Mapping Hydroelectric Projects in the Marañón Basin:

Methods and Uncertainty

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Front Cover : Photo of the Río Marañón provided by Rocky Contos (SierraRios).

Introduction

In April of 2011, President Alan García approved a decree stating that construction of a cascade of hydroelectric projects in the Marañón River basin was in the national interest. Decreto Supremo No. 020-2011-EM listed 20 hydroelectric projects with a MW Potential of approximately 12,400 MW (MEM, 2011). Two additional major projects have since also advanced on the Marañón - the Chadín 2 and Marañón.

Information on these 22 projects, except those that are in advanced stages of development, has been scarce. Beyond the head, MW Potential, and design flow, technical information on the dams and the potential reservoir inundation extent of most of the projects has not been made available to the public. This lack of transparency is unacceptable given the dramatic impacts these projects will have to local people as well as downstream ecosystems and livelihoods that currently depend on a healthy and free-flowing Marañón River.

This study attempted to piece together historic and current information to determine the reservoir inundation extents that would be caused by planned dam projects on the Marañón River.

Methods

Digital Elevation Model

Elevational data was collected from multiple sources for the Marañón River, as shown below in Table 1. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data was used as the main source for topographic data except in areas where this data had clear errors. The quality of the ASTER data in a mountainous region of the Brazilian Amazon has been found to fulfill requirements for Brazilian 1:100,000 A Class topo maps (RMSE ≤ 16.66 m) (Oliveira and Paradella, 2009). In comparison, the upper reaches of the Marañón have a much sparser canopy cover, and thus the ASTER data in these sections may have a lower RMSE, although the relief is perhaps steeper than the areas in the Brazilian study.

Name	Description	Resolution
Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) GDEM V2	Version 2 released on October 17, 2011 from the Ministry of Economy, Trade, and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA). ASTER GDEM is a product of METI and NASA. http://reverb.echo.nasa.gov/reverb/	30m
Shuttle Radar Topography Mission (SRTM) V2	Data gathered in February of 2000 using a specially modified radar system onboard the Space Shuttle Endeavor. http://www2.jpl.nasa.gov/srtm/	90m

Digitized contour maps	Contour maps published by the Instituto Geográfico Nacional (IGN). Provided by the Ministerio de Educación del Perú. http://escale.minedu.gob.pe/descargas/mapa.aspx	50m contour intervals

Table 1: Data sources for elevations used in study.

Dam Specifications

In the absence of detailed information for most of the dams listed in Decreto Supremo No. 020-2011-EM, these dams were matched to projects listed in the report "*Evaluación del Potencial Hidroeléctrico Nacional"* initiated in 1968 by the German & Peruvian governments (MEM, 1976). This study assessed the hydroelectric potential in Perú. Engineers developed a large list of projects in the Marañón basin for consideration, and for each location provided multiple project alternatives that could provide different levels of power production.

Projects were matched on the basis of latitude and longitude, MW Potential, and head to provide estimates, varying in accuracy, of the inundated area caused by currently planned dams. Interestingly, many of the currently planned projects were clearly located in the same exact locations as the projects considered in the 70s and 80s.

The MW Potential of dams in "*Evaluación del Potencial Hidroeléctrico Nacional"* was calculated using the formula.

$P = \rho g * Q_{mean} * \Delta H$

ρ = density of water (1000 kg/$m^{3)}$
g = gravitational acceleration (9.81 m/s^2)
Q_{mean} = mean flow (m^3/s)
ΔH = head available from the surface of the reservoir (m) to the river elevation below
P = power in W

In the historic study, the Q_{mean} was also considered the design flow (an assumption that all the water passing through the system could be used to generate electricity), and also that hydroelectricity would be produced with 100% efficiency (see Section 2.2 of MEM, 1976). A further assumption used in this study was that the maximum reservoir surface elevation occurred at the top of the dam, although the reservoir surface would likely be restricted to a few meters below this elevation.

This study's dependence on historic data was a major source of error. Presumably, the projects listed by Decreto Supremo No. 020-2011-EM have been further studied and more realistic estimates of design flow, head, and generation efficiency have been made (among other variables). In general, all matched hydroelectric projects displayed discrepancies between historic and current dam specifications. Due to these inconsistencies, the reservoir inundation area estimates were sorted by confidence in results into four classes:

Class 1 (High Confidence) – These inundation areas were calculated using data from more recent engineering studies for projects in advanced stages of development. High confidence in data on dam height and maximum reservoir surface elevation.

Class 2 (Medium Confidence) – Dam specifications were estimated from the "*Evaluación del Potencial Hidroeléctrico Nacional"* study. The total head and MW Potential matched to within 25%, and the coordinates of the projects were within 2 km of each other.

Class 3 – (Very Low Confidence) - Dam specifications were estimated from the "*Evaluación Del Potencial Hidroeléctrico Nacional"* study, and MW and total head Potential were greater than 25% apart. The coordinates for matched dams may have been greater than 2 river km apart.

Class 4 – Not enough data was available to estimate reservoir inundation extents.

Key Conclusions

This study found that if all the proposed projects mapped within this document were built in the Marañón basin, they would inundate an area of ~ 7100 km^2. Over 80% of the length of the mainstem river, starting at the outlet of Manseriche and ending at the most upstream extent of the Marañón project, would be inundated. The currently vibrant and free-flowing river would be almost completely drowned.

Additionally, Decreto Supremo No. 020-2011-EM stated that the 20 listed hydropower projects collectively had 12,430 MW Potential. However, this study found that, once Chadín 2 and Marañón were added to the list, a number of these projects could possibly overlap. The MW Potential was recalculated, adding on that of Chadín 2 and Marañón while subtracting that of Santa Rosa, Pión, and Pulpería (Pulpería overlaps with Rúpac, which has a higher MW Potential), to equal 12,561 MW. In addition, the Manseriche project as currently envisioned would likely flood too large of an area to be viable. Subtracting Manseriche's MW Potential, which currently makes up ~ 35% of the total basin MW Potential value, produces a MW Potential estimate for the basin of 8,061 MW.

This study's dependence on historic, and outdated, data highlights the need for the Peruvian government to release more information on its plans for the Marañón hydroelectric projects. The current lack of transparency will increase the hardships caused by these projects for local and downstream people. Experts in water resources planning and dam management agree that community participation in development of dam projects is necessary to mitigate their negative effects, as well as to determine if the potential costs of specific and series of dams outweigh their benefits. Furthermore, the government is responsible for ensuring that the benefits of these dams reach affected people; currently much of the development on the Marañón is driven by resource extraction industries as well as demand for power export to other countries. The government must increase its openness about the Marañón dams to ensure that further development is sustainable and equitable.

Key Terms

Lat/long – Dam site coordinates in World Geodetic System (WGS) 84

Distancia largo (km) – Distance between dam site coordinates from different data sources

Potencial (MW) – Megawatt Potential

Caída (m) – Head

Elevación (m.s.n.m.) – Elevation of the dam foundation

Altura de la presa (m) – Height of the dam

Caudal diseño (m^3/s) – Design flow

Caudal promedio (m^3/s) – Mean flow

Nivel máximo del agua (m.s.n.m.) – Maximum reservoir surface level

Nivel máximo de operación (m.s.n.m.) – Maximum level of operation

Área de embalse (km^2) – Reservoir area

La toma (m.s.n.m.) - Intake

La casa de máquinas (m.s.n.m.) - Powerhouse

Overview Map of Hydropower Project Locations
in the Marañón River basin

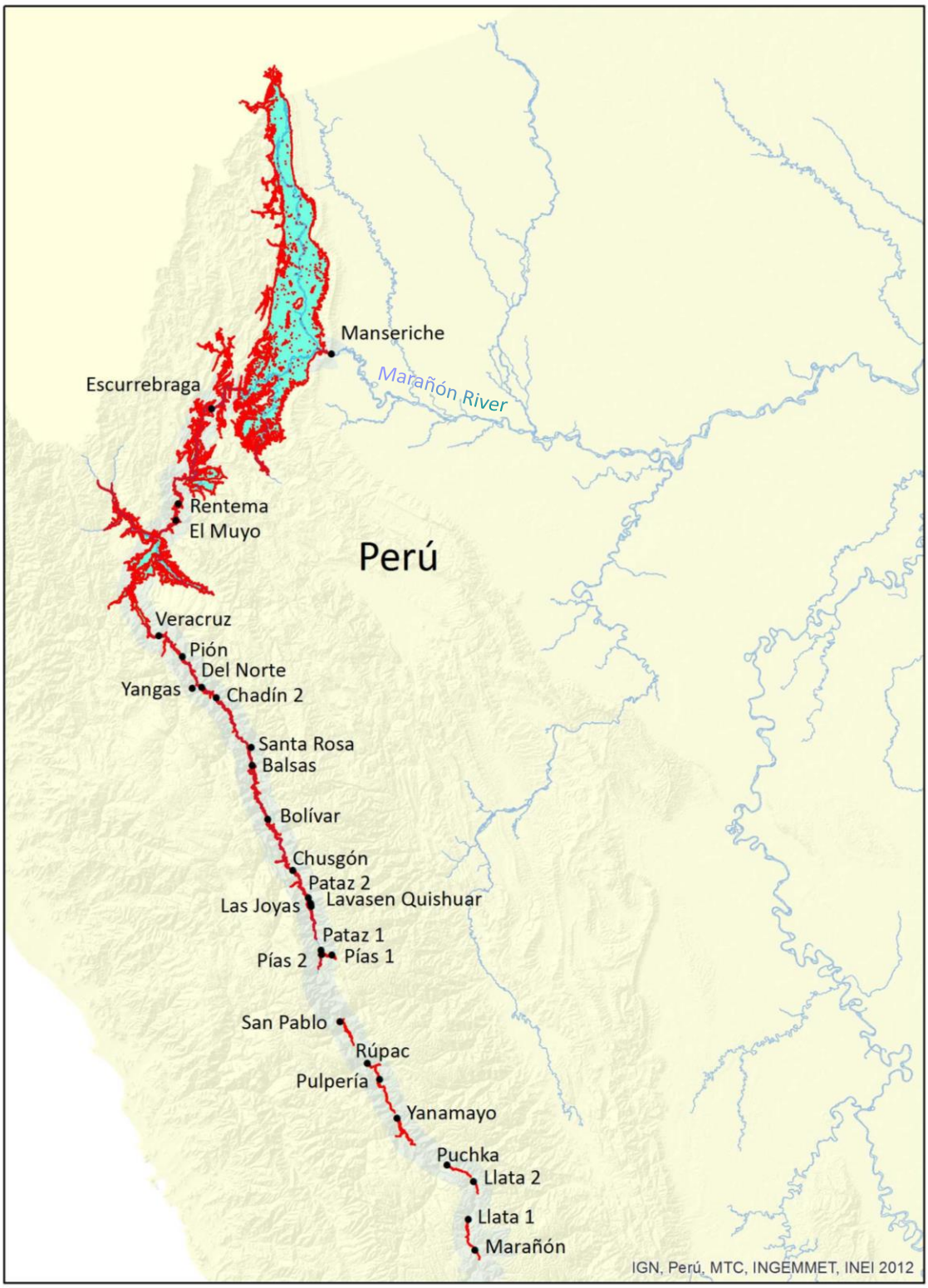

Fig. 1 : Map of planned and existing hydropower projects.

Manseriche

Río Marañón

Class 3 – Very Low Confidence

SOURCE	Finer and Jenkins, 2012	MARA570 - ALT 10 MEM, 1976	CNDEARM, 2011
Lat/long	-4.47241985309, -77.5367535057	-4.461274, -77.579638	
Distancia largo (km)	5		
Potencial (MW)		2009	4500
Caída (m)		110.7	100
Elevación (m.s.n.m.)	157	194	
Altura de la presa (m)		126	
Caudal diseño (m^3/s)			3500
Caudal promedio (m^3/s)		2177	

Table 2 : Data used for Manseriche

Notes : The coordinates of MARA570 designated a site where the river valley walls were fairly steep and close together. This site seemed more feasible for a large storage dam than the site indicated by Finer and Jenkins (2012), which occurred at a point where the valley widened considerably.

Although the MW Potential of MARA570 – ALT 10 was about 1/2 of the value for Manseriche provided by CNDEARM in 2011, the provided heads were very similar. In order to provide a conservative estimate for the area inundated by this project, and to account for the ASTER data potentially overestimating the elevations within the narrow river canyon, the dam base elevation provided by Finer and Jenkins was added to the dam height of MARA570-ALT10 to find the maximum water surface elevation.

Project Specifications	
Elevación (m.s.n.m.)	157
Altura de la presa (m)	126
Nivel máximo del agua (m.s.n.m.)	283
Área de embalse (km^2)	5470

Table 3 : Project specifications and estimated reservoir inundation area. .

Although the reservoir surface area of Manseriche in this map inundated portions of Ecuador, this estimate was created with very low confidence. The immensity of this project, as currently planned, makes it nonviable.

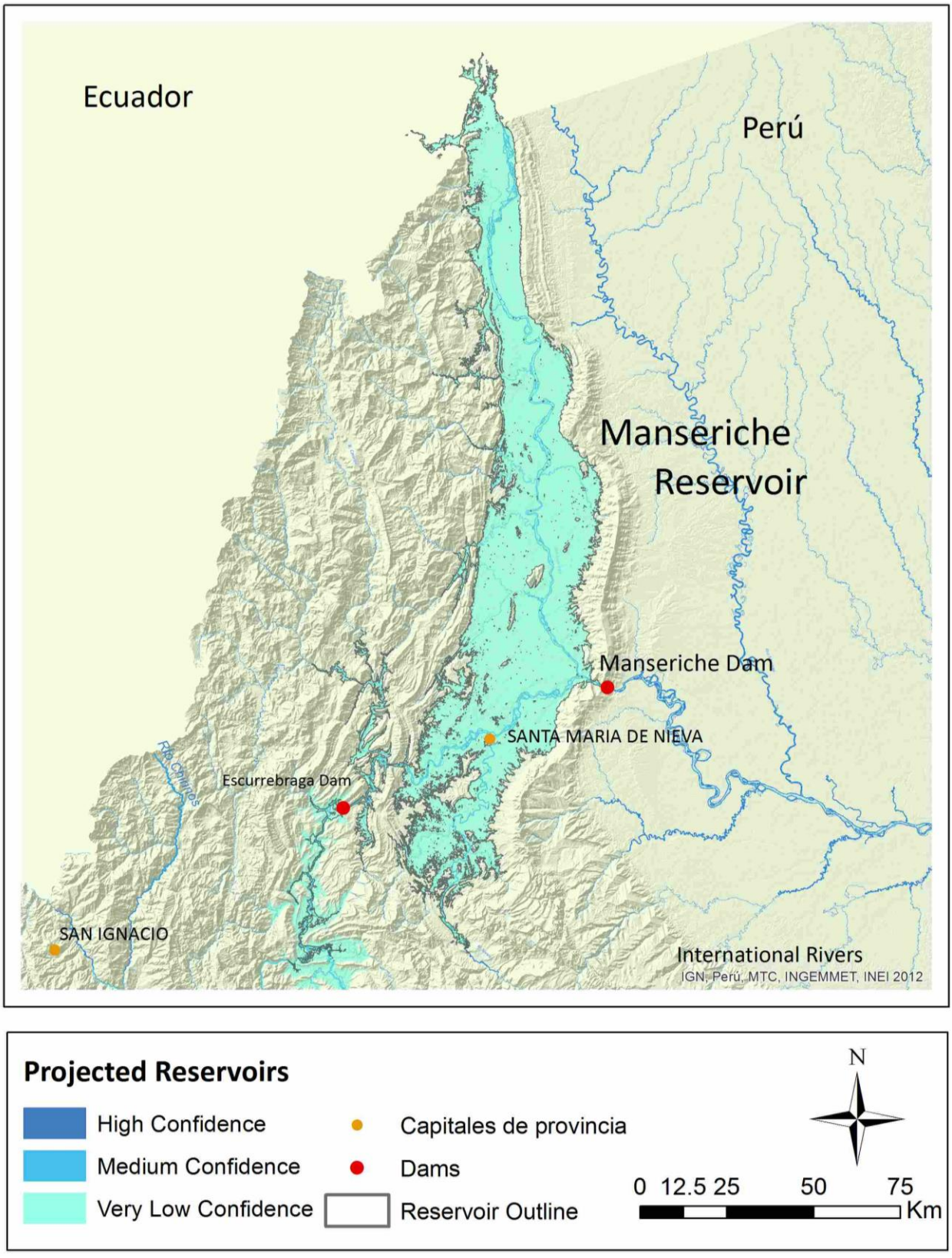

Fig. 2 : Map of projected reservoir surface area of Manseriche.

Escurrebraga

Río Marañón

Class 3 – Very Low Confidence

SOURCE	CNDEARM, 2011	Finer and Jenkins, 2012	MARA 550 - ALT 8 (MEM, 1976)
Lat/long		-4.77582, -78.2506	-4.77582, -78.2506
Distancia largo (km)		0	
Potencial (MW)	1800	1800	1428.3
Caída (m)	108		173
Altura de la presa (m)			195
Elevación (m.s.n.m.)		245	
Caudal diseño (m^3/s)	900		
Caudal promedio (m^3/s)			988

Table 4 : Data used for Escurrebraga.

Project Specifications	
Elevación (m.s.n.m.)	245
Altura de la presa (m)	195
Nivel máximo del agua (m.s.n.m.)	440
Área de embalse (km^2)	875

Table 5 : Project specifications and estimated reservoir inundation area. .

Notes : The estimated maximum water surface elevation was at 440 m.s.n.m. – however, if this was true this would cause the reservoir to spill over at two locations north and south of the dam. It is likely the reservoir surface inundation area was overestimated for this project due to the differences in head between the figures provided by CNDEARM and for MARA550 – ALT 8.

In the Utcubamba river there are several hydro projects that could potentially be affected by Escurrebraga.

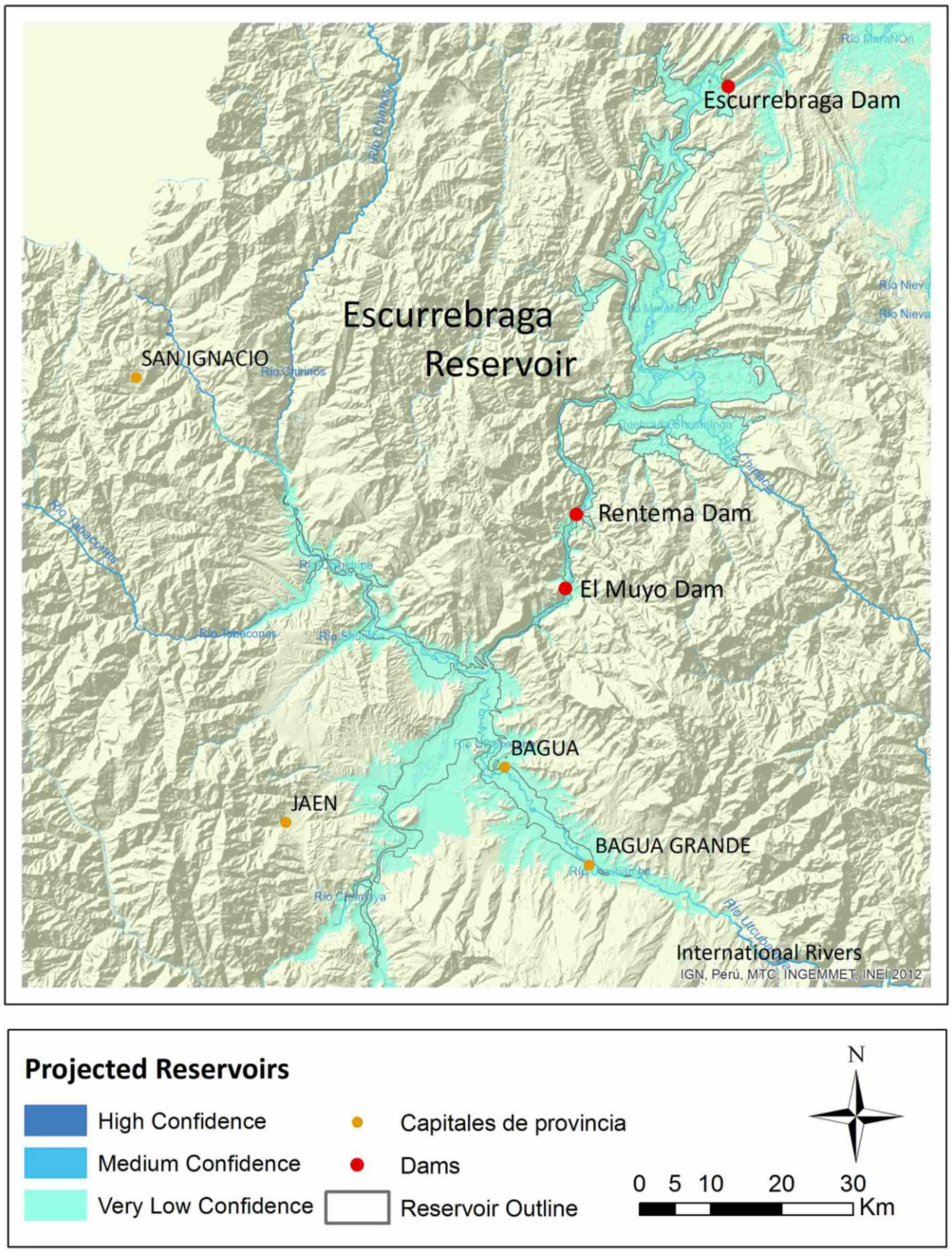

Fig. 3 : Map of projected reservoir surface area of Escurrebraga.

Rentema

Río Marañón

Class 3 – Very Low Confidence

SOURCE	Finer and Jenkins, 2012	MARA 520 - ALT 6 (MEM, 1976)	CNDEARM, 2011
Lat/long	-5.31769360917, -78.4426	-5.200010, -78.466669	
Distancia largo (km río)	16		
Potencial (MW)	1525	1355	1500
Caída (m)		180.3	100
Altura de la presa (m)		203	
Elevación (m.s.n.m.)	333		
Caudal diseño (m^3/s)			750
Caudal promedio (m3/s)		901	

Table 6 : Data used for Rentema.

Notes : In the case of Rentema, information beyond MW Potential and design flow was scarce. The closest project listed in the "*Evaluación Del Potencial Hidroeléctrico Nacional : Cuencas Marañon Y Afluentes"* (MARA 520 – ALT 6) was located 16 river km away from the project's current coordinates. However, the Potential MW values for these two were very similar, although the head for the MARA 520 – ALT 6 was almost twice as high as that provided by CNDEARM 2011. Therefore, the following estimate is provided with very low confidence.

Project Specifications	
Elevación (m.s.n.m.)	333
Altura de la presa (m)	203
Nivel máximo del agua (m.s.n.m.)	536
Área de embalse (km^2)	874

Table 7 : Project specifications and estimated reservoir inundation area.

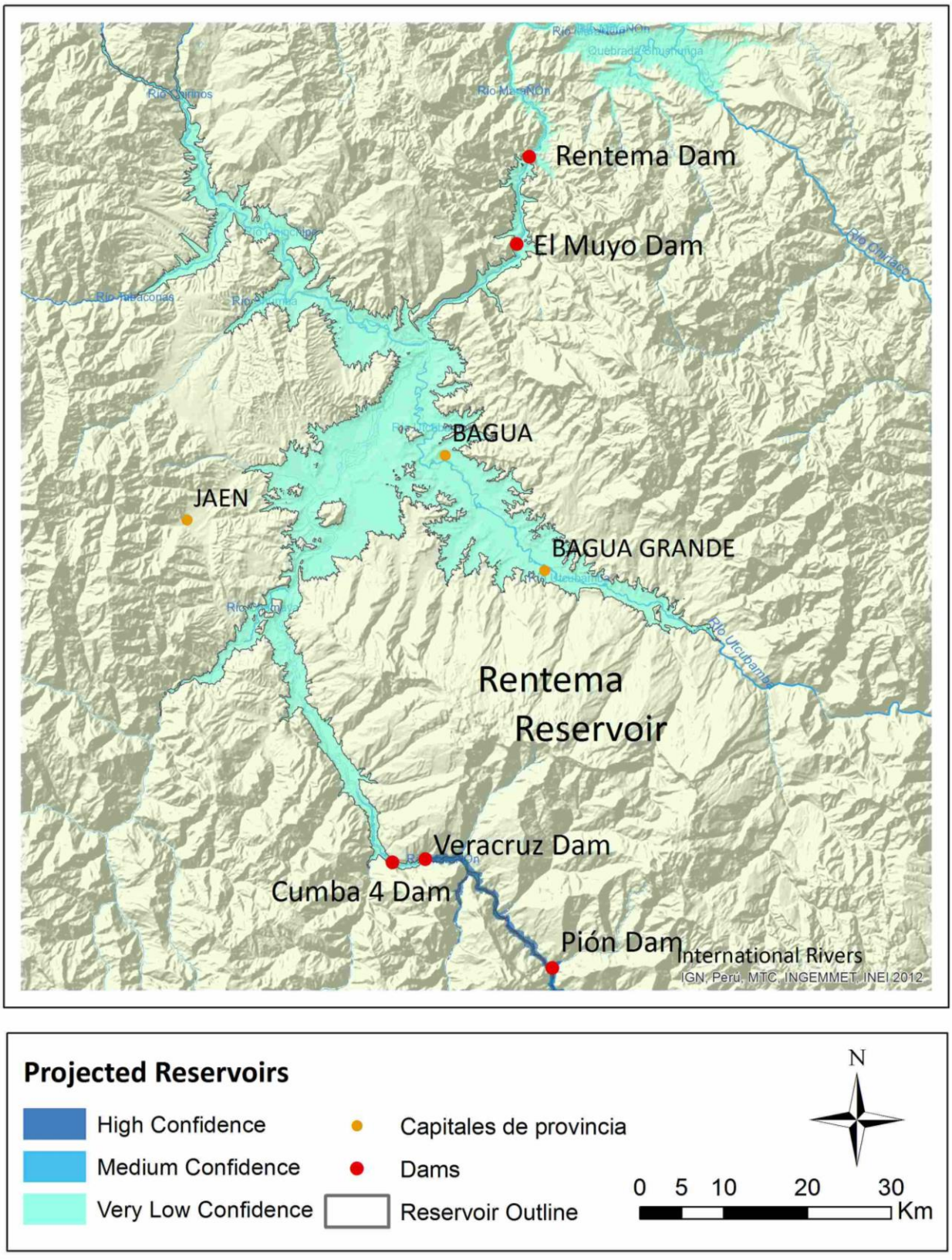

Fig. 4 : Map of projected reservoir surface area of Rentema.

Veracruz

Río Marañón

Class 1 - High Confidence

SOURCE	O. Y. Ingeniería, 2009
Lat/long	- 6.072454, - 78.5483
Potencial (MW)	730
Caída bruta (m)	150
Altura de la presa (m)	168
Nivel máximo de operación (m.s.n.m.)	660
Área de embalse (km^2)	36
Caudal diseño (m^3/s)	600
Caudal promedio (m^3/s)	532

Table 8 : Project specifications and estimated reservoir inundation area. .

Notes : Two projects with different dimensions have been documented for nearly the same site on the Marañón – of these two, the Veracruz project has since replaced the Cumba 4 project. The area of the estimated reservoir inundation shapefile was calculated to be 38 km^2, a figure which was fairly close to the official estimated area.

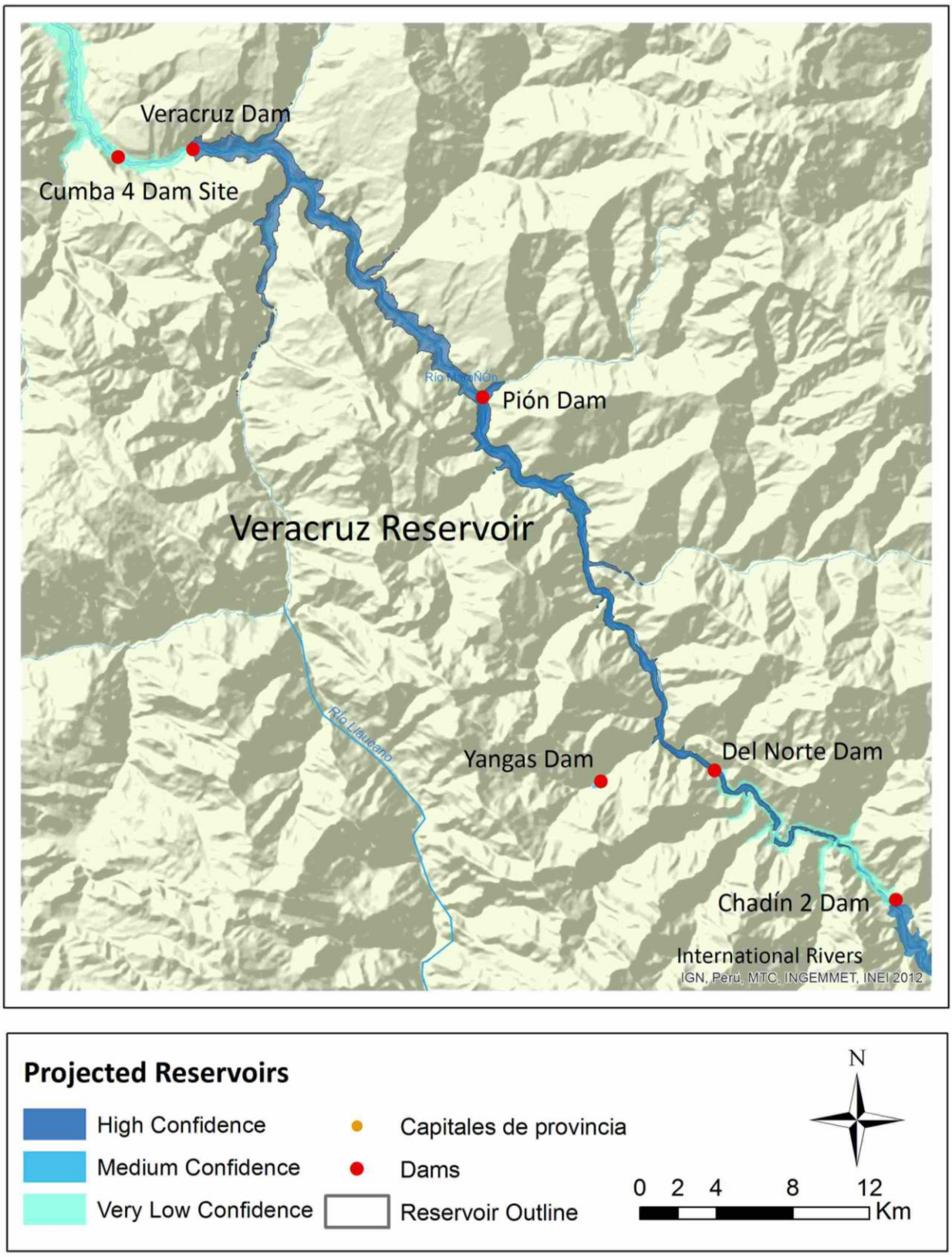

Fig. 5 : Map of projected reservoir surface area of Veracruz.

Pión (Unlikely)

Río Marañón

Class 2 – Medium Confidence

SOURCE	Finer and Jenkins, 2012	MARA450 - ALT 1 (MEM, 1976)	CNDEARM, 2011
Lat/long	-6.18863325922, -78.418077131	-6.185495, -78.417066	
Distancia largo (km)	0		
Potencial (MW)	350	300.7	350
Caída (m)		79.2	100
Altura de la presa (m)		90	
Elevación (m.s.n.m.)	585		
Caudal diseño (m^3/s)			222
Caudal promedio (m^3/s)		455	

Table 9 : Data used for Pión.

Notes : The MW Potential and heads were very similar between different considered dam projects (CNDEARM 2011 and MARA450 – ALT 1). However, the design flow of MARA450 – ALT 1 was more than twice the flow of the other.

It is unlikely that this dam will be built since Veracruz, which inundates Pión's dam site, is further along in the pipeline.

Project Specifications	
Elevación (m.s.n.m.)	585
Altura de la presa (m)	90
Nivel máximo del agua (m.s.n.m.)	675
Embalse (km^2)	17

Table 10 : Project specifications and estimated reservoir inundation area. .

Fig. 6 : Map of projected reservoir surface area of Pión.

Del Norte (Unlikely)

Río Marañón

Class 3 – Very Low Confidence

SOURCE	Cardó, 2012	Finer and Jenkins, 2012
Lat/long		-6.36429642524, -78.33089435346
Potencial (MW)		600
Elevación (m.s.n.m.)		610
Altura de la presa (m)	210	
Cota máxima de Embalse (m.s.n.m.)	822	

Table 11 : Data used for Del Norte.

Notes : No mentions of this dam were found in government sources- the only mention of this dam was from a document by Cardó, 2012 and from Finer and Jenkins, 2012. This dam was within 20km of the dam site for Chádin 2 and its reservoir would likely inundate the Chádin 2 dam site, so it is unlikely that Del Norte will be built.

Project Specifications	
Elevación (m.s.n.m.)	612
Altura de la presa (m)	210
Nivel máximo del agua (m.s.n.m.)	822
Área de embalse (km^2)	37

Table 12 : Project specifications and estimated reservoir inundation area. .

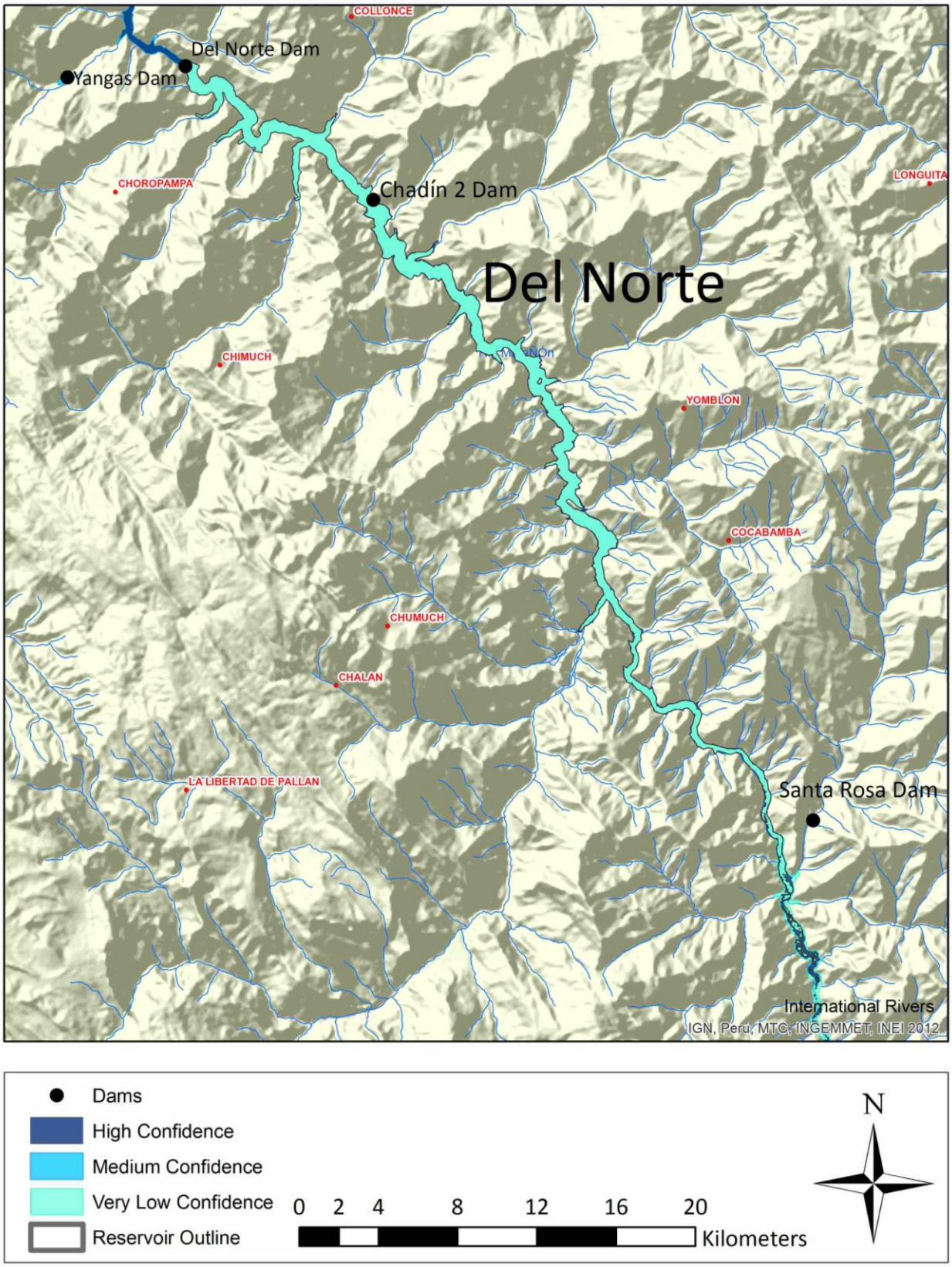

Fig. 7 : Map of projected reservoir surface area of Del Norte.

Yangas

Río Artesamayo

Class 2 – Medium Confidence

SOURCE	Finer and Jenkins, 2012	MARA440 - ALT 1 (MEM, 1976)	(CNDEARM, 2011)
Lat/long	-6.3695193945, -78.3624404035	-6.367, -78.37	
Distancia largo (km)	0		
Potencial (MW)	330	315.2	330
Caída (m)		88	90
Elevación (m.s.n.m.)	968		
Altura de la presa (m)		100	
Caudal diseño (m^3/s)			205
Caudal promedio (m^3/s)		428.8	

Table 13 : Data used for Yangas.

Notes : There was a large discrepancy in flow rates between considered projects.

Project Specifications	
Elevación (m.s.n.m.)	968
Altura de la presa (m)	100
Nivel máximo del agua (m.s.n.m.)	1068
Área de embalse (km^2)	.2

Table 14 : Project specifications and estimated reservoir inundation area. .

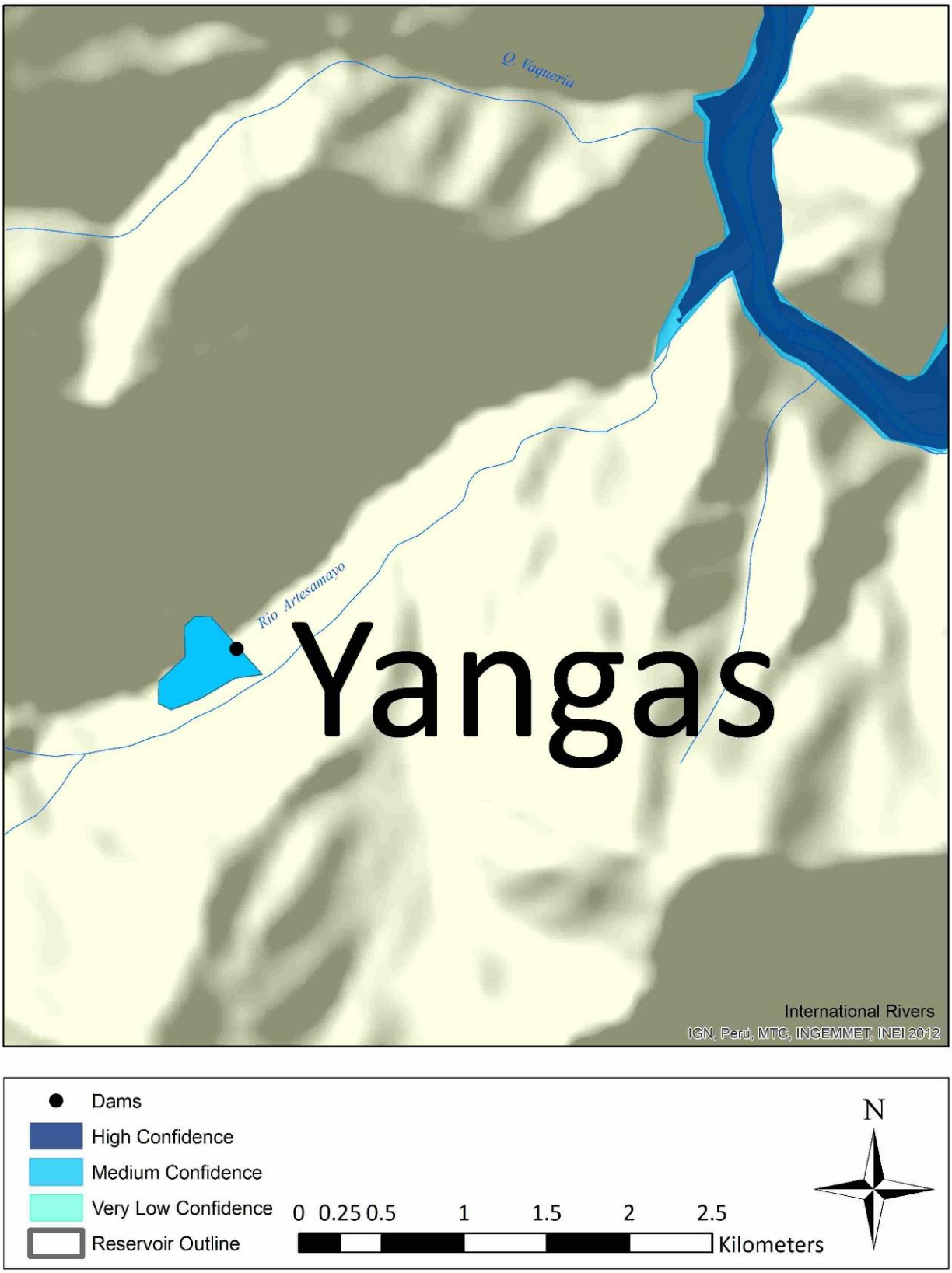

Fig. 8 : Map of projected reservoir surface area of Yangas.

Chadín 2

Río Marañón

Class 1 – High Confidence

SOURCE	AC Energía S.A., 2011
Lat/long	-6.42258, -78.224826
Potencial (MW)	600
Caída bruta (m)	150
Altura de la presa (m)	175
Caudal diseño (m^3/s)	385
Cota máxima de Embalse (m.s.n.m.)	832
Área de embalse (km^2)	32.5

Table 15 : Project specifications and estimated reservoir inundation area. .

Notes : This study estimated the área de embalse as 30 km^2 .

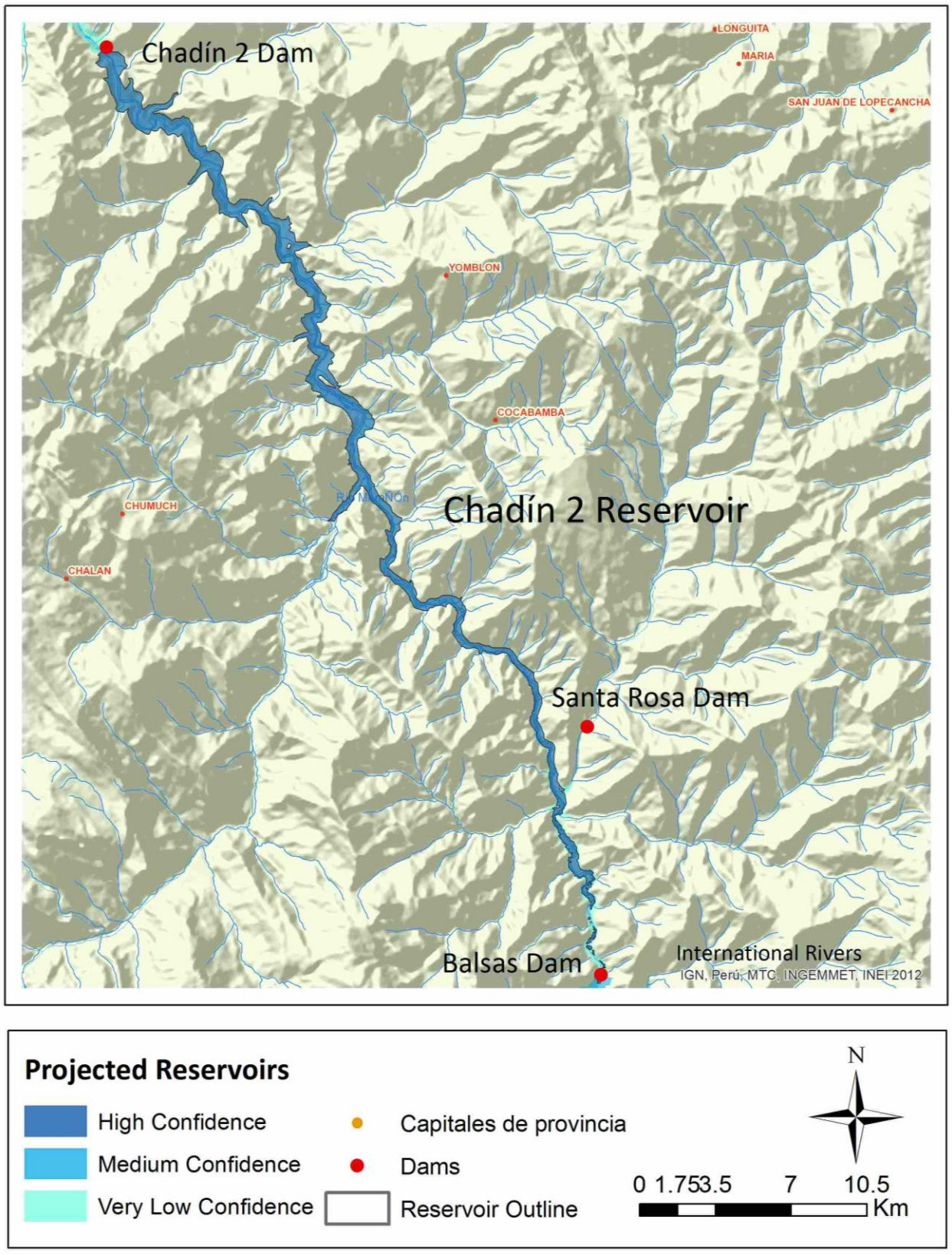

Fig. 9 : Map of projected reservoir surface area of Chadín 2.

Santa Rosa (Unlikely)

Río Marañón

Class 3 – Very Low Confidence

SOURCE	Finer and Jenkins, 2012	MARA420 - ALT 1 (MEM, 1976)	CNDEARM, 2011
Lat/long	-6.70746, -78.024	-6.7, -78.033	
Distancia largo (km)	1.3		
Potencial (MW)	340	189.5	340
Caída (m)		61.7	95
Elevación (m.s.n.m.)	966		
Altura de la presa (m)		70	
Caudal diseño (m^3/s)			201
Caudal promedio (m^3/s)		368.3	

Table 16 : Data used for Santa Rosa.

Notes : The coordinate provided from Finer (2012) suggested that this dam did not occur on the mainstem Marañón, but instead on the Quebrada Soledad, a tributary to the Marañón. The MARA420 coordinate was up on a hillslope as well – however, many of the dam coordinates from the 1970s document were not directly on the river most likely due to the lack of space-based satellite navigation systems. Therefore, due to the design flow for this project being comparable to that of the mainstem projects (CNDEARM, 2011), this study determined that the Santa Rosa was located on the mainstem Marañón.

The estimated inundated area provided by this study is likely a conservative estimate.

Additionally, the construction of Chádin 2 would likely inundate Santa Rosa's dam site, thus potentially making this project unviable.

Project Specifications	
Elevación (m.s.n.m.)	790
Altura de la presa (m)	70
Nivel máximo del agua (m.s.n.m.)	860
Área de embalse (km^2)	9

Table 17 : Project specifications and estimated reservoir inundation area. .

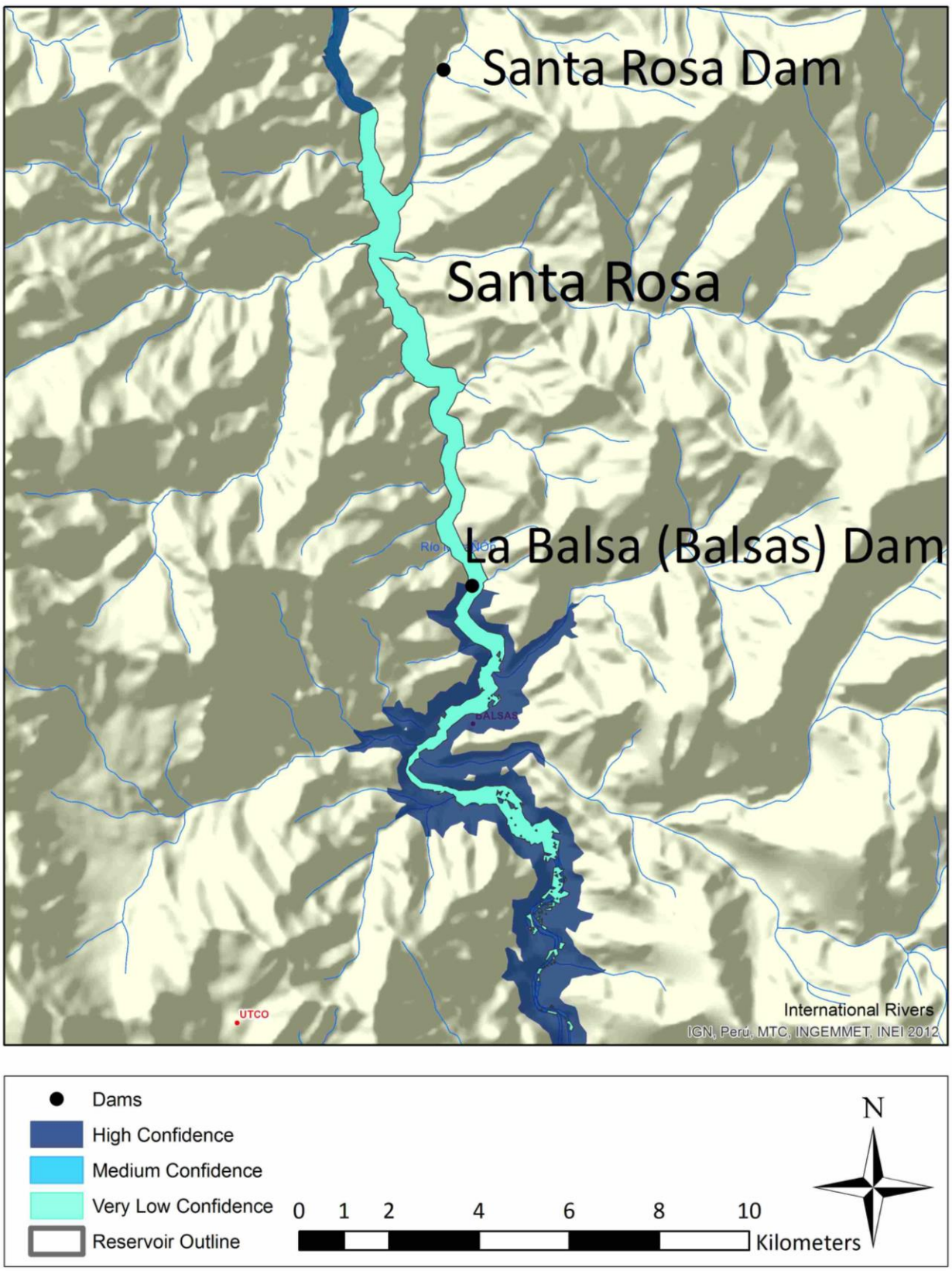

Fig. 10 : Map of projected reservoir surface area of Santa Rosa.

Balsas

Río Marañón

Class 2 – Medium Confidence

SOURCE	MEM, 2007	SNC for Electroperú, 1986
Lat/long	-6.81055555579, -78.0183333333	-6.810556, -78.018333
Potencial (MW)	915	585
Caída (m)	(efectiva) 193	150
Altura de la presa (m)	210	175
Caudal diseño (m^3/s)	550	425
Cota máxima de Embalse (m.s.n.m.)	1020	960

Table 18 : Data used for Balsas.

Notes : The design flow for Balsas that was listed in the MEM, 2007 document was higher than that of Chádin 2, located downstream, which was puzzling. This dam is listed as Medium Confidence because the Decreto Supremo No. 020-2011-EM lists the Potential MW as much less (350 MW Potential) than that provided by MEM, 2007 (915 MW).

Project Specifications	
Elevación (m.s.n.m.)	810
Altura de la presa (m)	210
Nivel máximo del agua (m.s.n.m.)	1020
Área de embalse (km^2)	56

Table 19 : Project specifications and estimated reservoir inundation area. .

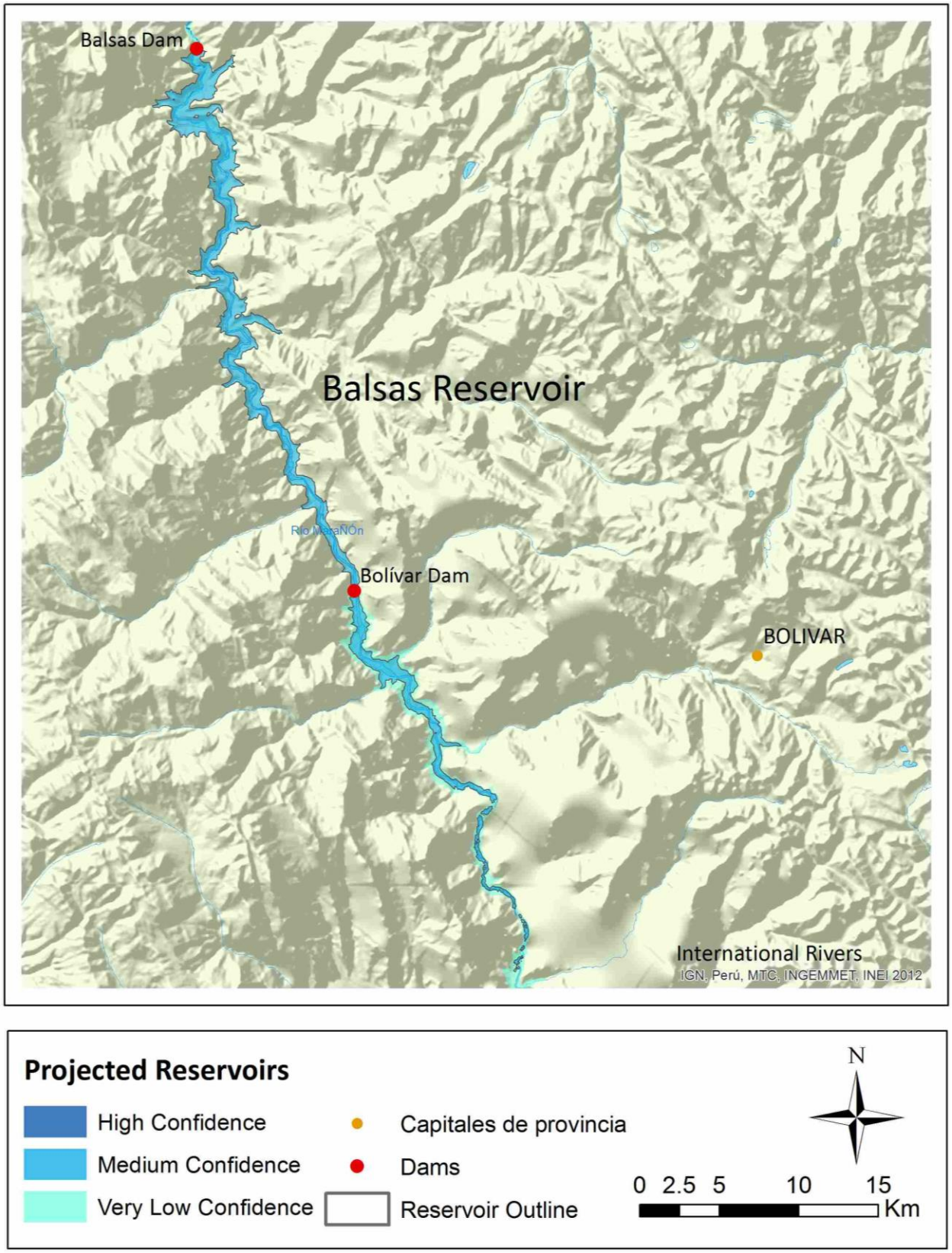

Fig. 11 : Map of projected reservoir surface area of Balsas.

Bolívar

Río Marañón

Class 3 – Very Low Confidence

SOURCE	CNDEARM, 2011	Finer and Jenkins, 2012	MARA390 - ALT 3 (MEM, 1976)
Lat/long		-7.11724225023, -77.929380994	-7.11667, -77.933331
Distancia largo (km)		0	
Potencial (MW)	290	290	324
Caída (m)	85		114.5
Elevación (m.s.n.m.)		993	
Altura de la presa (m)			130
Caudal diseño (m^3/s)	190		
Caudal promedio (m^3/s)			339.5

Table 20 : Data used for Bolívar.

Notes : MARA390 ALT 3 has higher values for head and Potential MW than that provided by CNDEARM, 2011. Therefore, the reservoir shape file likely overestimated the inundated area.

According to local people an engineering team surveyed this area in 2013. They were interested either in Bolívar or Chusgón.

Project Specifications	
Elevación (m.s.n.m.)	993
Altura de la presa (m)	130
Nivel máximo del agua (m.s.n.m.)	1123
Área de embalse (km^2)	56

Table 21 : Project specifications and estimated reservoir inundation area. .

Fig. 12 : Map of projected reservoir surface area of Bolívar.

Chusgón

Río Marañón

Class 2 – Medium Confidence

SOURCE	CNDEARM, 2011	Finer and Jenkins, 2012	MARA370 - ALT 3 (MEM, 1976)
Lat/long		-7.40859132643, -77.7865550806	-7.400011, -77.783328
Distancia largo (km)		0	
Potencial (MW)	240	240	259.7
Caída (m)	90		92.1
Altura de la presa (m)			105
Elevación (m.s.n.m.)		1268 (***see note)	
Caudal diseño (m^3/s)	148		
Caudal promedio (m^3/s)			338

Table 22 : Data used for Chusgón.

Notes : ***Although Finer and Jenkins (2012) provides an elevation of 1268m for this dam, the elevation of the ASTER DEM at the coordinate provided by Finer and Jenkins (2012) is located at approximately 1050 m.s.n.m.. Therefore, 1050 m.s.n.m. was used as the base elevation.

Project Specifications	
Elevación (m.s.n.m.)	1050
Altura de la presa (m)	105
Nivel máximo del agua (m.s.n.m.)	1155
Área de embalse (km^2)	25

Table 23 : Project specifications and estimated reservoir inundation area. .

Fig. 13 : Map of projected reservoir surface area of Chusgón.

Pataz 2

Río Marañón

Class 2 – Medium Confidence

SOURCE	CNDEARM, 2011	Finer and Jenkins, 2012	MARA350 - ALT 3 (MEM, 1976)
Lat/long		-7.56589045858, -77.6977066579	-7.56589, -77.6977
Distancia largo (km)		0	
Potencial (MW)	240	240	216.4
Caída (m)	100		88
Elevación (m.s.n.m.)		1114	
Altura de la presa (m)			100
Caudal diseño (m^3/s)	136		
Caudal promedio (m^3/s)			294.7

Table 24 : Data used for Pataz 2.

Notes : The local population reported high activity in this area in 2013 of engineers on behalf of Generalima. Generalima is a subsidiary of ENDESA-Chile, a company that belongs to ENEL of Italy.

Generalima has temporary concessions to study hydroelectric projects Marañón 1, 2, 3 and 4, adding up to 1,525 MW. The Colectivo Amazonía e Hidroeléctricas does not yet know the exact location of these projects.

Project Specifications	
Elevación (m.s.n.m.)	1114
Altura de la presa (m)	100
Nivel máximo del agua (m.s.n.m.)	1214
Área de embalse (km^2)	17

Table 25 : Project specifications and estimated reservoir inundation area. .

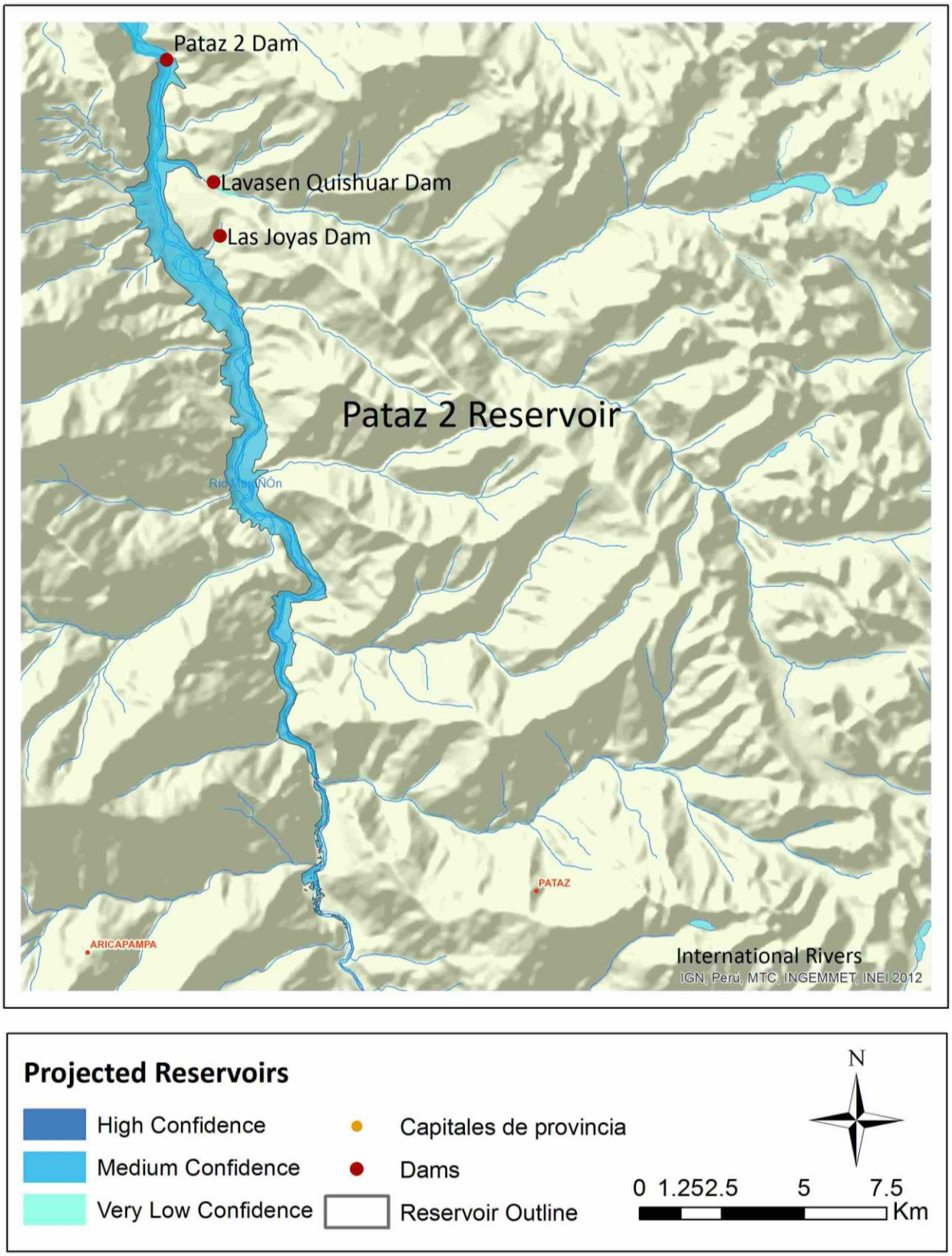

Fig. 14 : Map of projected reservoir surface area of Pataz 2.

Lavasen Quishuar

Río Lavasen y Río Quishuar

Class 3 – Low Confidence

SOURCE	Finer and Jenkins, 2012.	CESEL Ingenieros, 2014
Lat/long	-7.59914, -77.6848	
Distancia largo (km)		
Potencial (MW)	64.2	42
Caída (m)		590,590,510
Elevación (m.s.n.m.)	1278	
Altura de la presa (m)		15
Caudal diseño (m^3/s)		3.1,3.1,3.4

Table 26 : Data used for Lavasen Quishuar.

Notes : Resolución Directoral Nº0316-2010-ANA-DARH del 01 de octubre del 2010 approved the hydrological study of hydroelectric generation in the Lavasen-Quishuar basin, a tributary to the Marañón. The project seemed to be composed of a series of small hydroelectric projects, including Cativen I, Cativen II and Nimpana (14MW each). Flow rates are 3.1, 3.1, and 3.4 m^3/s. The project included an earth fill dam 15m high on Quishuar. These projects were also listed in the *Portafolio De Proyectos De Generación Y Transmisión En El Sistema Eléctrico Interconectado Nacional (SEIN)* (MEM, 2008).

This Project is listed as Class 3 because the exact location of the earthen dam, 15m high, may not correspond exactly to the coordinates provided by Finer and Jenkins, 2012.

Project Specifications	
Elevación (m.s.n.m.)	1278
Altura de la presa (m)	15
Nivel máximo del agua (m.s.n.m.)	1293
Área de embalse (km^2)	.2

Table 27 : Project specifications and estimated reservoir inundation area. .

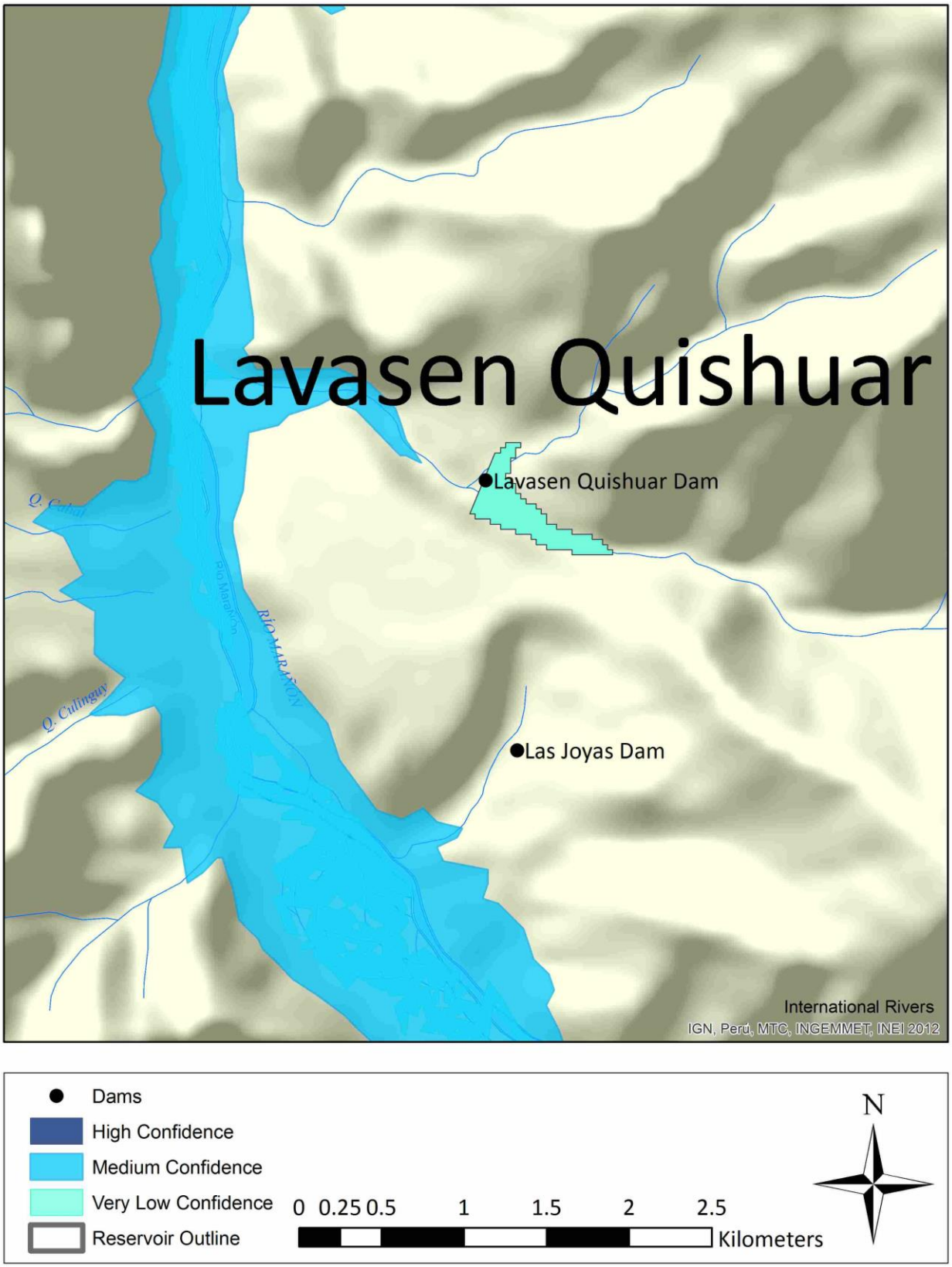

Fig. 15 : Map of projected reservoir surface area of Lavasen Quishuar.

Las Joyas

Río Lavasen y Río Quishuar

Class 4

NAME	Finer and Jenkins, 2012	MEM, 2008
Lat/long	-7.6138603154, -77.6831192479	
Potencial (MW)	61	61
Caída (m)		950
Caudal diseño (m^3/s)		8

Table 28 : Data compiled for Las Joyas.

Pataz 1

Río Marañón

Class 2 – Medium Confidence

SOURCE	Finer and Jenkins, 2012	MARA 320 - ALT 5 (MEM, 1976)	CNDEARM, 2011
Lat/long	-7.86423724955, -77.6243019799	-7.866667, -77.616667	
Distancia largo (km)	1 (up on hillslope)		
Potencial (MW)	320	283	320
Caída (m)		120.4	140
Elevación (m.s.n.m.)	1309(***see note)		
Altura de la presa (m)		90	
Caudal diseño (m^3/s)			130
Caudal promedio (m^3/s)		281.8	

Table 29 : Data used for Pataz 1.

Notes : ***The elevation provided by Finer was much greater than the elevation from the ASTER data, which was at ~1250 m.s.n.m..

Project Specifications	
Elevación (m.s.n.m.)	1250
Altura de la presa (m)	90
Nivel máximo del agua (m.s.n.m.)	1340
Área de embalse (km^2)	4

Table 30 : Project specifications and estimated reservoir inundation area. .

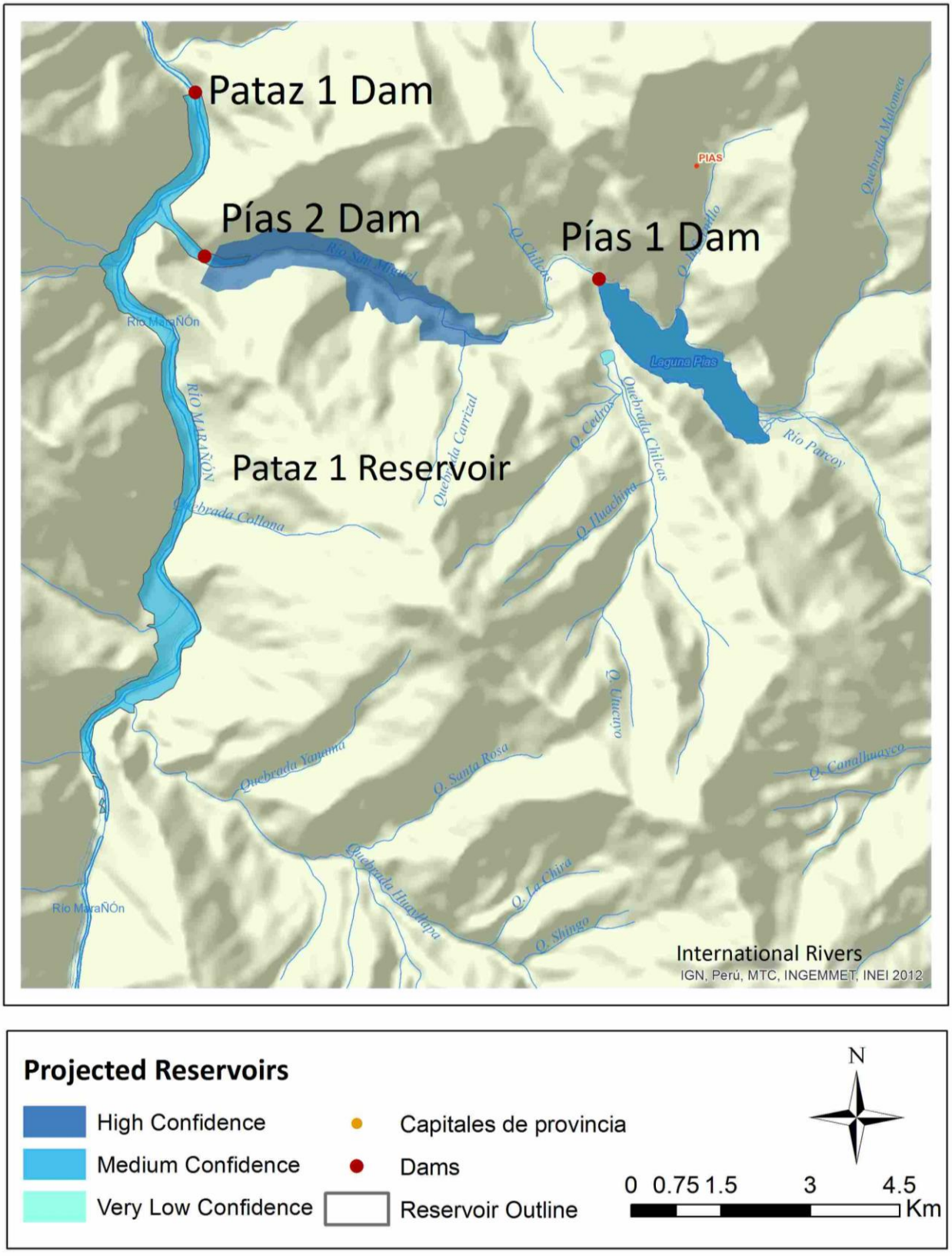

Fig. 16 : Map of projected reservoir surface area of Pataz 1.

Pías 2

Río San Miguel

Class 1 – High Confidence

SOURCE	Finer and Jenkins, 2012	Consorcio Minero Horizonte, 2014	MEM, 2008
Lat/long	-7.87988603861, -77.62842249		
Potencial (MW)	16.6	16 – 24	16.6
Caída (m)		325	270
Elevación (m.s.n.m.)	1298		
Altura de la presa (m)	-	-	-
Caudal diseño (m^3/s)		9	6
Cota máxima de Embalse (m.s.n.m.)		1605	

Table 31 : Data used for Pías 2.

Notes : The location of Pías 2 was directly below that of Pías 1, forming a cascade starting from Yuracyacu and passing through Pías 1. The MW Potential was still under study and was a project of the Consorcio Minero Horizonte. Although the coordinate provided by Finer and Jenkins (2012) was directly at the confluence of the Marañón and Río San Miguel, it was assumed that the dam would be placed slightly upstream from the confluence on the tributary.

Project Specifications	
Elevación (m.s.n.m.)	1303
Altura de la presa (m)	302 ***
Nivel máximo del agua (m.s.n.m.)	1605
Área de embalse (km^2)	3

Table 32 : Project specifications and estimated reservoir inundation area. .

***Note that the altura de la presa (m) was calculated by subtracting the elevation of the estimated dam site from the cota máximo de embalse (m.s.n.m.) provided by the Consorcio Minero Horizonte. A 302 m tall dam is very unlikely at this site; the inundated area is most definitely overestimated.

Pías 1

Río San Miguel

Class 1 – High Confidence

SOURCE	Consorcio Minero Horizonte, 2014b
Lat/long	-7.889548, -77.568110
Potencial (MW)	12.67
Caída bruta (m)	250.8
Caída neta (m)	235
Altura de la presa (m)	19
Caudal diseño (m^3/s)	6

Table 33 : Project specifications.

Notes : This project has already been built by the Consorcio Minero Horizonte. The lat/long was taken from google earth imagery of the reservoir. Note that in the map, the point provided by Finer and Jenkins (2012) is close to where the powerhouse is located and not the actual structure of the dam. The outline of the flooded area was traced from the Peruvian Cartography Server provided by INGEMMET through GEOCATMIN (INGEMMET, 2014). The área de embalse was calculated to be 2 km^2.

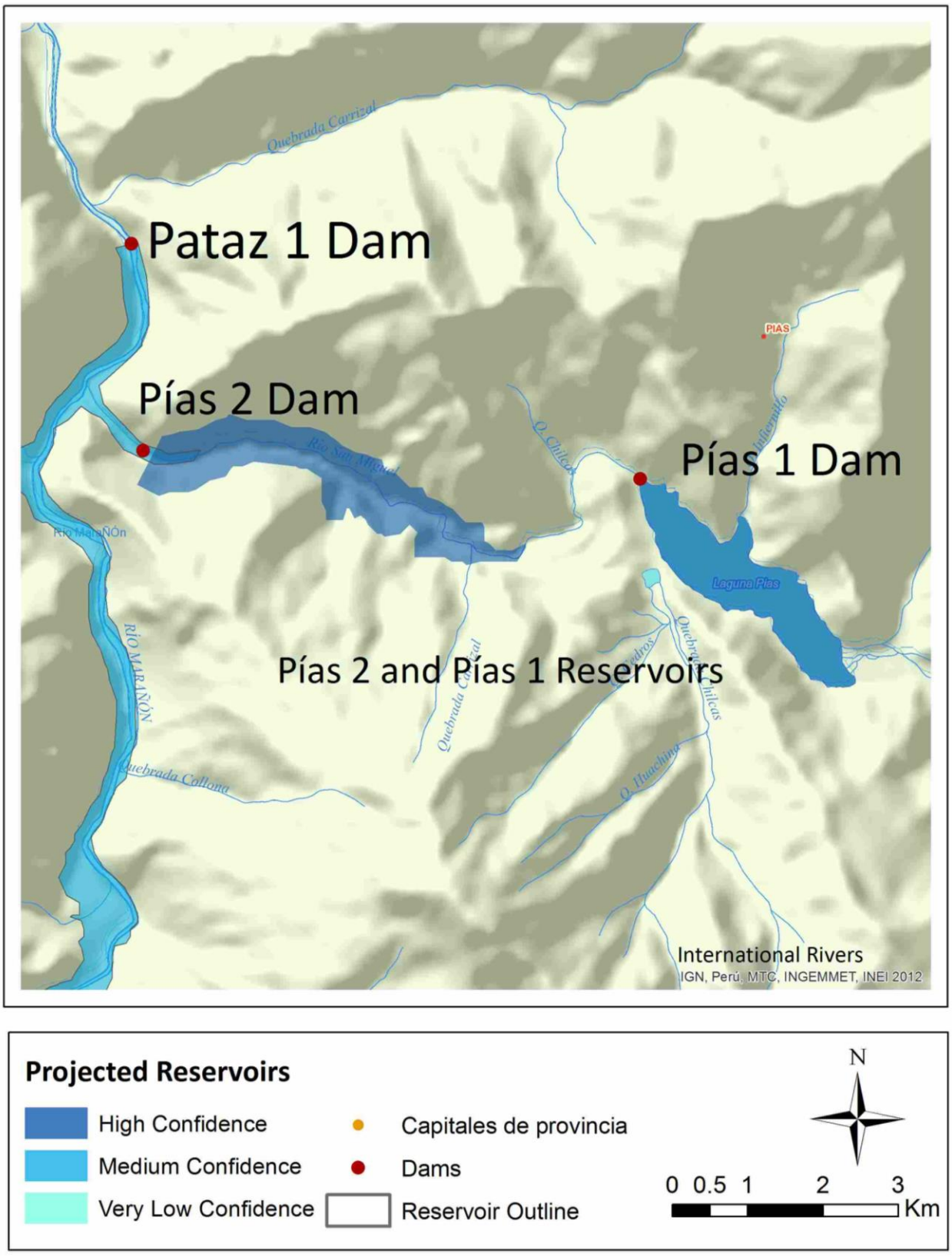

Fig. 17 : Map of projected reservoir surface area of Pías 2 and Pías 1.

Yuracyacu

Río Yuracyacu

Class 4

SOURCE	Consorcio Minero Horizonte (2012, 2014c)
Lat/long	-7.921491,-77.522965
Potencial (MW)	7
Caída bruta (m)	485
Altura de la presa (m)	unknown
Caudal diseño (m^3/s)	2
La casa de máquinas (m.s.n.m.)	1918
La toma (m.s.n.m.)	~2347

Table 34 : Data gathered on Yuracyacu.

San Pablo

Río Marañón

Class 2 – Medium Confidence

SOURCE	Finer and Jenkins, 2012	MARA290 - ALT 7 (MEM, 1976)	CNDEARM, 2011
Lat/long	-8.27210963155, -77.51751492	-8.2667, -77.517	
Distancia largo (km)	0.6		
Potencial (MW)	390	379.5	390
Caída (m)		173.7	185
Elevación (m.s.n.m.)	1575		
Altura de la presa (m)		73	
Caudal diseño (m^3/s)			118
Caudal promedio (m^3/s)		262	

Table 35 : Data gathered for San Pablo.

Notes : The coordinate for MARA290 was on the hillside, but was very close to the point provided by Finer and Jenkins (2012) in the river once a line was drawn perpendicular to the river streamline from that point.

Project Specifications	
Elevación (m.s.n.m.)	1575
Altura de la presa (m)	73
Nivel máximo del agua (m.s.n.m.)	1648
Área de embalse (km^2)	9

Table 36 : Project specifications and estimated reservoir inundation area. .

Fig. 18 : Map of projected reservoir surface area of San Pablo.

Rúpac

Río Marañón

Class 3 – Very Low Confidence

SOURCE	Finer and Jenkins, 2012	MARA250 - ALT 3 (MEM, 1976)	CNDEARM, 2011
Lat/long	-8.51114367394, -77.3606	-8.5,-77.35	
Distancia largo (km)	1.6		
Potencial (MW)	300	283	300
Caída (m)		138.7	175
Elevación (m.s.n.m.)	1698 (***see note)		
Altura de la presa (m)		159	
Caudal diseño (m^3/s)			98
Caudal promedio (m^3/s)		244.7	

Table 37 : Data used for Rúpac.

Notes : The coordinate for MARA250 was on the hillside, but when a line was drawn from this point to the river at a perpendicular angle to the streamline, the line truncated at a point very close to the coordinate provided by Finer et al. (2012). ***Note that the base elevation from the ASTER data was ~ 1730 m.s.n.m., which was used to calculate the reservoir surface elevation.

Project Specifications	
Elevación (m.s.n.m.)	1730
Altura de la presa (m)	159
Nivel máximo del agua (m.s.n.m.)	1889
Área de embalse (km^2)	15

Table 38 : Project specifications and estimated reservoir inundation area. .

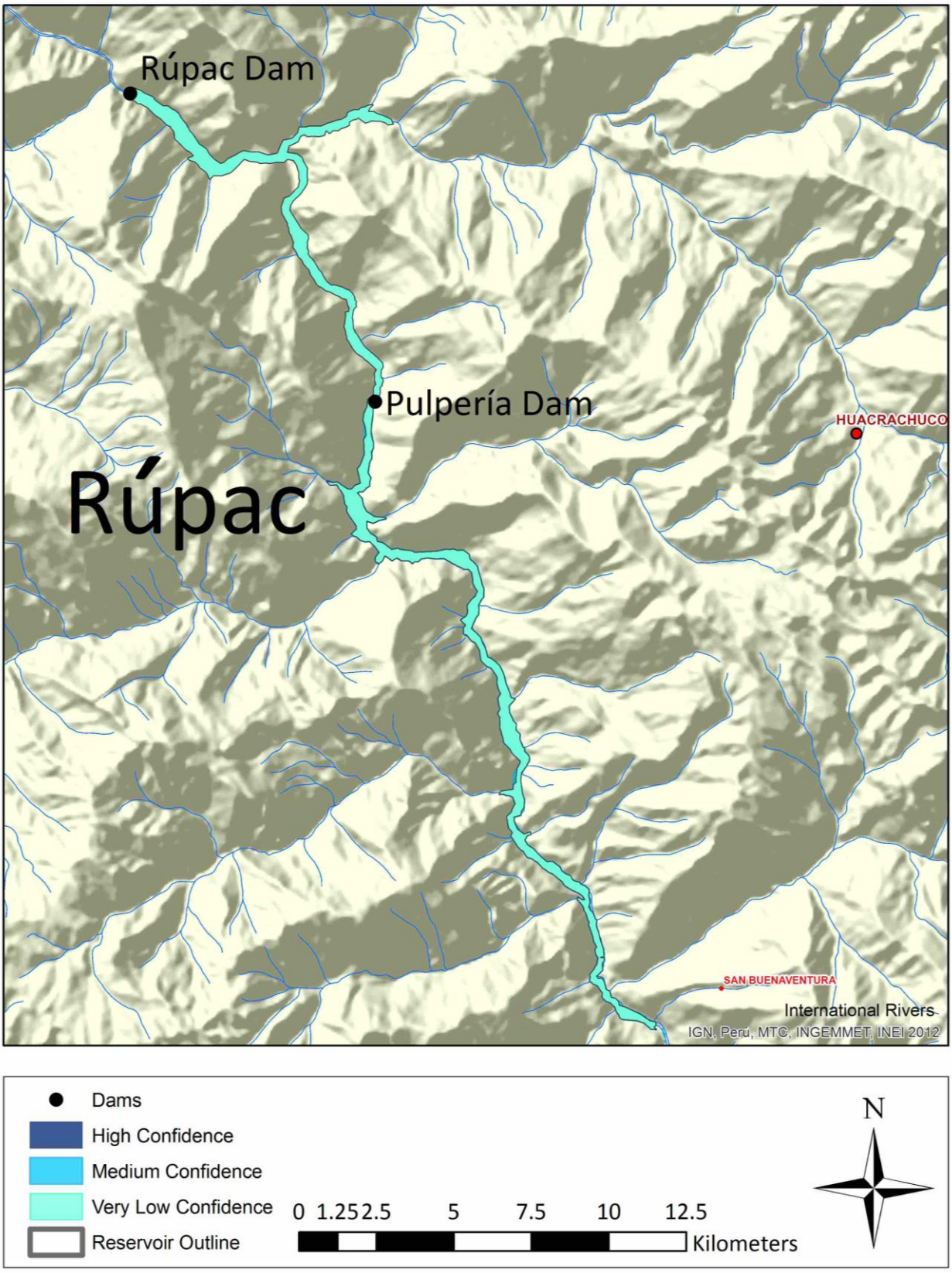

Fig. 19 : Map of projected reservoir surface area of Rúpac.

Pulpería

Río Marañón

Class 2 – Medium Confidence

SOURCE	Finer and Jenkins, 2012	MARA230 - ALT 5 (MEM, 1976)	CNDEARM, 2011
Lat/long	-8.60056, -77.2895	-8.6, -77.2833	
Distancia largo (km)	0.7		
Potencial (MW)	220	247.5	220
Caída (m)		133.3	150
Elevación (m.s.n.m.)	2054 (***note)		
Altura de la presa (m)		88	
Caudal diseño (m^3/s)			82
Caudal promedio (m^3/s)		222.6	

Table 39 : Data collected for Pulpería.

Notes : An alternative for MARA230 with 252.4 MW Potential had a dam height of 121m, which was 33m higher than ALT-5 listed above although the MW value was only 4.9 higher than that of Alternative 5 listed above. *** In the ASTER data, the base elevation of this dam was ~ 1800 m.a.s.l. - this was used to create the inundation shapefile.

Given the similar maximum reservoir water surface elevations of Pulpería and Rupac, it is unlikely that both would be built.

Project Specifications	
Elevación (m.s.n.m.)	1800
Altura de la presa (m)	88
Nivel máximo del agua (m.s.n.m.)	1888
Área de embalse (km^2)	8

Table 40 : Project specifications and estimated reservoir inundation area. .

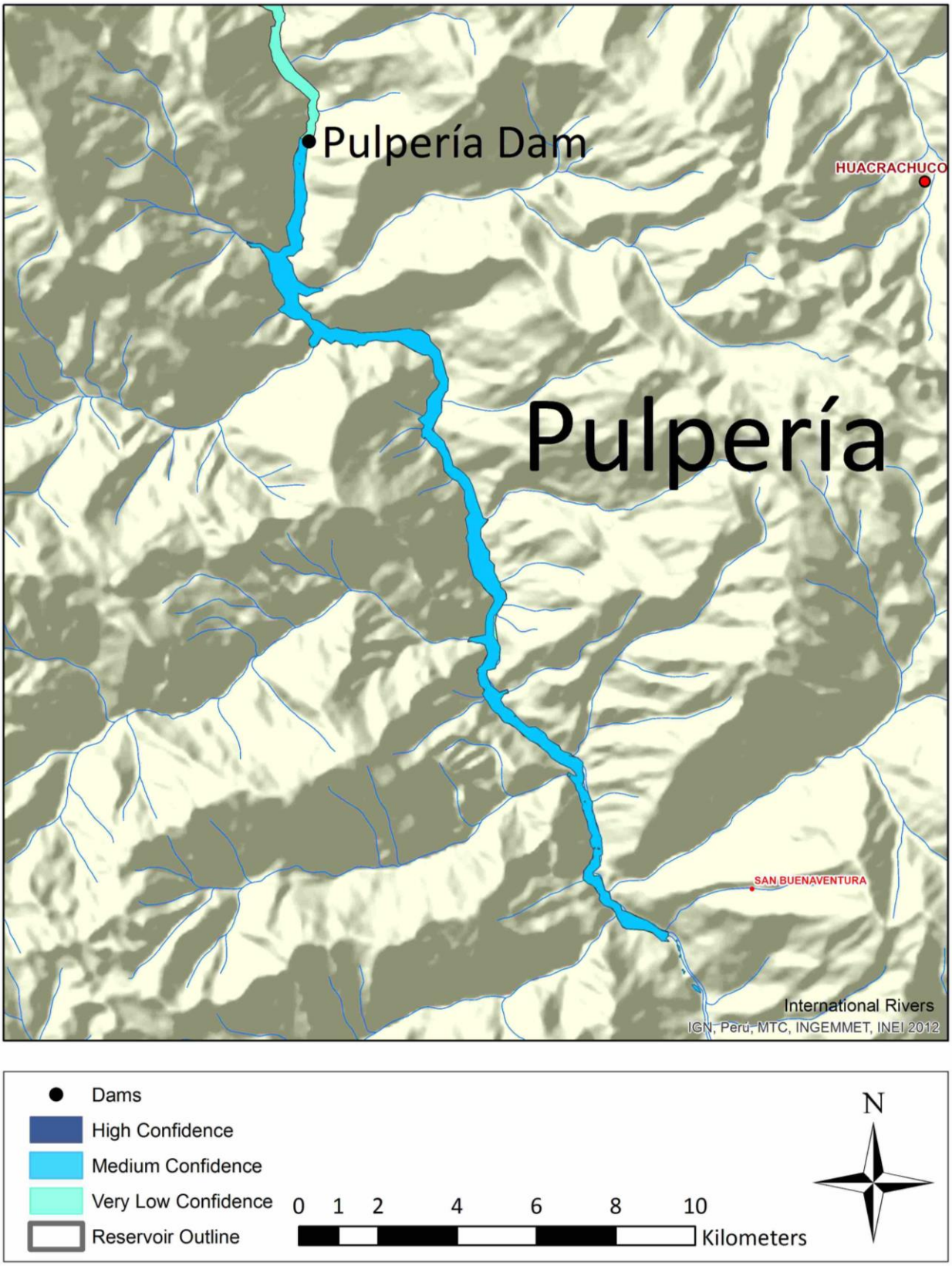

Fig. 20 : Map of projected reservoir surface area of Pulpería.

Yanamayo

Río Marañón

Class 3 – Very Low Confidence

NAME	Finer and Jenkins, 2012	MARA210 - ALT 2 (MEM, 1976)	CNDEARM, 2011
Lat/long	-8.82239307248, -77.19002419	-8.817,-77.183	
Distancia largo (km)	1		
Potencial (MW)	160	206.2	160
Caída (m)		117.2	160
Elevación (m.s.n.m.)	1885		
Altura de la presa (m)		111	
Caudal diseño (m^3/s)			75
Caudal promedio (m3/s)		211	

Table 41 : Data collected for Yanamayo.

Notes : The coordinates for MARA210 were on a hillside. Once a line was drawn from this coordinate to the river that was perpendicular to the river streamline, it almost intersected the coordinate provided by Finer and Jenkins (2012).

Project Specifications	
Elevación (m.s.n.m.)	1885
Altura de la presa (m)	111
Nivel máximo del agua (m.s.n.m.)	1996
Área de embalse (km^2)	16

Table 42 : Project specifications and estimated reservoir inundation area.

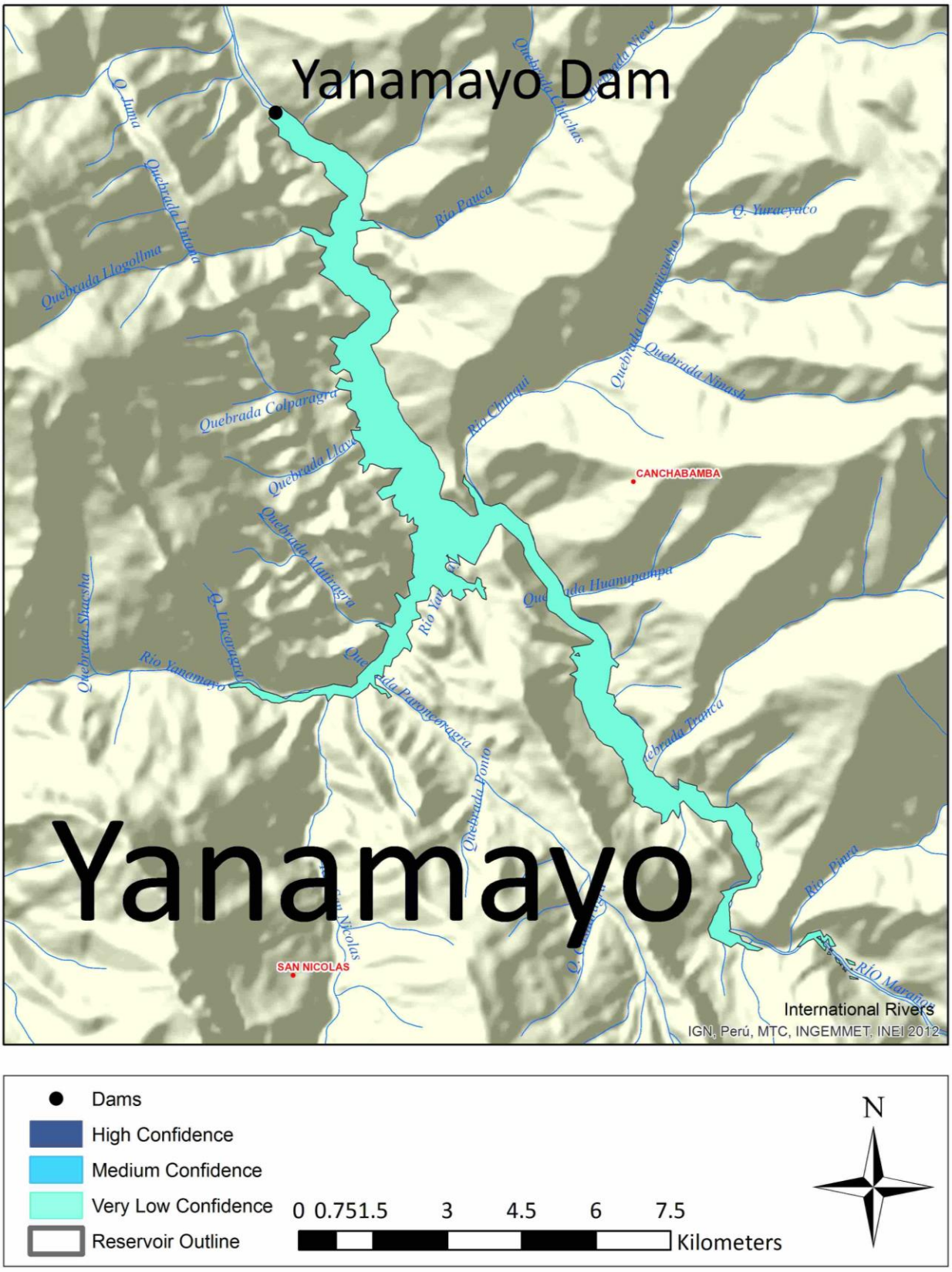

Fig. 21 : Map of the projected reservoir surface area of Yanamayo.

Puchka

Río Marañón

Class 2 – Medium Confidence

SOURCE	Finer and Jenkins, 2012	MARA 180 - ALT 3 (MEM, 1976)	CNDEARM, 2011
Lat/long	-9.09071998544, -76.9053388676	-9.083,-76.9	
Distancia largo (km)	1		
Potencial (MW)	140	140.2	140
Caída (m)		153.7	130
Elevación (m.s.n.m.)	2622 (*** see note)		
Altura de la presa (m)		175	
Caudal diseño (m^3/s)			56.5
Caudal promedio (m3/s)		109.4	

Table 43 : Data collected for Puchka.

Notes : The coordinate for MARA180 was on a hillside but matched up well with the position of the dam according to Finer and Jenkins (2012) in the river. The elevation provided by Finer and Jenkins may be too high – in the ASTER dataset, the map displayed distortions around this area. However, a contour map provided by the government of Perú (IGN, 50m contours) displayed a 2200 m.s.n.m. contour ending close to this coordinate. This elevation was used for the dam base elevation. Since a large portion of the ASTER map was distorted in this area, the 50-m contour map was used to define the elevations for the estimated reservoir shapefile.

Project Specifications	
Elevación (m.s.n.m.)	2200
Altura de la presa (m)	175
Nivel máximo del agua (m.s.n.m.)	2375
Área de embalse (km^2)	6

Table 44 : Project specifications and estimated reservoir inundation area.

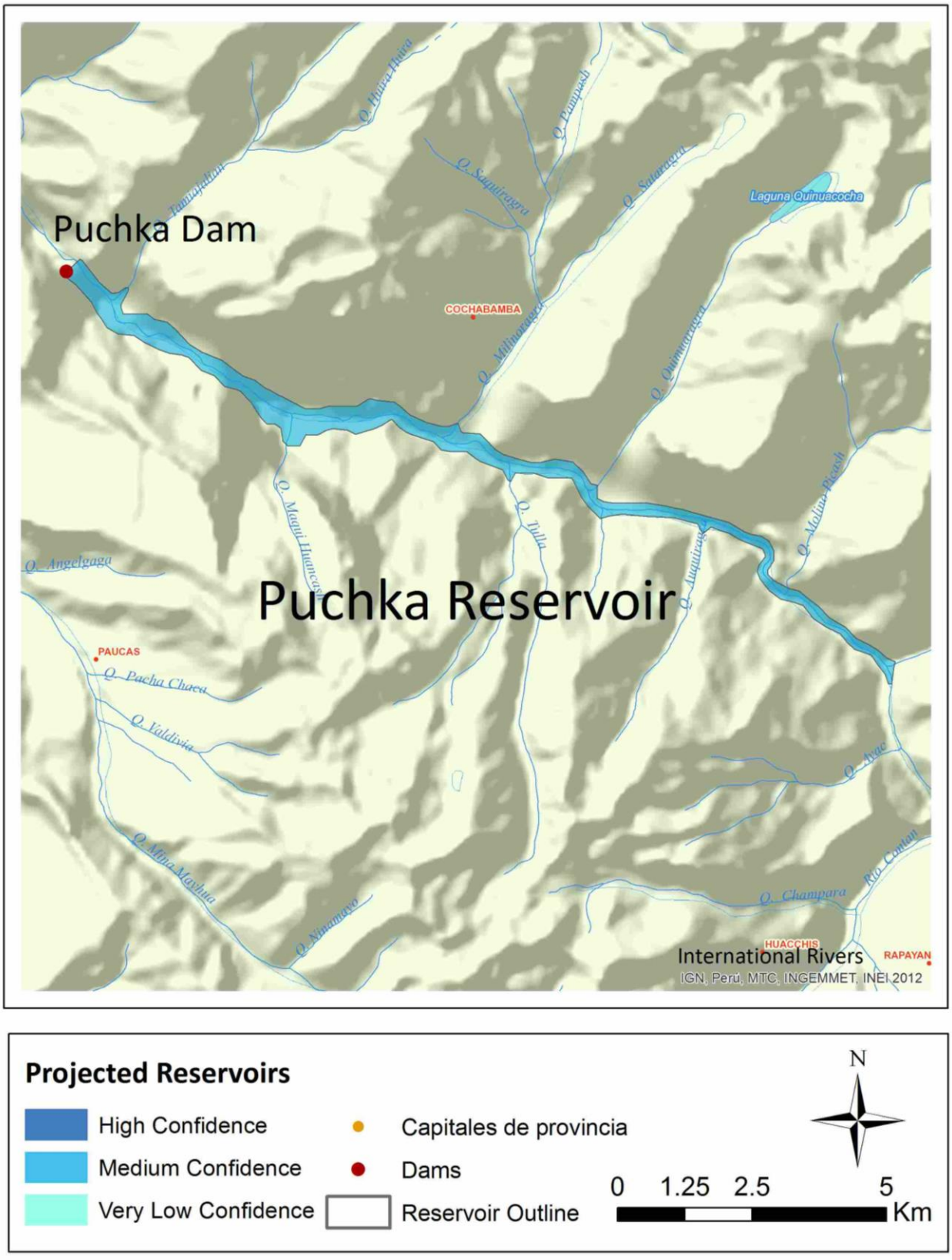

Fig. 22 : Map of the projected reservoir surface area of Puchka.

Llata 2

Río Marañón

Class 3 – Very Low Confidence

SOURCE	Finer and Jenkins, 2012	MARA 150 - ALT 6 (MEM, 1976)	CNDEARM, 2011
Lat/long	-9.18582,-76.7529	-9.183,-76.75	
Distancia largo (km)	0.4		
Potencial (MW)	200	185	200
Caída (m)		213	300
Elevación (m.s.n.m.)	2501 (*** see note)		
Altura de la presa (m)		71	
Caudal diseño (m^3/s)			37.5
Caudal promedio (m3/s)		104	

Table 45 : Data collected for Llata 2.

Notes : The coordinate for MARA150 was on a hillside but matches up well with the position of the dam according to Finer and Jenkins (2012) in the river. ***The base elevation on the ASTER DEM was 2410 m.s.n.m. and was used for the reservoir shapefile.

Project Specifications	
Elevación (m.s.n.m.)	2410
Altura de la presa (m)	71
Nivel máximo del agua (m.s.n.m.)	2481
Área de embalse (km^2)	2

Table 46 : Project specifications and estimated reservoir inundation area for Llata 2.

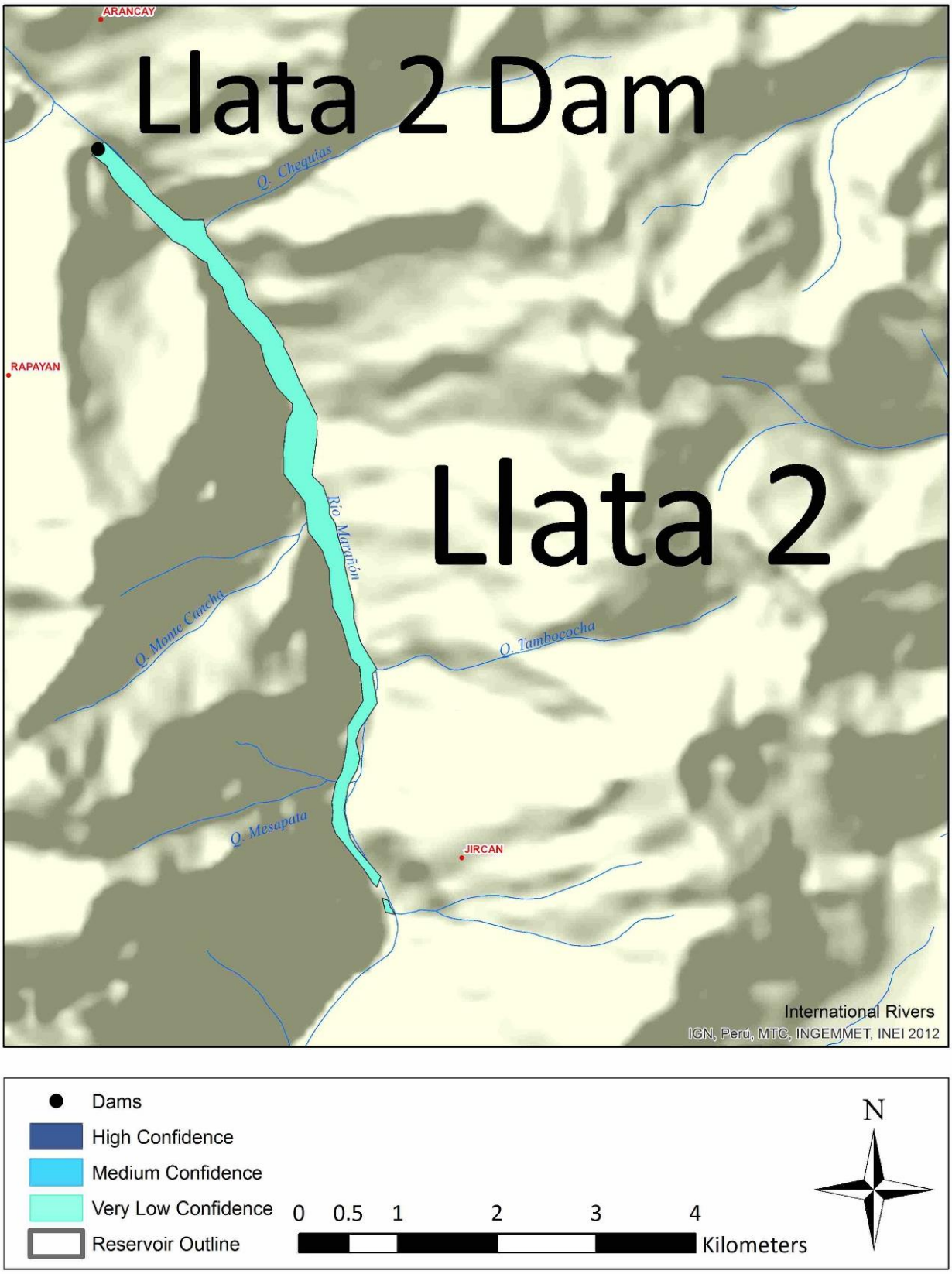

Fig. 23 : Map of the projected reservoir surface area of Llata 2.

Llata 1
Río Marañón

Class 2 – Medium Confidence

SOURCE	Finer and Jenkins, 2012	MARA120 - ALT 6 (MEM, 1976)	CNDEARM, 2011
Lat/long	-9.4,-76.7833	-9.4,-76.7833	
Distancia largo (km)	0		
Potencial (MW)	210	251.4	210
Caída (m)		322	325
Elevación (m.s.n.m.)	2787(***see note)		
Altura de la presa (m)		120	
Caudal diseño (m^3/s)			36
Caudal promedio (m^3/s)		93.6	

Table 47 : Data collected for Llata 1.

Notes : ***An elevation of 2750 m.s.n.m. was used for the base level of the dam after comparing the elevation of the coordinate on the ASTER DEM and the IGN 50-meter contour maps.

Project Specifications	
Elevación (m.s.n.m.)	2750
Altura de la presa (m)	120
Nivel máximo del agua (m.s.n.m.)	2870
Área de embalse (km^2)	9

Table 48 : Project specifications and estimated reservoir inundation area for Llata 1.

Fig. 24 : Map of the projected reservoir surface area of Llata 1.

Marañón

Río Marañón

Class 1 – High Confidence

SOURCE	Hidroeléctrica Marañon S.R.L., 2012
Lat/long	-9.577280, -76.745088
Potencial (MW)	88.3
Caída neta (m)	89.6
Altura de la presa (m)	17.5
Caudal diseño (m^3/s)	110
Cota máxima de Embalse (m.s.n.m.)	2955

Table 49 : Project specifications used for Marañón.

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Notes : The calculated área de embalse (km^2) was 2 km^2.

Fig. 25 : Map of the projected reservoir surface area of Marañón.

Vizcarra

Río Marañón

Class 4

SOURCE	CNDEARM, 2011
Potencial (MW)	140
Caída (m)	250
Caudal diseño (m^3/s)	31

Table 50 : Data collected for Vizcarra.

Notes : Information on this dam was difficult to obtain. The exact location was unknown, although its location according to a map from CNDEARM (2011) was near the Vizcarra confluence. It was upstream of the Marañón Dam.

Additional Dams

Table 51 lists additional dams that exist in the Marañón watershed that are not located on the mainstem river.

	Source	Potencial (MW)	Altitud (m.s.n.m.)	Caída (m)	Caudal diseño (m^3/s)
El Muyo (Existing)	(Vidal, 2010; Alumnos de la Universidad nacional de Cajamarca, 2013)	5.4	497	200	5
La Pelota (Existing)	Centro de Conservación de Energía y del Ambiente, 2011	3	882	285	1.32
Caclic (Existing)	MEM, 2001	4.8	-	-	-
Centauro I (In construction)	MEM, 2001	9.9	-	-	-
Centauro II (Planned)	MEM, 2001	20	-	-	-
Maria Jiray (Existing)	MEM, 2001	1.54	-	-	-
Tulpac/Palenque (Pusac) (Planned)	Lynge, 2002	16	620	472	3.85

Huallanca Nueva (Existing)	MEM, 2001	4.3			
Santa Fortunata (Planned)	Finer and Jenkins, 2012	25.2	2818		

Table 51: Additional dams in the Marañón Basin.

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