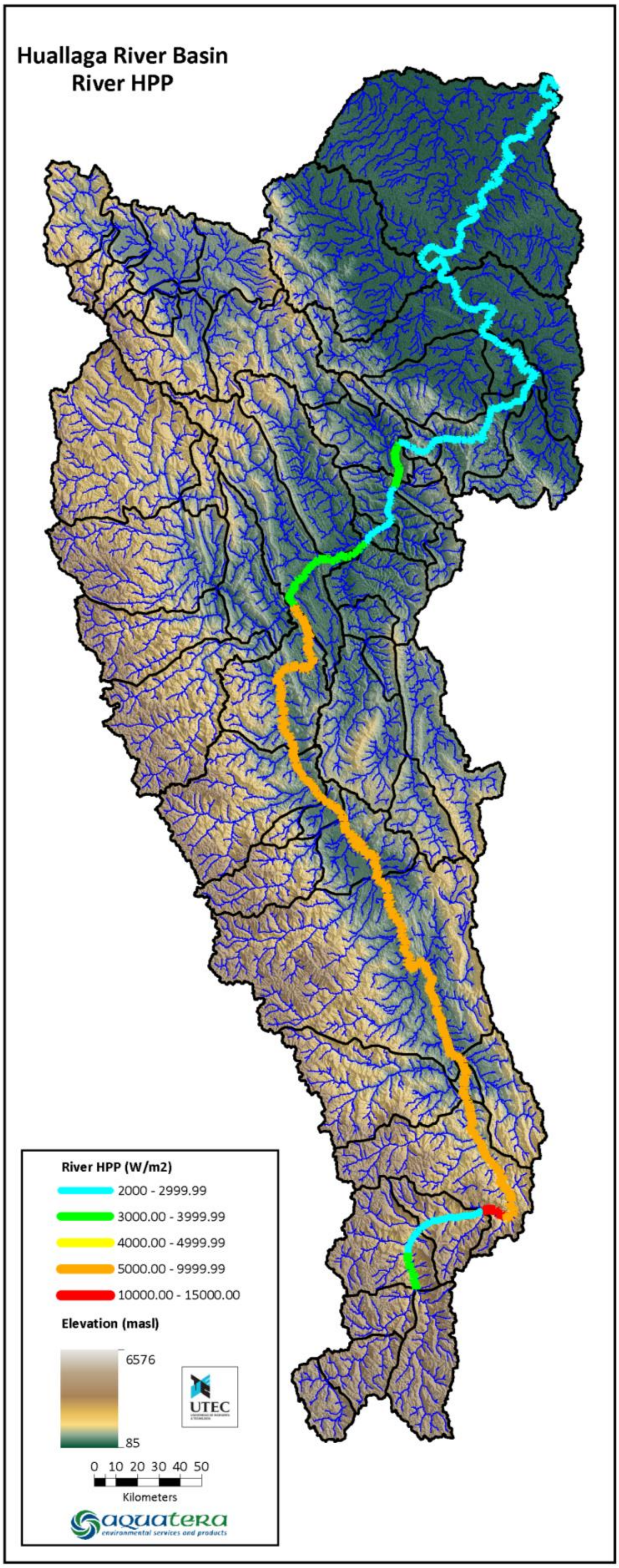

Santa River Basin
River Depth
River Depth
0 - 0.5
0.5 - 1.00
1.00 - 1.5
Elevation (masl)
6685
5
UTEC
0
10
20
Kilometers
aquatera
environmental services and products

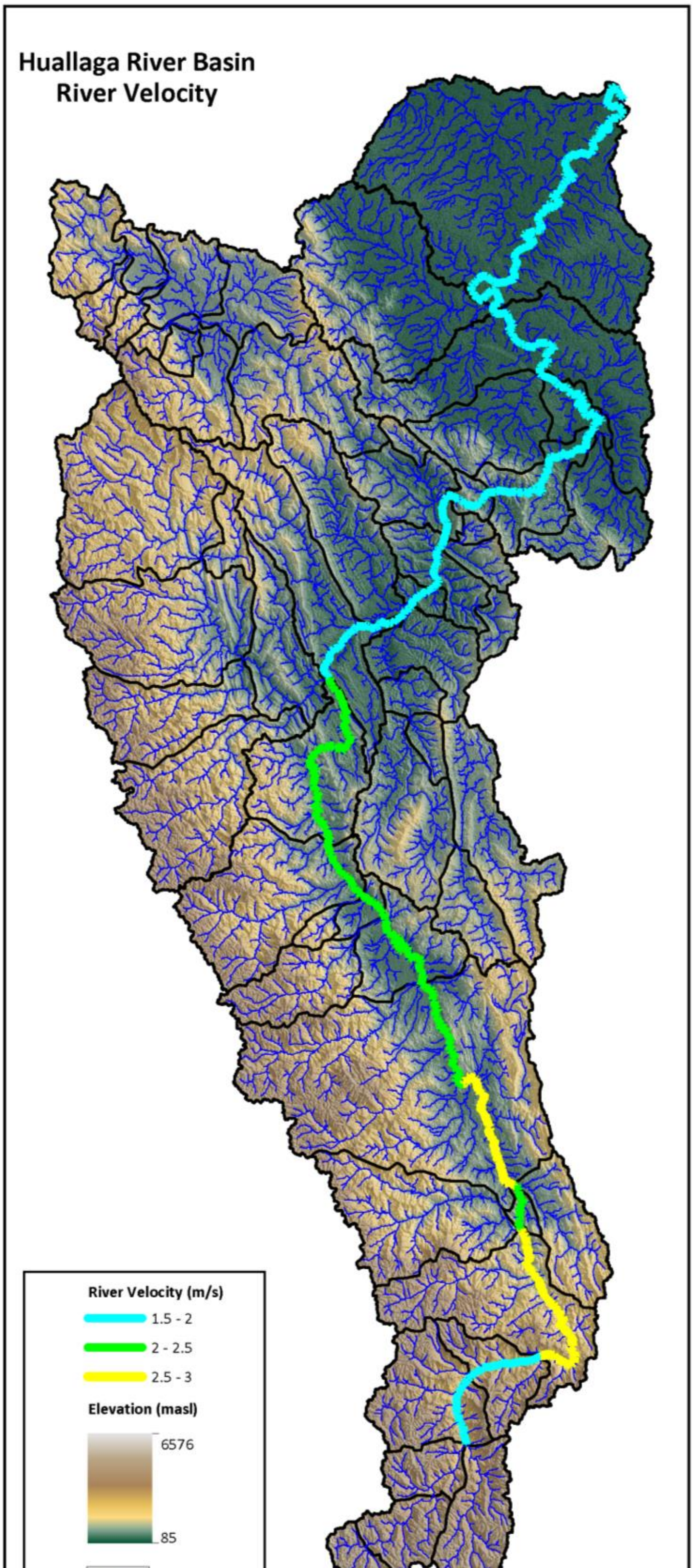

Santa River Basin
River HPP
River HPP (W/m2)
0 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 5000
Elevation (masl)
6685
5
UTEC
0
10
20
Kilometers
aquatera
environmental services and products


Santa River Basin
River Velocity
River Velocity (m/s)
0.5 - 1
1 - 1.5
1.5 - 2
2 - 2.5
Elevation (masl)
6685
5
UTEC
0
10
20
Kilometers
aquatera
environmental services and products

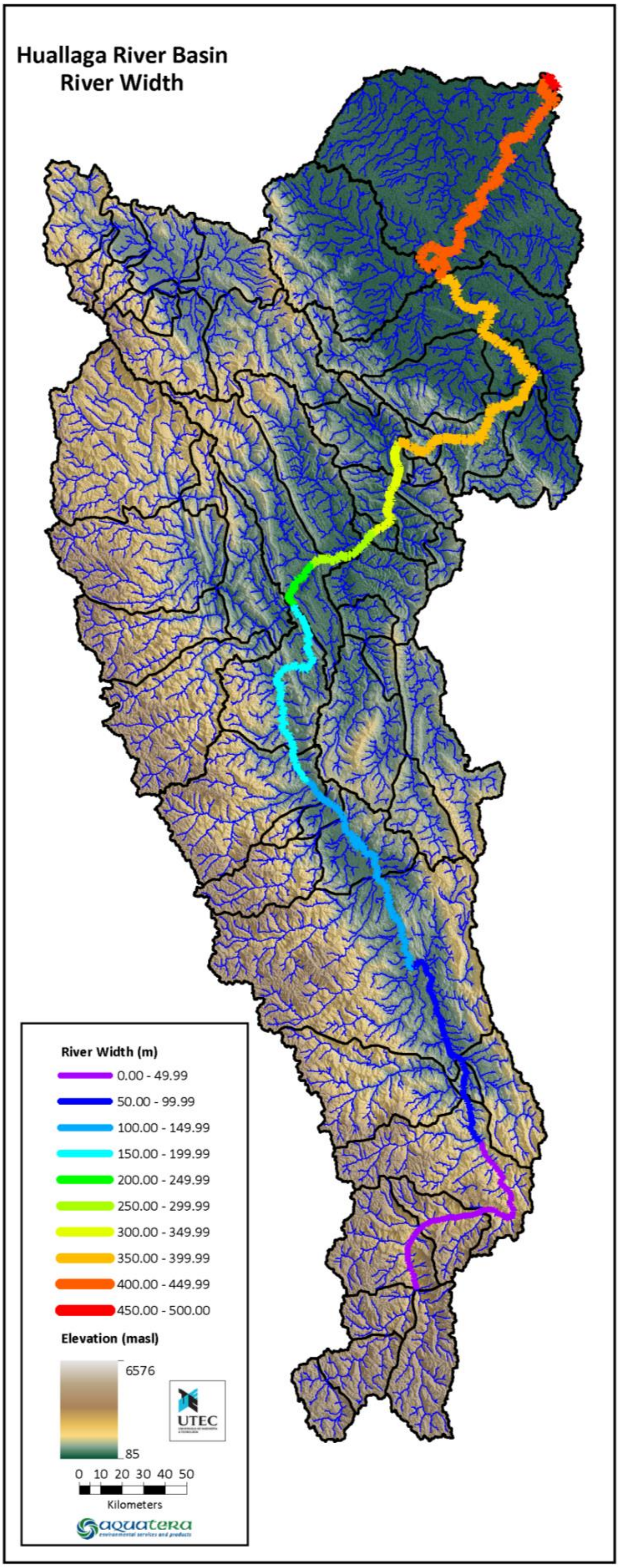

Santa River Basin
River Width
River Width (m)
0 - 50
50 - 100
Elevation (masl)
6685
5
UTEC
0
10
20
Kilometers
aquatera
environmental services and products

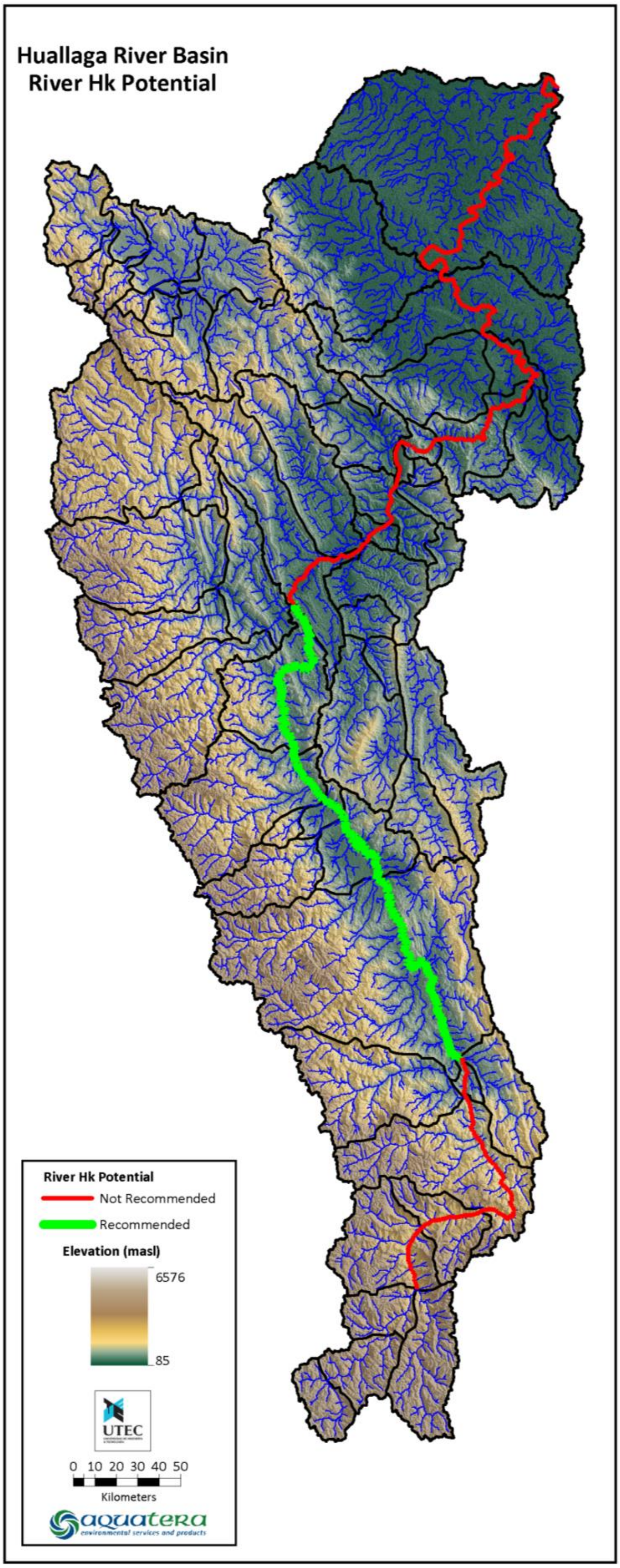

Huallaga River Basin
River Depth
River Depth (m)
1.29 - 2
2 - 3
3 - 4
4 - 5
5 - 5.04
Elevation (masl)
6576
85
UTEC
0 10 20 30 40 50
Kilometers
aquatera

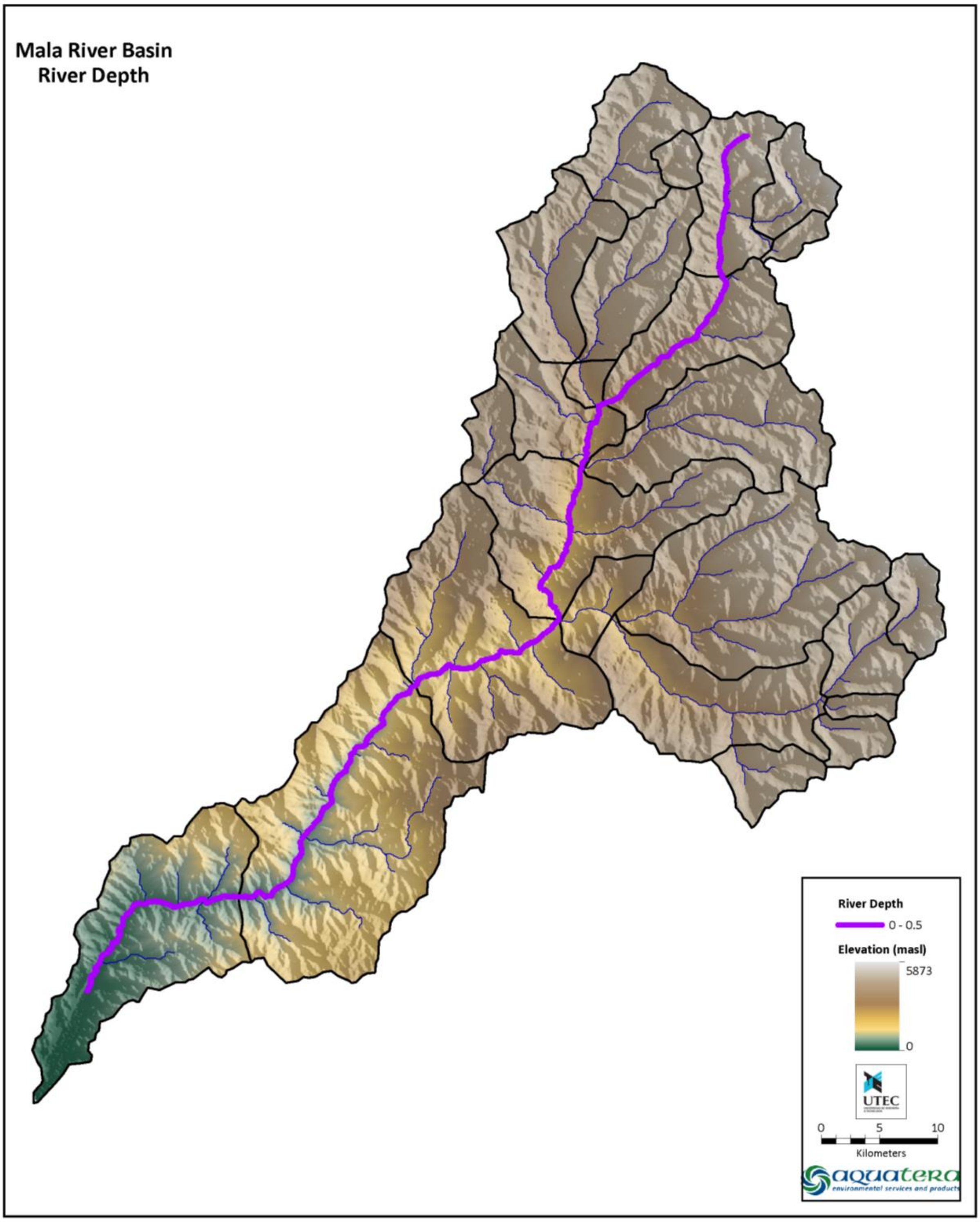

Huallaga River Basin
River HPP
River HPP (W/m2)
2000 - 2999.99
3000.00 - 3999.99
4000.00 - 4999.99
5000.00 - 9999.99
10000.00 - 15000.00
Elevation (masl)
6576
85
0 10 20 30 40 50
Kilometers
UTEC
aquatera
environmental services and products

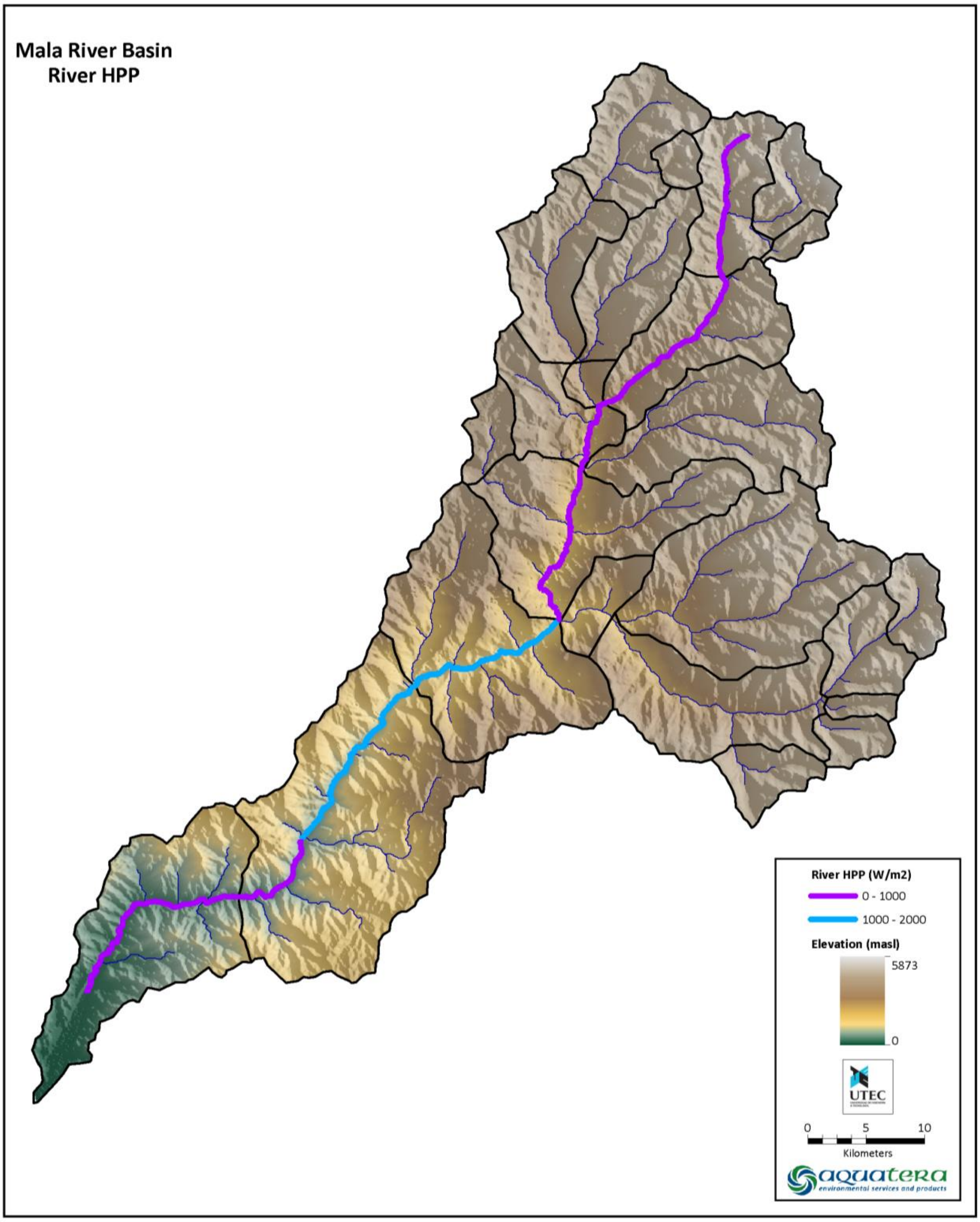


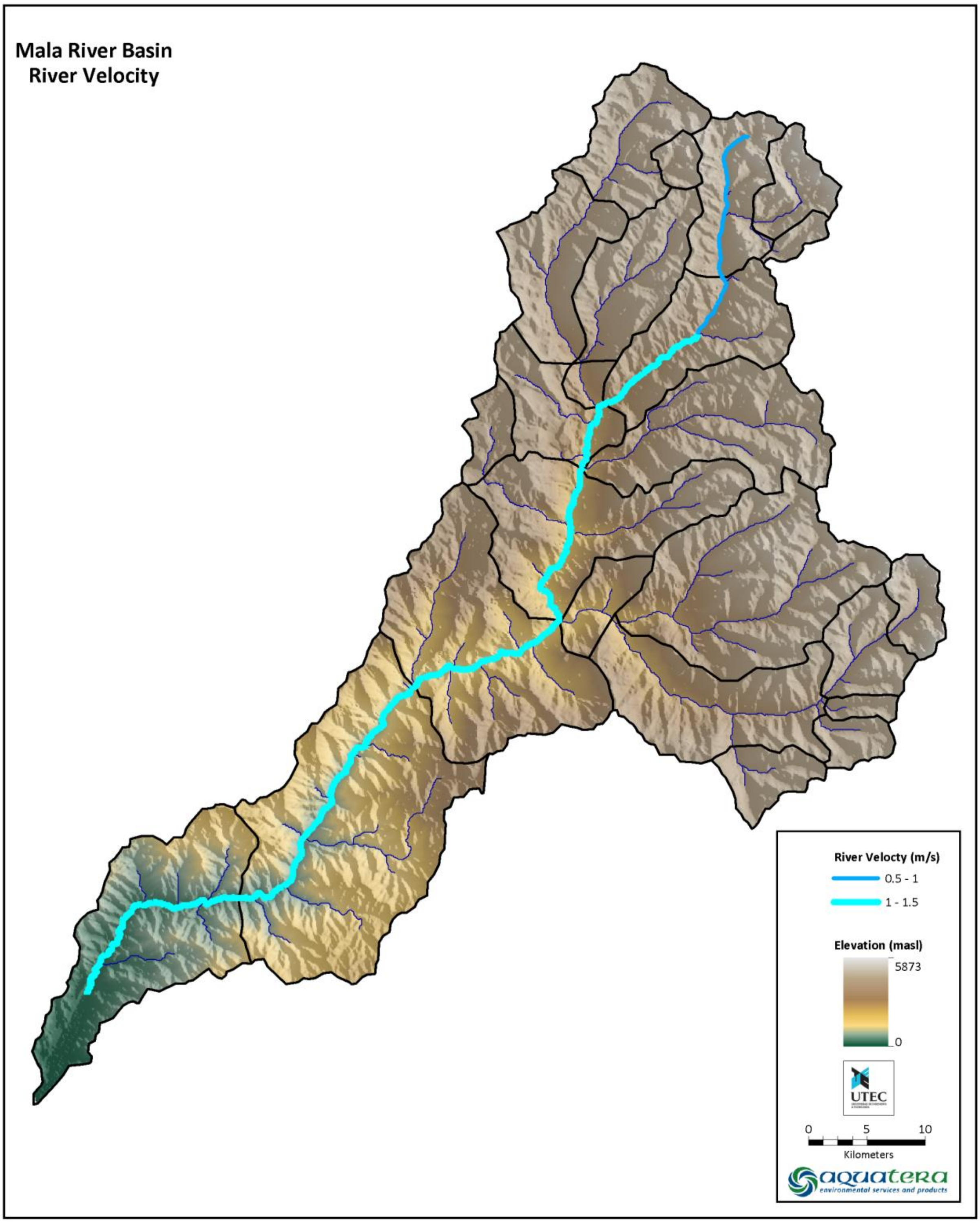
Huallaga River Basin
River Velocity
River Velocity (m/s)
1.5 - 2
2 - 2.5
2.5 - 3
Elevation (masl)
6576
85
UTEC
0 10 20 30 40 50
Kilometers
aquatera

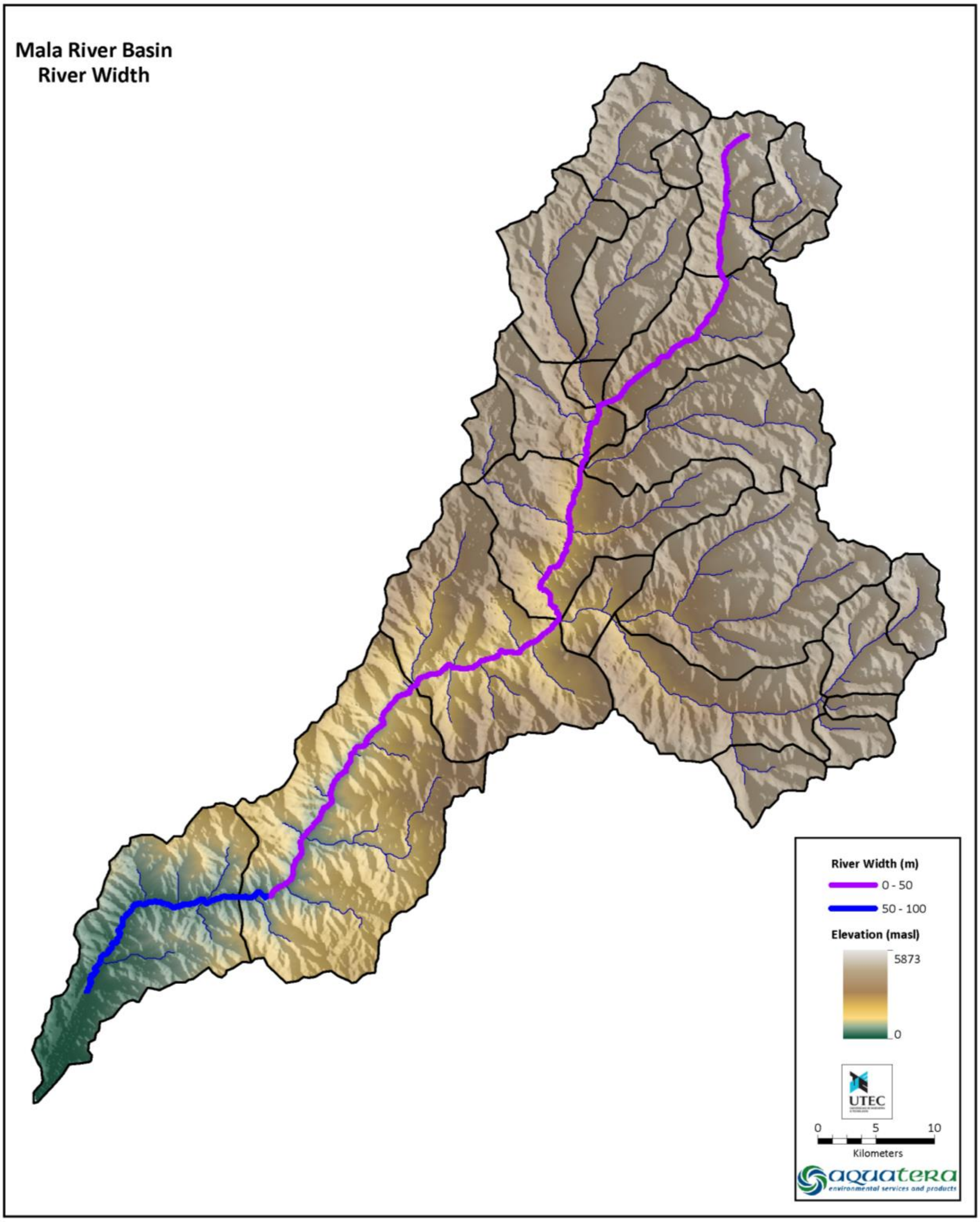

Huallaga River Basin
River Width
River Width (m)
0.00 - 49.99
50.00 - 99.99
100.00 - 149.99
150.00 - 199.99
200.00 - 249.99
250.00 - 299.99
300.00 - 349.99
350.00 - 399.99
400.00 - 449.99
450.00 - 500.00
Elevation (masl)
6576
85
0 10 20 30 40 50
Kilometers
UTEC
aquatera

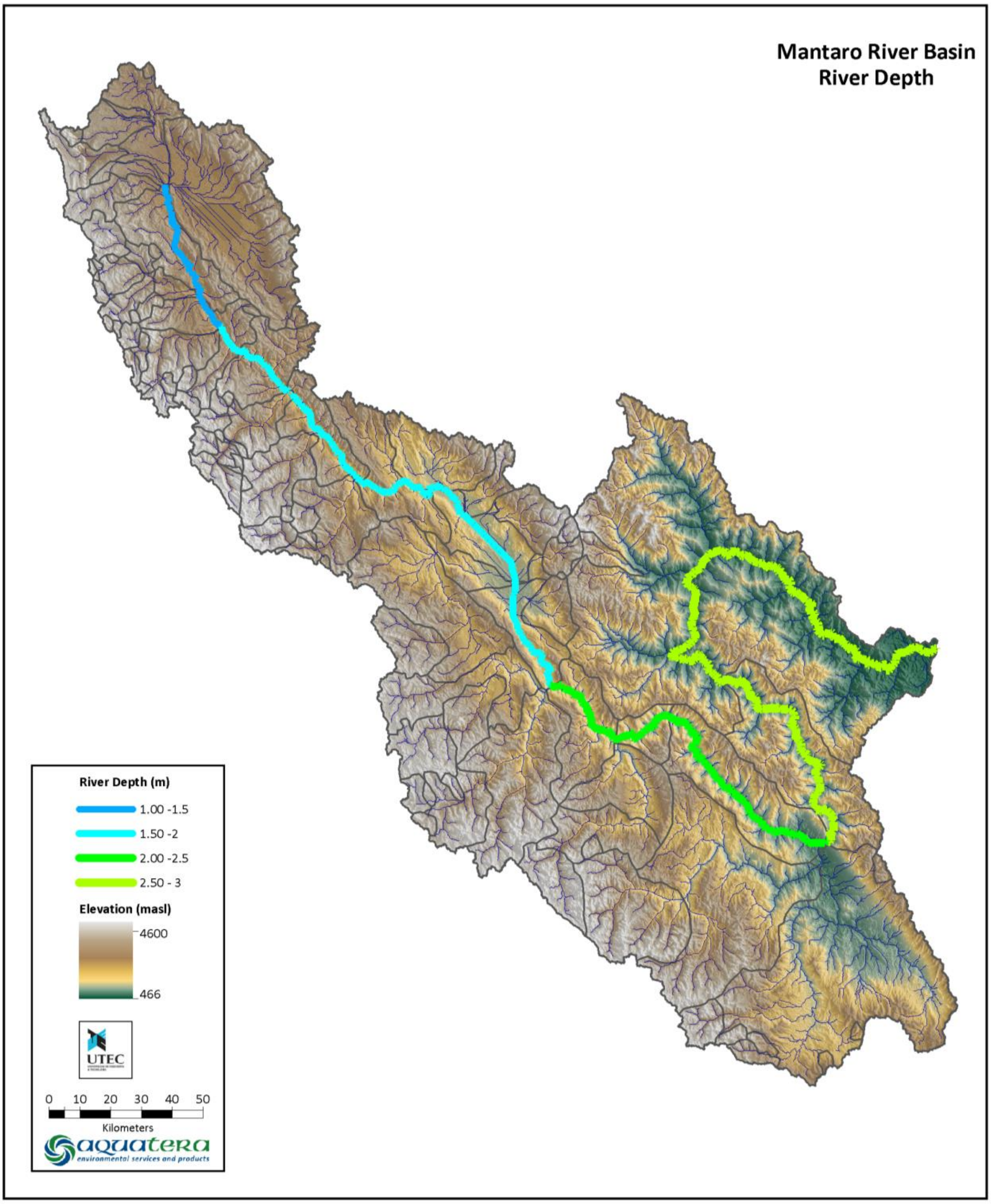

Huallaga River Basin
River Hk Potential
River Hk Potential
Not Recommended
Recommended
Elevation (masl)
6576
85
UTEC
0 10 20 30 40 50
Kilometers
aquatera
environmental services and products

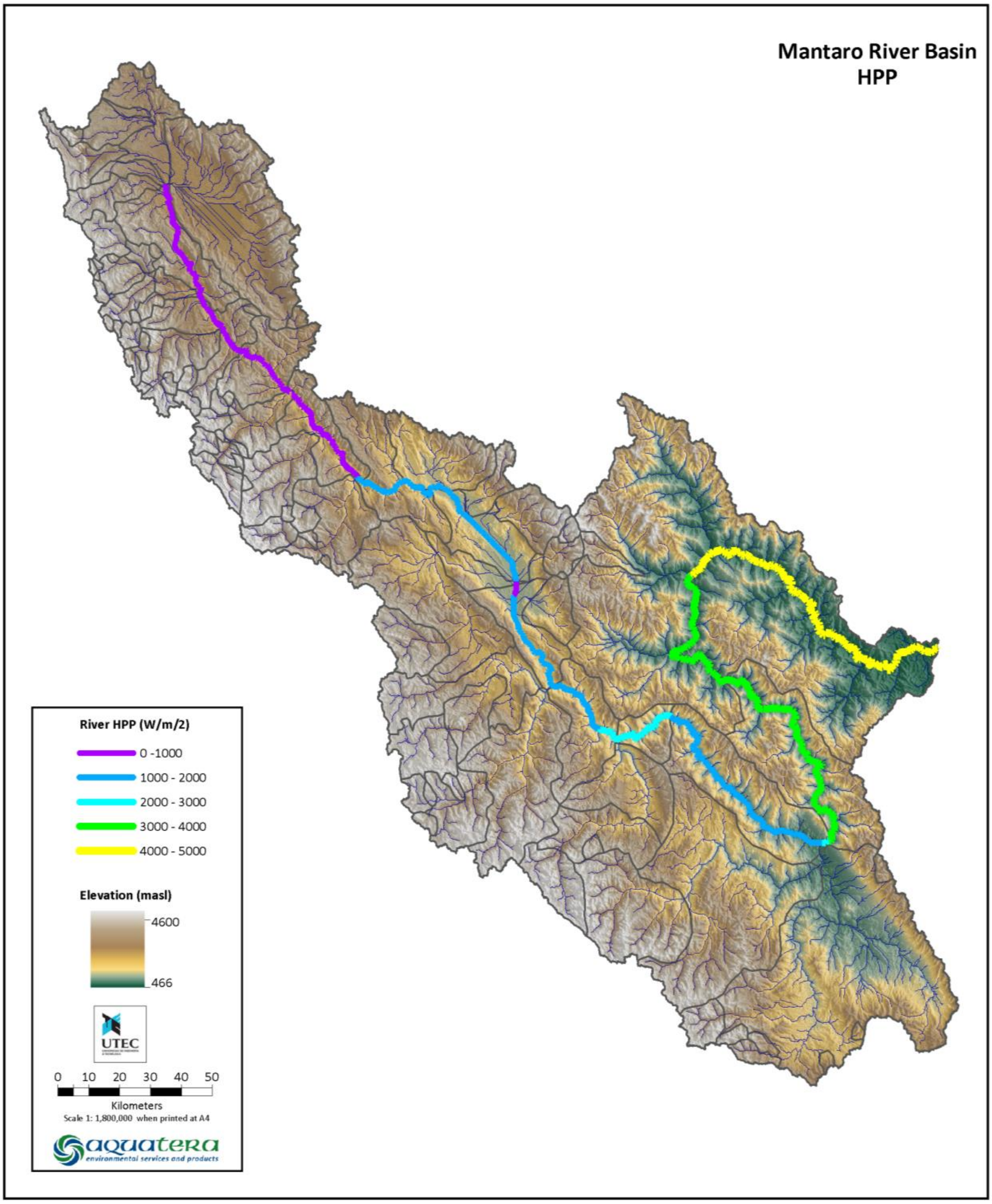

Mala River Basin
River Depth
River Depth
0 - 0.5
Elevation (masl)
5873
0
UTEC
0
5
10
Kilometers
aquatera
environmental services and products

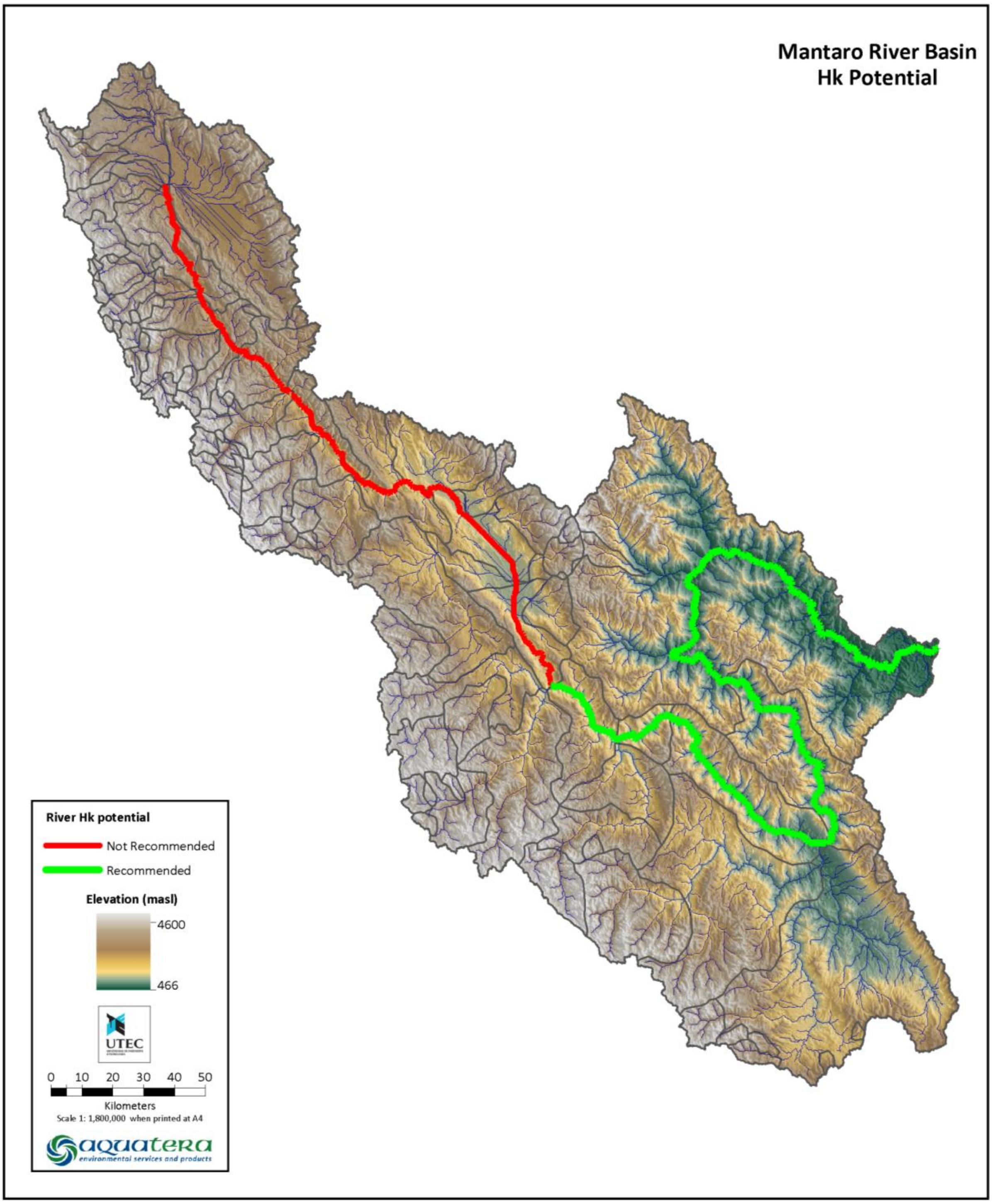

Mala River Basin
River HPP
River HPP (W/m2)
0 - 1000
1000 - 2000
Elevation (masl)
5873
0
UTEC
0
5
10
Kilometers
aquatera
environmental services and products

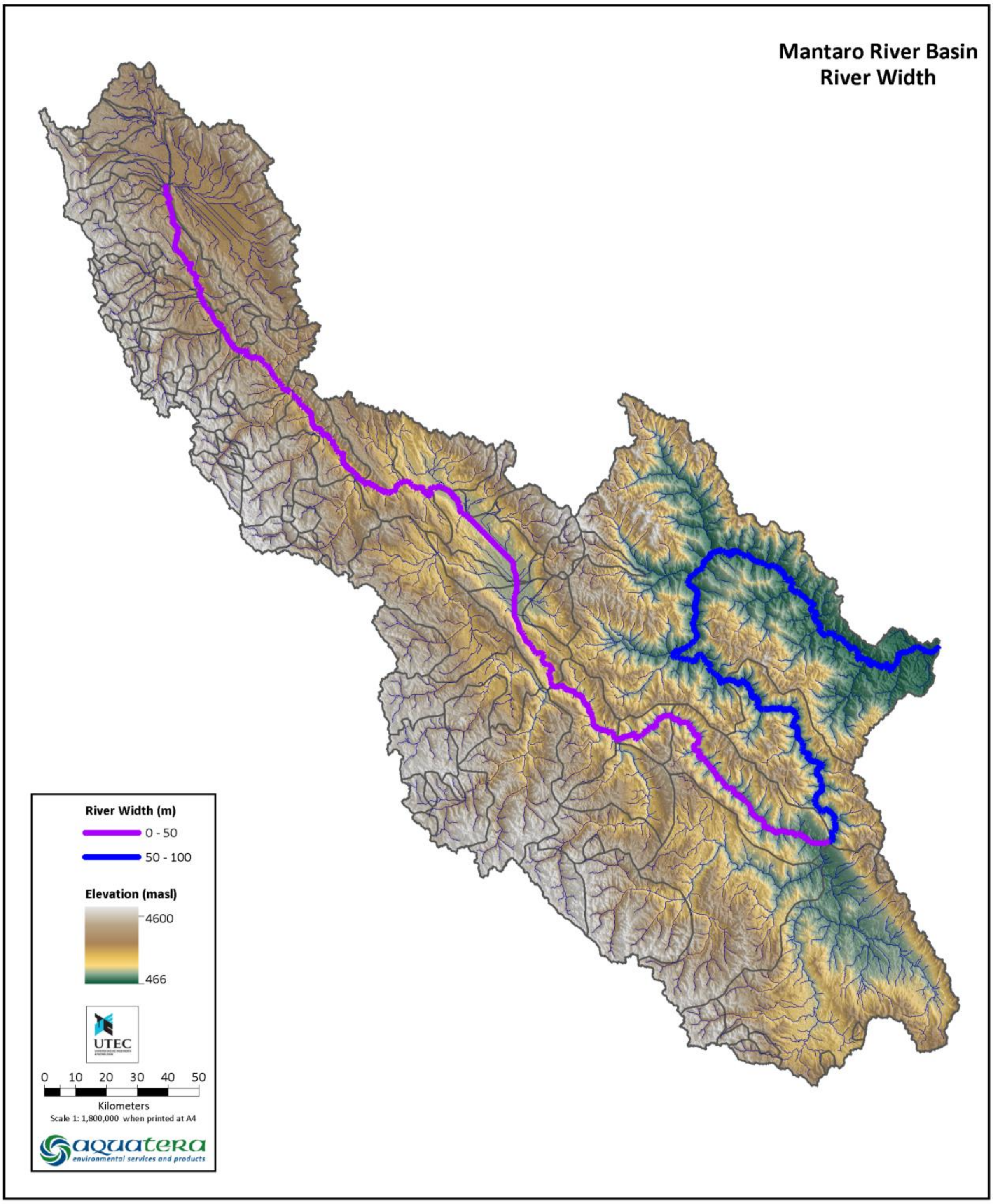

Mala River Basin
River Velocity
River Velocty (m/s)
0.5 - 1
1 - 1.5
Elevation (masl)
5873
0
UTEC
0
5
10
Kilometers
aquatera
environmental services and products

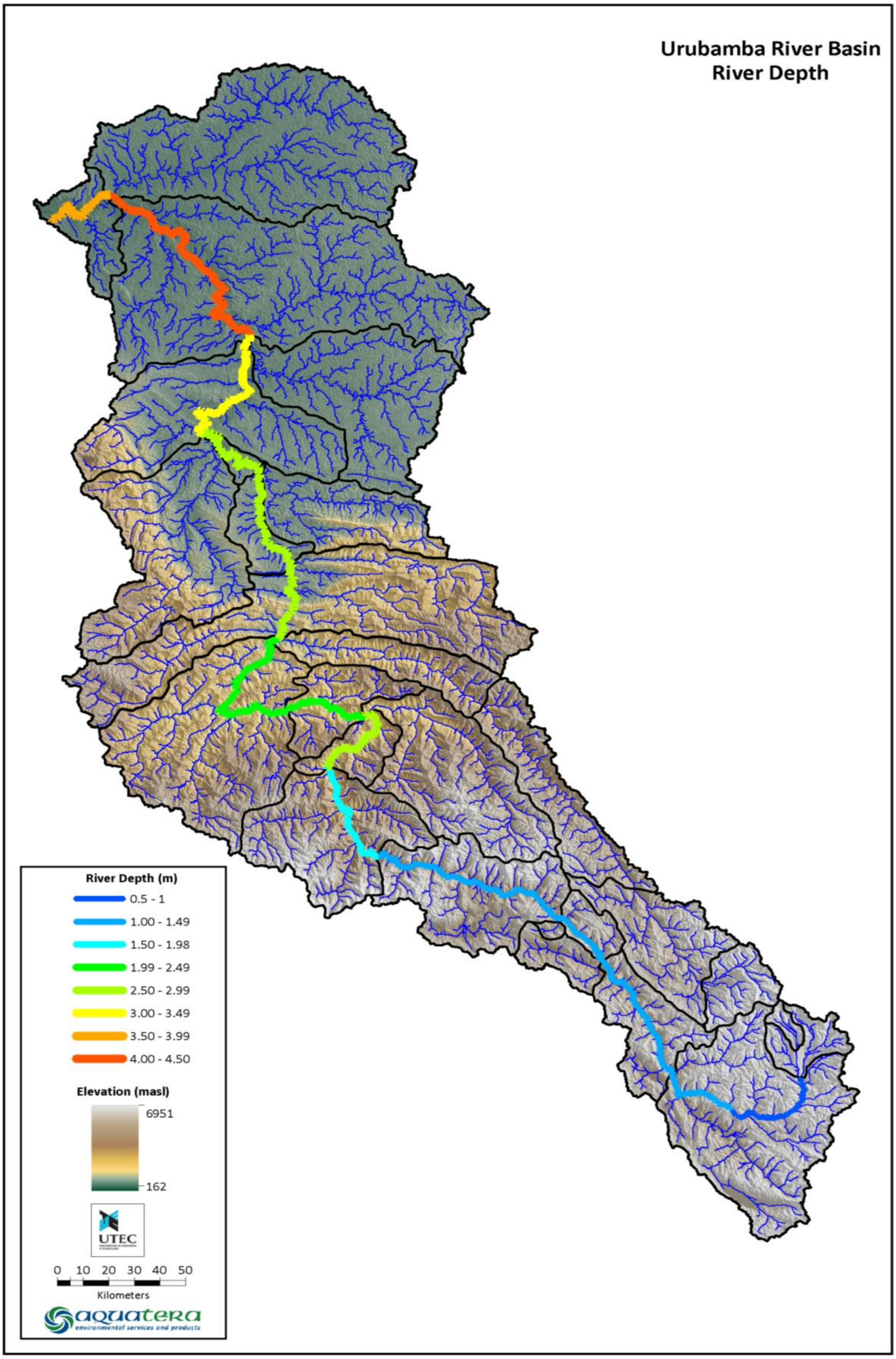

Mala River Basin
River Width
River Width (m)
0 - 50
50 - 100
Elevation (masl)
5873
0
UTEC
0
5
10
Kilometers
aquatera
environmental services and products

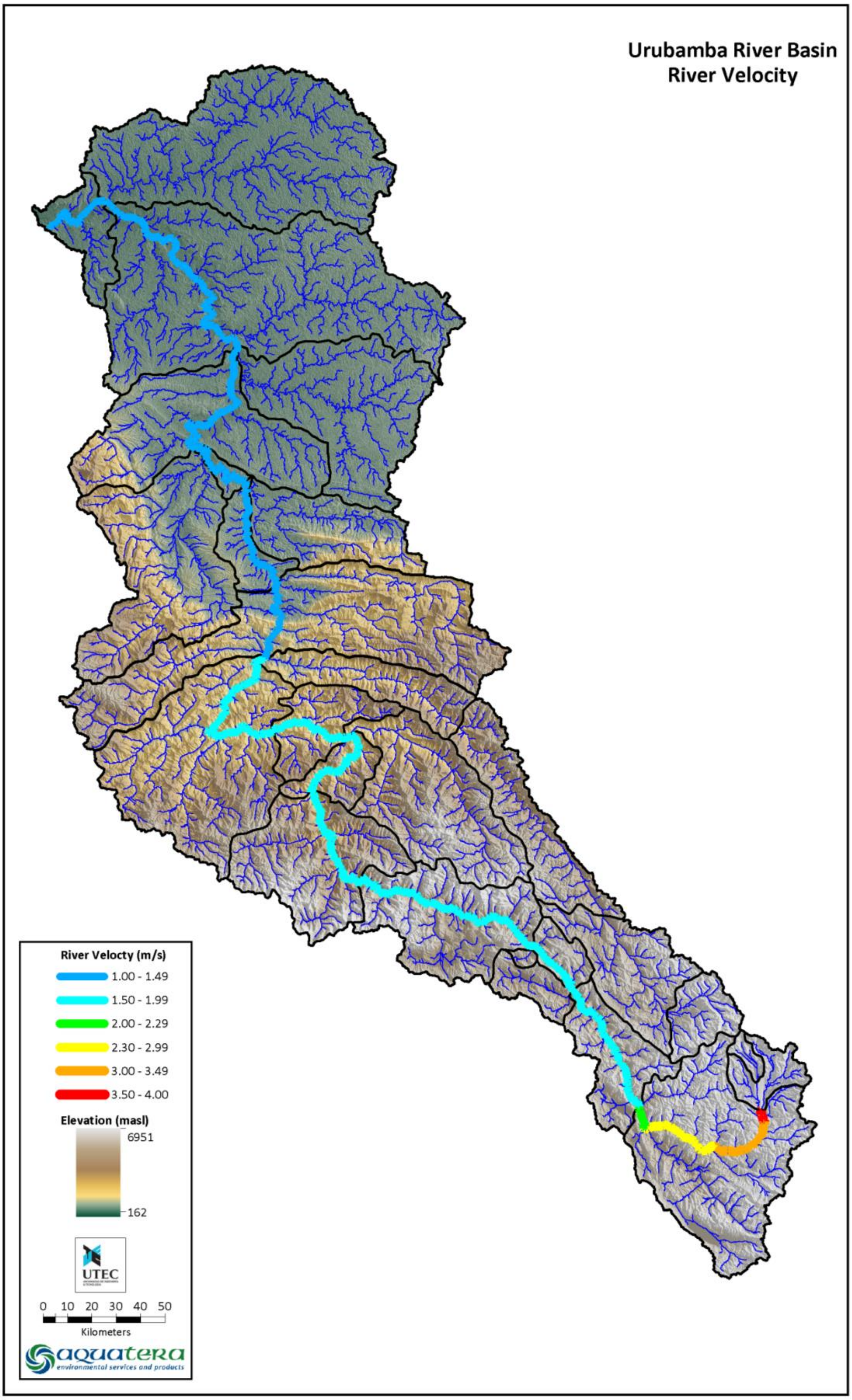

Mantaro River Basin
River Depth
River Depth (m)
1.00 -1.5
1.50 -2
2.00 -2.5
2.50 - 3
Elevation (masl)
4600
466
UTEC
0 10 20 30 40 50
Kilometers
aquatera
environmental services and products

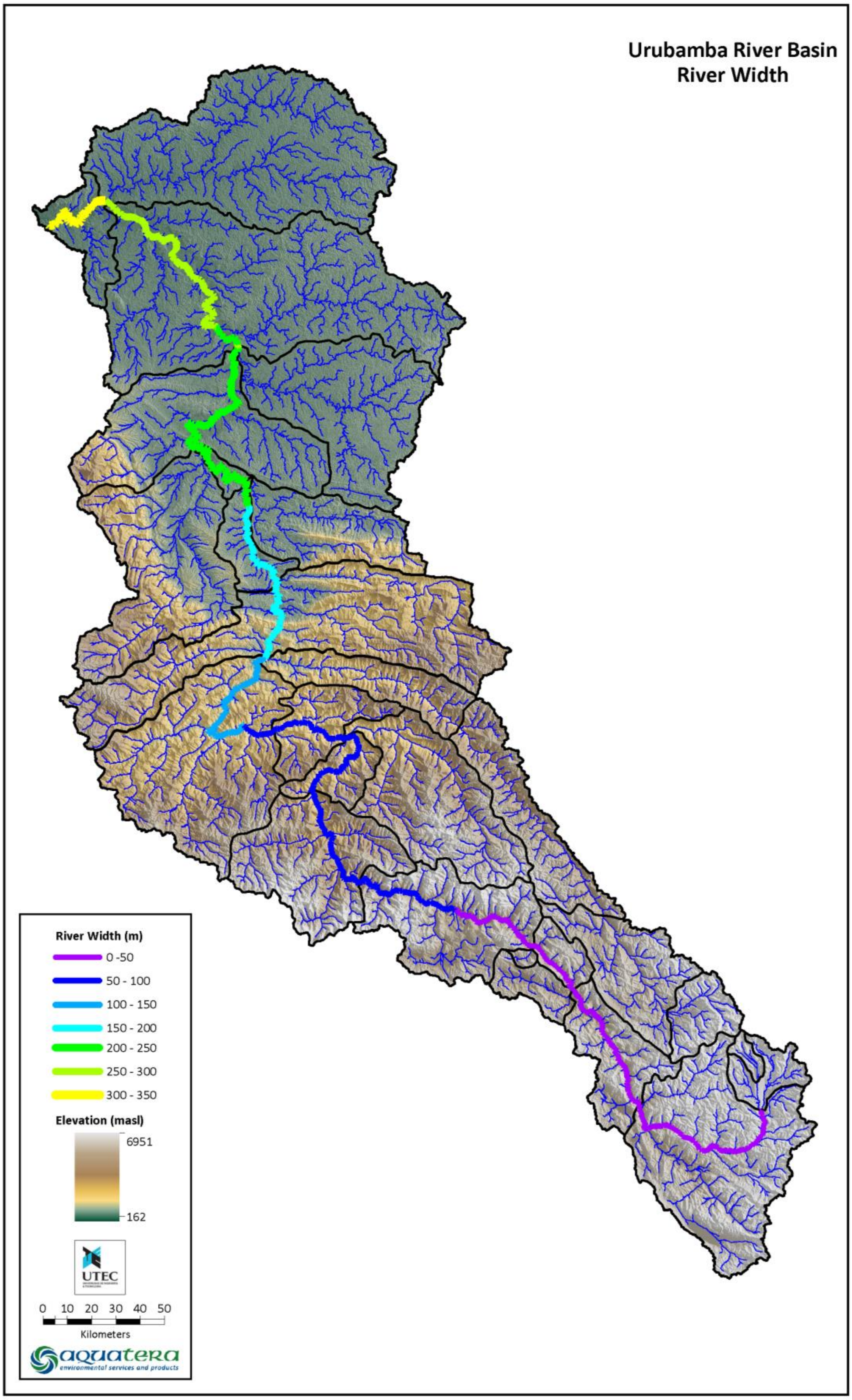

Mantaro River Basin
HPP
River HPP (W/m/2)
0 -1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 5000
Elevation (masl)
4600
466
UTEC
0 10 20 30 40 50
Kilometers
Scale 1: 1,800,000 when printed at A4
aquatera
environmental services and products

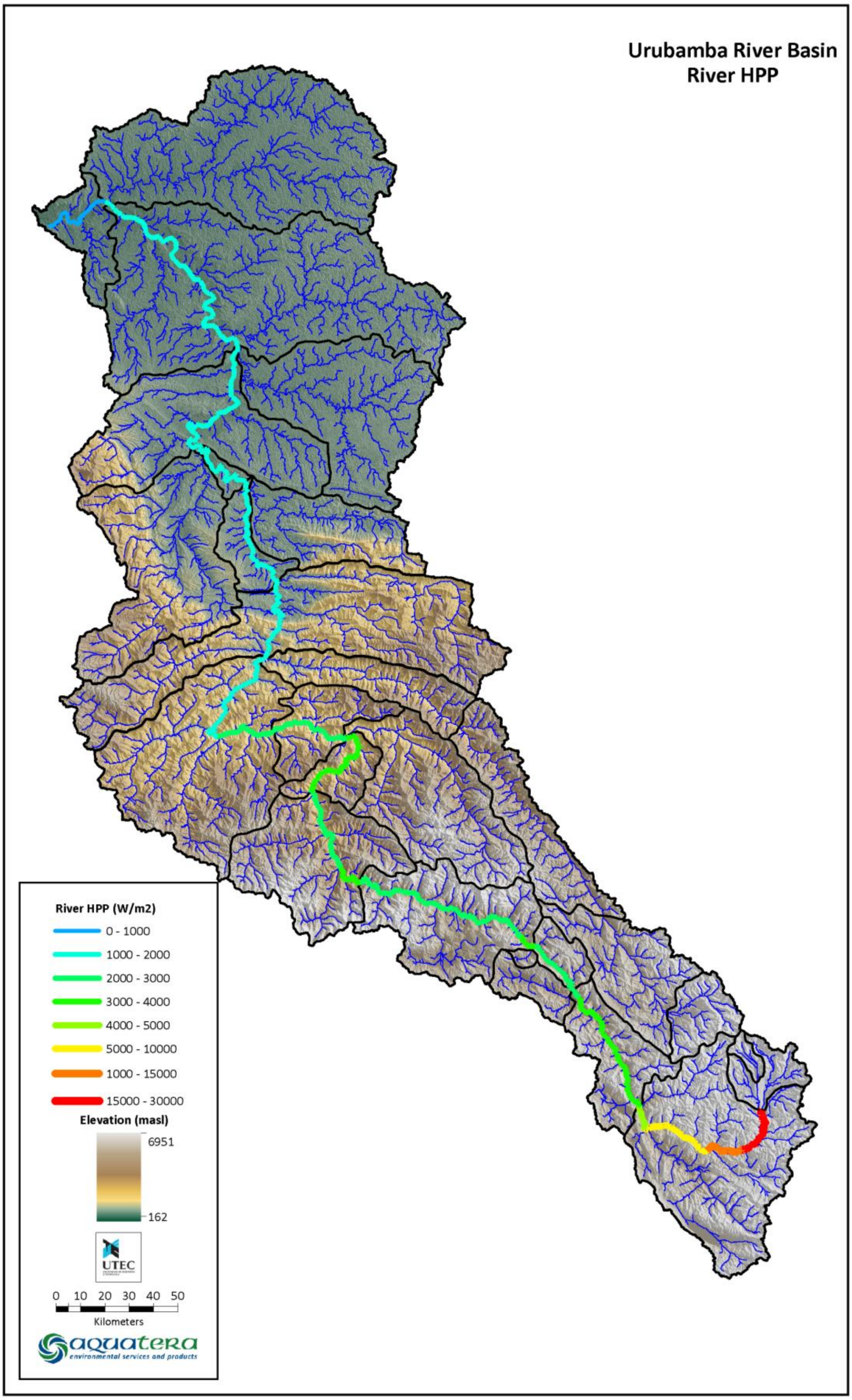

Mantaro River Basin
Hk Potential
River Hk potential
Not Recommended
Recommended
Elevation (masl)
4600
466
UTEC
0 10 20 30 40 50
Kilometers
Scale 1: 1,800,000 when printed at A4
aquatera
environmental services and products

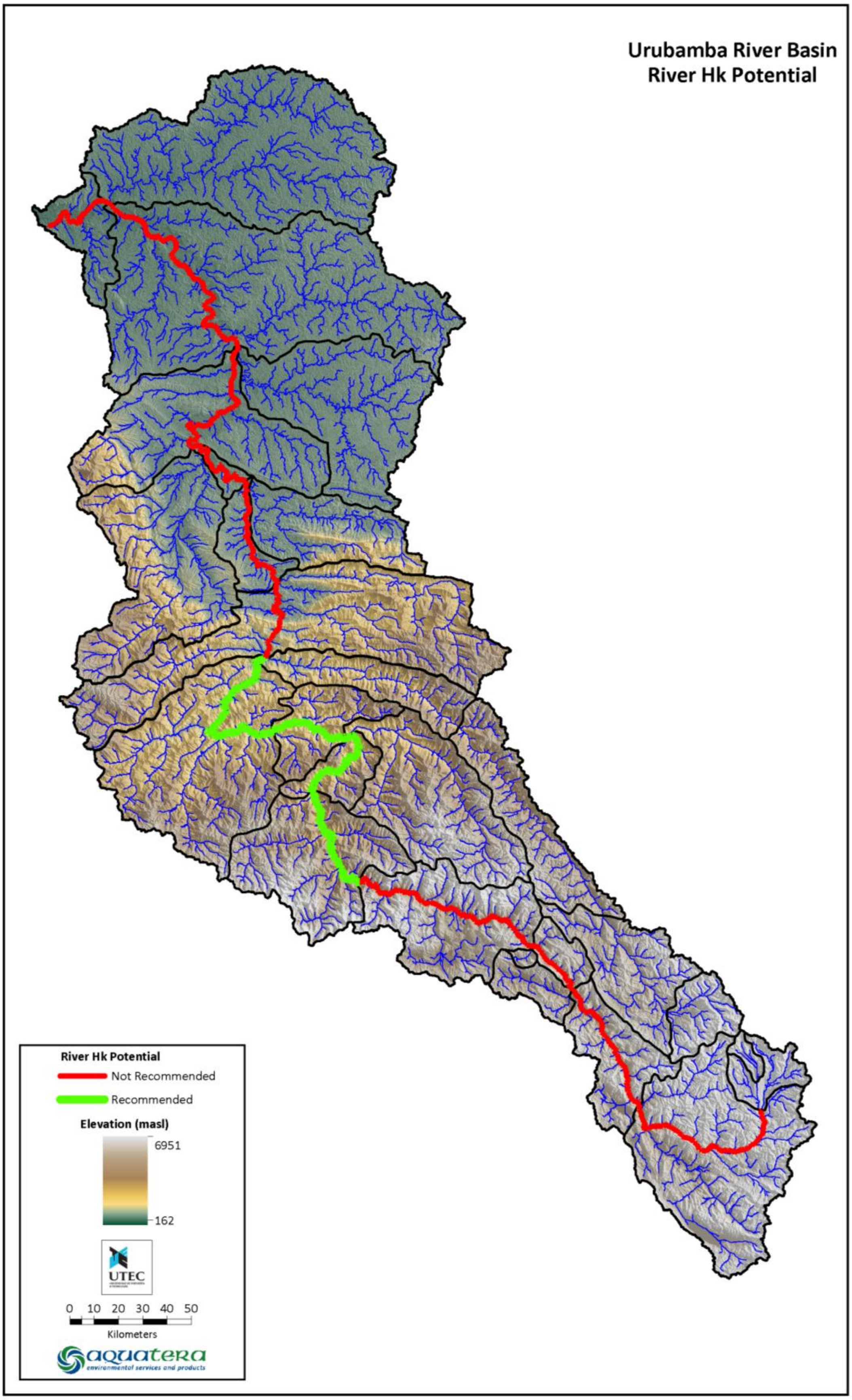

Mantaro River Basin
River Width
River Width (m)
0 - 50
50 - 100
Elevation (masl)
4600
466
UTEC
0 10 20 30 40 50
Kilometers
Scale 1: 1,800,000 when printed at A4
aquatera
environmental services and products

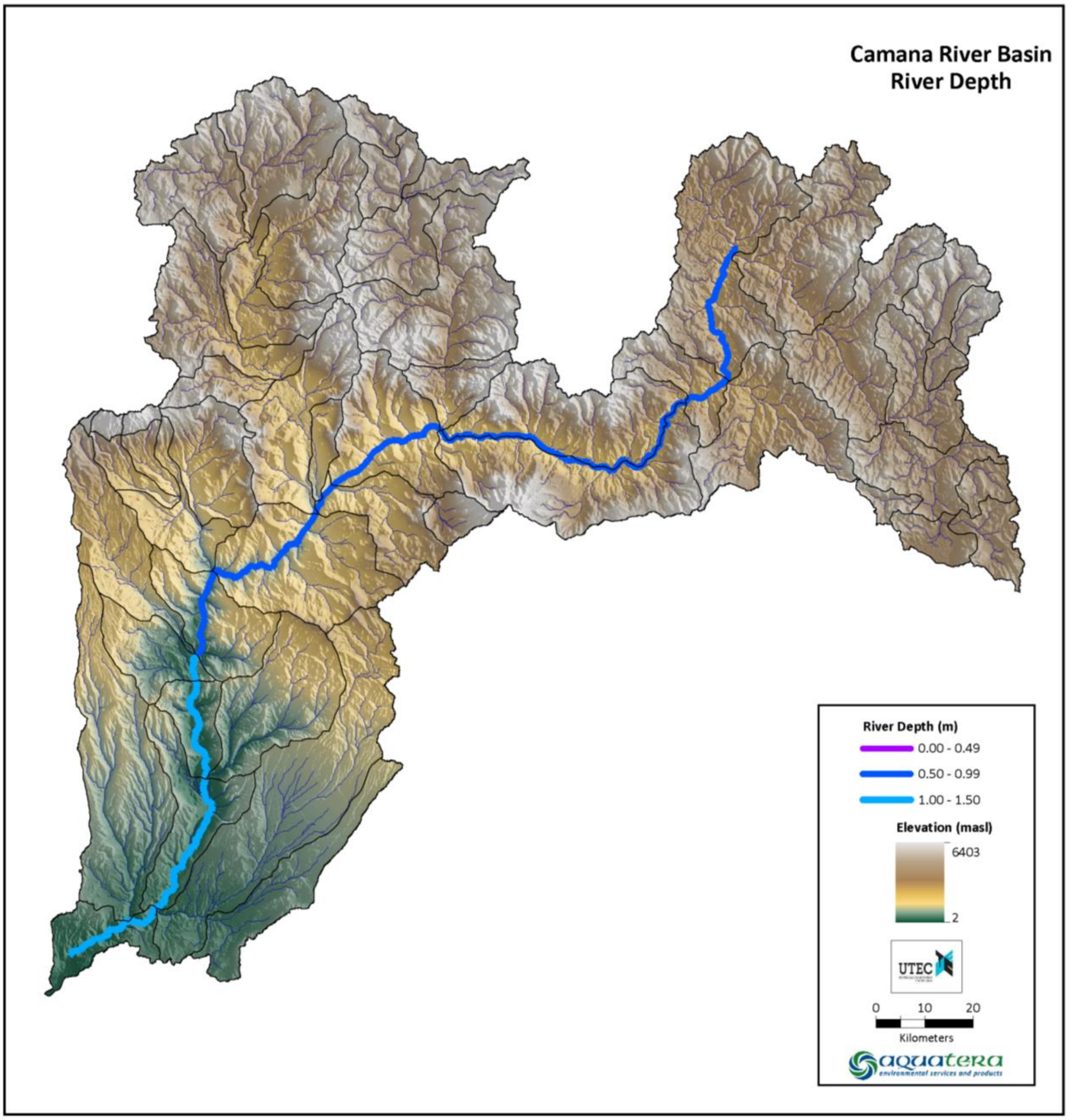

Urubamba River Basin
River Depth
River Depth (m)
0.5 - 1
1.00 - 1.49
1.50 - 1.98
1.99 - 2.49
2.50 - 2.99
3.00 - 3.49
3.50 - 3.99
4.00 - 4.50
Elevation (masl)
6951
162
UTEC
0 10 20 30 40 50
Kilometers
aquatera
environmental services and products

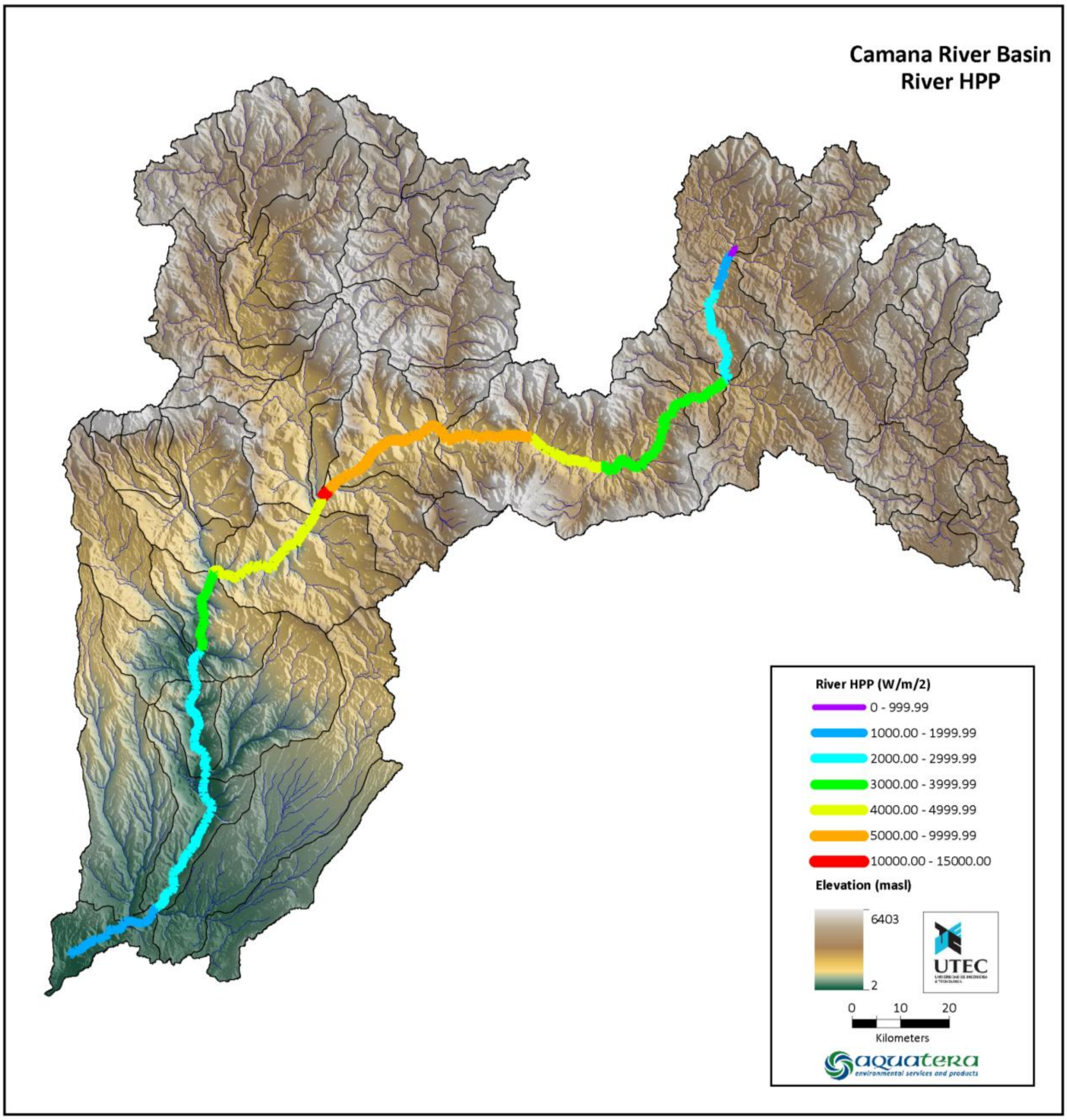

Urubamba River Basin
River Velocity
River Velocty (m/s)
1.00 - 1.49
1.50 - 1.99
2.00 - 2.29
2.30 - 2.99
3.00 - 3.49
3.50 - 4.00
Elevation (masl)
6951
162
UTEC
0 10 20 30 40 50
Kilometers
aquatera
environmental services and products

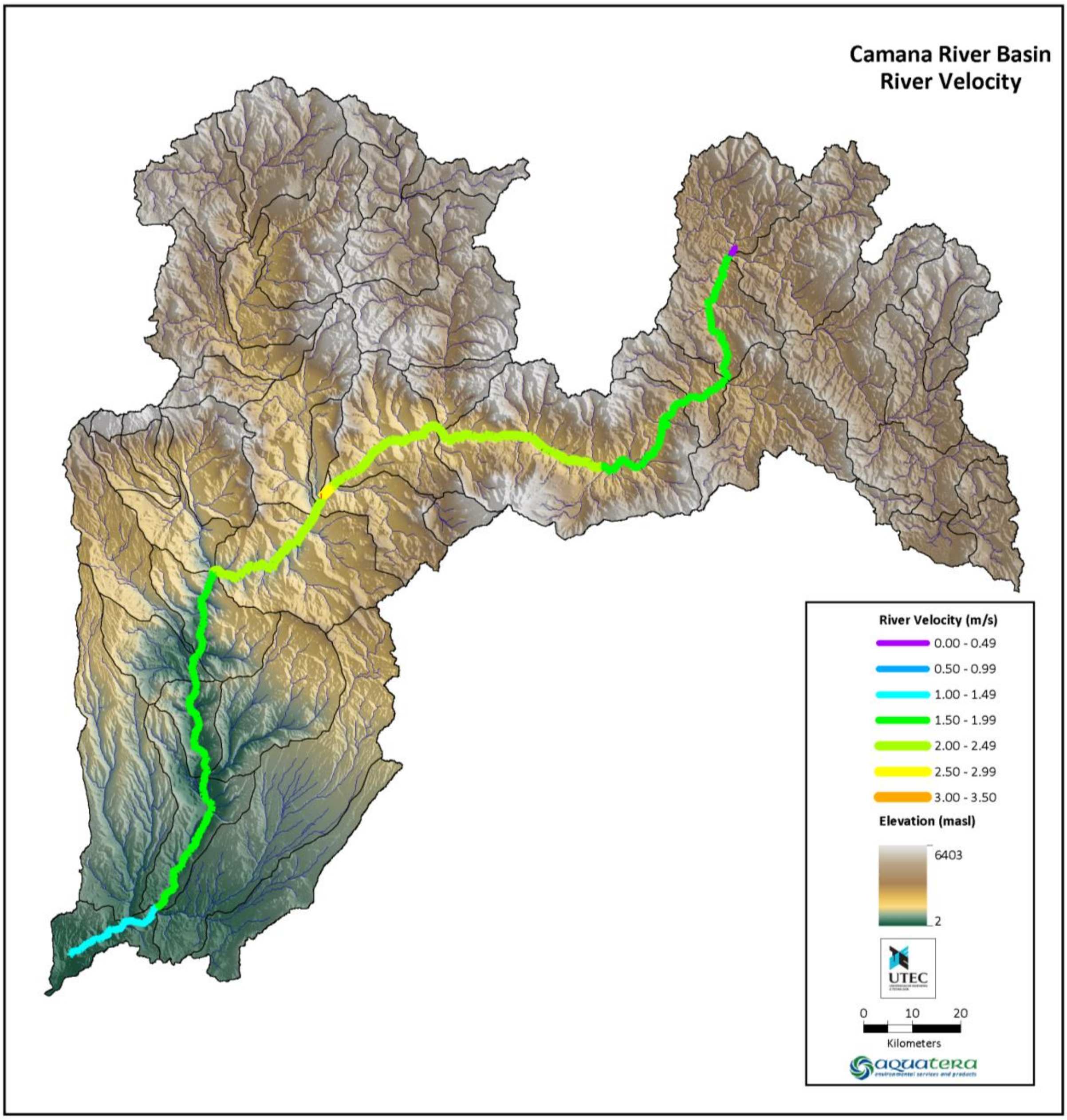

Urubamba River Basin
River Width
River Width (m)
0 -50
50 - 100
100 - 150
150 - 200
200 - 250
250 - 300
300 - 350
Elevation (masl)
6951
162
UTEC
0 10 20 30 40 50
Kilometers
aquatera
environmental services and products

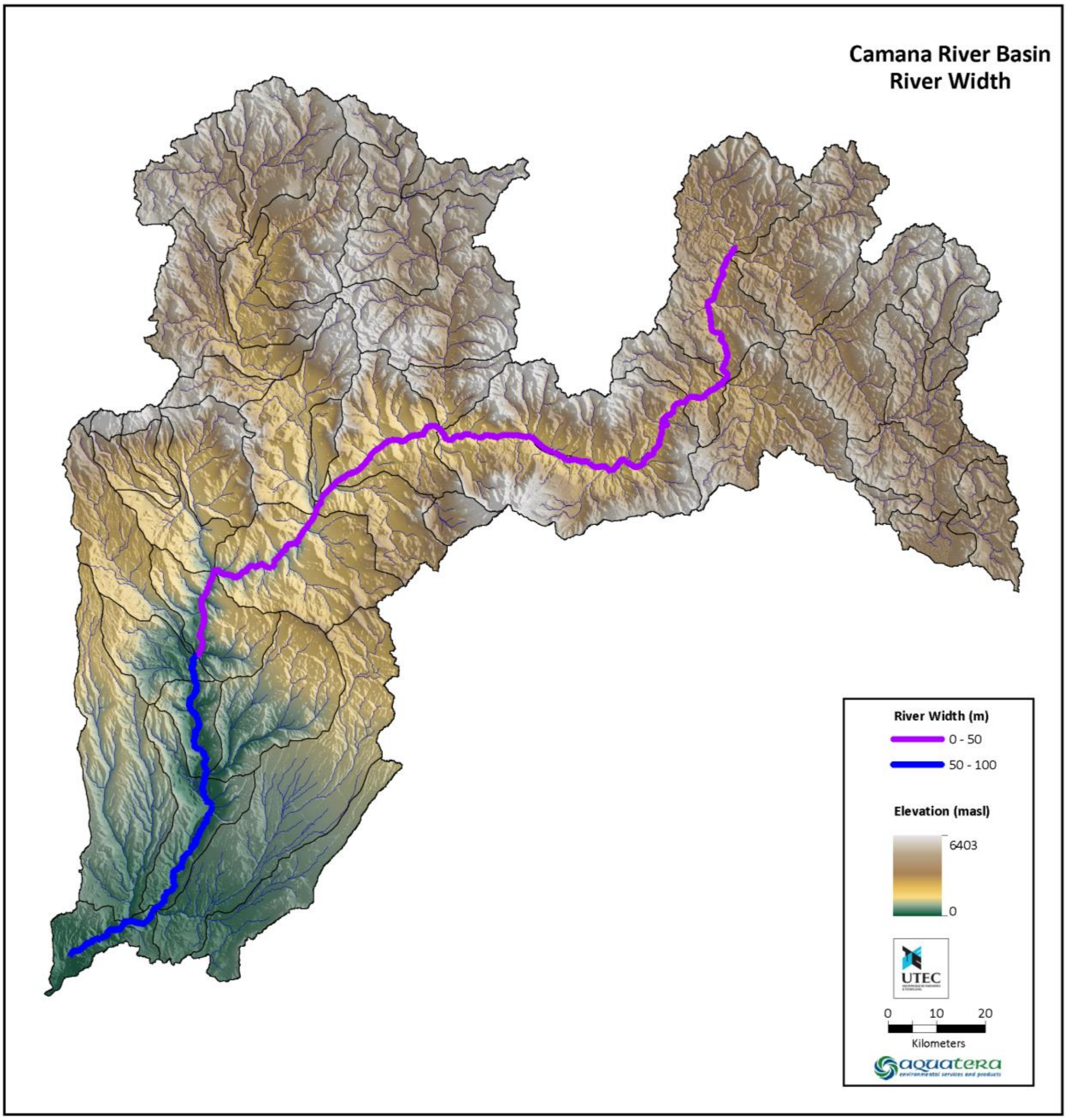

Urubamba River Basin
River HPP
River HPP (W/m2)
0 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 5000
5000 - 10000
1000 - 15000
15000 - 30000
Elevation (masl)
6951
162
UTEC
0 10 20 30 40 50
Kilometers
aquatera
environmental services and products

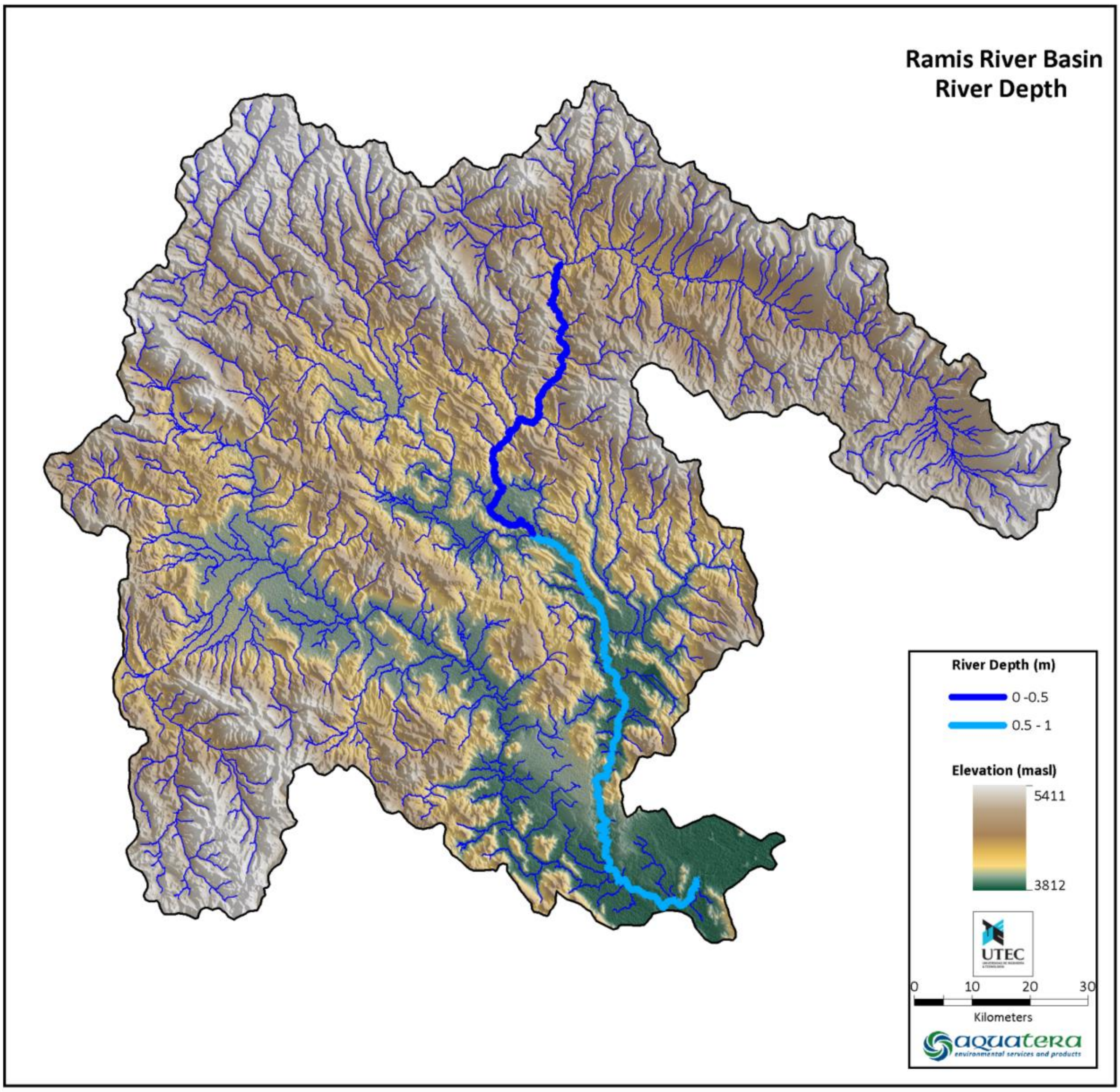

Urubamba River Basin
River Hk Potential
River Hk Potential
Not Recommended
Recommended
Elevation (masl)
6951
162
UTEC
0 10 20 30 40 50
Kilometers
aquatera
environmental services and products

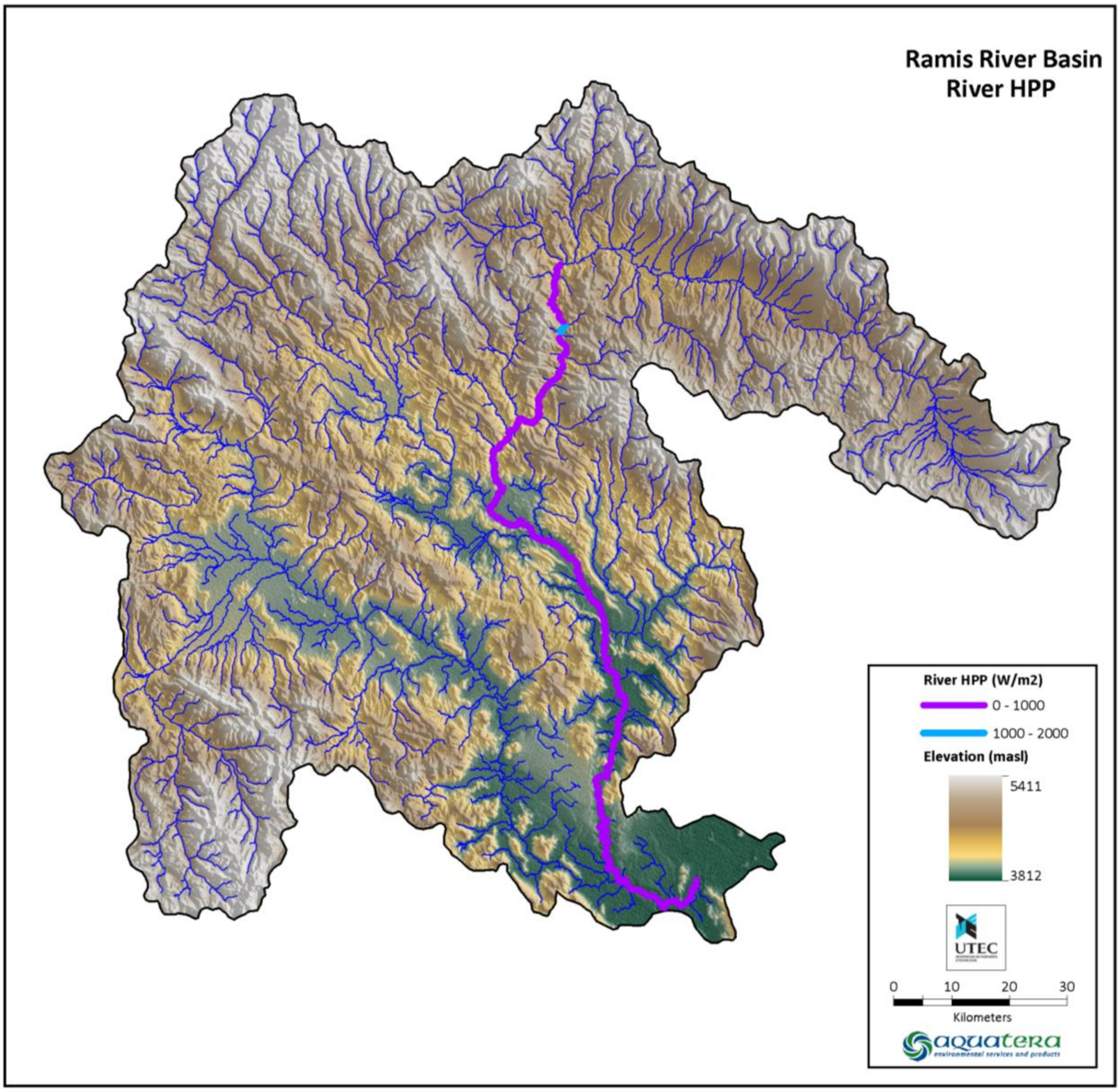

Camana River Basin
River Depth
River Depth (m)
0.00 - 0.49
0.50 - 0.99
1.00 - 1.50
Elevation (masl)
6403
2
UTEC
0
10
20
Kilometers
aquatera
environmental services and products

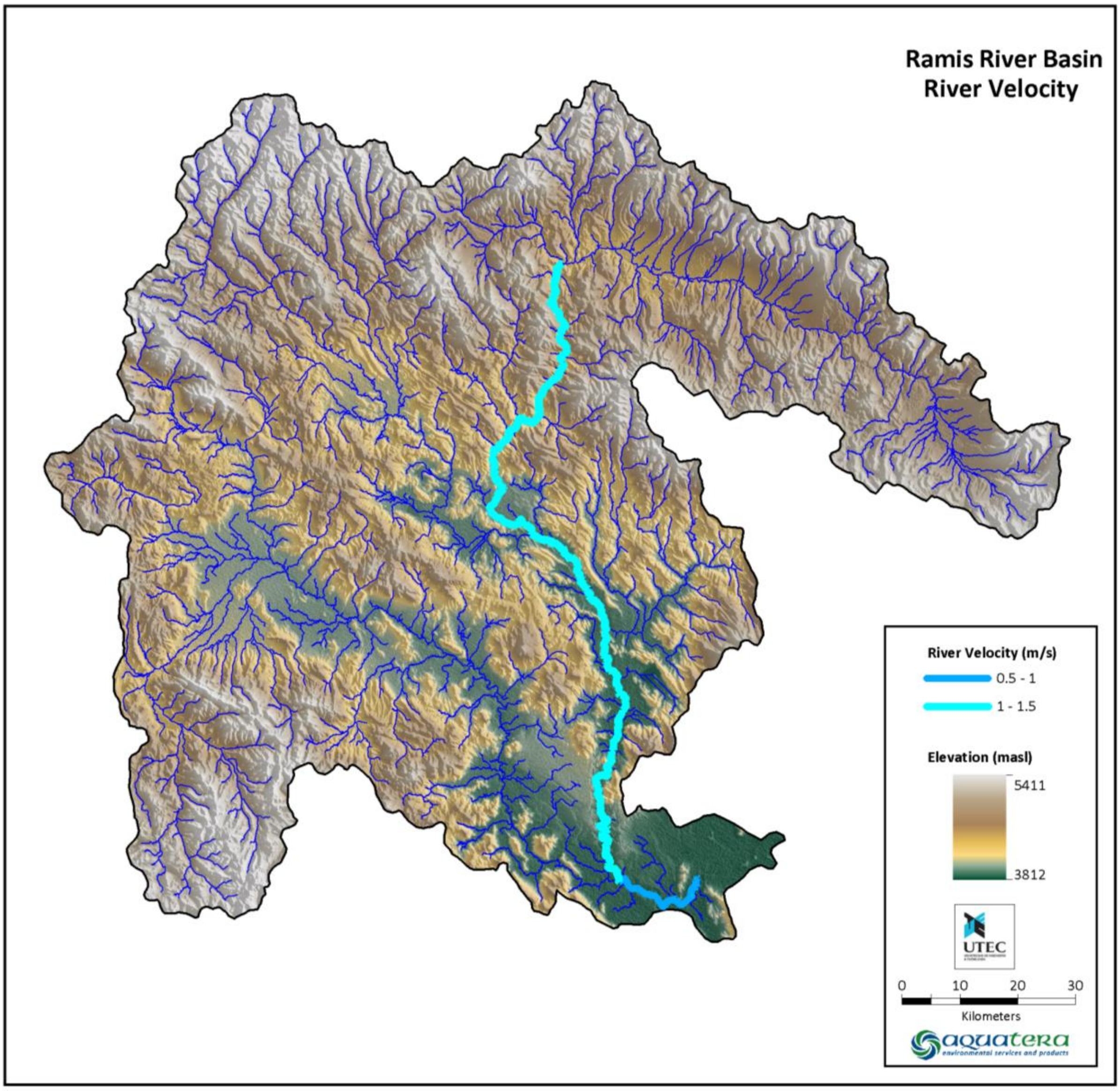

Camana River Basin
River HPP
River HPP (W/m/2)
0 - 999.99
1000.00 - 1999.99
2000.00 - 2999.99
3000.00 - 3999.99
4000.00 - 4999.99
5000.00 - 9999.99
10000.00 - 15000.00
Elevation (masl)
6403
2
UTEC
0
10
20
Kilometers
aquatera
environmental services and products

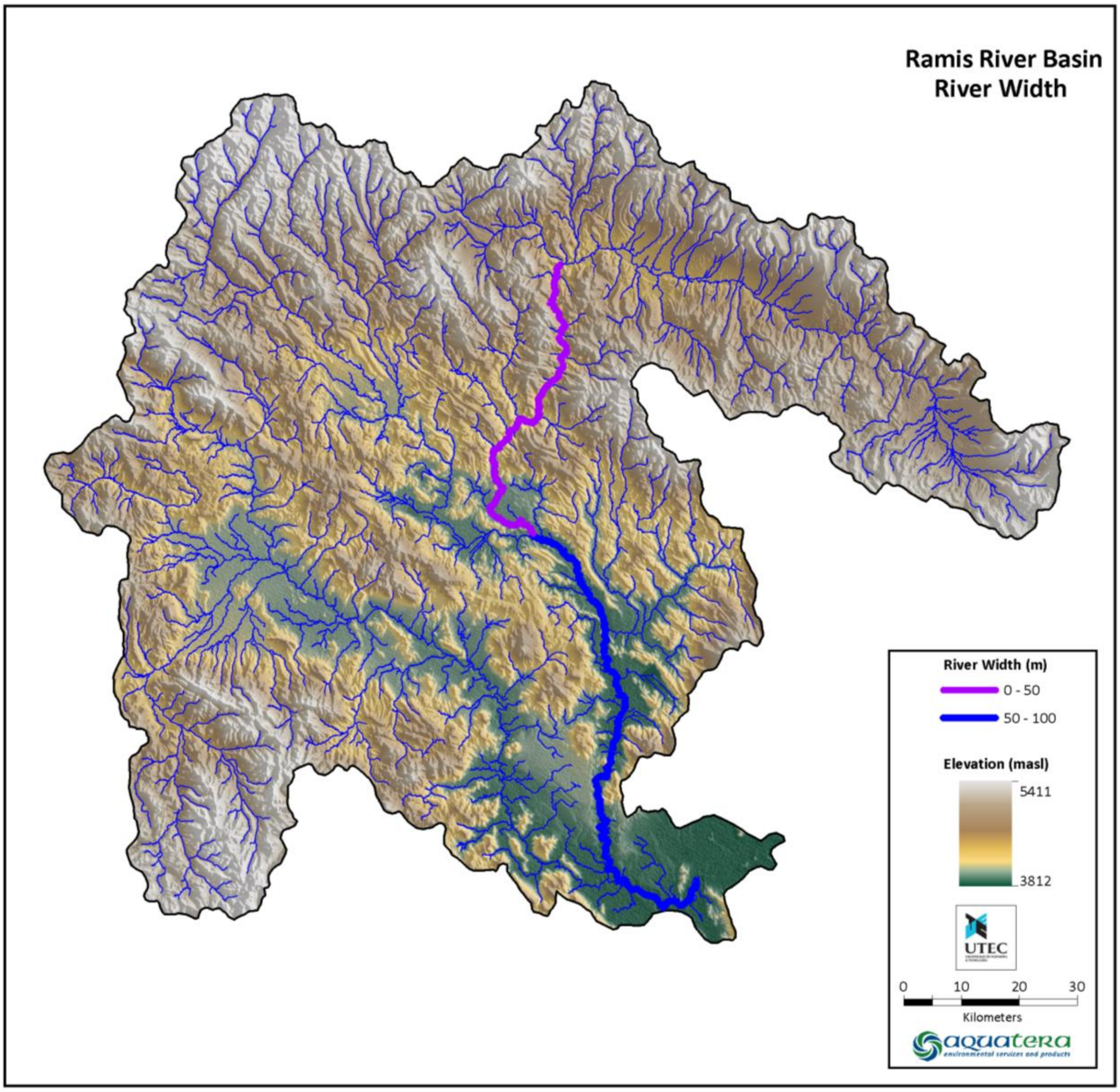

Camana River Basin
River Velocity
River Velocity (m/s)
0.00 - 0.49
0.50 - 0.99
1.00 - 1.49
1.50 - 1.99
2.00 - 2.49
2.50 - 2.99
3.00 - 3.50
Elevation (masl)
6403
2
UTEC
0
10
20
Kilometers
aquatera
environmental services and products


Camana River Basin
River Width
River Width (m)
0 - 50
50 - 100
Elevation (masl)
6403
0
UTEC
0
10
20
Kilometers
aquatera
environmental services and products


Ramis River Basin
River Depth
River Depth (m)
0 -0.5
0.5 - 1
Elevation (masl)
5411
3812
UTEC
0
10
20
30
Kilometers
aquatera
environmental services and products


Ramis River Basin
River HPP
River HPP (W/m2)
0 - 1000
1000 - 2000
Elevation (masl)
5411
3812
UTEC
0
10
20
30
Kilometers
aquatera
environmental services and products


Ramis River Basin
River Velocity
River Velocity (m/s)
0.5 - 1
1 - 1.5
Elevation (masl)
5411
3812
UTEC
0
10
20
30
Kilometers
aquatera
environmental services and products


Ramis River Basin
River Width
River Width (m)
0 - 50
50 - 100
Elevation (masl)
5411
3812
UTEC
0
10
20
30
Kilometers
aquatera
environmental services and products

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APPENDIX C A3 MAPS

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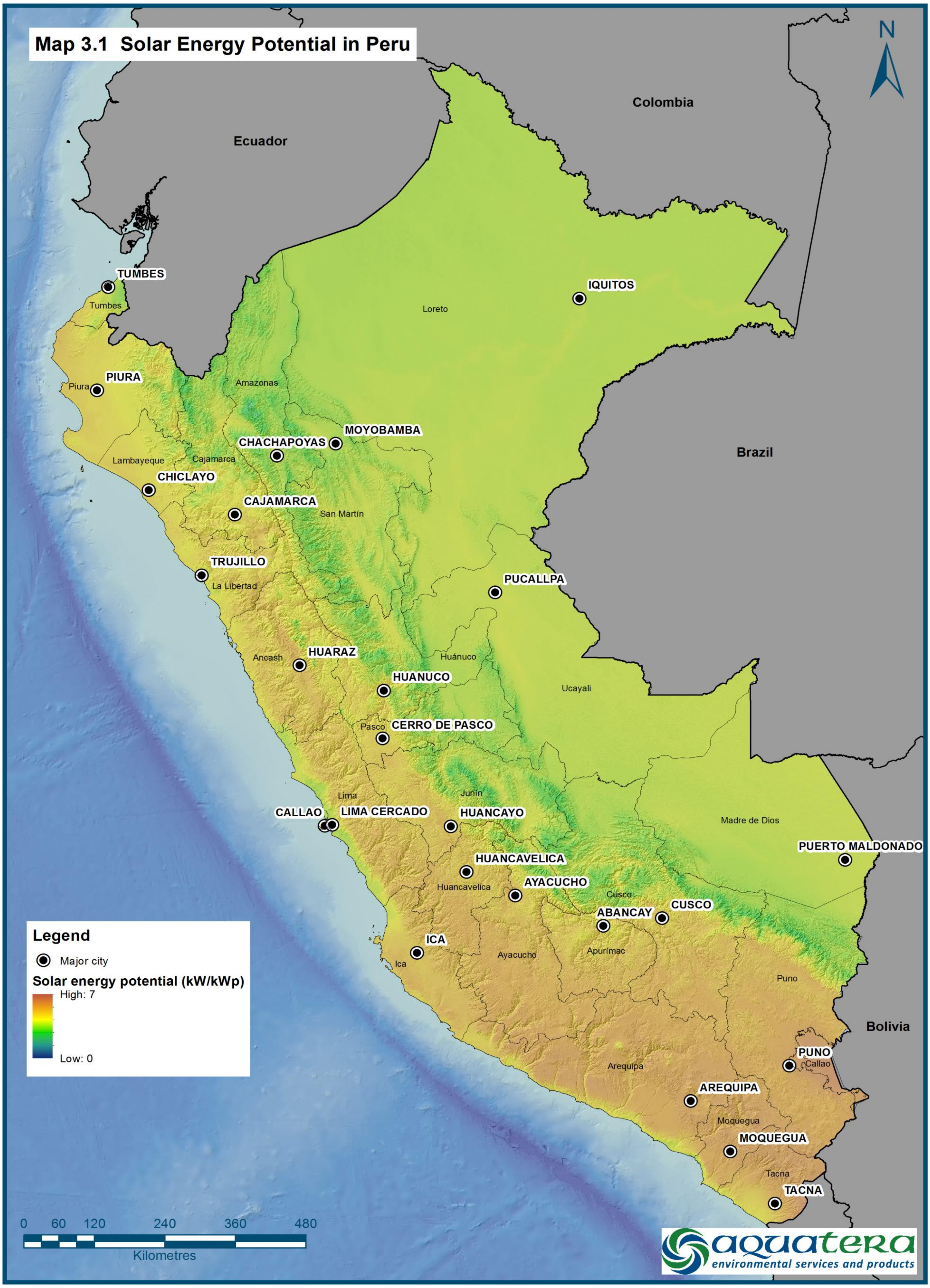
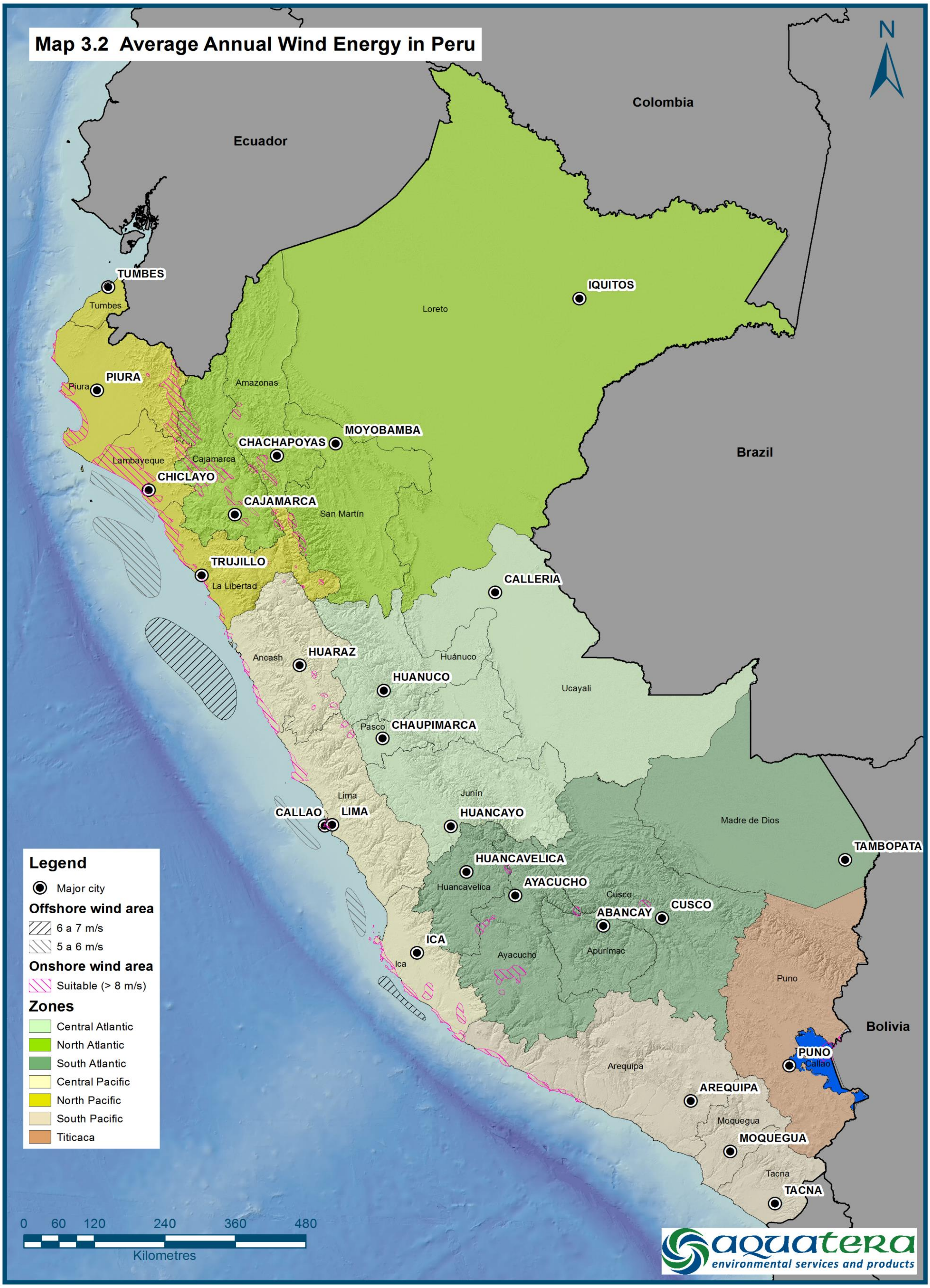
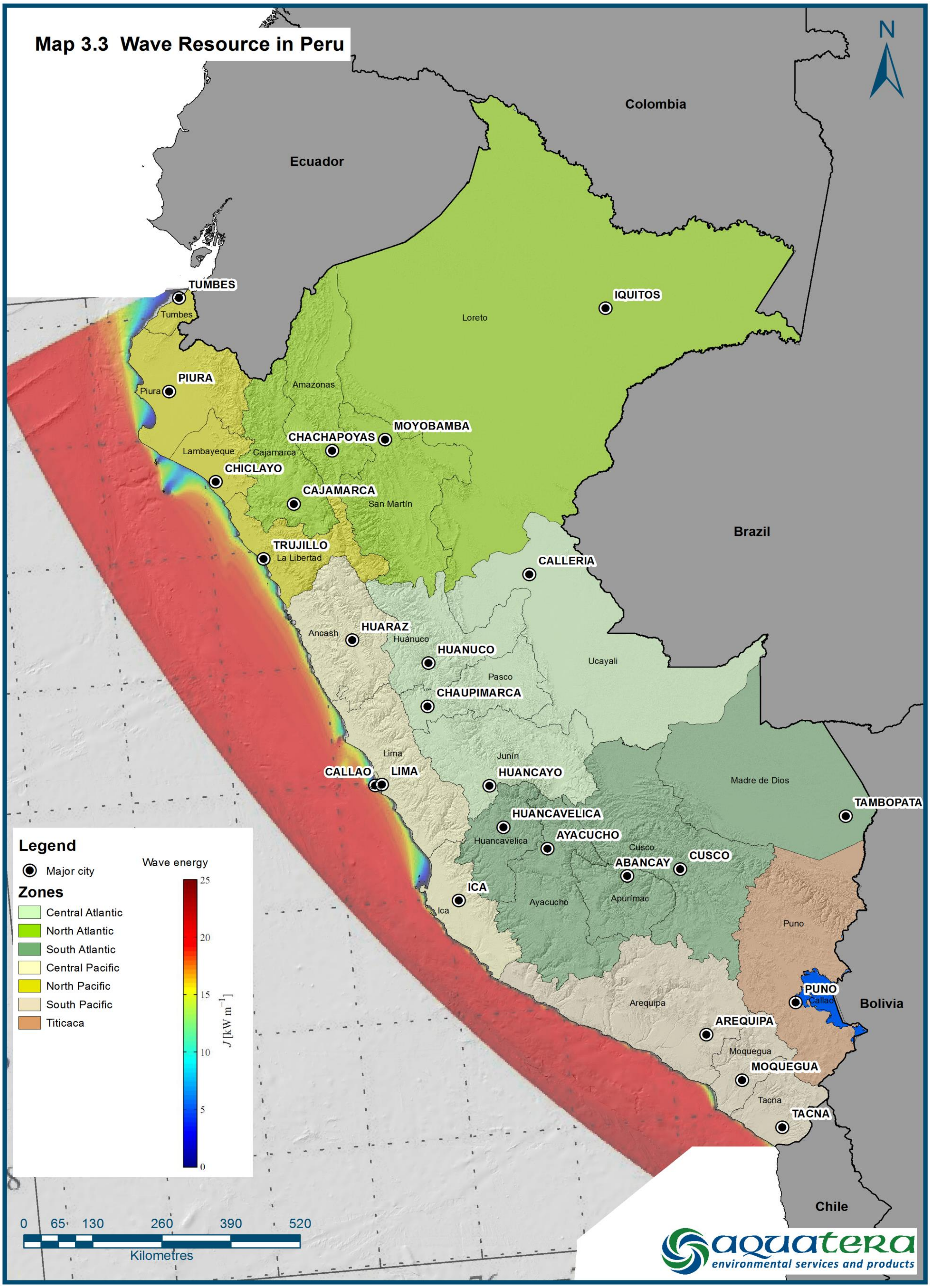
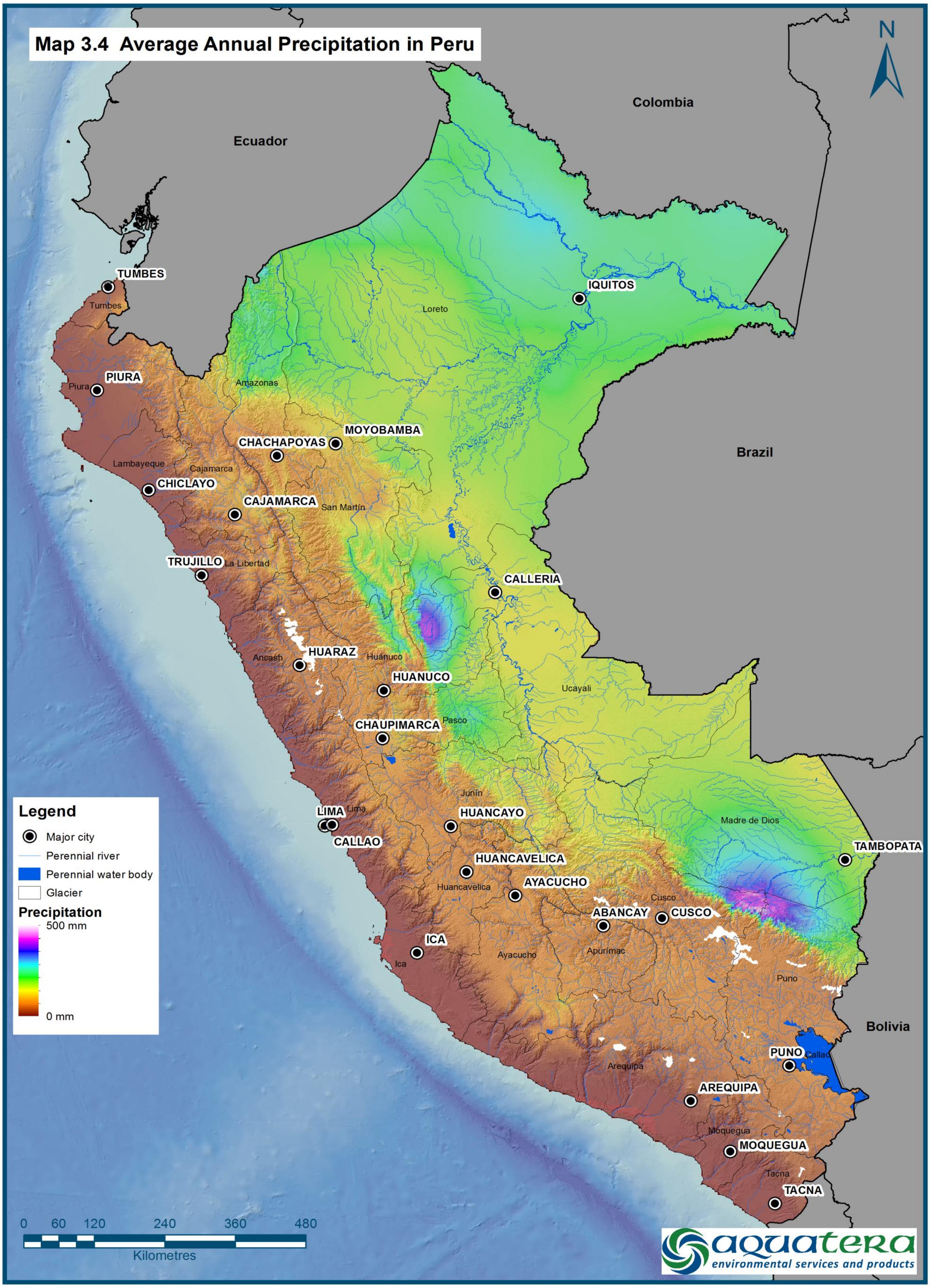

Map 3.1 Solar Energy Potential in Peru
N
Colombia
Ecuador
Brazil
Bolivia
TUMBES
Tumbes
IQUITOS
Loreto
PIURA
Piura
Amazonas
MOYOBAMBA
CHACHAPOYAS
Lambayeque
Cajamarca
CHICLAYO
CAJAMARCA
San Martín
TRUJILLO
La Libertad
PUCALLPA
Ancash
HUARAZ
Huánuco
HUANUCO
Ucayali
Pasco
CERRO DE PASCO
Lima
Junín
CALLAO
LIMA CERCADO
HUANCAYO
Madre de Dios
PUERTO MALDONADO
HUANCAVELICA
Huancavelica
AYACUCHO
Cusco
ABANCAY
CUSCO
ICA
Ica
Ayacucho
Apurímac
Puno
PUNO
Callao
Arequipa
AREQUIPA
Moquegua
MOQUEGUA
Tacna
TACNA
Legend
Major city
Solar energy potential (kW/kWp)
High: 7
Low: 0
0 60 120 240 360 480
Kilometres
aquatera
environmental services and products

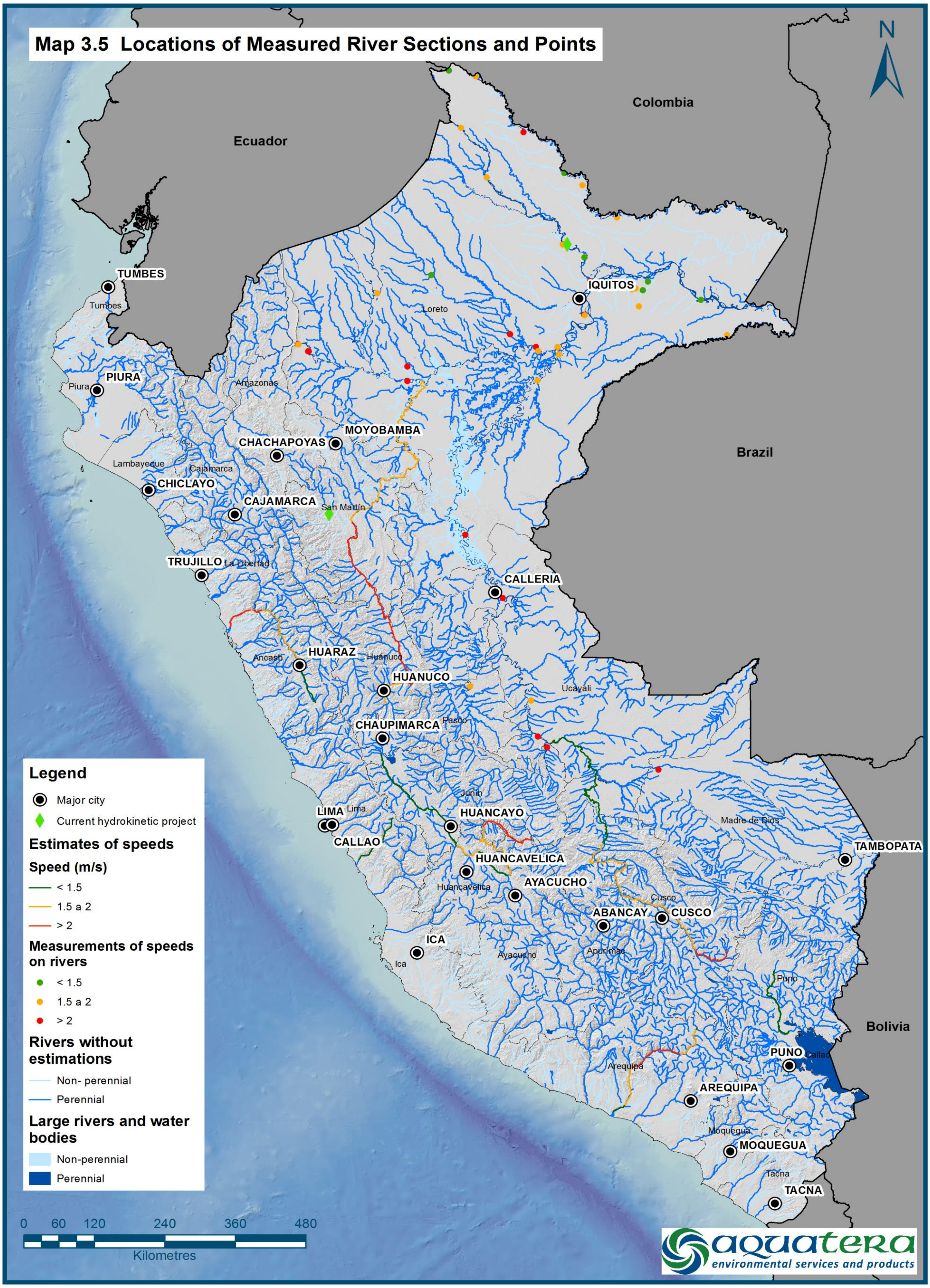


Map 3.2 Average Annual Wind Energy in Peru
N
Colombia
Ecuador
Brazil
Bolivia
TUMBES
Tumbes
PIURA
Piura
IQUITOS
Loreto
Amazonas
MOYOBAMBA
CHACHAPOYAS
Lambayeque
Cajamarca
CHICLAYO
CAJAMARCA
San Martín
TRUJILLO
La Libertad
CALLERIA
HUARAZ
Ancash
Huánuco
HUANUCO
Ucayali
Pasco
CHAUPIMARCA
Lima
Junín
CALLAO
LIMA
HUANCAYO
Madre de Dios
TAMBOPATA
HUANCAVELICA
Huancavelica
AYACUCHO
Cusco
ABANCAY
CUSCO
ICA
Ica
Ayacucho
Apurímac
Puno
PUNO
Callao
Arequipa
AREQUIPA
Moquegua
MOQUEGUA
Tacna
TACNA
Legend
Major city
Offshore wind area
6 a 7 m/s
5 a 6 m/s
Onshore wind area
Suitable (> 8 m/s)
Zones
Central Atlantic
North Atlantic
South Atlantic
Central Pacific
North Pacific
South Pacific
Titicaca
0 60 120 240 360 480
Kilometres
aquatera
environmental services and products

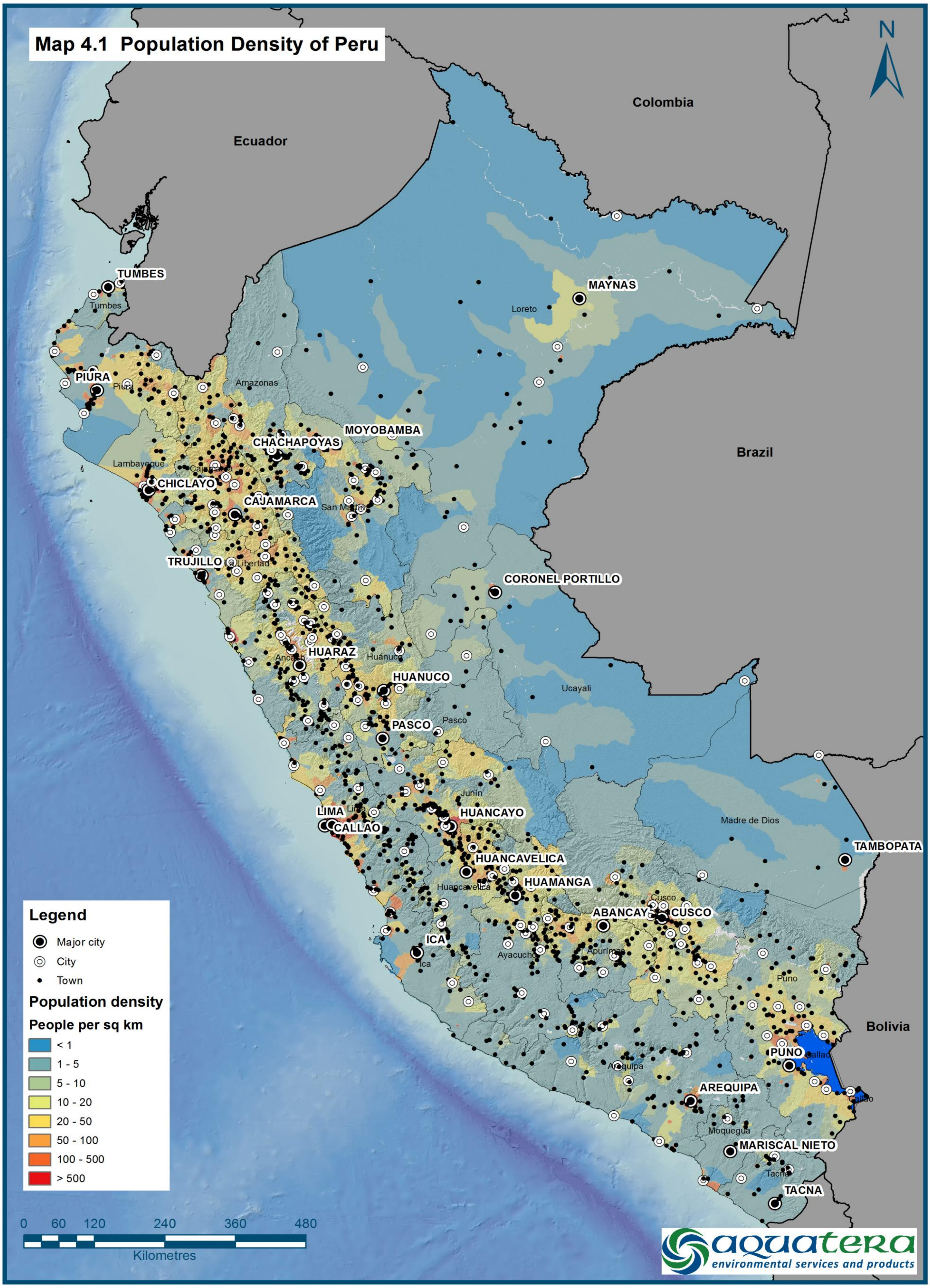

Map 3.3 Wave Resource in Peru
Colombia
Ecuador
Brazil
Bolivia
Chile
N
TUMBES
Tumbes
IQUITOS
Loreto
PIURA
Piura
Amazonas
MOYOBAMBA
CHACHAPOYAS
Lambayeque
Cajamarca
CHICLAYO
CAJAMARCA
San Martín
TRUJILLO
La Libertad
CALLERIA
HUARAZ
Ancash
Huánuco
HUANUCO
Ucayali
Pasco
CHAUPIMARCA
Lima
Junín
CALLAO
LIMA
HUANCAYO
Madre de Dios
TAMBOPATA
HUANCAVELICA
Huancavelica
AYACUCHO
Cusco
ABANCAY
CUSCO
ICA
Ica
Ayacucho
Apurímac
Puno
PUNO
Callao
Arequipa
AREQUIPA
Moquegua
MOQUEGUA
Tacna
TACNA
Legend
Major city
Zones
Central Atlantic
North Atlantic
South Atlantic
Central Pacific
North Pacific
South Pacific
Titicaca
Wave energy
25
20
15
10
5
0
J [kW m^-1]
0 65 130 260 390 520
Kilometres
aquatera
environmental services and products

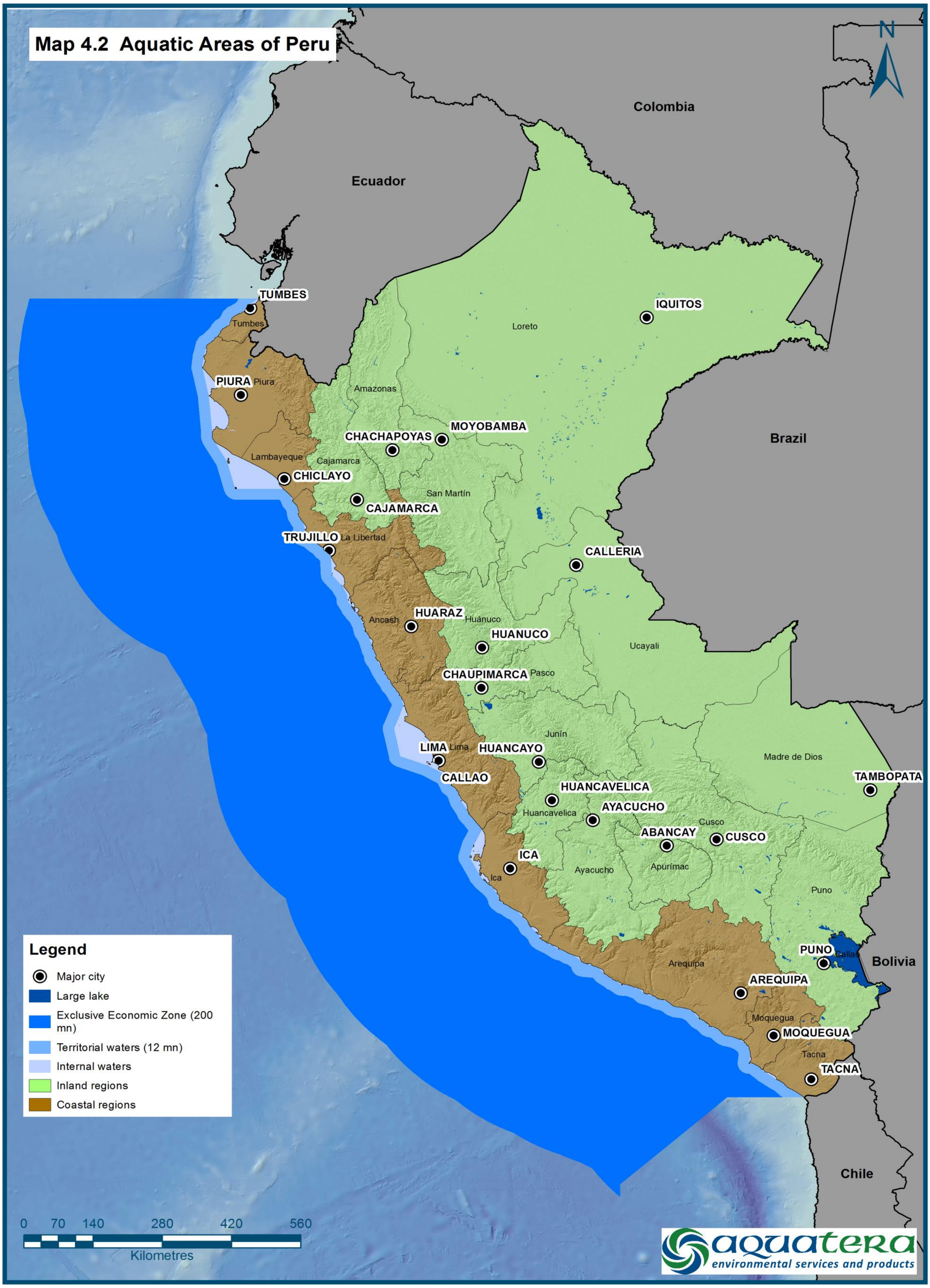


Map 3.4 Average Annual Precipitation in Peru

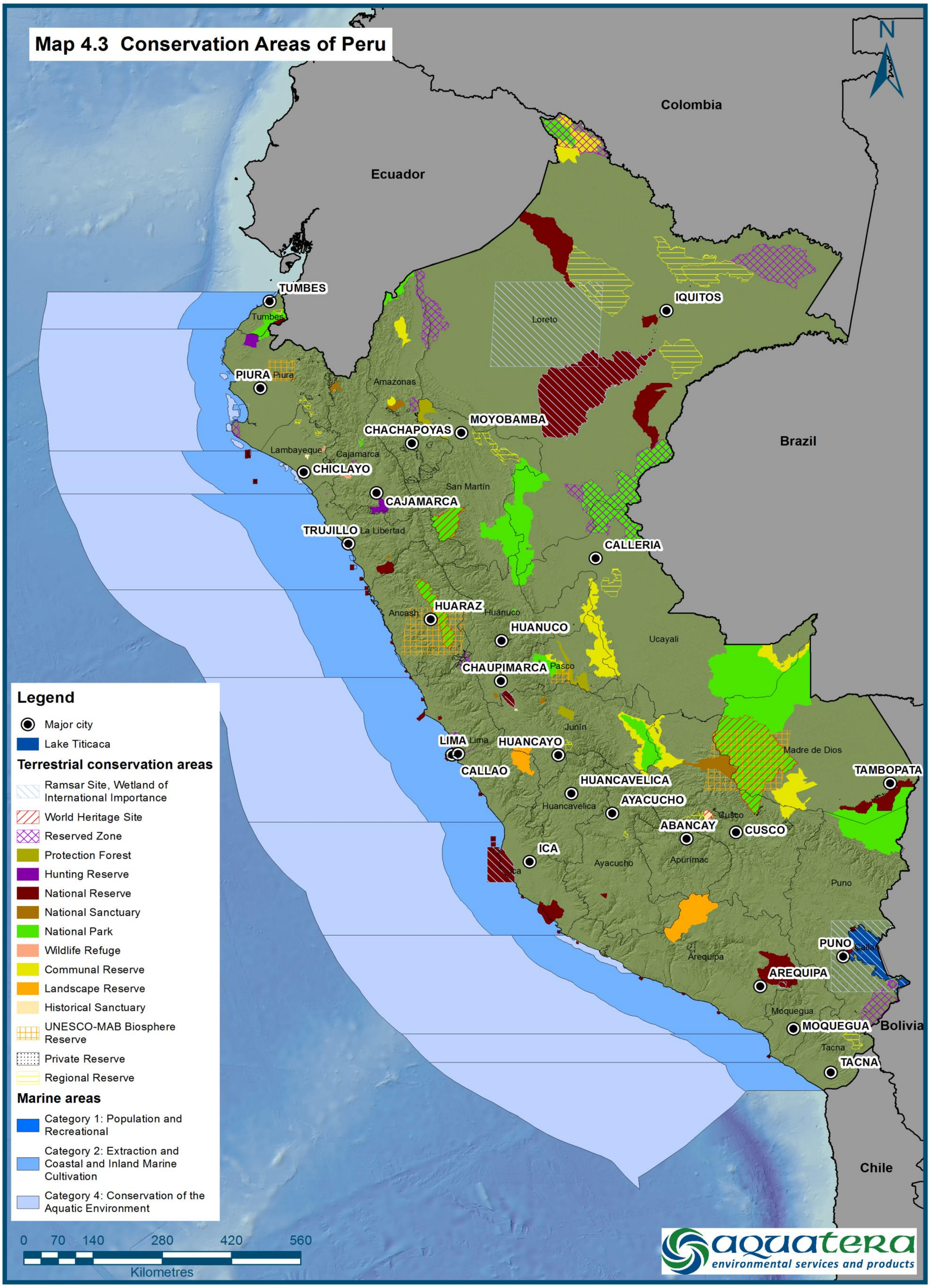


Map 3.5 Locations of Measured River Sections and Points

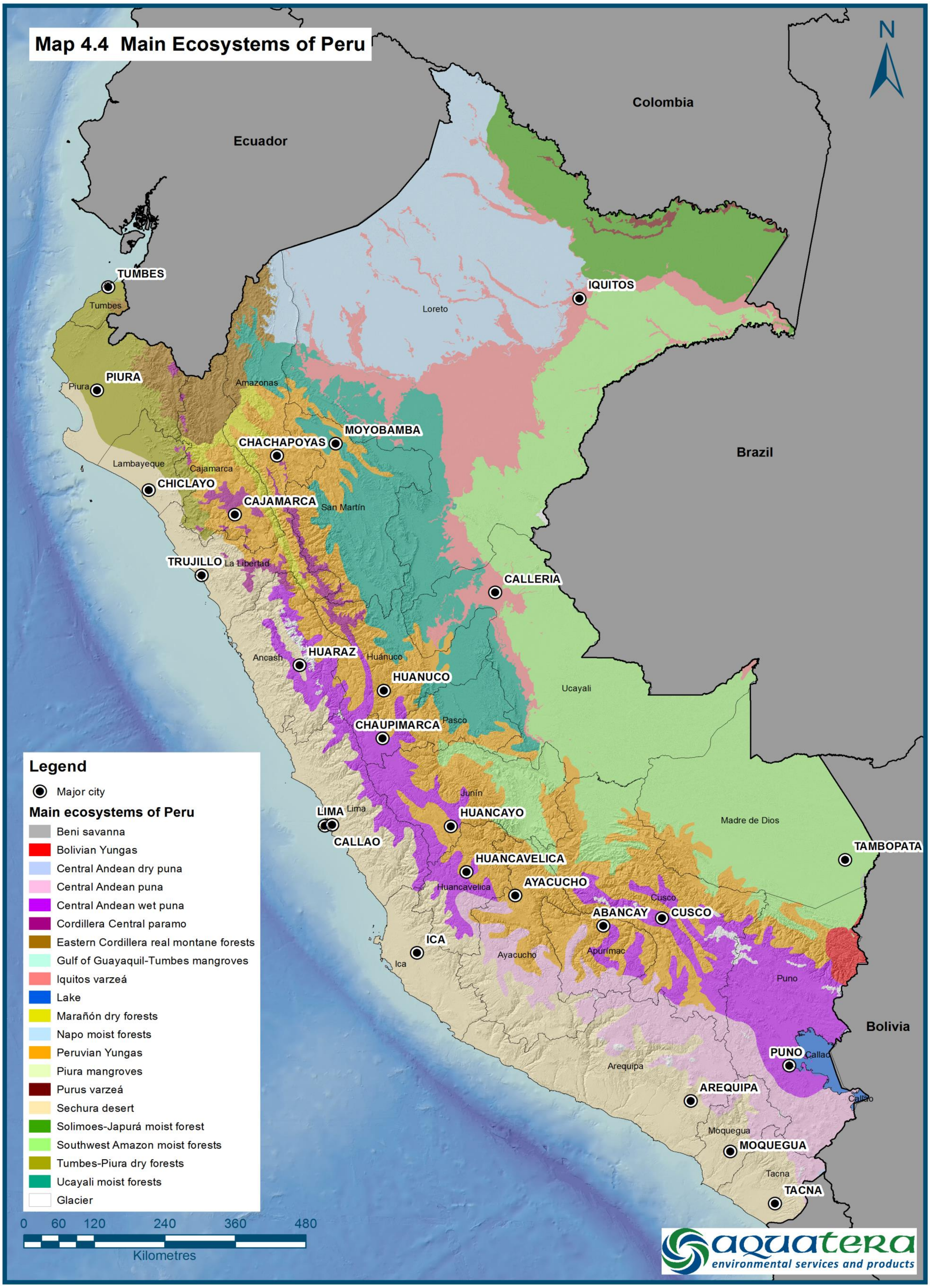

Map 4.1 Population Density of Peru
N
Colombia
Ecuador
Brazil
Bolivia
TUMBES
Tumbes
PIURA
Piura
MAYNAS
Loreto
Amazonas
MOYOBAMBA
CHACHAPOYAS
Lambayeque
Cajamarca
CHICLAYO
CAJAMARCA
San Martin
TRUJILLO
La Libertad
CORONEL PORTILLO
HUARAZ
Ancash
Huanuco
HUANUCO
Ucayali
PASCO
Pasco
Junín
LIMA
Lima
CALLAO
HUANCAYO
Madre de Dios
TAMBOPATA
HUANCAVELICA
Huancavelica
HUAMANGA
Cusco
ABANCAY
CUSCO
Apurímac
ICA
Ica
Ayacucho
Puno
PUNO
Callao
AREQUIPA
Arequipa
Moquegua
MARISCAL NIETO
Tacna
TACNA
Legend
Major city
City
Town
Population density
People per sq km
< 1
1 - 5
5 - 10
10 - 20
20 - 50
50 - 100
100 - 500
> 500
0 60 120 240 360 480
Kilometres
aquatera
environmental services and products



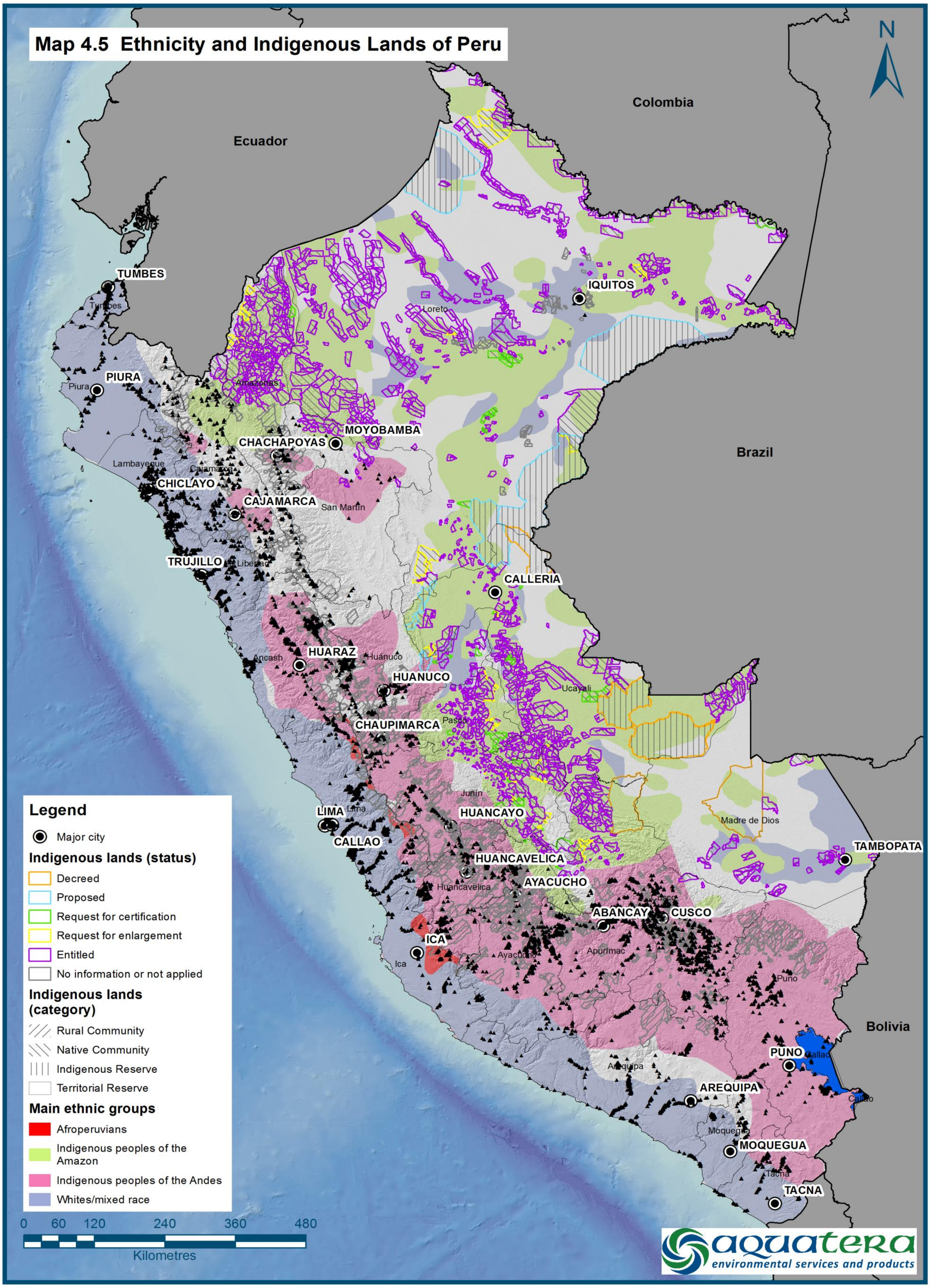
Map 4.2 Aquatic Areas of Peru
N
Colombia
Ecuador
Brazil
Bolivia
Chile
TUMBES
Tumbes
PIURA
Piura
IQUITOS
Loreto
Amazonas
MOYOBAMBA
CHACHAPOYAS
Lambayeque
Cajamarca
CHICLAYO
San Martín
CAJAMARCA
TRUJILLO
La Libertad
CALLERIA
HUARAZ
Ancash
Huánuco
HUANUCO
Ucayali
CHAUPIMARCA
Pasco
Junín
LIMA
Lima
HUANCAYO
CALLAO
Madre de Dios
TAMBOPATA
HUANCAVELICA
Huancavelica
AYACUCHO
Cusco
ABANCAY
CUSCO
ICA
Ica
Ayacucho
Apurímac
Puno
PUNO
Arequipa
AREQUIPA
Moquegua
MOQUEGUA
Tacna
TACNA
Legend
Major city
Large lake
Exclusive Economic Zone (200 mn)
Territorial waters (12 mn)
Internal waters
Inland regions
Coastal regions
0 70 140 280 420 560
Kilometres
aquatera
environmental services and products

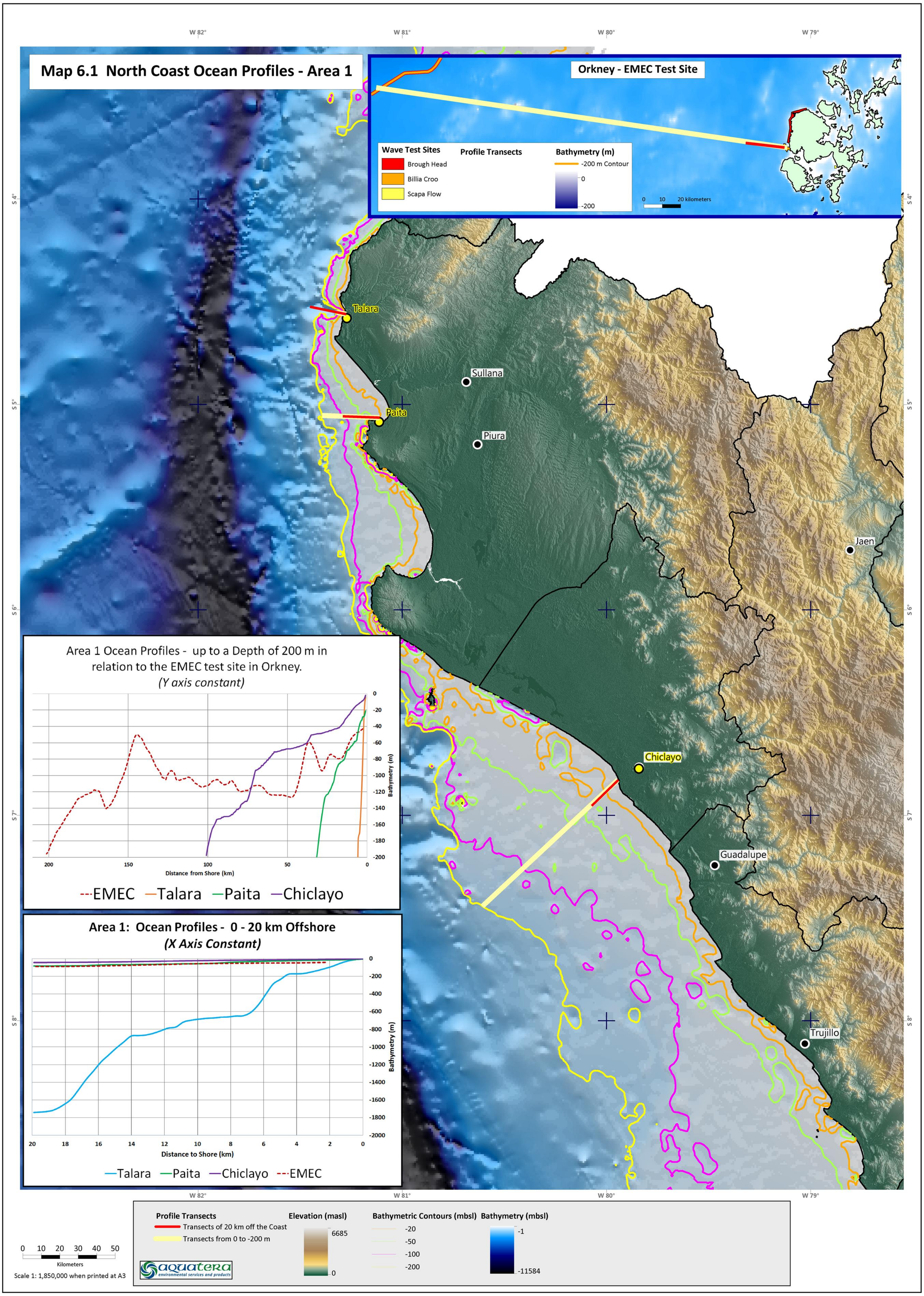


Map 4.3 Conservation Areas of Peru
Colombia
Ecuador
Brazil
Bolivia
Chile
N
TUMBES
Tumbes
IQUITOS
Loreto
PIURA
Piura
Amazonas
MOYOBAMBA
CHACHAPOYAS
Lambayeque
Cajamarca
CHICLAYO
San Martín
CAJAMARCA
TRUJILLO
La Libertad
CALLERIA
Ancash
HUARAZ
Huánuco
HUANUCO
Ucayali
CHAUPIMARCA
Pasco
Junín
LIMA
Lima
HUANCAYO
CALLAO
Madre de Dios
TAMBOPATA
HUANCAVELICA
Huancavelica
AYACUCHO
Cusco
ABANCAY
CUSCO
ICA
Ayacucho
Apurímac
Puno
PUNO
Arequipa
AREQUIPA
Moquegua
MOQUEGUA
Tacna
TACNA
Legend
Major city
Lake Titicaca
Terrestrial conservation areas
Ramsar Site, Wetland of International Importance
World Heritage Site
Reserved Zone
Protection Forest
Hunting Reserve
National Reserve
National Sanctuary
National Park
Wildlife Refuge
Communal Reserve
Landscape Reserve
Historical Sanctuary
UNESCO-MAB Biosphere Reserve
Private Reserve
Regional Reserve
Marine areas
Category 1: Population and Recreational
Category 2: Extraction and Coastal and Inland Marine Cultivation
Category 4: Conservation of the Aquatic Environment
0 70 140 280 420 560
Kilometres
aquatera
environmental services and products

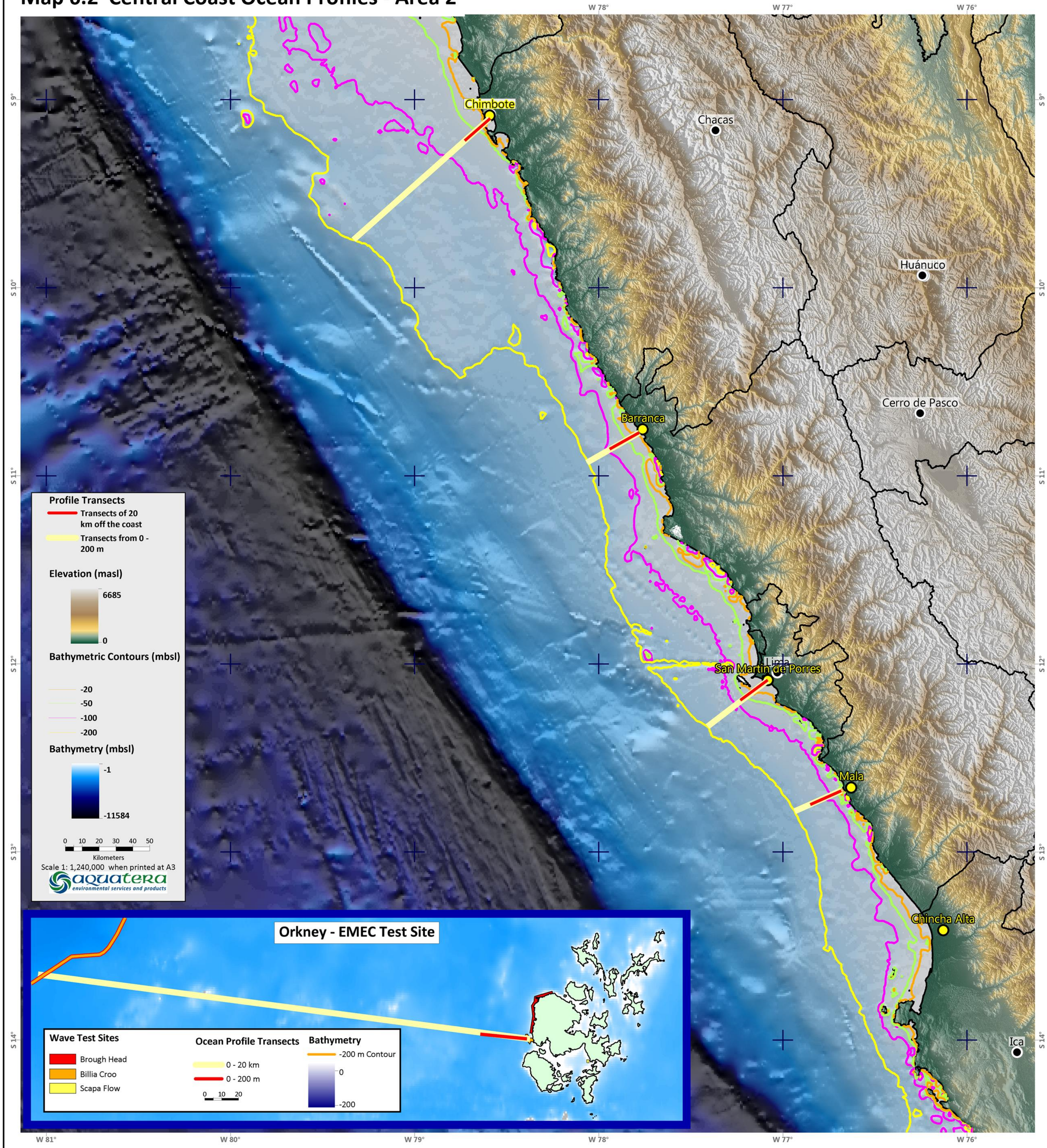

Map 4.4 Main Ecosystems of Peru
N
Colombia
Ecuador
Brazil
Bolivia
TUMBES
Tumbes
PIURA
Piura
Lambayeque
CHICLAYO
Amazonas
CHACHAPOYAS
MOYOBAMBA
Cajamarca
CAJAMARCA
San Martín
TRUJILLO
La Libertad
Loreto
IQUITOS
CALLERIA
Ucayali
Ancash
HUARAZ
Huánuco
HUANUCO
Pasco
CHAUPIMARCA
Junín
LIMA
Lima
CALLAO
HUANCAYO
HUANCAVELICA
Huancavelica
AYACUCHO
Ayacucho
ICA
Ica
ABANCAY
Apurímac
CUSCO
Cusco
Madre de Dios
TAMBOPATA
Puno
PUNO
Callao
Arequipa
AREQUIPA
Moquegua
MOQUEGUA
Tacna
TACNA
Legend
Major city
Main ecosystems of Peru
Beni savanna
Bolivian Yungas
Central Andean dry puna
Central Andean puna
Central Andean wet puna
Cordillera Central paramo
Eastern Cordillera real montane forests
Gulf of Guayaquil-Tumbes mangroves
Iquitos varzeá
Lake
Marañón dry forests
Napo moist forests
Peruvian Yungas
Piura mangroves
Purus varzeá
Sechura desert
Solimoes-Japurá moist forest
Southwest Amazon moist forests
Tumbes-Piura dry forests
Ucayali moist forests
Glacier
0 60 120 240 360 480
Kilometres
aquatera
environmental services and products

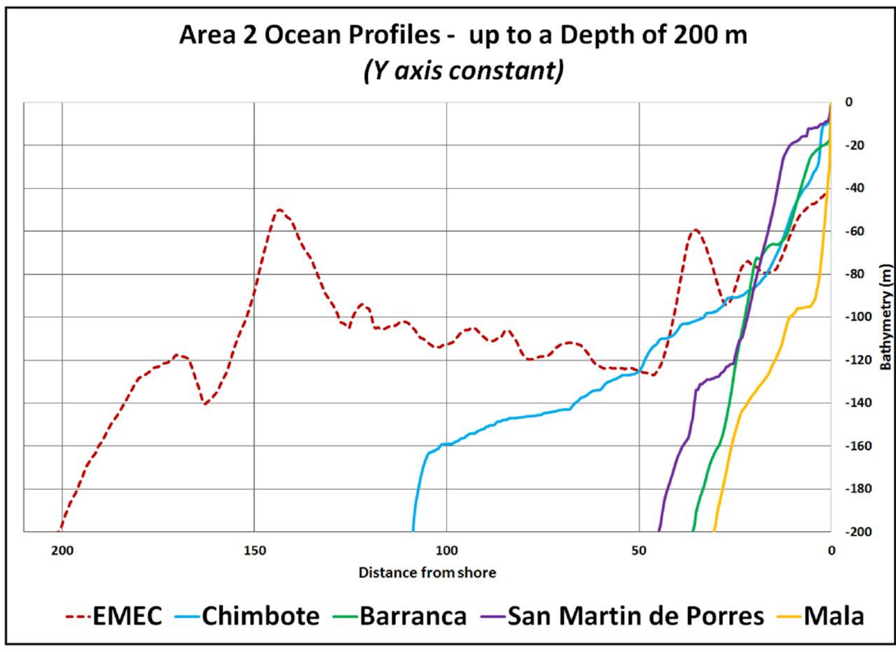
Map 4.5 Ethnicity and Indigenous Lands of Peru

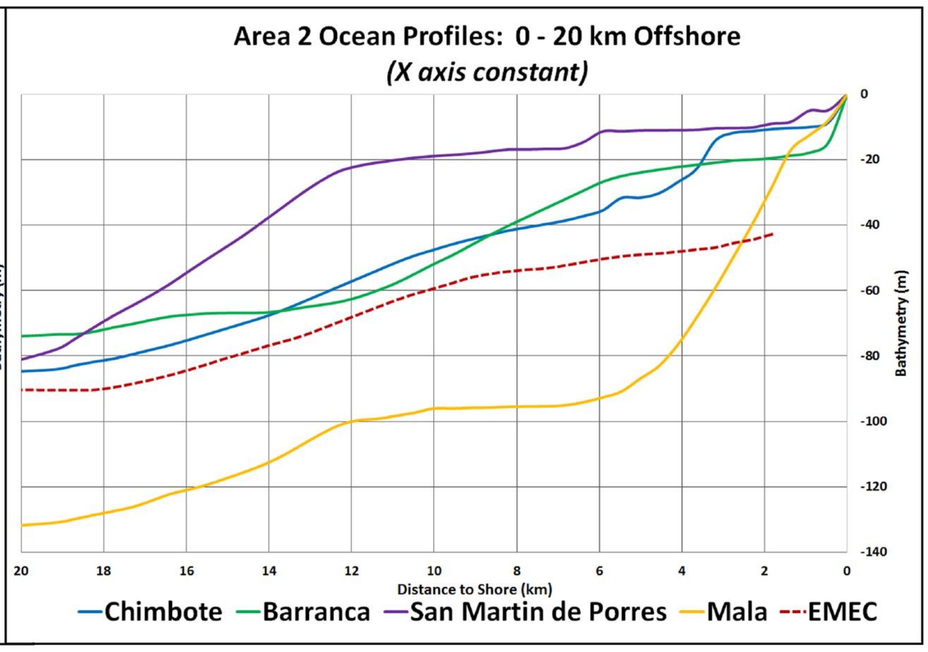


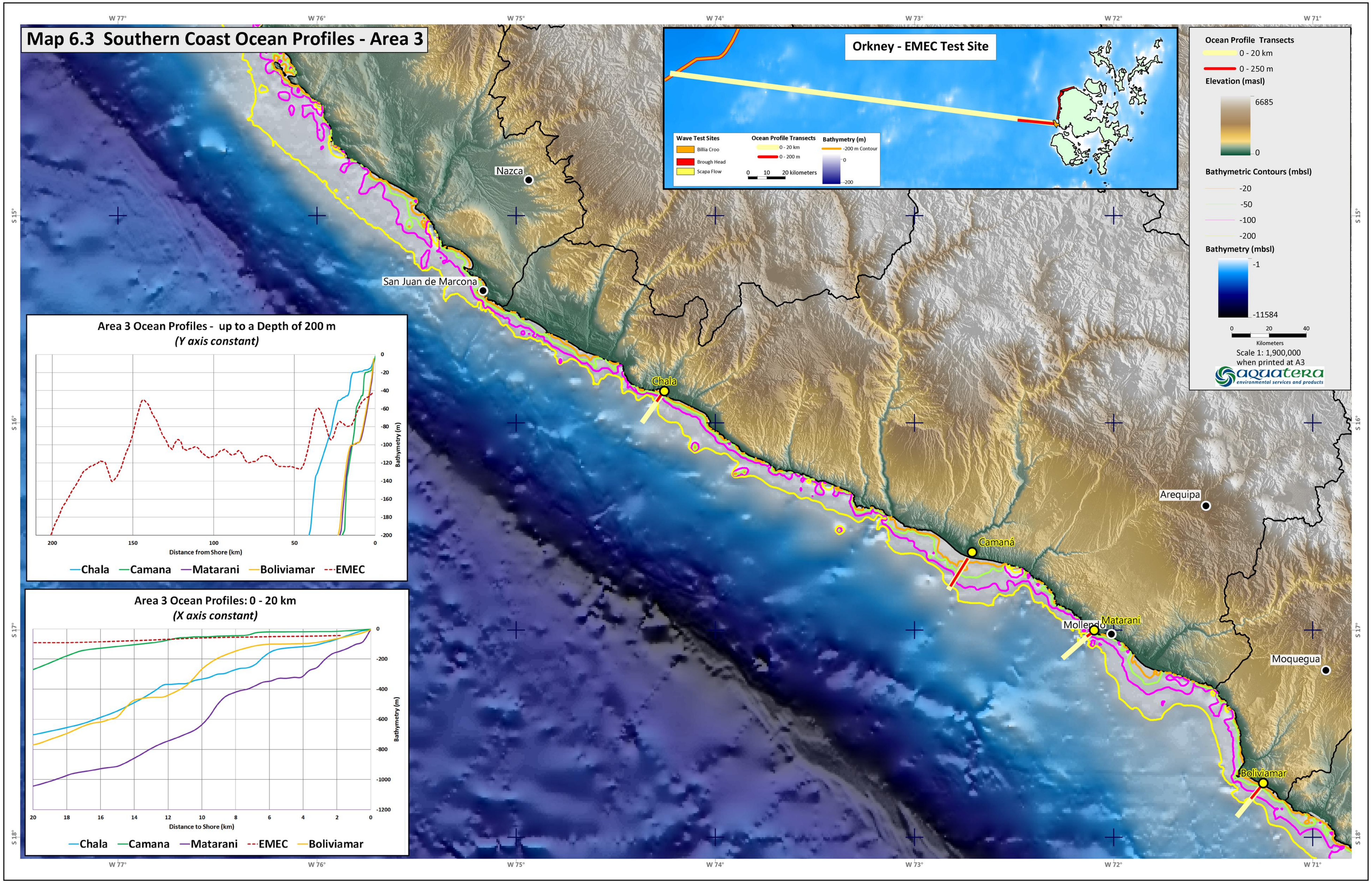

Map 6.1 North Coast Ocean Profiles - Area 1
Orkney - EMEC Test Site
Wave Test Sites
Brough Head
Billia Croo
Scapa Flow
Profile Transects
Bathymetry (m)
-200 m Contour
0
-200
0 10 20 kilometers
W 82°
W 81°
W 80°
W 79°
S 4°
S 5°
S 6°
S 7°
S 8°
Talara
Sullana
Paita
Piura
Jaen
Chiclayo
Guadalupe
Trujillo
Area 1 Ocean Profiles - up to a Depth of 200 m in relation to the EMEC test site in Orkney.
(Y axis constant)
Bathymetry (m)
Distance from Shore (km)
EMEC
Talara
Paita
Chiclayo
Area 1: Ocean Profiles - 0 - 20 km Offshore
(X Axis Constant)
Bathymetry (m)
Distance to Shore (km)
Talara
Paita
Chiclayo
EMEC
Profile Transects
Transects of 20 km off the Coast
Transects from 0 to -200 m
Elevation (masl)
6685
0
Bathymetric Contours (mbsl)
-20
-50
-100
-200
Bathymetry (mbsl)
-1
-11584
0 10 20 30 40 50
Kilometers
Scale 1: 1,850,000 when printed at A3
aquatera
environmental services and products

Map 6.2 Central Coast Ocean Profiles - Area 2

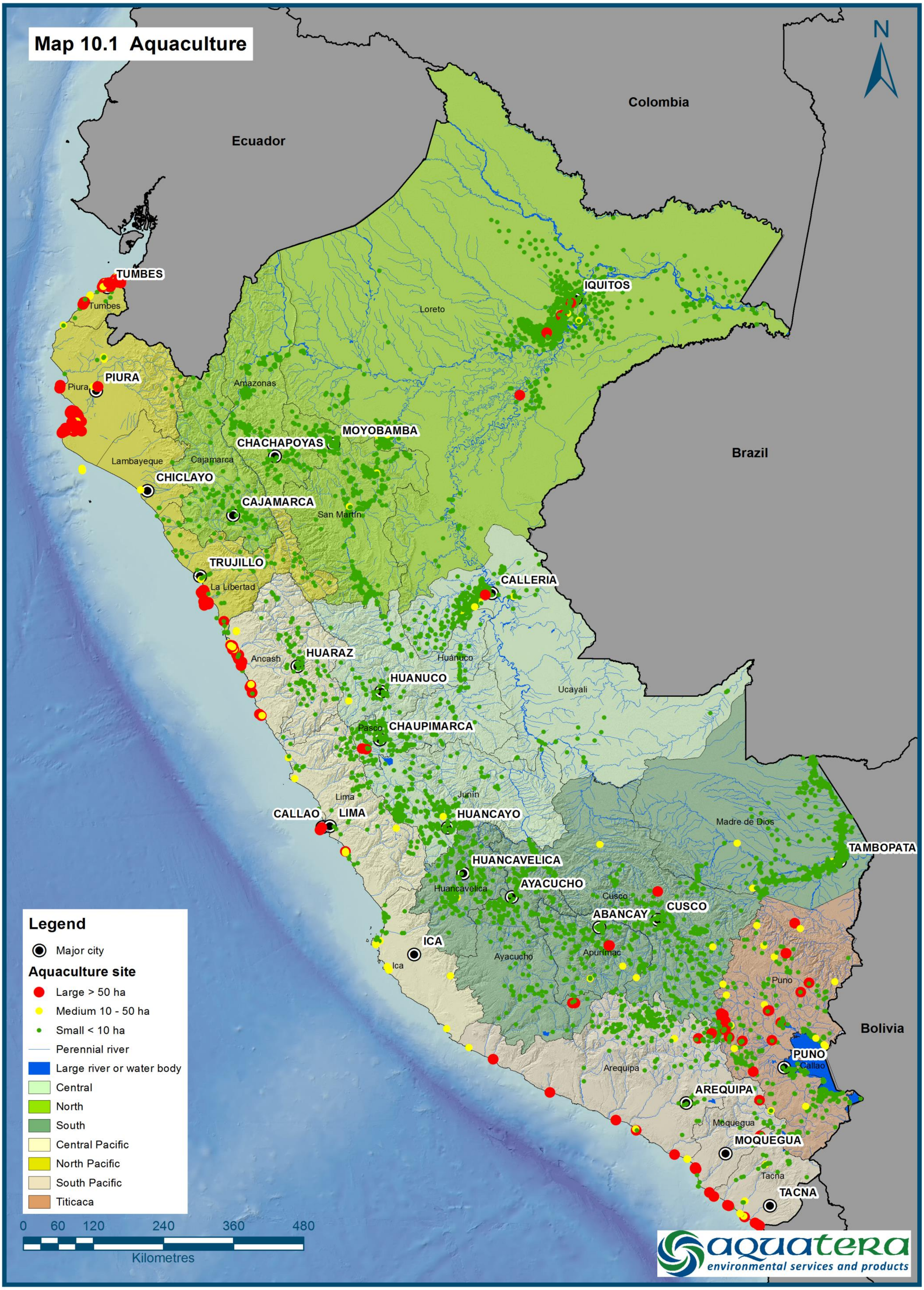








Map 6.3 Southern Coast Ocean Profiles - Area 3
Orkney - EMEC Test Site
Wave Test Sites
Billia Croo
Brough Head
Scapa Flow
Ocean Profile Transects
0 - 20 km
0 - 200 m
Bathymetry (m)
-200 m Contour
0 10 20 kilometers
Nazca
San Juan de Marcona
Chala
Camaná
Mollendo
Matarani
Arequipa
Moquegua
Boliviamar
Ocean Profile Transects
0 - 20 km
0 - 250 m
Elevation (masl)
6685
0
Bathymetric Contours (mbsl)
-20
-50
-100
-200
Bathymetry (mbsl)
-1
-11584
0 20 40
Kilometers
Scale 1: 1,900,000
when printed at A3
aquatera
environmental services and products
Area 3 Ocean Profiles - up to a Depth of 200 m
(Y axis constant)
Bathymetry (m)
Distance from Shore (km)
Chala
Camana
Matarani
Boliviamar
EMEC
Area 3 Ocean Profiles: 0 - 20 km
(X axis constant)
Bathymetry (m)
Distance to Shore (km)
Chala
Camana
Matarani
EMEC
Boliviamar
W 77°
W 76°
W 75°
W 74°
W 73°
W 72°
W 71°
S 15°
S 16°
S 17°
S 18°

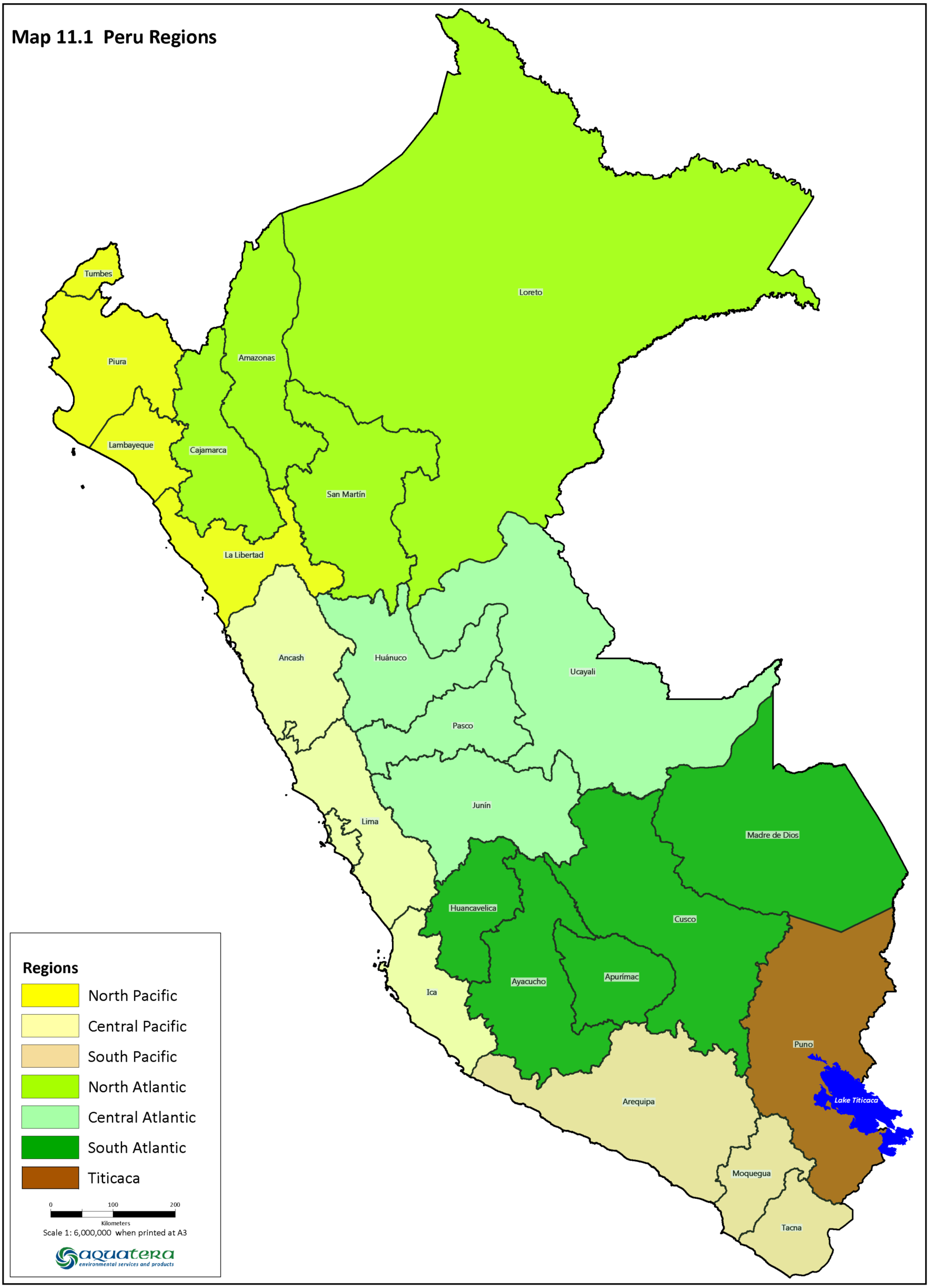


Map 10.1 Aquaculture

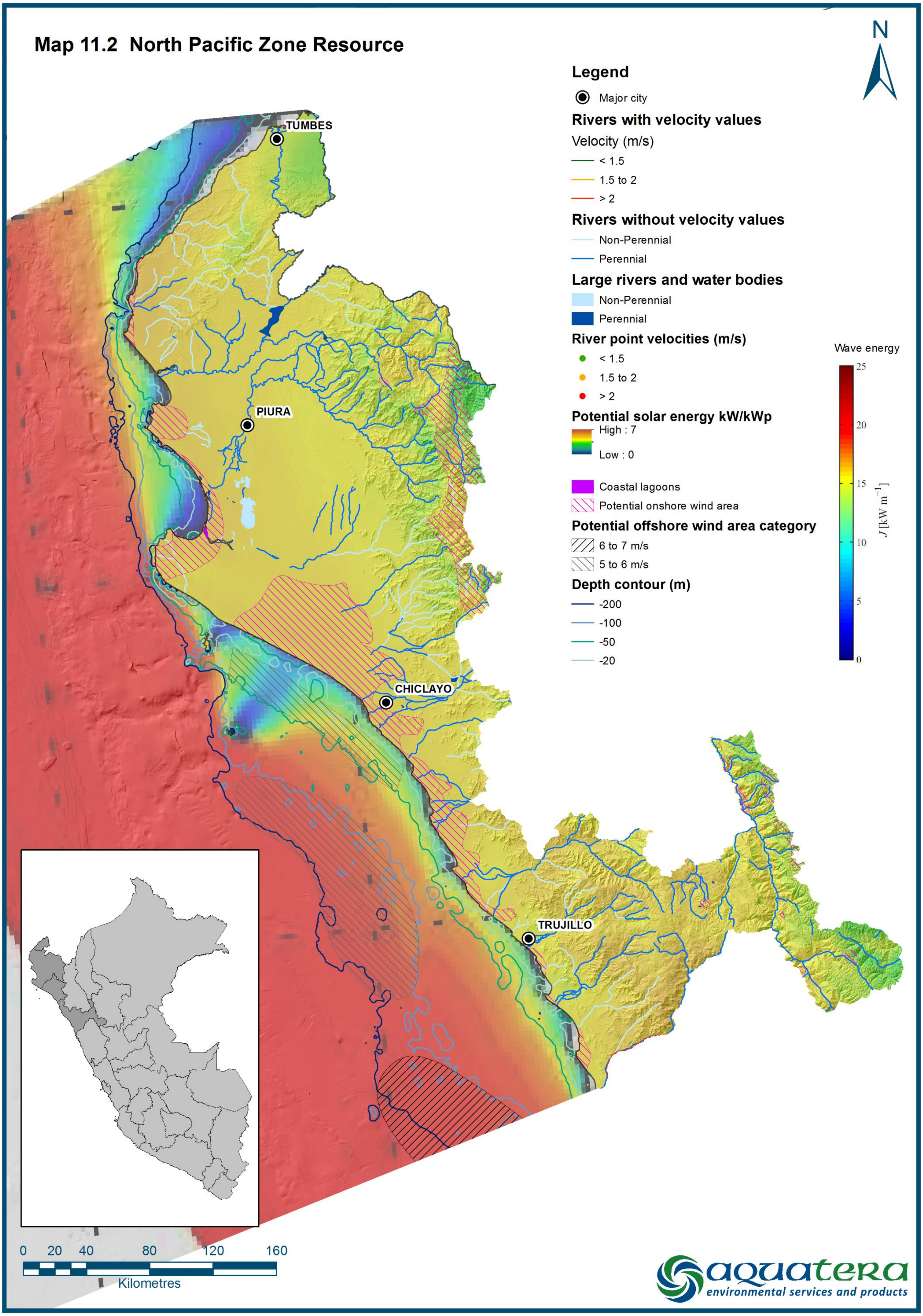

Map 10.2 Current Mining Projects in Peru
N
Colombia
Ecuador
Brazil
Bolivia
TUMBES
Tumbes
IQUITOS
Loreto
PIURA
Piura
Amazonas
MOYOBAMBA
CHACHAPOYAS
Cajamarca
Lambayeque
CHICLAYO
CAJAMARCA
San Martín
TRUJILLO
La Libertad
CALLERIA
Ancash
HUARAZ
Huánuco
HUANUCO
Ucayali
Pasco
CHAUPIMARCA
Lima
Junín
CALLAO
LIMA
HUANCAYO
Madre de Dios
TAMBOPATA
HUANCAVELICA
Huancavelica
AYACUCHO
Cusco
ABANCAY
CUSCO
ICA
Ica
Ayacucho
Apurímac
Puno
PUNO
Callao
Arequipa
AREQUIPA
Moquegua
MOQUEGUA
Tacna
TACNA
Legend
Major city
Mining
Commodity
Antimony
Barite
Bentonite
Bismuth
Cement
Copper
Dolomite
Gold
Iron Ore
Lead
Molybdenum
Natural gas
Petroleum: crude
Petroleum: refinery products
Phosphate rock
Silica sand
Silver
Steel
Tellurium
Tin
Tungsten
Zinc
Perennial river
Lake Titicaca
0 60 120 240 360 480
Kilometres
aquatera
environmental services and products

Map 10.3 Potential Mining Projects in Peru

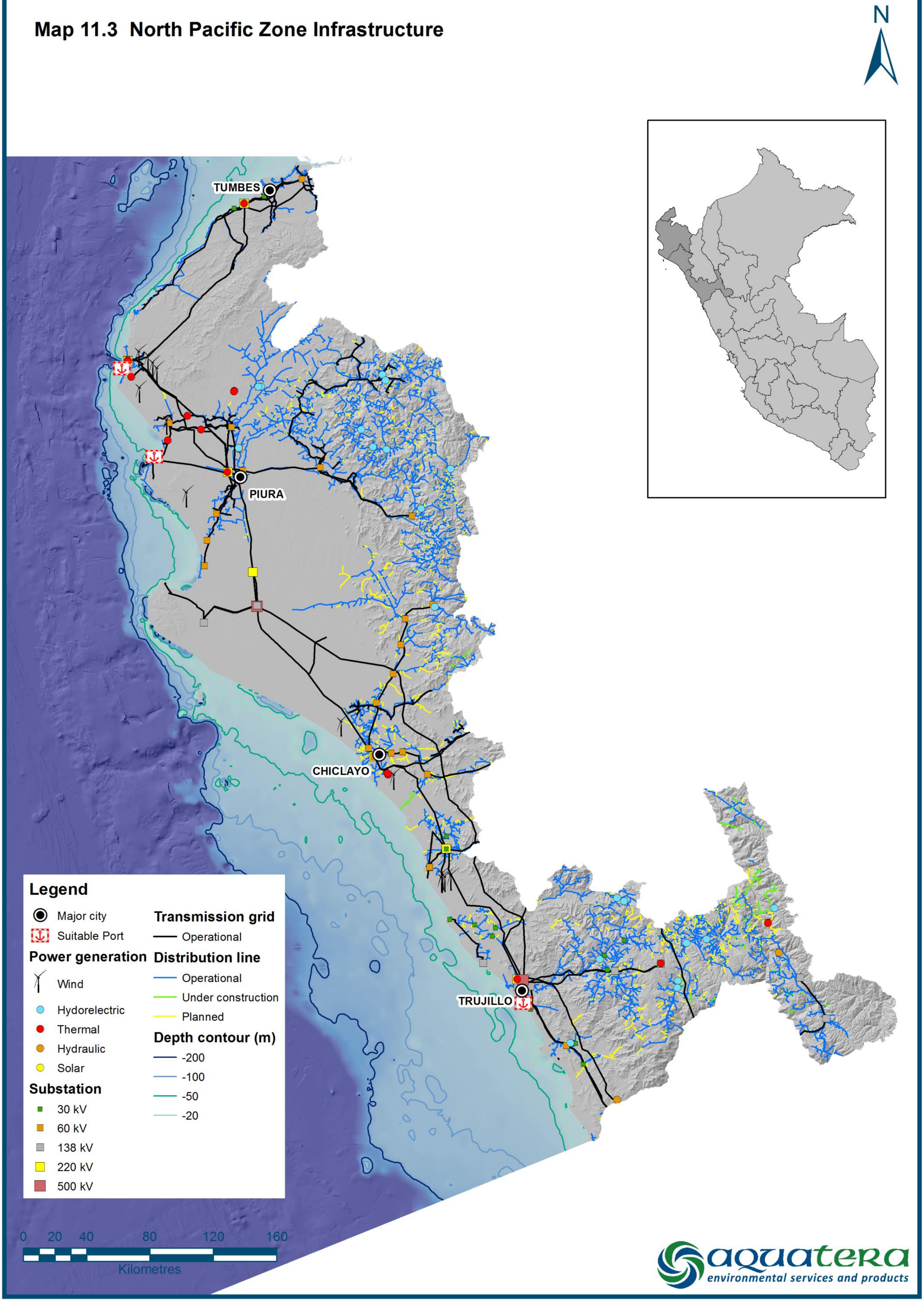
Map 11.1 Peru Regions



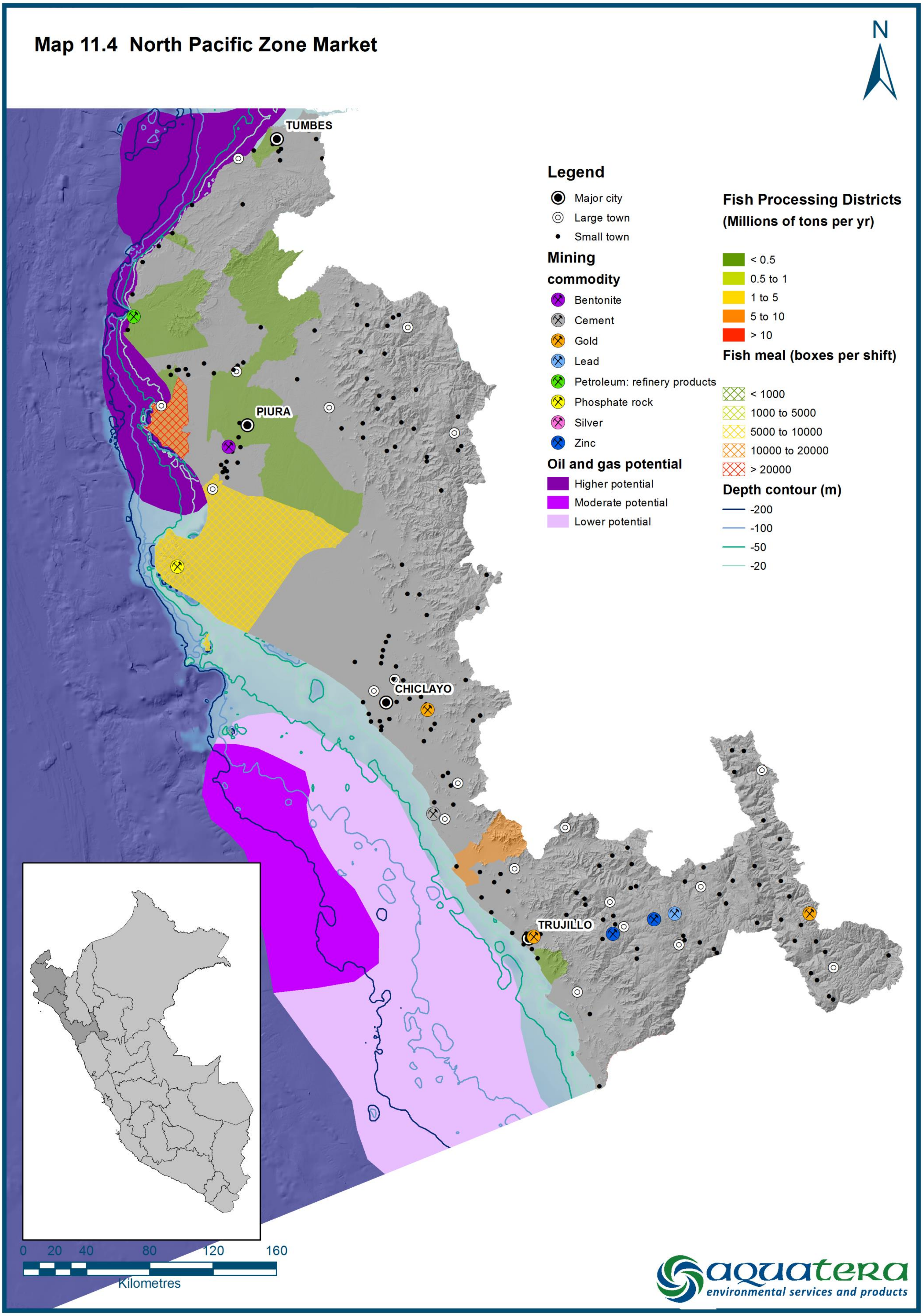
Map 11.2 North Pacific Zone Resource



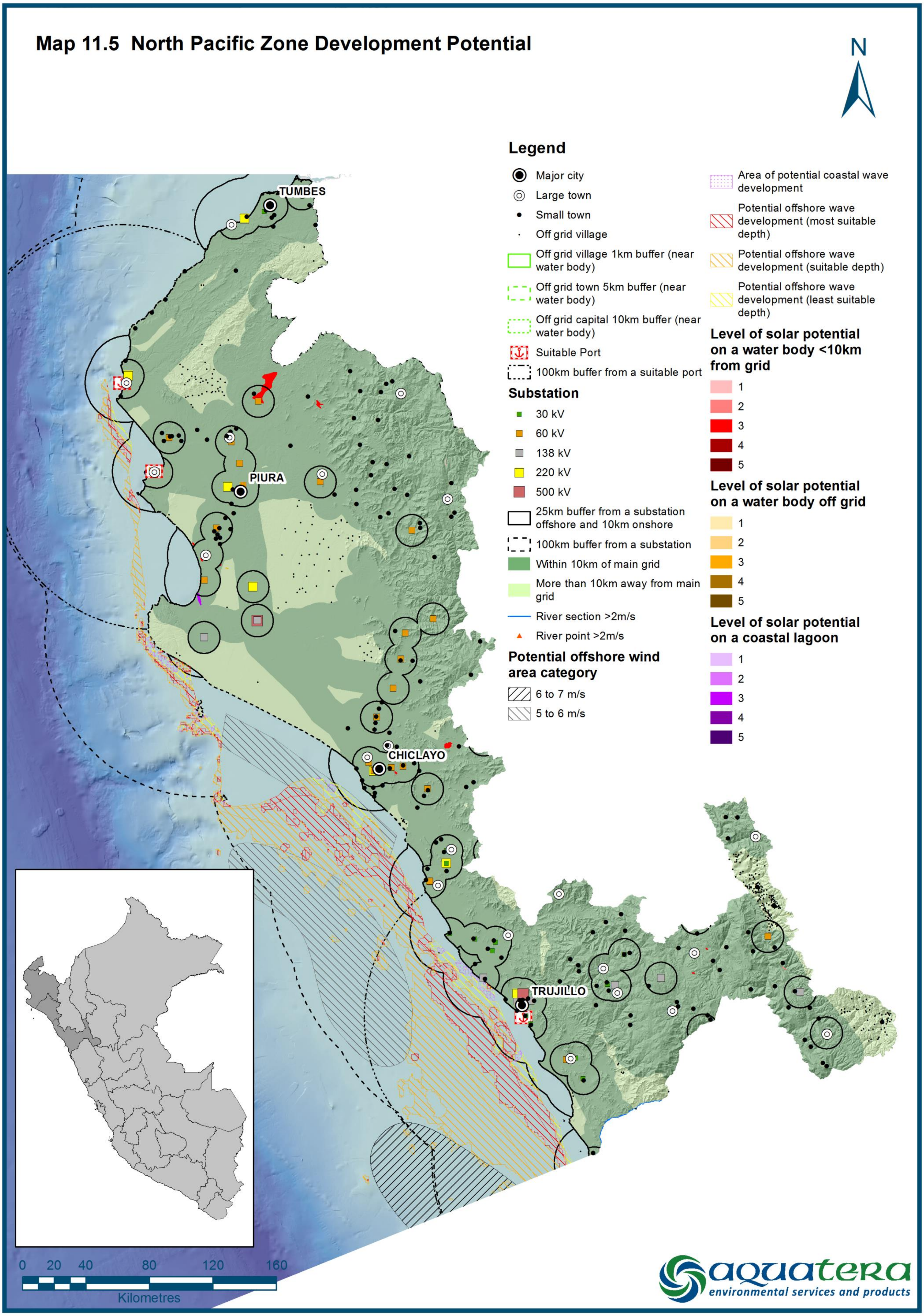
Map 11.3 North Pacific Zone Infrastructure

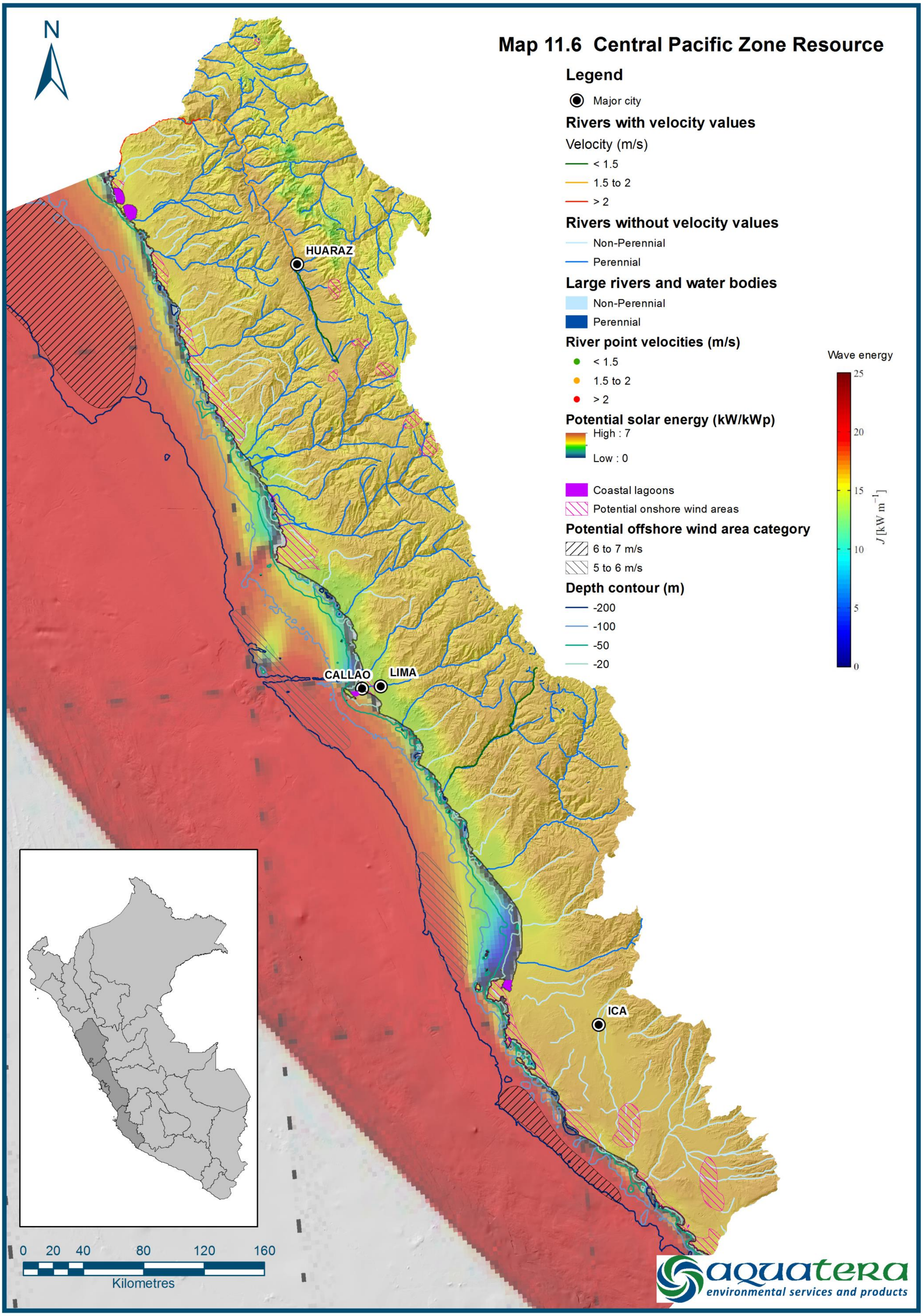


Map 11.4 North Pacific Zone Market

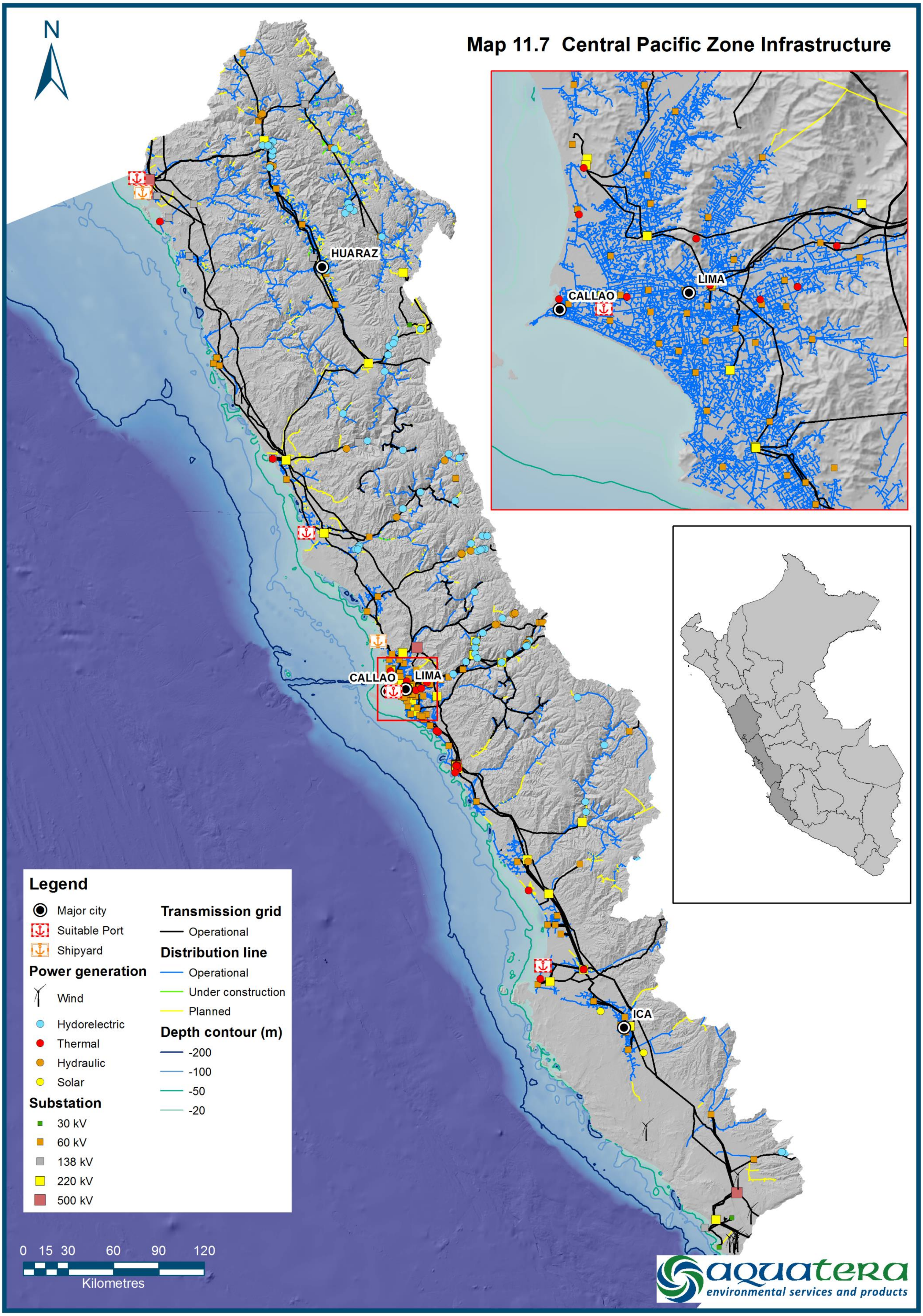


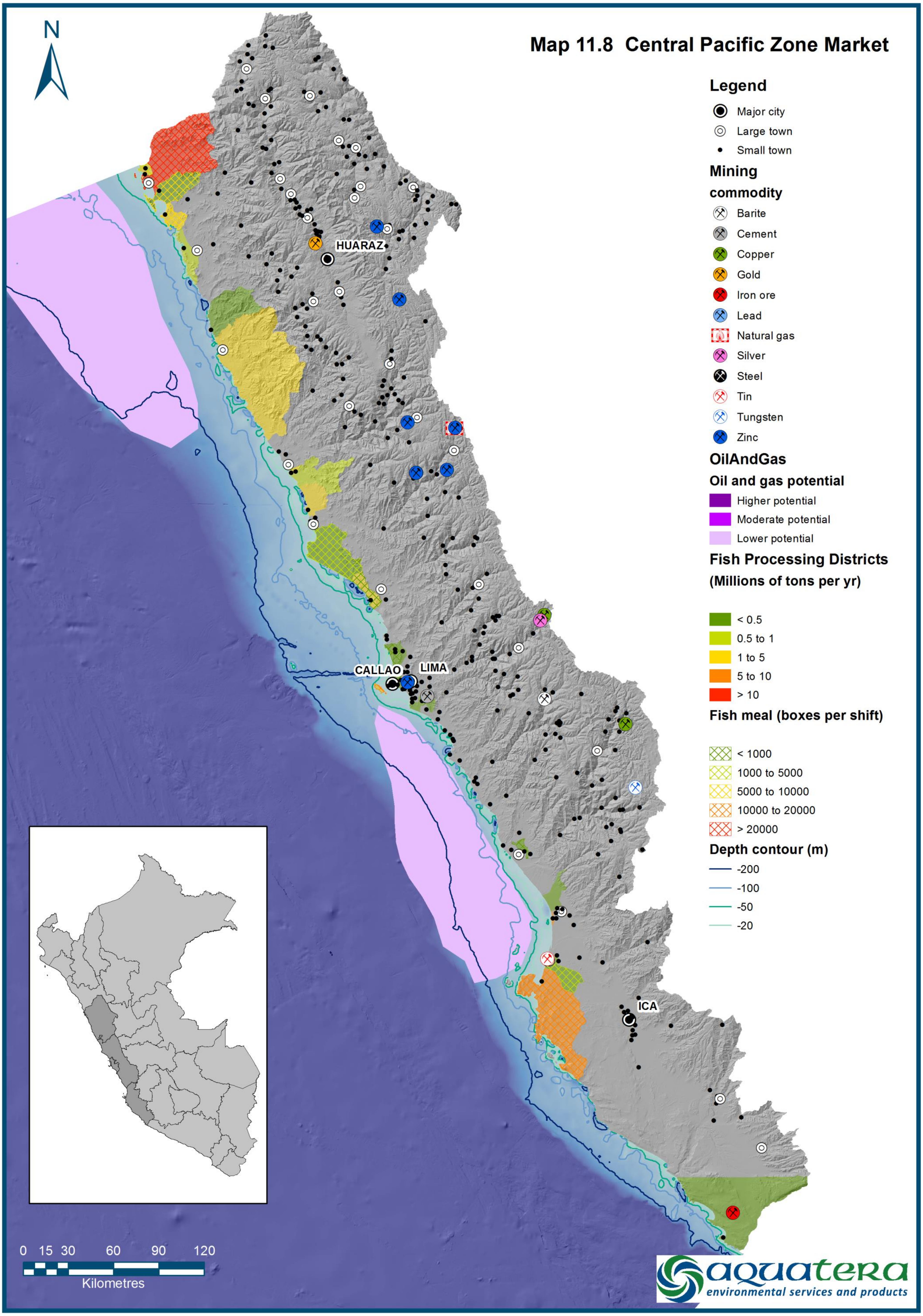
Map 11.5 North Pacific Zone Development Potential



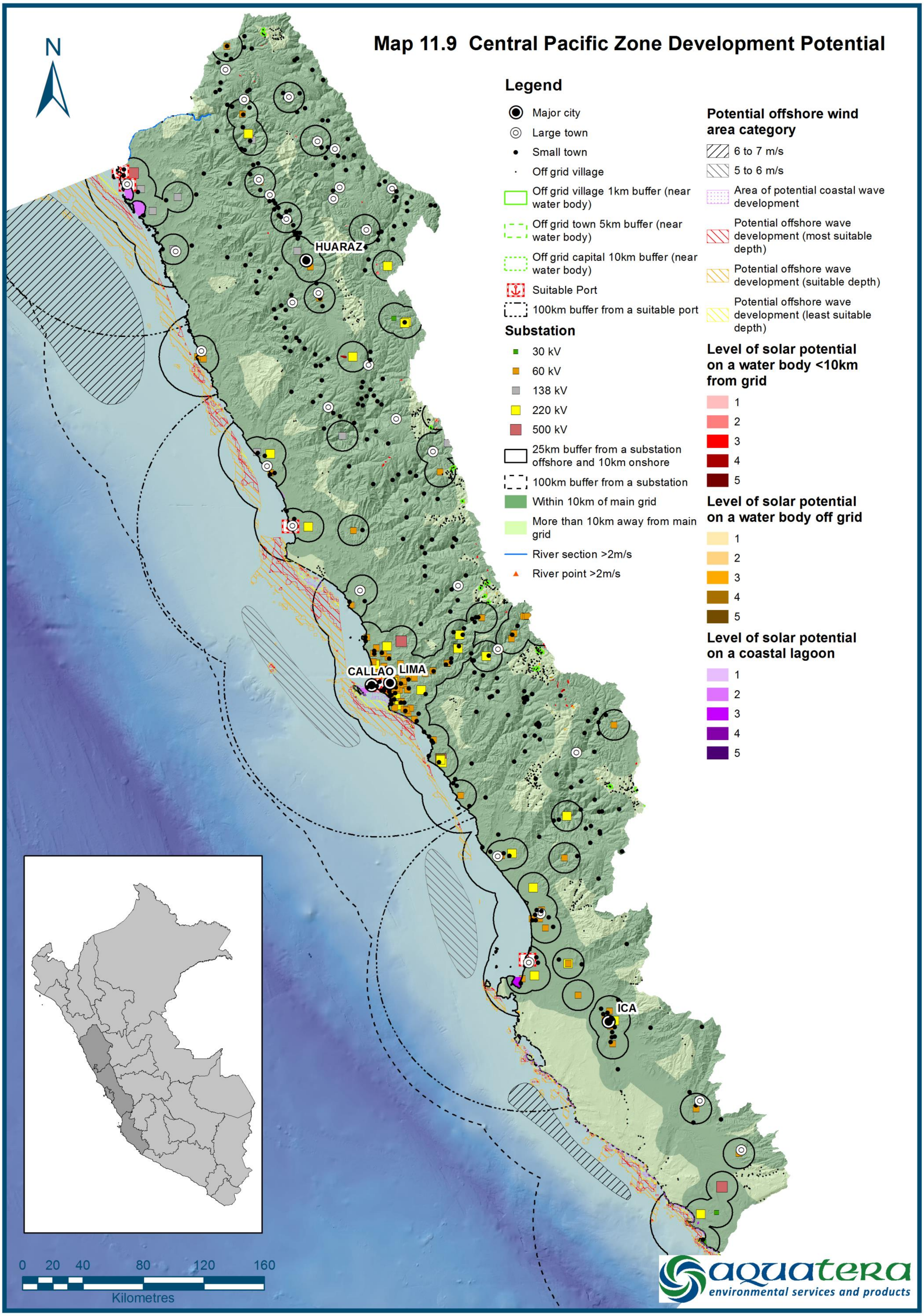


N
Map 11.6 Central Pacific Zone Resource
Legend
Major city
Rivers with velocity values
Velocity (m/s)
< 1.5
1.5 to 2
> 2
Rivers without velocity values
Non-Perennial
Perennial
Large rivers and water bodies
Non-Perennial
Perennial
River point velocities (m/s)
< 1.5
1.5 to 2
> 2
Potential solar energy (kW/kWp)
High : 7
Low : 0
Coastal lagoons
Potential onshore wind areas
Potential offshore wind area category
6 to 7 m/s
5 to 6 m/s
Depth contour (m)
-200
-100
-50
-20
Wave energy
25
20
15
10
5
0
J [kW m-1]
HUARAZ
CALLAO
LIMA
ICA
0 20 40 80 120 160
Kilometres
aquatera
environmental services and products

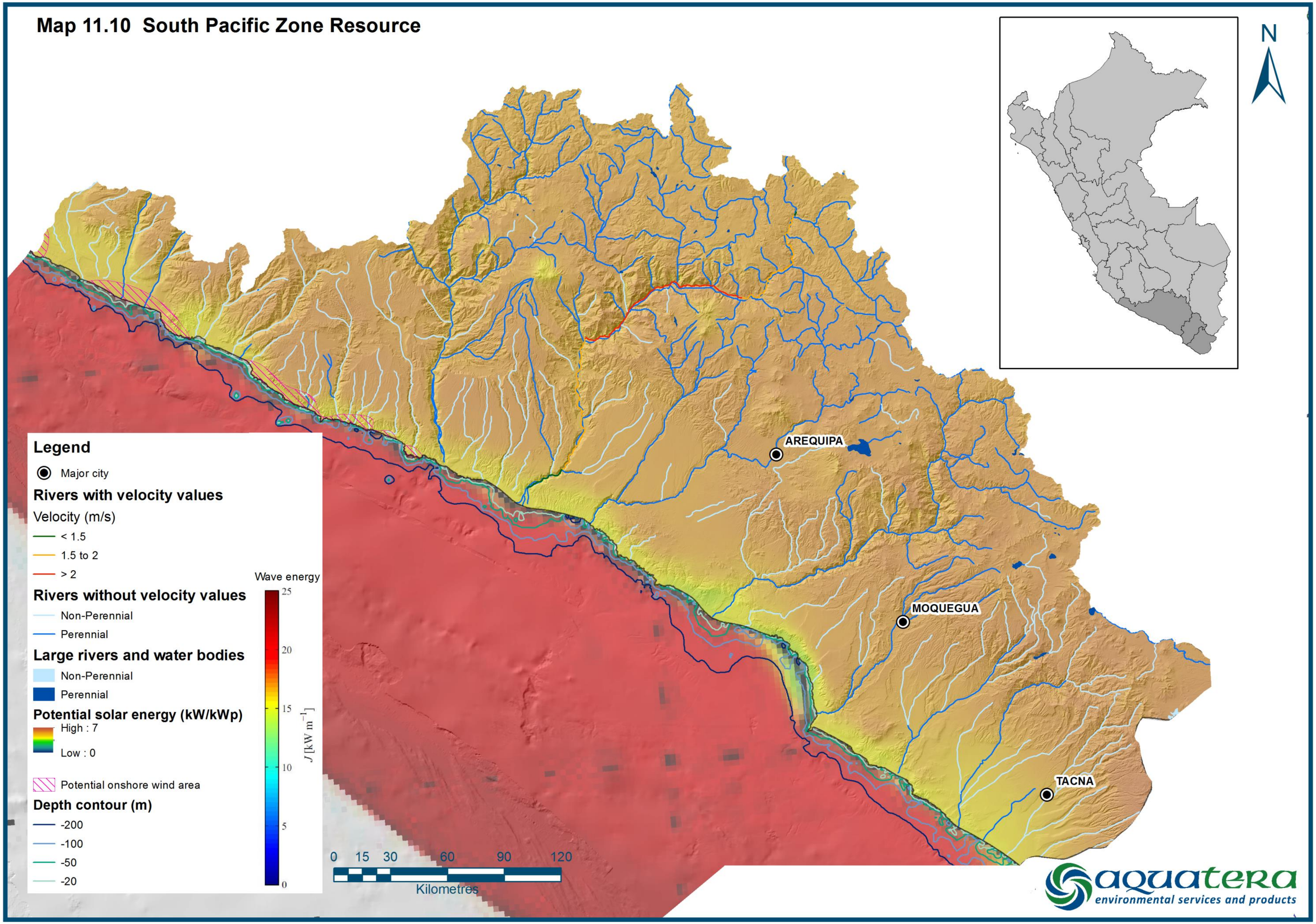

Map 11.7 Central Pacific Zone Infrastructure
N
HUARAZ
CALLAO
LIMA
ICA
Legend
Major city
Suitable Port
Shipyard
Power generation
Wind
Hydorelectric
Thermal
Hydraulic
Solar
Substation
30 kV
60 kV
138 kV
220 kV
500 kV
Transmission grid
Operational
Distribution line
Operational
Under construction
Planned
Depth contour (m)
-200
-100
-50
-20
0 15 30 60 90 120
Kilometres
aquatera
environmental services and products



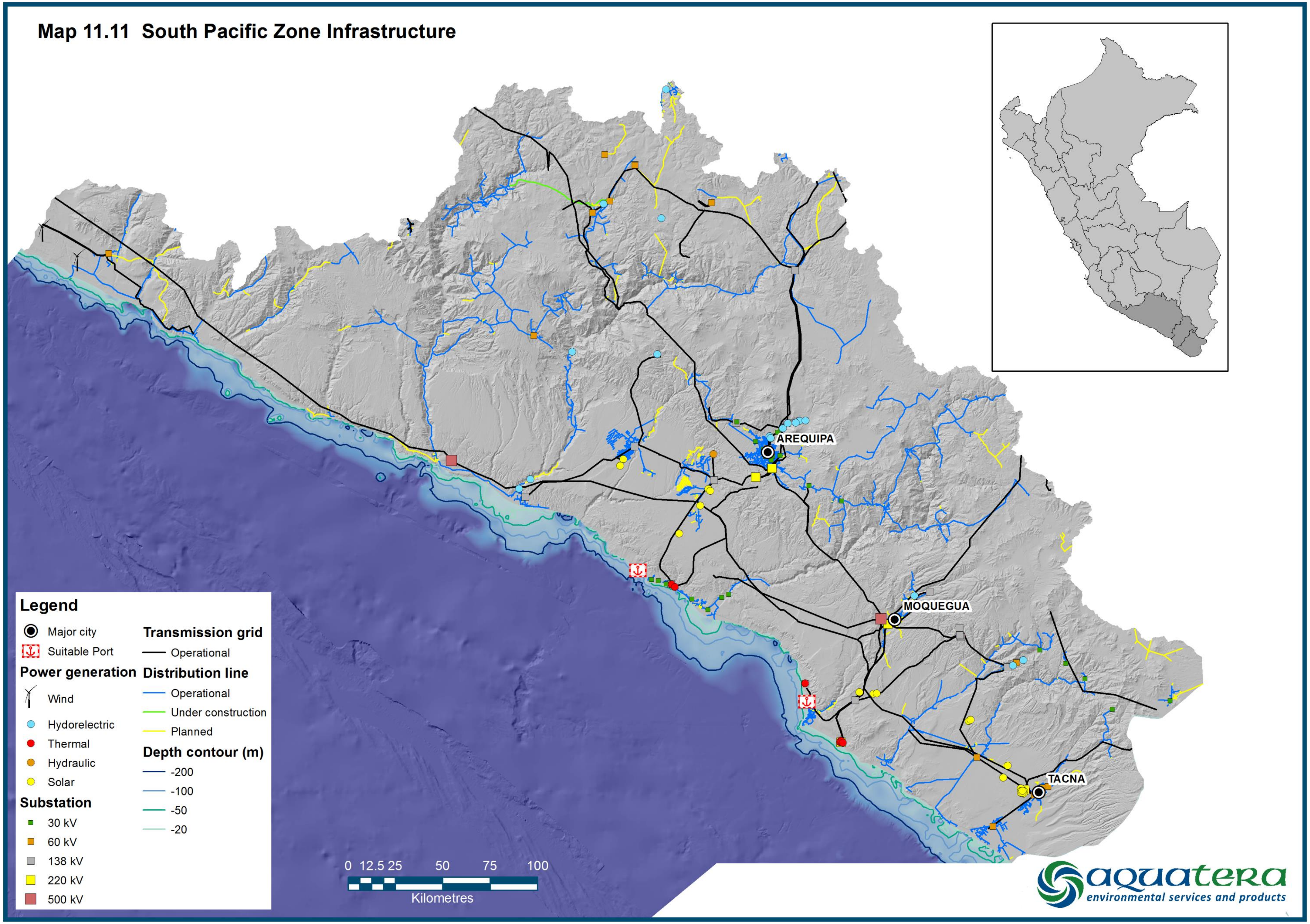
Map 11.8 Central Pacific Zone Market

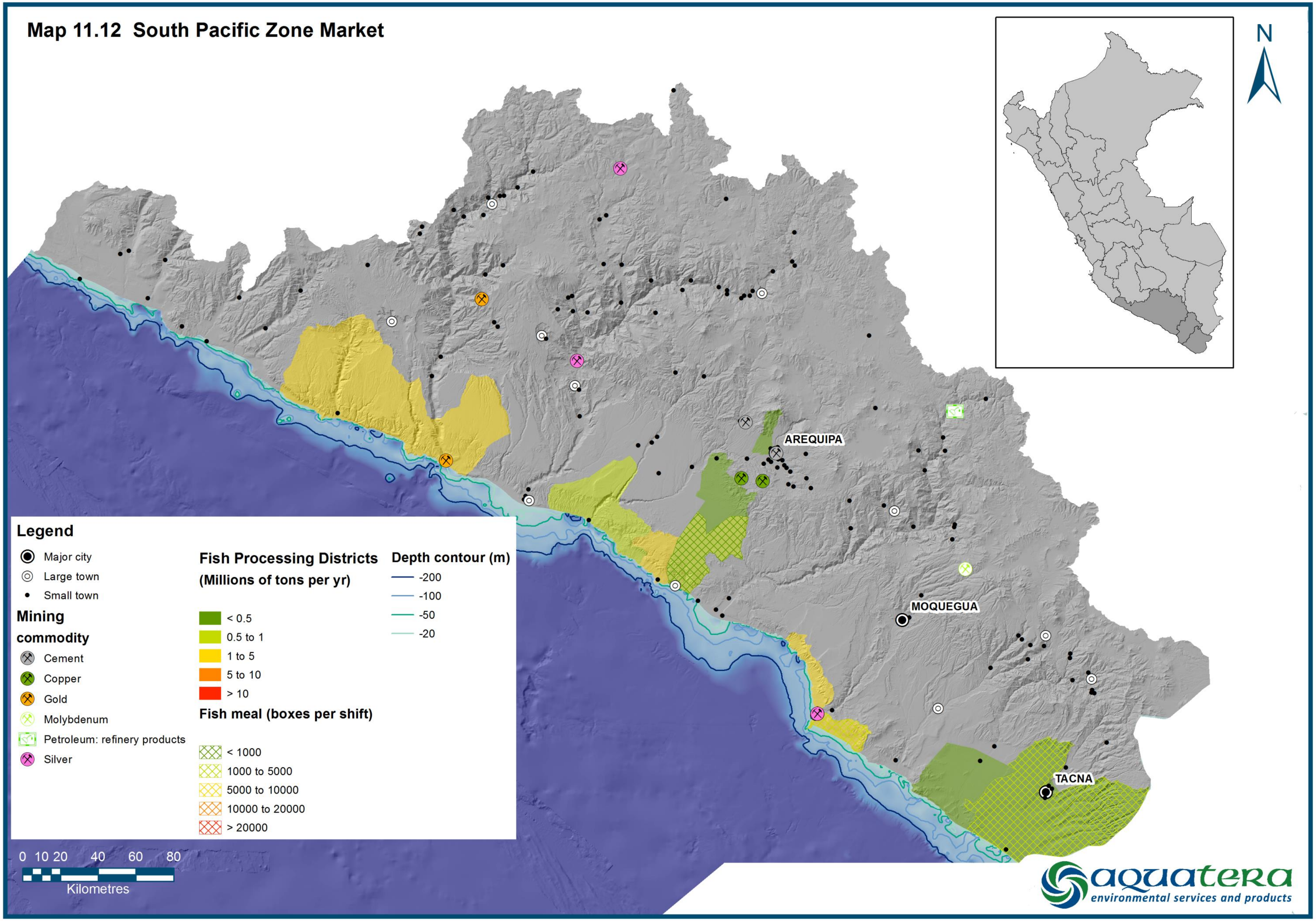

Map 11.9 Central Pacific Zone Development Potential
N
Legend
Major city
Large town
Small town
Off grid village
Off grid village 1km buffer (near water body)
Off grid town 5km buffer (near water body)
Off grid capital 10km buffer (near water body)
Suitable Port
100km buffer from a suitable port
Substation
30 kV
60 kV
138 kV
220 kV
500 kV
25km buffer from a substation offshore and 10km onshore
100km buffer from a substation
Within 10km of main grid
More than 10km away from main grid
River section >2m/s
River point >2m/s
Potential offshore wind area category
6 to 7 m/s
5 to 6 m/s
Area of potential coastal wave development
Potential offshore wave development (most suitable depth)
Potential offshore wave development (suitable depth)
Potential offshore wave development (least suitable depth)
Level of solar potential on a water body <10km from grid
1
2
3
4
5
Level of solar potential on a water body off grid
1
2
3
4
5
Level of solar potential on a coastal lagoon
1
2
3
4
5
HUARAZ
CALLAO
LIMA
ICA
0 20 40 80 120 160
Kilometres
aquatera
environmental services and products

Map 11.10 South Pacific Zone Resource

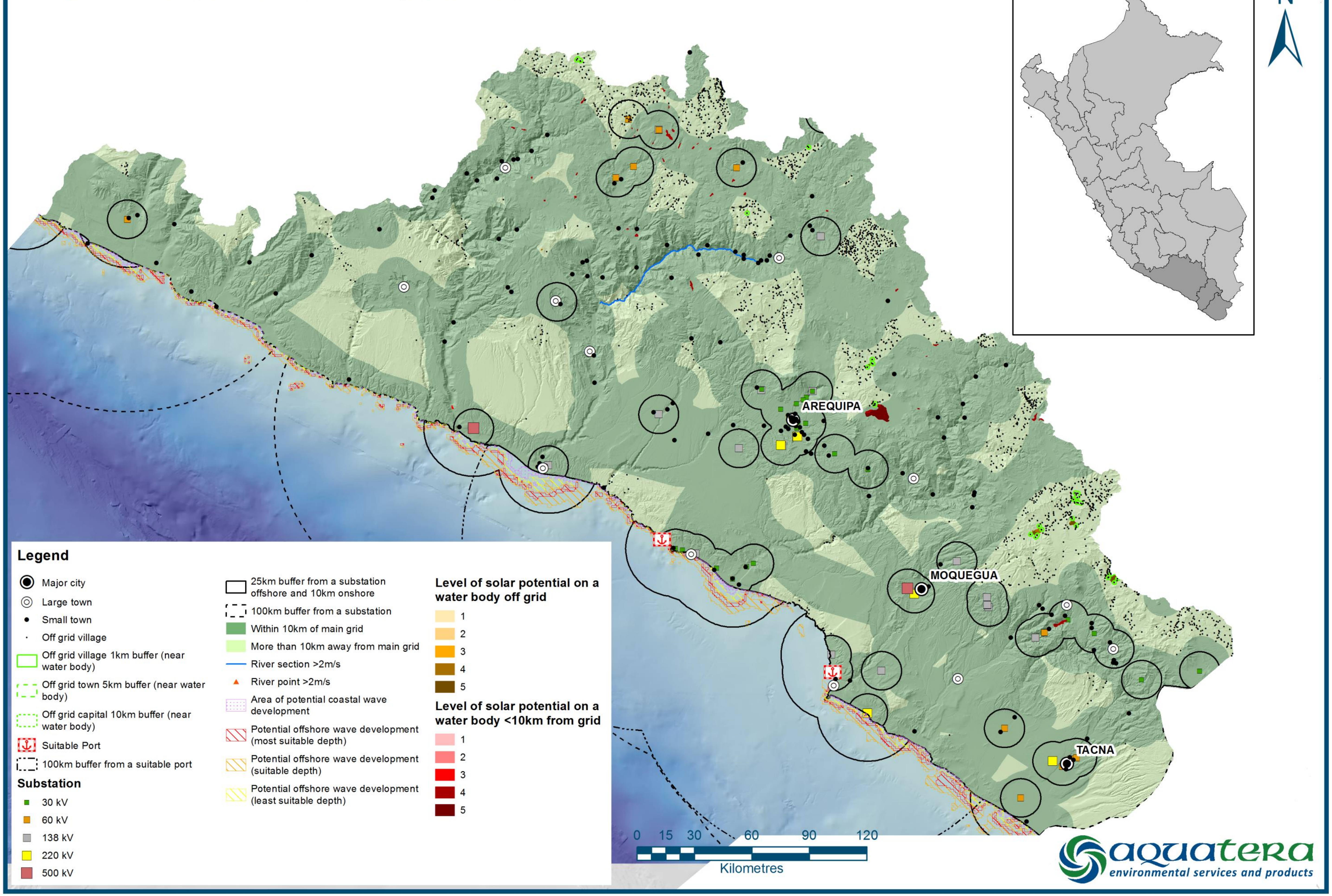


Map 11.11 South Pacific Zone Infrastructure

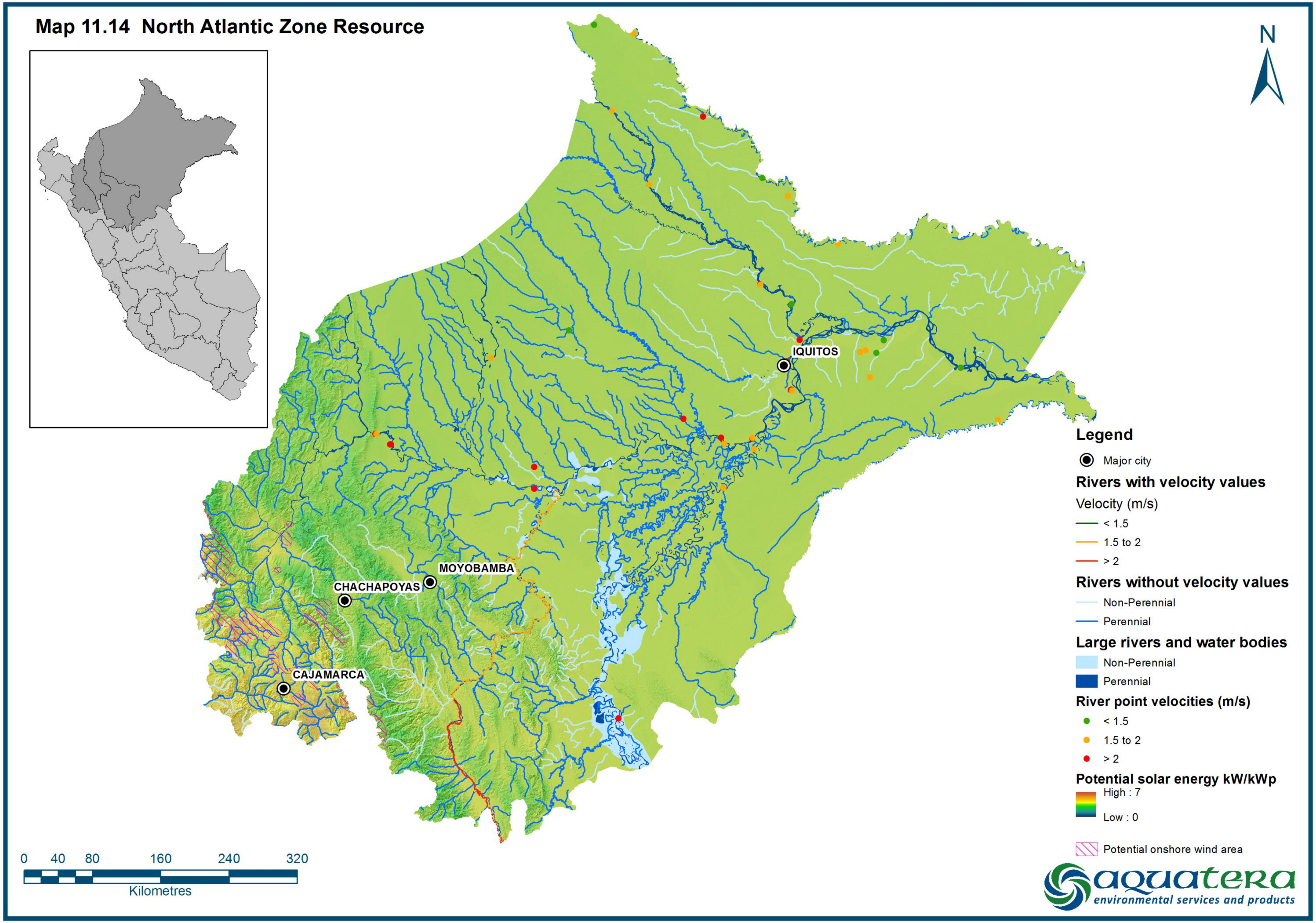



Map 11.12 South Pacific Zone Market
N
AREQUIPA
MOQUEGUA
TACNA
Legend
Major city
Large town
Small town
Mining
commodity
Cement
Copper
Gold
Molybdenum
Petroleum: refinery products
Silver
Fish Processing Districts
(Millions of tons per yr)
< 0.5
0.5 to 1
1 to 5
5 to 10
> 10
Fish meal (boxes per shift)
< 1000
1000 to 5000
5000 to 10000
10000 to 20000
> 20000
Depth contour (m)
-200
-100
-50
-20
0 10 20 40 60 80
Kilometres
aquatera
environmental services and products

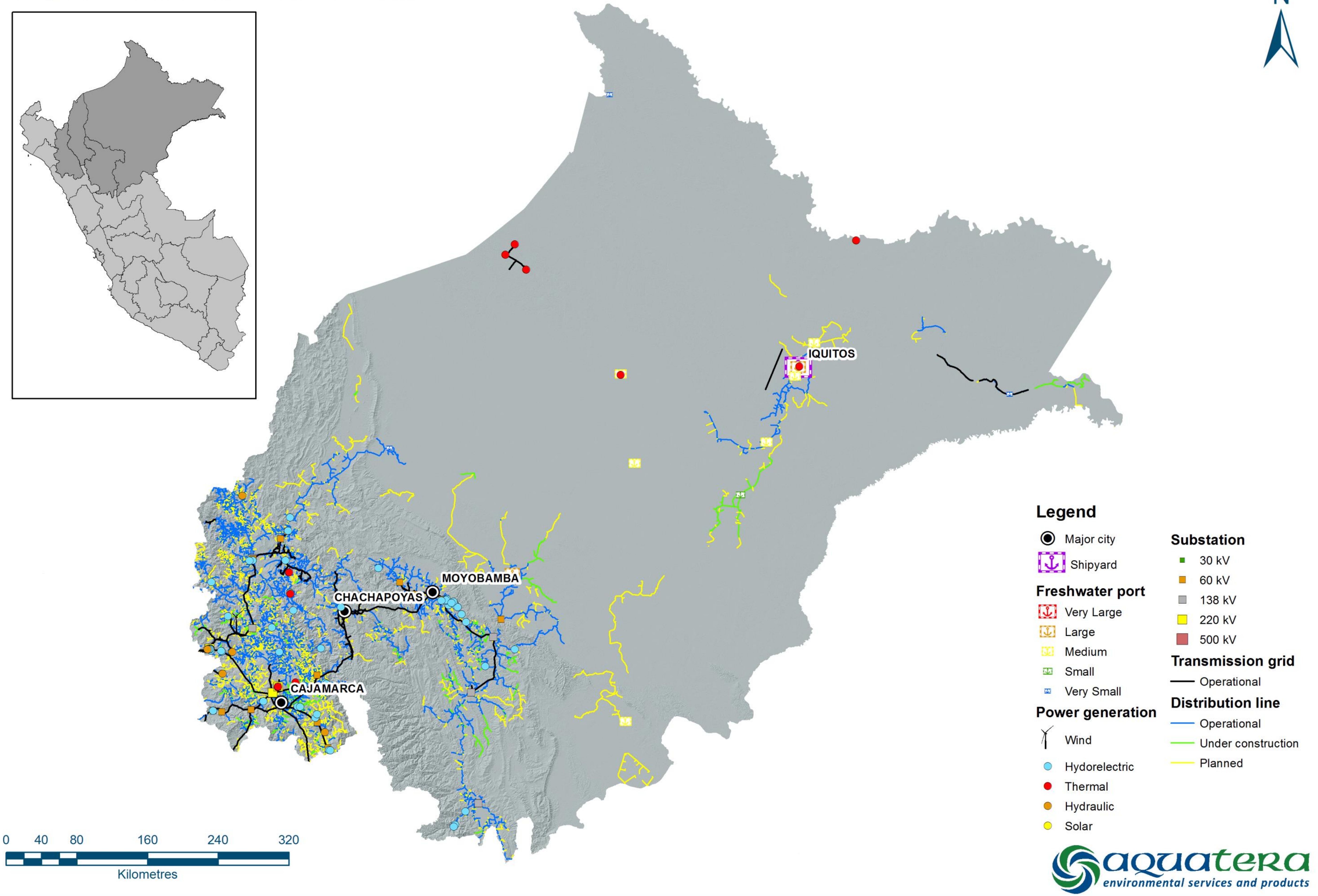
Map 11.13 South Pacific Zone Development Potential



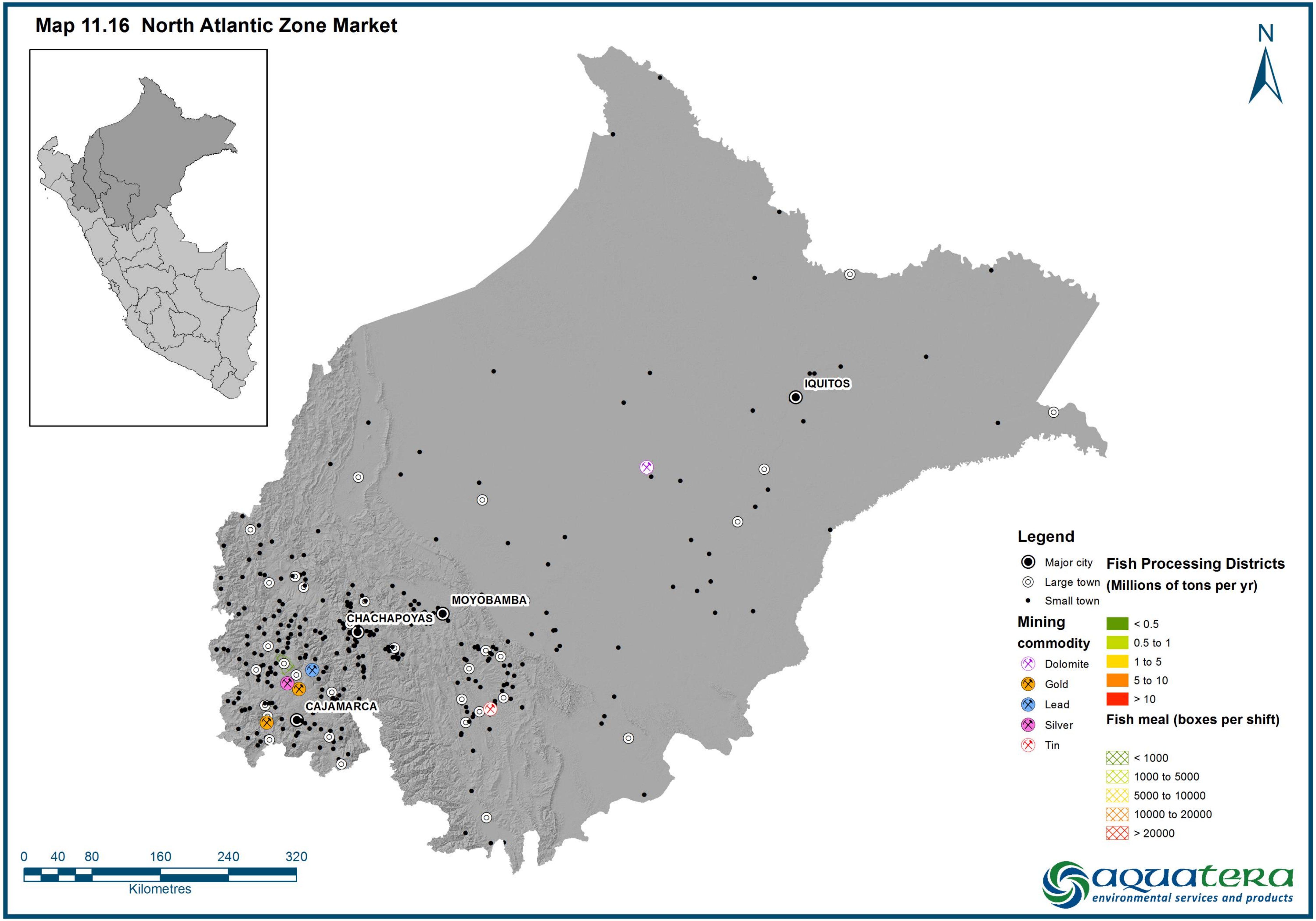
Map 11.14 North Atlantic Zone Resource



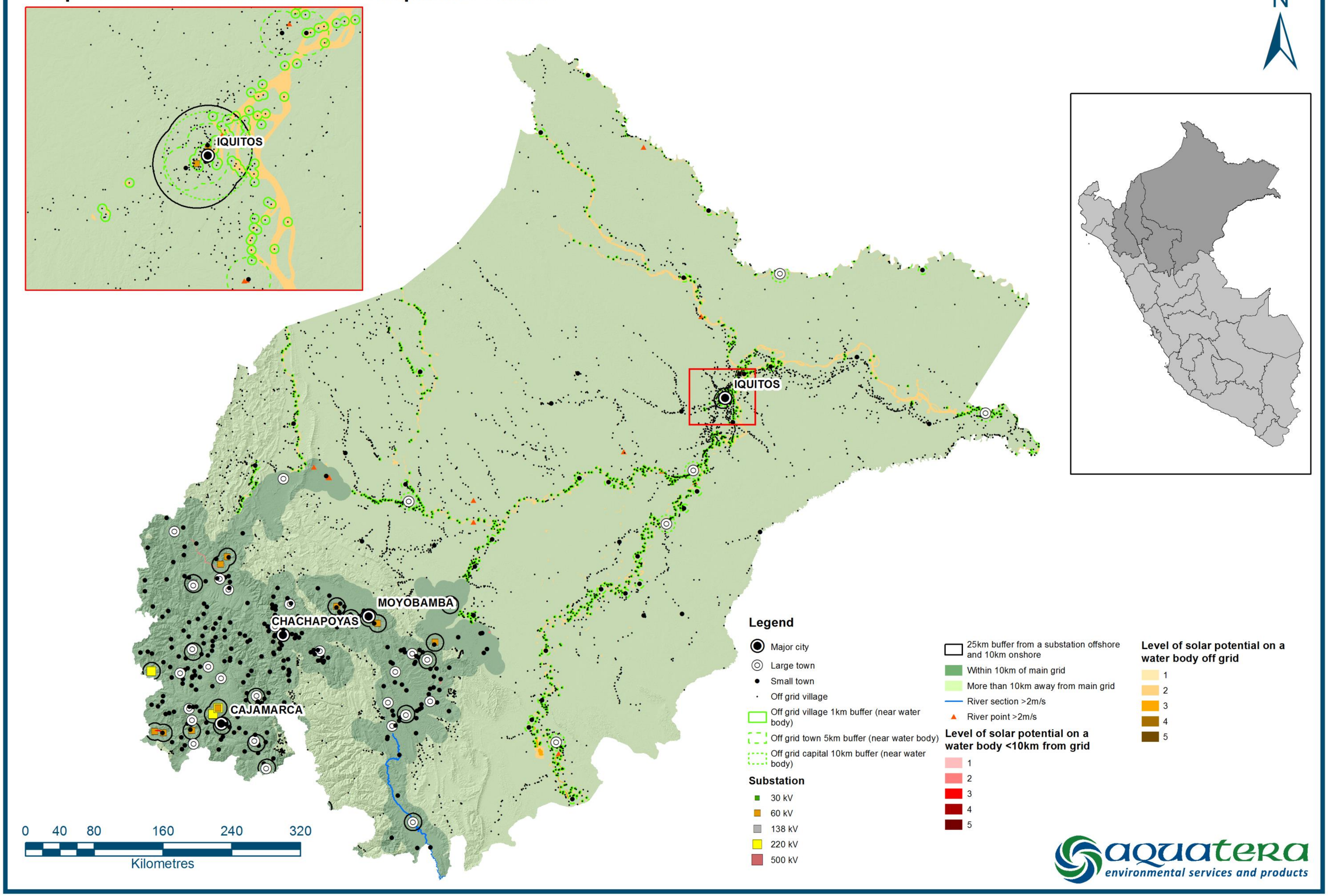
Map 11.15 North Atlantic Zone Infrastructure



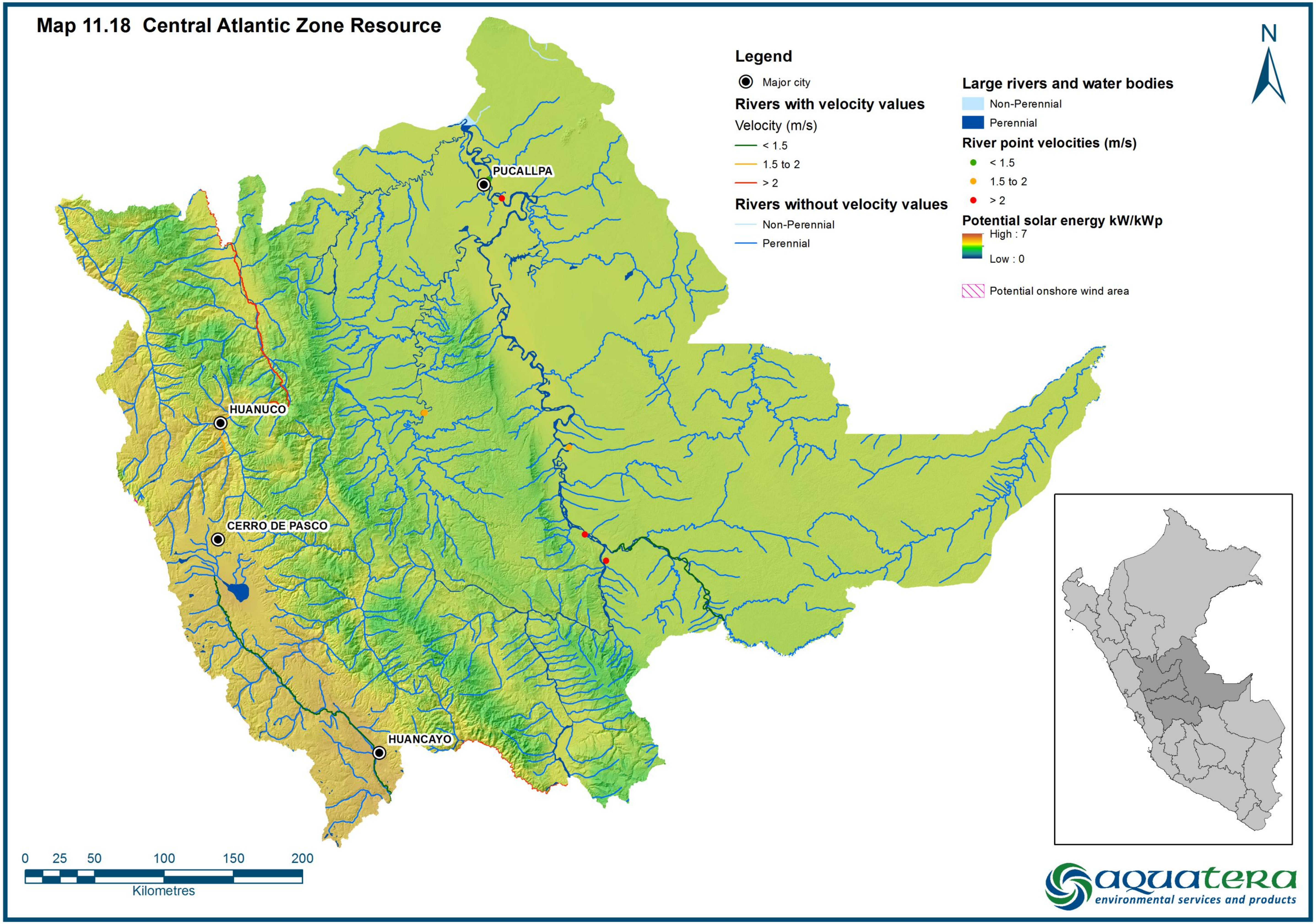
Map 11.16 North Atlantic Zone Market

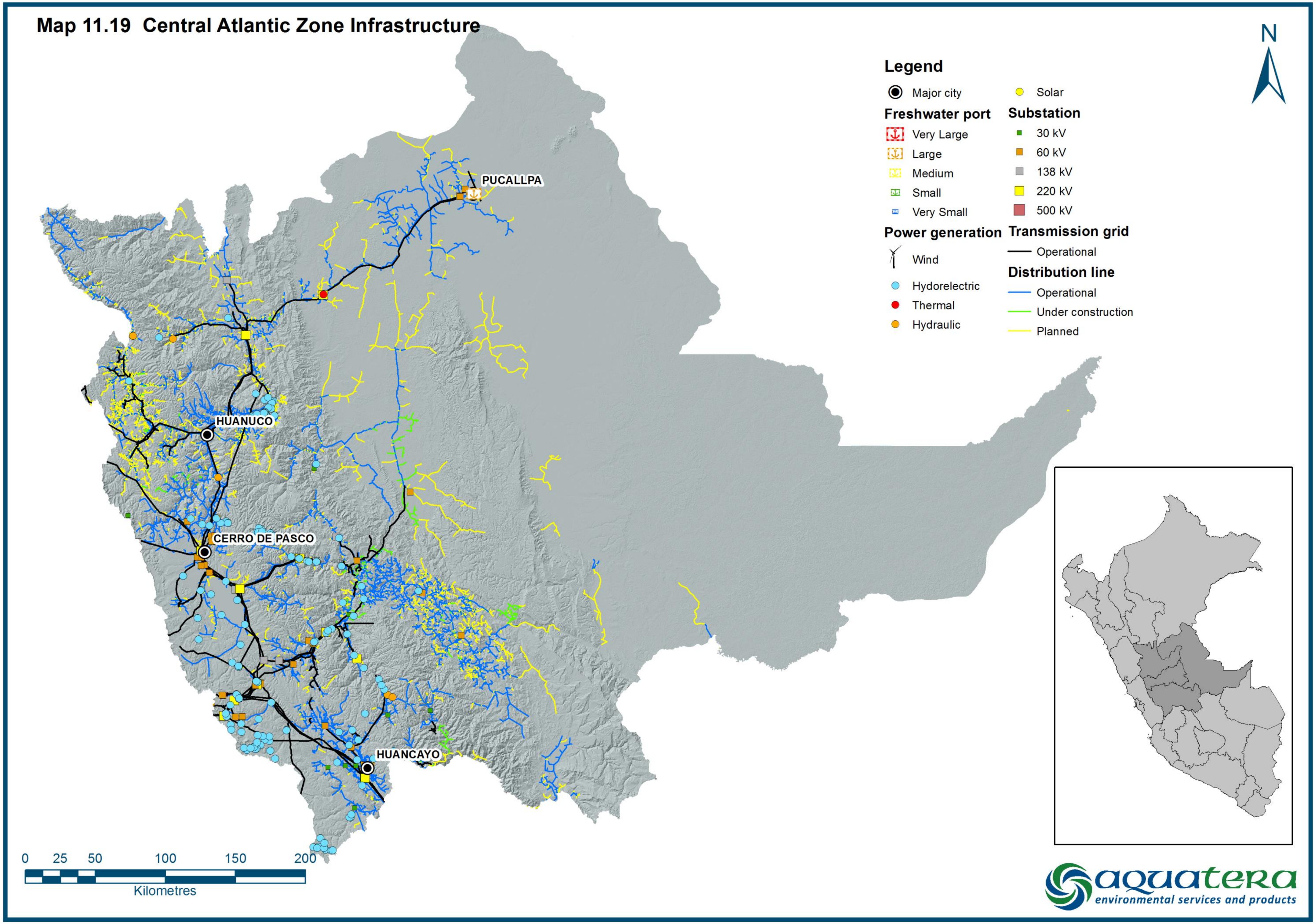


Map 11.17 North Atlantic Zone Development Potential



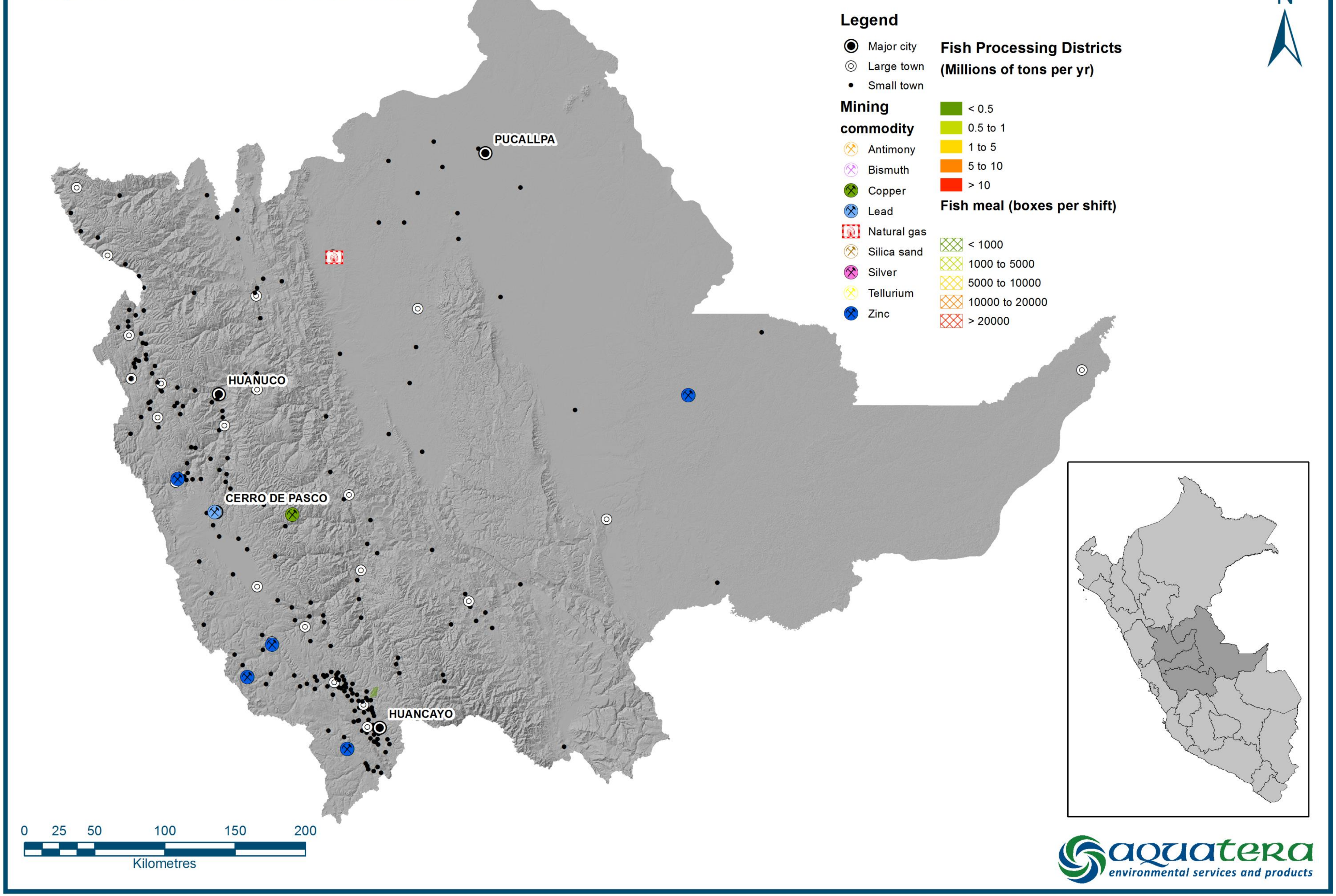
Map 11.18 Central Atlantic Zone Resource

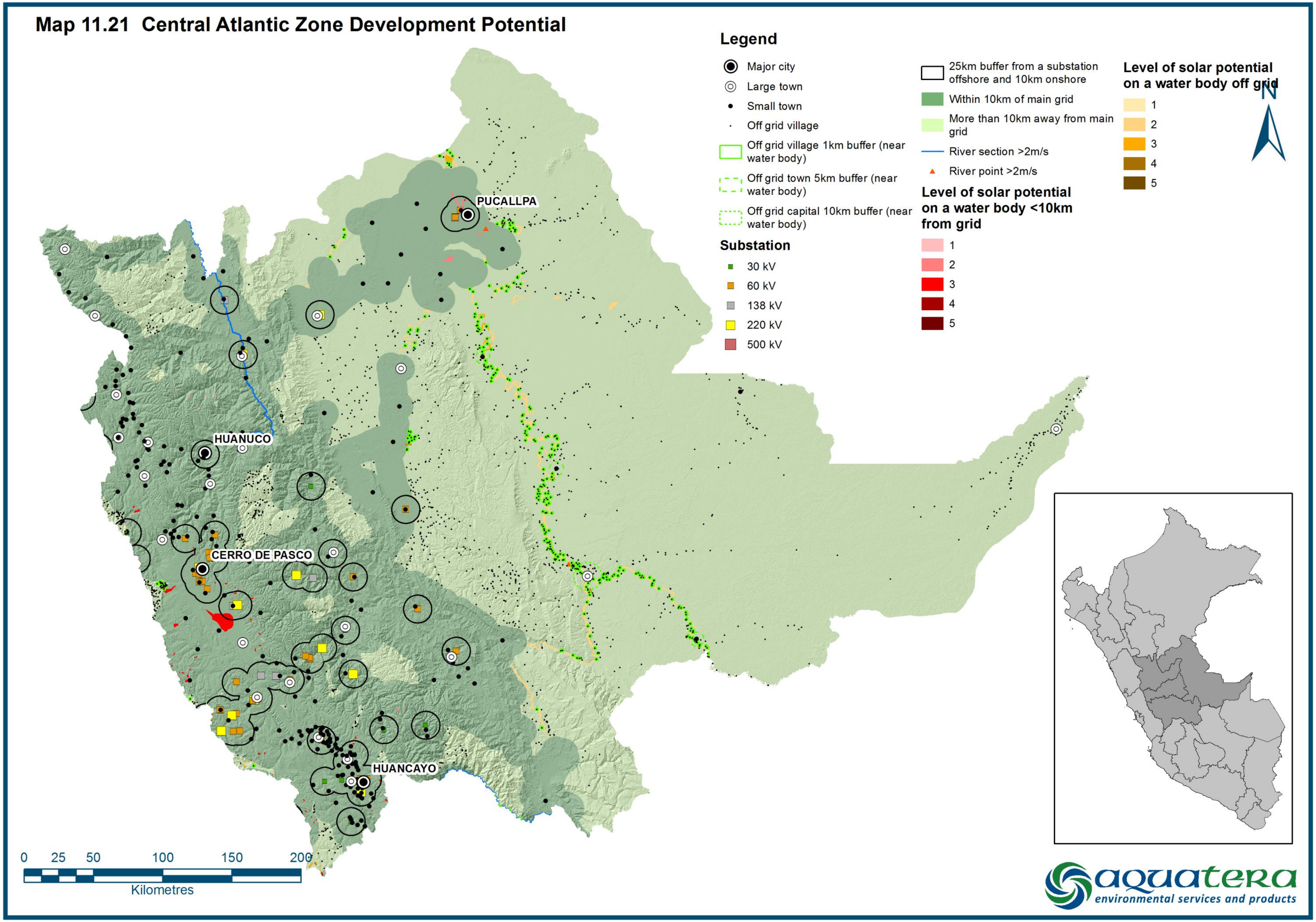




Map 11.19 Central Atlantic Zone Infrastructure
N
Legend
Major city
Solar
Freshwater port
Very Large
Large
Medium
Small
Very Small
Substation
30 kV
60 kV
138 kV
220 kV
500 kV
Power generation
Wind
Hydroelectric
Thermal
Hydraulic
Transmission grid
Operational
Distribution line
Operational
Under construction
Planned
PUCALLPA
HUANUCO
CERRO DE PASCO
HUANCAYO
0 25 50 100 150 200
Kilometres
aquatera
environmental services and products

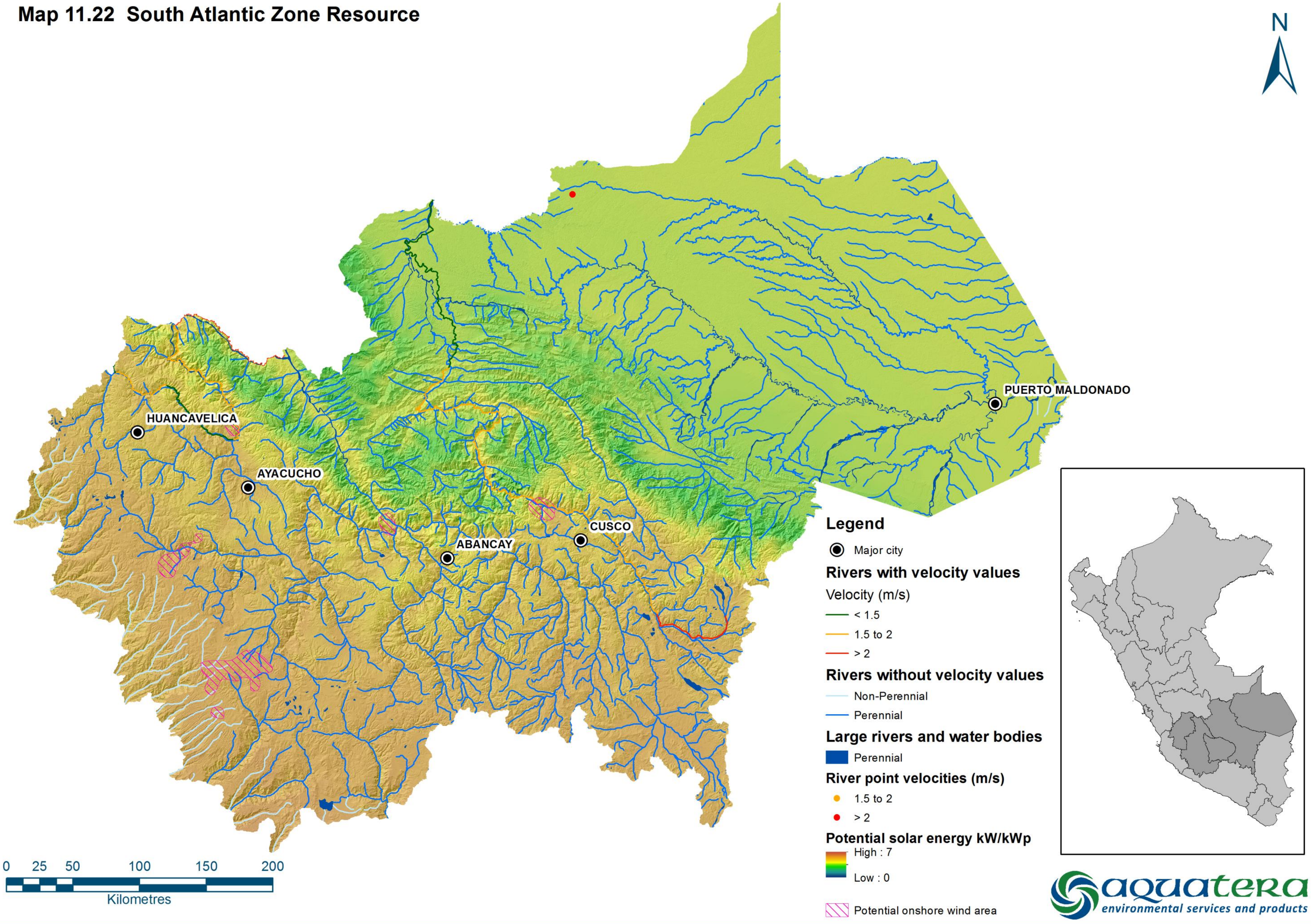
Map 11.20 Central Atlantic Zone Market



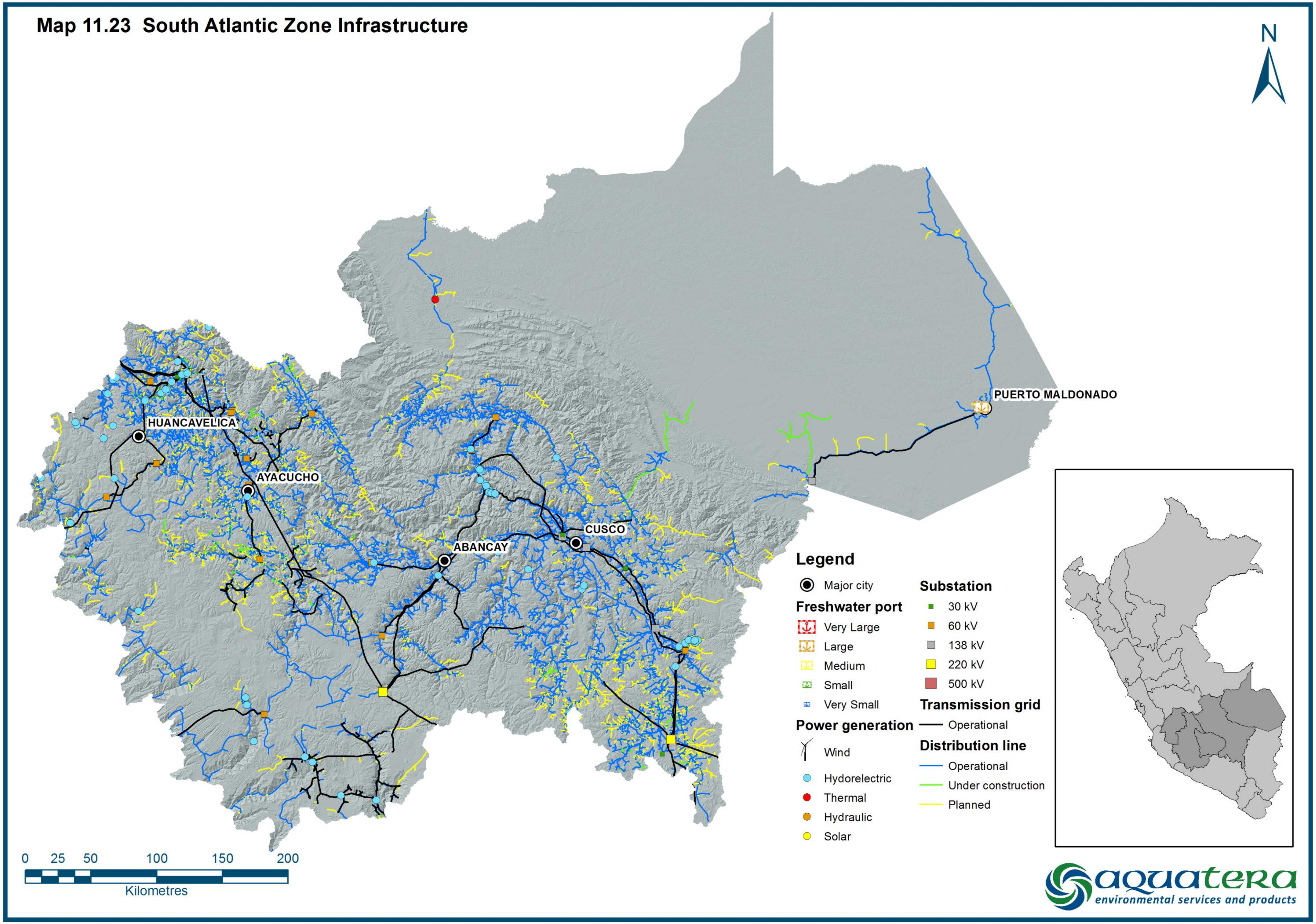


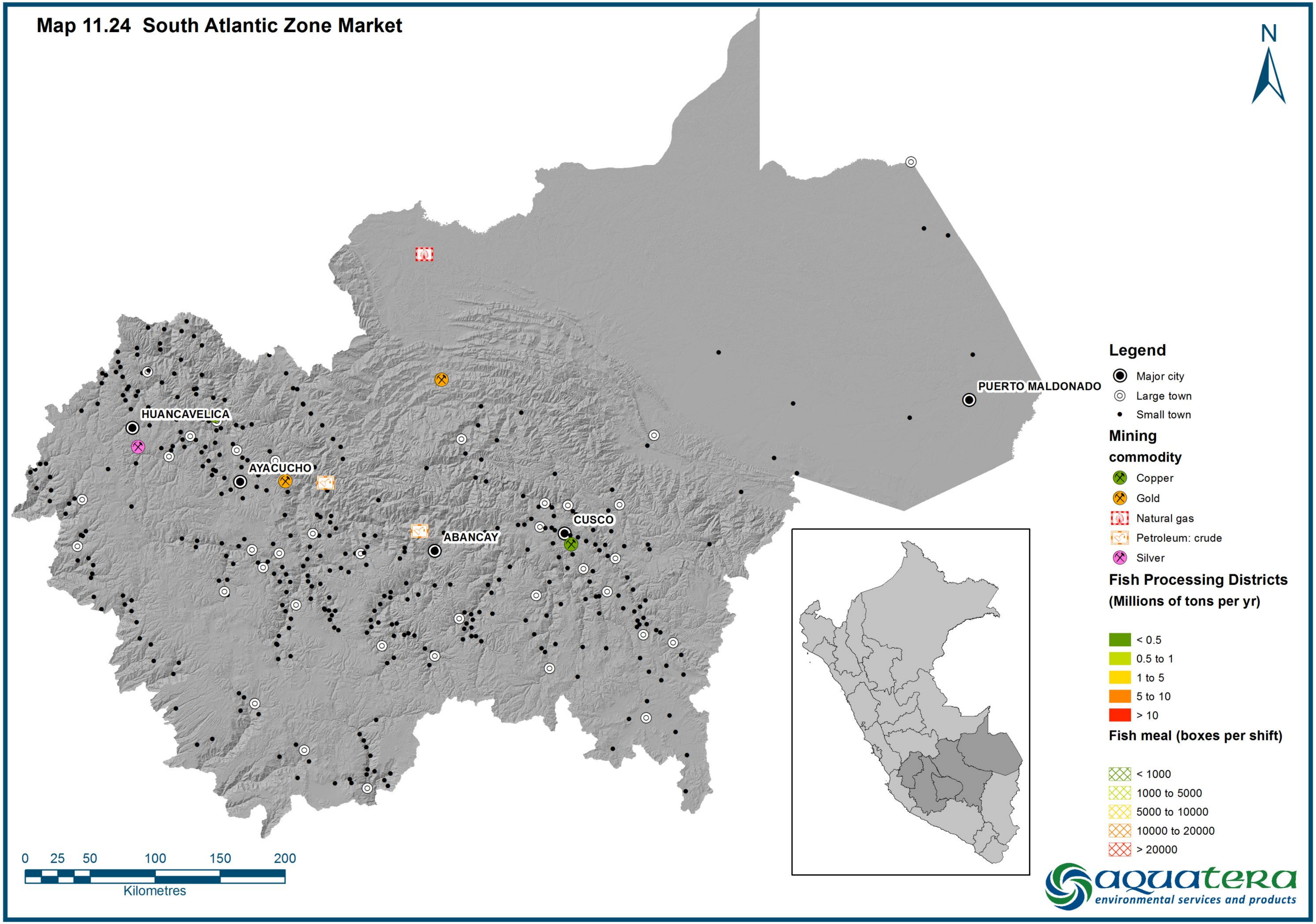
Map 11.21 Central Atlantic Zone Development Potential
Legend
Major city
Large town
Small town
Off grid village
Off grid village 1km buffer (near water body)
Off grid town 5km buffer (near water body)
Off grid capital 10km buffer (near water body)
Substation
30 kV
60 kV
138 kV
220 kV
500 kV
25km buffer from a substation offshore and 10km onshore
Within 10km of main grid
More than 10km away from main grid
River section >2m/s
River point >2m/s
Level of solar potential on a water body <10km from grid
1
2
3
4
5
Level of solar potential on a water body off grid
1
2
3
4
5
N
PUCALLPA
HUANUCO
CERRO DE PASCO
HUANCAYO
0 25 50 100 150 200
Kilometres
aquatera
environmental services and products

Map 11.22 South Atlantic Zone Resource



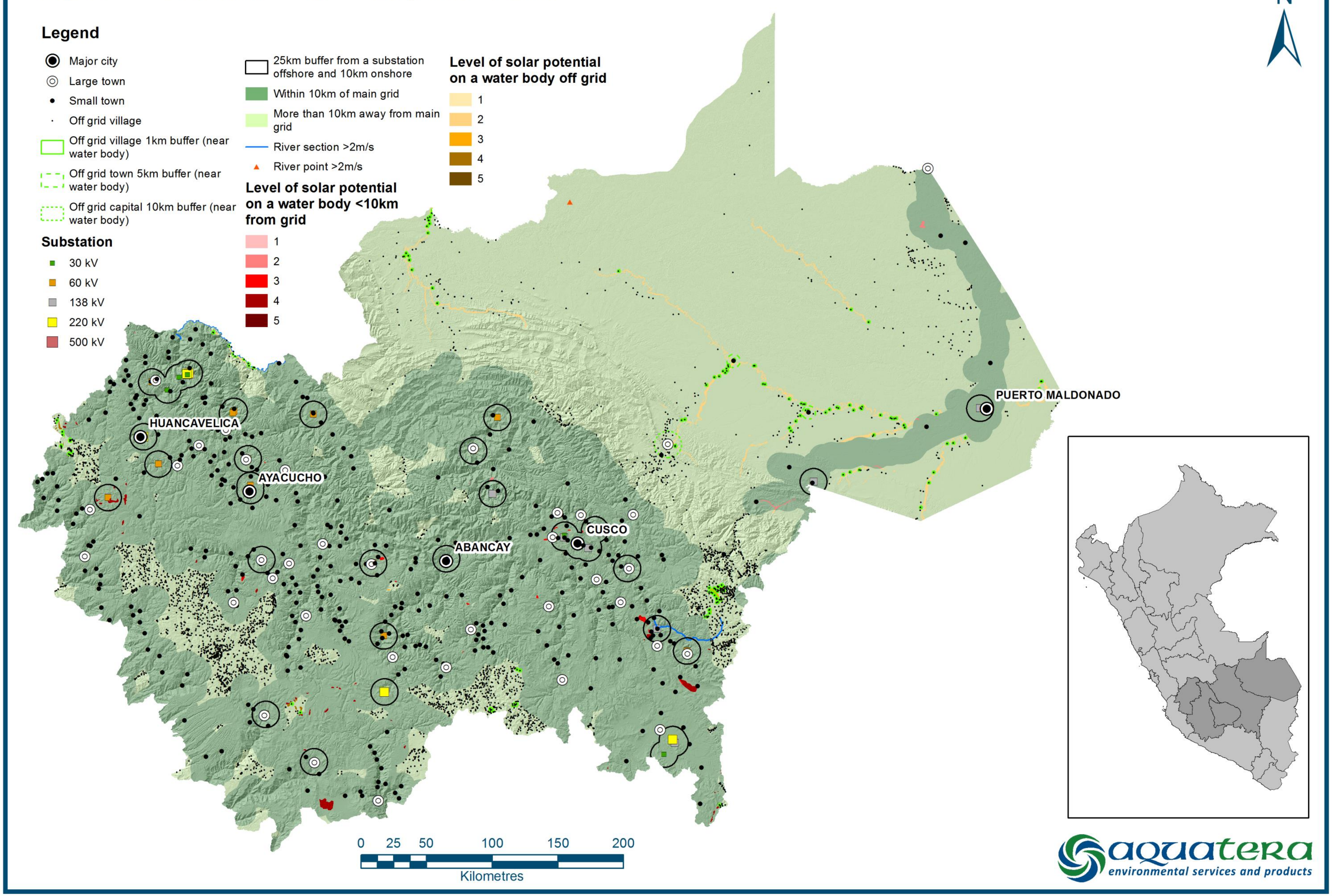
Map 11.23 South Atlantic Zone Infrastructure



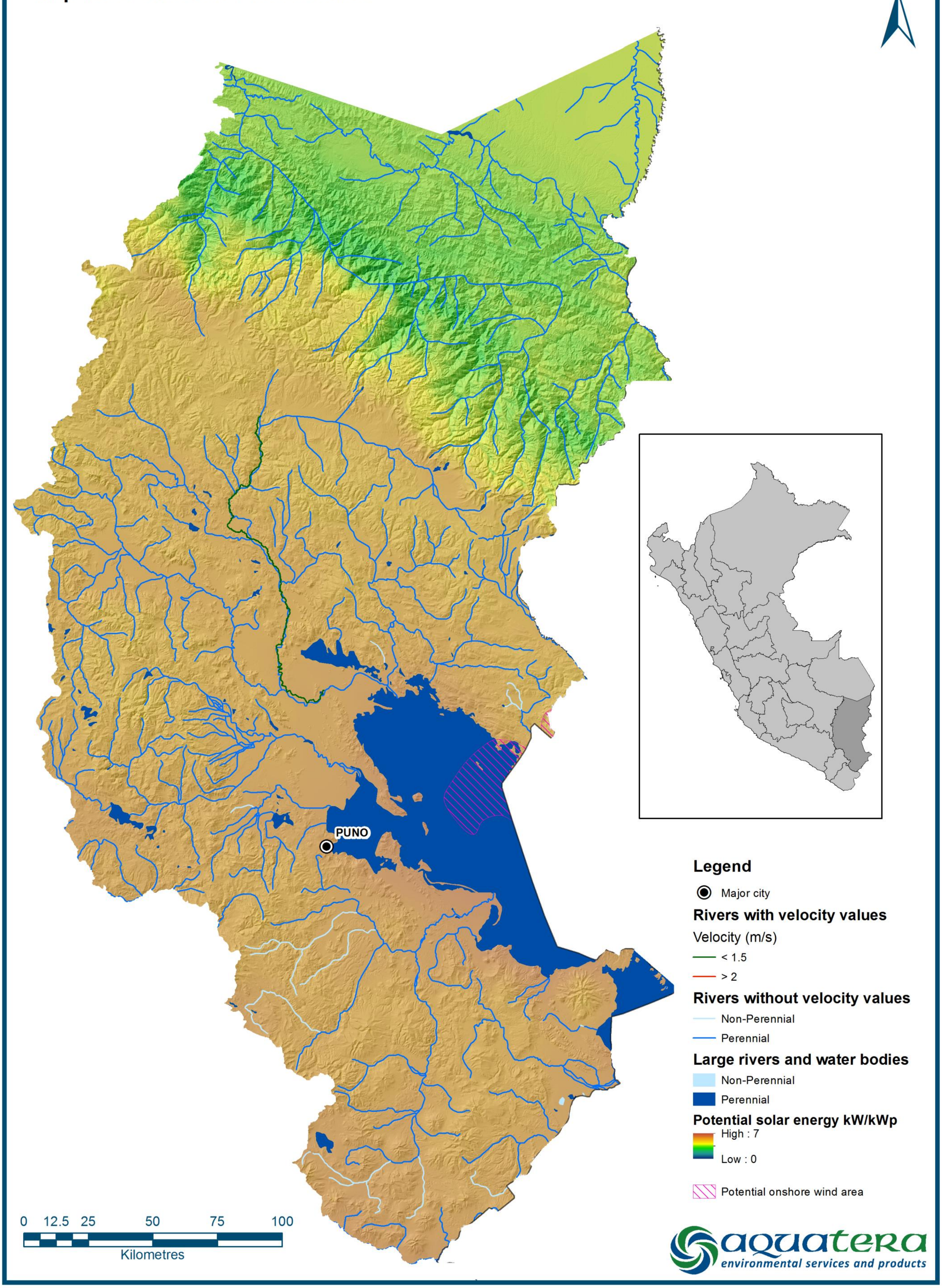


Map 11.24 South Atlantic Zone Market
N
HUANCAVELICA
AYACUCHO
ABANCAY
CUSCO
PUERTO MALDONADO
Legend
Major city
Large town
Small town
Mining commodity
Copper
Gold
Natural gas
Petroleum: crude
Silver
Fish Processing Districts (Millions of tons per yr)
< 0.5
0.5 to 1
1 to 5
5 to 10
> 10
Fish meal (boxes per shift)
< 1000
1000 to 5000
5000 to 10000
10000 to 20000
> 20000
0 25 50 100 150 200
Kilometres
aquatera environmental services and products

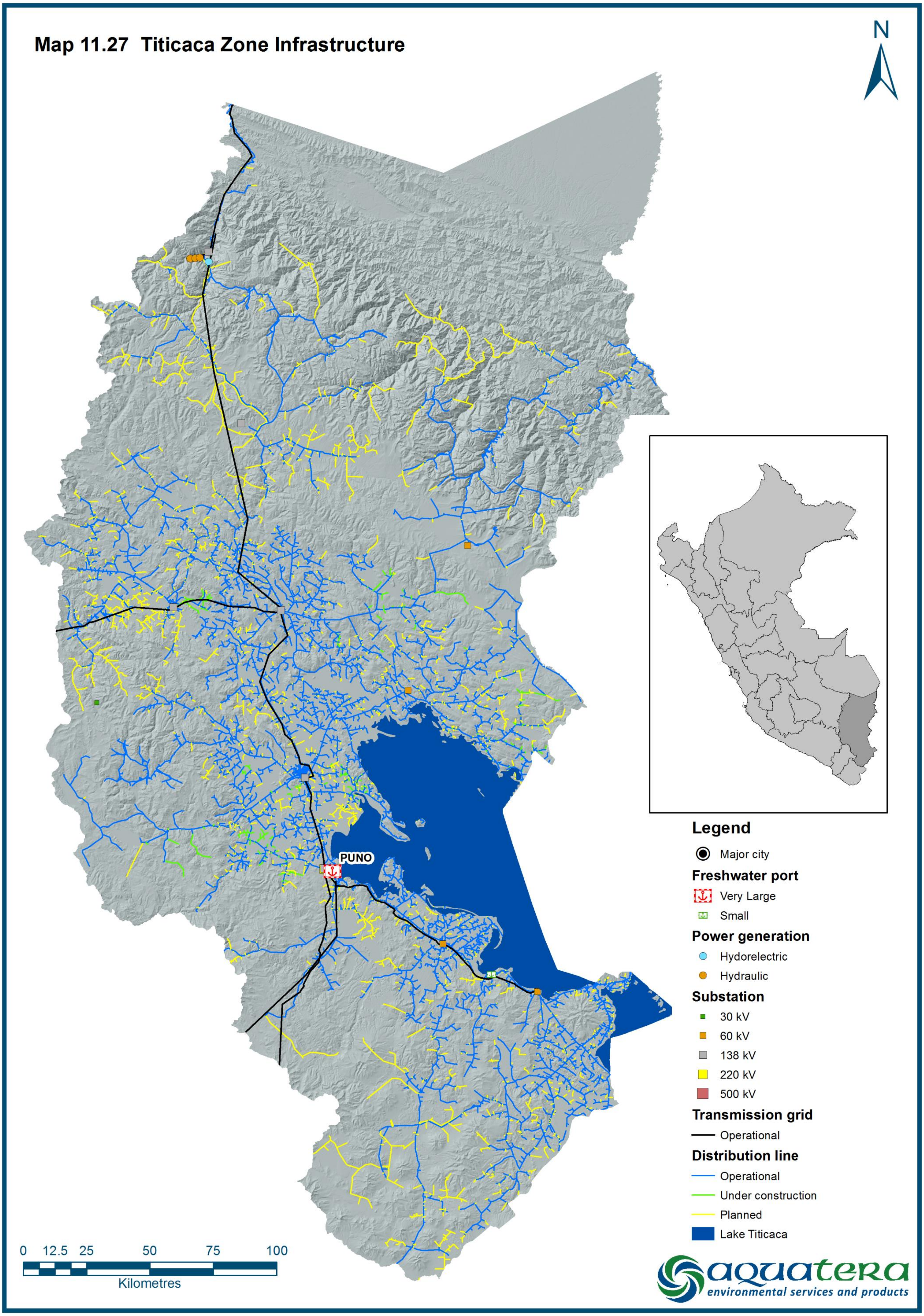
Map 11.25 South Atlantic Zone Development Potential



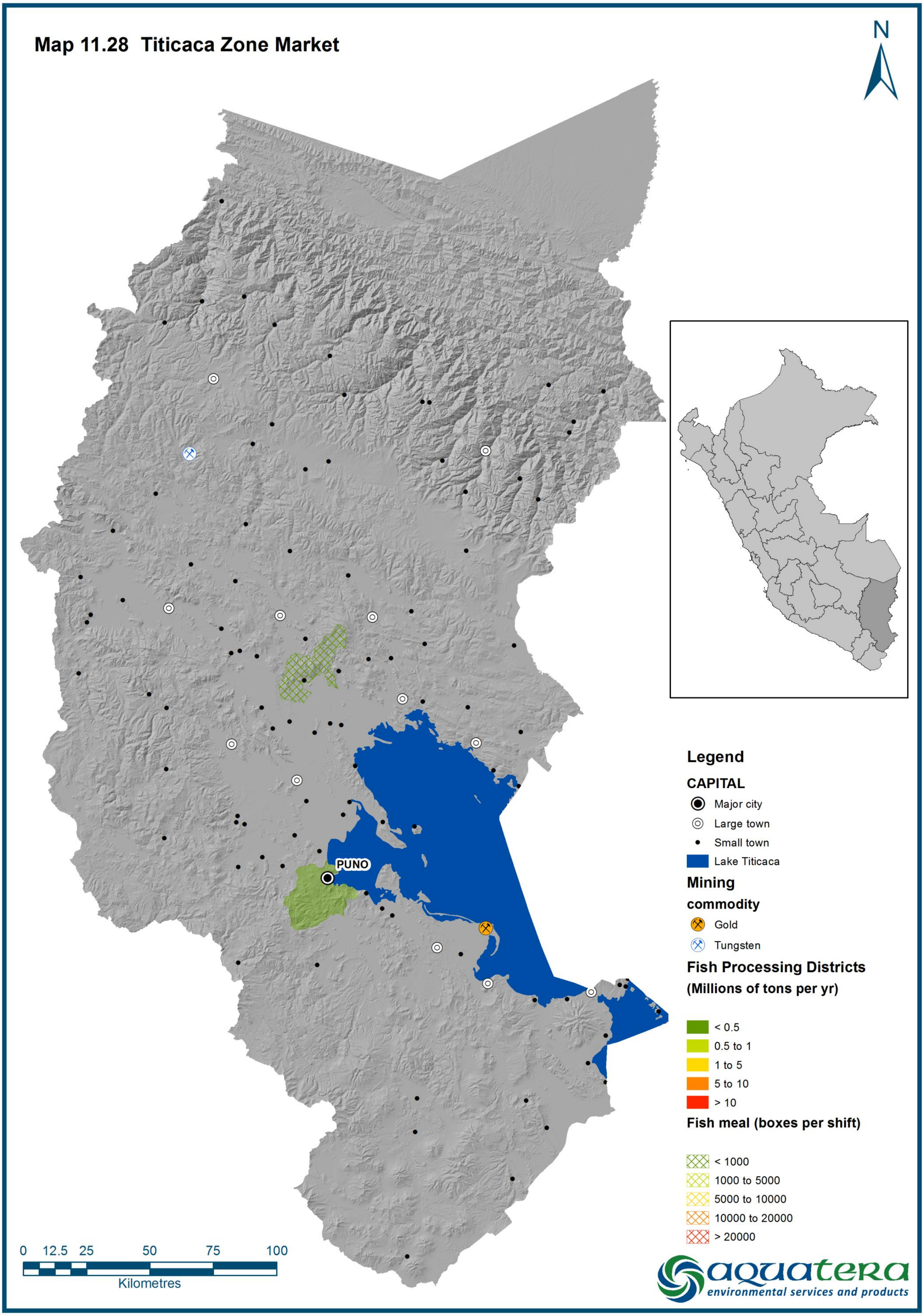
Map 11.26 Titicaca Zone Resource



Map 11.27 Titicaca Zone Infrastructure



Map 11.28 Titicaca Zone Market



Map 11.29 Titicac Zone Development Potential