INTERNATIONAL COURT OF JUSTICE

DISPUTE OVER THE STATUS AND USE OF THE WATERS OF THE SILALA

(CHILE v. BOLIVIA)

MEMORIAL OF THE REPUBLIC OF CHILE

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CHAPTER 1
INTRODUCTION

A. Introductory remarks

1.1. The present proceedings were commenced by the Application of the Government of the Republic of Chile ("Chile") lodged with the Registry of the Court on 6 June 2016. This Memorial is submitted by Chile in accordance with the time-limits fixed by the Court in its Order of 1 July 2016 with respect to the filing of written pleadings by Chile and the Government of the Plurinational State of Bolivia ("Bolivia").

1.2. Chile seeks a declaration from the Court to the effect that the watercourse that is the subject of these proceedings, the Silala River,[1] is an international watercourse with ensuing rights and obligations for its riparian States.

1.3. The case is a straightforward one.

(a) The Silala River rises from groundwater springs located at above 4323 metres altitude in Bolivia, at a few kilometres north-east of the Chile-Bolivia boundary. The Silala River then descends from that point down a natural slope and crosses the boundary at an altitude of 4277 metres. The Silala River is thus an international watercourse as recognised in international law: it is a system of surface waters and groundwaters that, by virtue of their physical relationship, constitute a unitary whole flowing into a common

[1] In historic maps and documents sometimes also referred to as "Río Siloli" or "Río Cajón"; or not differentiated from "Río San Pedro" to which it is a tributary.

terminus, while parts of the river are situated in different States, namely, Bolivia and Chile. Chile and Bolivia have also recognised the international status of the Silala River for more than one hundred years.

(b) A number of well-established rights and obligations for Bolivia and Chile follow from the status of the Silala River as an international watercourse. So far as is material for the current case, these concern rights to equitable and reasonable use, as well as obligations with respect to prevention of harm, cooperation, notification and exchange of information and, where appropriate, the conduct of environmental impact assessment.

(c) The relevant standards are now well-established as a matter of customary international law, and their application in this case raises few issues of complexity given the essential facts. As to these, the basic position is that Chile has made use of the waters of the Silala River for more than 100 years, whilst Bolivia has to date made virtually no use of those waters in Bolivia.

(d) It is emphasised that Chile is not seeking through declaratory relief to impinge on any future use by Bolivia of the Silala River – to the extent, of course, that any such future use is consistent with international law. Thus, any such future use of Bolivia would need to meet the standard of equitable and reasonable utilization, while there would always have to be compliance by Bolivia with the obligation not to cause significant harm, as well as the related obligations concerning cooperation, notification, exchange of information and, where appropriate, the conduct of environmental impact assessment.

1.4. In addition, by way of essential background, the Court should be aware that the Silala River is located in one of the driest places on earth. It follows that, although it is only small in size (with a flow when entering Chile of an average of 170 litres per second (l/s)), the waters of the Silala River have had and still have a very particular importance for Chile. Thus Chile has been, and still is, using the waters of the Silala for various municipal and industrial uses in this exceptionally arid part of Chile. The city of Antofagasta (at a distance of about 300 kilometres to the south-west of the Silala River) and the towns of Sierra Gorda and Baquedano, among others, have at different times relied on Silala waters. Around 30% of the water currently extracted from the Silala River is still used for human consumption at various mining installations. It is in light of the particular importance of the Silala waters to Chile, and in response to a series of challenges by Bolivia to the status and usage of the Silala River, that this case has been brought.

B. The dispute before the Court

1.5. The dispute now before the Court concerning the status and use of the Silala River is limited in nature. By its Application, Chile asks the Court to determine the status of the Silala River system as an international watercourse, the use of which is governed by customary international law. As a natural corollary of this, Chile asks the Court to declare that Chile is entitled to the equitable and reasonable use of the waters of the Silala River and, in addition, to declare that – pursuant to that standard of equitable and reasonable utilization – Chile is entitled to its current use. The dispute also concerns the obligations of Bolivia that arise by virtue of the status of the Silala River system as an international watercourse.

1.6. It is Chile's position that, once the status of the Silala River has been confirmed, the issues of use and restrictions on use can be decided with little difficulty. The declarations sought by Chile merely call for the application of well-established principles of general international law against a backdrop of unusually straightforward facts.

1.7. As to the issue of status, it is to be noted that, up until 1999, there was no dispute of any kind between the Parties as to the status of the Silala River as an international watercourse. In multiple different ways, and at multiple different occasions across a period of almost 100 years, Bolivia had recognised such status.

1.8. From September 1999, however, Bolivia has made various claims with respect to the Silala River, including that the Silala is not a river at all, that it is an exclusively Bolivian water resource originating from springs in Bolivian territory, that the waters of these springs are diverted to Chile by means of an artificial system of channels, and that Bolivia is owed economic compensation for past and present use of the waters of the Silala. Such claims culminated in statements made in March 2016 by the President of Bolivia, Mr. Evo Morales, that Chile was "stealing" Silala waters from Bolivia and that Bolivia would present a claim before this Court.[2] It was, however, announced shortly afterwards by the Bolivian Minister of Foreign Affairs that the preparation of the claim would take at least two years.[3]

1.9. In these circumstances, and bearing in mind the particular importance to it of the waters of the Silala River, Chile took the decision to bring the current proceedings without delay. As follows from what has been said

[2] Página Siete Digital, "*Bolivia Will Sue Chile over the Silala in The Hague*", La Paz, 26 March 2016. **Chile's Memorial ("CM") Annex 72.3.**

[3] La Razón, "*The Minister of Foreign Affairs Foresees Two Years to Prepare the Claim for the Silala*", La Paz, 8 April 2016. **CM Annex 73.**

above, Chile considers the issues now in dispute to be legally clear cut. However, it also considers it undesirable – both to relations between these two States and to the legal certainty needed by Chilean users of the waters of the Silala – for Chile to have been placed in a position where its rights as a riparian State are being contested, and its legitimate use of the waters of the Silala River referred to as theft. Hence, Chile lodged the current Application on 6 June 2016.

C. Jurisdiction of the Court

1.10. The position on jurisdiction is straightforward and, in light of the announcements of Bolivia of March-April 2016 referred to above, it is presumed that there will be no issue between the Parties in this respect.

1.11. Both Bolivia and Chile are parties to the American Treaty on Pacific Settlement, the "Pact of Bogota", of 30 April 1948. Chile ratified the Pact of Bogotá on 21 August 1967.[4] Bolivia did so on 9 June 2011, with a reservation to Article VI in as much as it considered that "pacific procedures may also be applied to controversies arising from matters settled by arrangement between the Parties, when the said arrangement affects vital interests of a State".[5] Chile submitted an objection to this reservation and declared that it precludes the entry into force of the Pact of Bogotá between Chile and Bolivia.[6] Bolivia withdrew

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[4] Chilean Supreme Decree N° 526 enacting the Pact of Bogotá, 21 August 1967. **CM Annex 57.** See also: http://www.oas.org/juridico/english/sigs/a-42.html

[5] Note OEA-SG-111-11 from the Bolivian Mission before the OEA (Organization of American States or OAS in English), 9 June 2011, attaching the Instrument of Ratification of the Pact of Bogotá. **CM Annex 53.1.**

[6] Chile's Objection to the Reservation by Bolivia to the Pact of Bogotá, 10 June 2011. **CM Annex 62.**

this reservation on 3 April 2013.[7] No pertinent reservation made by either Party is in force.

1.12. The Court therefore has jurisdiction over the present dispute in accordance with the provisions of Article 36 of its Statute and by virtue of Article XXXI of the Pact of Bogota, which reads as follows:

> "In conformity with Article 36, paragraph 2, of the Statute of the International Court of Justice, the High Contracting Parties declare that they recognize in relation to any other American State, the jurisdiction of the Court as compulsory *ipso facto*, without the necessity of any special agreement so long as the present Treaty is in force, in all disputes of a juridical nature that arise among them concerning:
>
> (a) The interpretation of a treaty;
>
> (b) Any question of international law;
>
> (c) The existence of any fact which, if established, would constitute the breach of an international obligation;
>
> (d) The nature or extent of the reparation to be made for the breach of an international obligation."[8]

1.13. The dispute now before the Court concerns matters falling under (b), (c) and (d) of Article XXXI, i.e. various questions of international law, as well as issues of breach and of reparation.

1.14. Chile has sought, without success, to resolve the disputed issues as to the status and use of the Silala River through negotiations with Bolivia. The two Parties were engaged in a series of bilateral meetings on these issues between

[7] Note MPB-OEA-ND-039-13 from the Bolivian Mission before the OEA, 8 April 2013, attaching the Instrument of Withdrawal of Reservation to the Pact of Bogotá. **CM Annex 53.2.**

[8] American Treaty on Pacific Settlement (Pact of Bogotá), signed at Bogotá on 30 April 1948. **CM Annex 4.**

the years 2000 and 2010. Ultimately, these meetings terminated without result, due to Bolivia's insistence – also reiterated on various occasions since 2010 – on denying that the Silala River is an international watercourse or even a watercourse at all, and that it has rights to 100 per cent use of its waters.

D. Summary of Chile's case

1.15. There are two elements to Chile's case.

1.16. The **first** element concerns the status of the Silala River as an international watercourse. This should (still) be a matter of common ground between the Parties.

(a) The Silala River is a watercourse as that term has come to be defined as a matter of international law. As is clear from any visual inspection, and as has been set out in detail in the reports of the experts Drs. Howard Wheater and Denis Peach instructed by Chile,[9] the Silala River is a naturally flowing body of water. In particular, the Silala River constitutes a system of surface waters and groundwaters that, by virtue of their physical relationship, constitute a unitary whole and flow into a common terminus. As is also as clear as can be, parts of the river and of the river system are situated in different States, namely, Bolivia and Chile. It is therefore an international watercourse.

(b) Further, in numerous maps, and through a series of official acts and statements, the Silala River has been recognized by Bolivia as

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[9] Wheater, H.S. and Peach, D.W., *The Silala River Today – Functioning of the Fluvial System* (**Exp. Rep. 1)** and Peach, D.W. and Wheater, H.S., *The Evolution of the Silala River, Catchment and Ravine* **(Exp. Rep. 2)**.

a river that flows from Bolivia into Chile, i.e. as an international watercourse. The many maps and documents that evidence this date from 1904 or earlier (a map showing (*inter alia*) the Silala River crossing from Bolivia into Chile was appended to the 1904 Treaty of Peace and Amity between Bolivia and Chile) up to 1999.

(c) The assertion that the Silala River was diverted into Chilean territory through the construction of channels is obviously incorrect. The Silala River has flowed down along its current path, along a naturally-incised ravine, for at least 8,400 years. In simple terms, there is nowhere for the waters of the Silala to flow except down the slopes of the Bolivian highlands into Chile. The construction of channels to which Bolivia has referred could make, and did make, no difference to the direction of flow. It should however be noted that the channels at issue were constructed in 1928 pursuant to a concession granted by Bolivia itself some 20 years earlier in 1908. It is thus all the more difficult to see how Bolivia can make a point by reference to the existence of these channels given that (i) it consented to their construction and (ii) the water was in any event flowing into Chile and being used without interruption in Chile in the many years prior to construction of these channels (in 1928).

1.17. The **second** element of Chile's case concerns the legal consequences that flow from the status of the Silala River as an international watercourse.

(a) The first such consequence is that Chile has, what the Court has called a basic right to an equitable and reasonable sharing of the

resources of an international watercourse,[10] here the waters of the Silala River. As to this, Chile's utilization of the Silala River, which dates back more than 100 years, has always been and remains equitable and reasonable. As a result of various offtakes and pipelines constructed in the first half of the twentieth century, the waters have been used to supply the Chilean port city of Antofagasta as well as various other towns of drinking water, alongside use for railways (steam trains), mining and industry. The water has been, and is, of great importance to this arid region. Bolivia, by contrast, has never made any significant use of the waters. There is no Bolivian town or location for industry (or other potential usage) within close range of the source of the river in Bolivia, and the natural flow of the river is in one direction only – away from the source and across the border into Chile. Accordingly, and by reference to the standard of what is reasonable and equitable, Chile is – by reference to the facts as they now stand and without prejudice to any question of what may be reasonable and equitable in the future – entitled to its current use of the waters of the Silala River.

(b) The second consequence is that Bolivia has an obligation to take all appropriate measures to prevent and control pollution and other forms of harm to Chile resulting from any activities in the vicinity of the Silala River. This follows from principles that are long-established as a matter of customary international law.

(c) The third consequence is that Bolivia is also subject to a series of procedural obligations. It has an obligation to cooperate and to

[10] *Gabčíkovo-Nagymaros Project (Hungary/Slovakia), Judgment, I.C.J. Reports 1997,* p. 54, para. 78.

provide Chile with timely notification of any planned measures which may have an adverse effect on the shared water resource, to exchange data and information and to conduct, where appropriate an environmental impact assessment, in order to enable Chile to evaluate the possible effects of any such planned measures. Bolivia has announced certain measures including in May 2012 the construction of a fish farm, a dam and a mineral water bottling plant while, more recently, it has constructed ten houses close to the river. Given the relatively low flow of the Silala River, and its location in such an arid area, such measures might readily have an adverse effect on the shared water resource. However, although Chile has repeatedly sought information from Bolivia as to the nature and extent of the measures announced and has specifically sought information with respect to the use of the river for sanitary arrangements with respect to the recent new constructions, Bolivia has provided no substantive response. Until such time as Bolivia provides information showing the absence of risk of adverse impact and/or confirmation that the announced measures will not in fact proceed, Chile considers that Bolivia is in breach of its procedural obligations and seeks a declaration accordingly.

E. Structure of the Memorial

1.18. The structure of this Memorial is as follows: **chapter 2** sets out the technical facts concerning the Silala River system as well as the history of its use by Chile; **chapter 3** traces the development of the dispute, commencing with the evidence of Bolivia's longstanding acknowledgment of the international nature of the Silala River, but leading to Bolivia's radical change of position in 1999 and the subsequent events that have led to the commencement of the current proceedings; **chapter 4** sets out Chile's case that, contrary to Bolivia's recent assertions, the Silala River system does indeed qualify as an "international watercourse" as that term is defined in international law, and as is also confirmed by a long-standing practice of the Parties; **chapter 5** establishes the legal consequences, i.e. the rights and obligations of the Parties, that follow from that status; finally, in **chapter 6**, Chile turns briefly to the remedies sought (declaratory relief).

1.19. The Memorial is supported by two expert reports by Drs. Howard Wheater and Denis Peach that address the question of whether the Silala River is an international watercourse from a scientific and technical perspective, examining the geological evolution of the river as well as its current status. Their reports are in turn supported by a number of underlying studies into the Silala River system that are annexed to the Memorial.

CHAPTER 2
THE SILALA RIVER SYSTEM

2.1. In this chapter and supporting expert reports, Chile will demonstrate that the Silala River is an international watercourse which has been relied upon in Chile over the course of more than a century.

2.2. Section A establishes that the Silala River is and has long been an active fluvial system, flowing through a natural ravine shaped by the river itself over the course of thousands of years, which begins on what is now Bolivian territory and crosses the border into Chile, following the topographical gradient. Section B describes the municipal, industrial and mining uses of the Silala River in Chile from the beginning of the twentieth century up to today, accounting for the significance of this natural resource for the livelihood and development of one of the driest regions on the planet.

A. The Silala River is and has long been an active fluvial system

2.3. The Silala River originates in the Potosí region in Bolivia, from groundwater springs in the Orientales and Cajones wetlands, located at high altitude, above 4323 metres above sea level ("m.a.s.l.").[11] In Bolivia, the discharge from the Orientales springs enters a ravine where it is joined by the discharge from the Cajones springs. After this junction, the river flows within the ravine across the Chile-Bolivia boundary at 4277 m.a.s.l. and is supplemented by further groundwater sources in Chile.[12] The Silala River is one of the main tributaries of the San Pedro River, which in turn is a tributary to the Loa River,

[11] **Exp. Rep. 1**, p. 7.

[12] **Exp. Rep. 1**, p. 7.

the main watercourse in the Atacama Desert in the Chilean Antofagasta Region (Figure 1).

2.4. Figure 2 shows the main topographic features of the Silala River basin, the key features of the river network, and relevant installations in Bolivian and Chilean territory, including the Military Post in Bolivia, the Inacaliri Police Station in Chile, and the two intakes (FCAB Intake and CODELCO Intake), also in Chile.

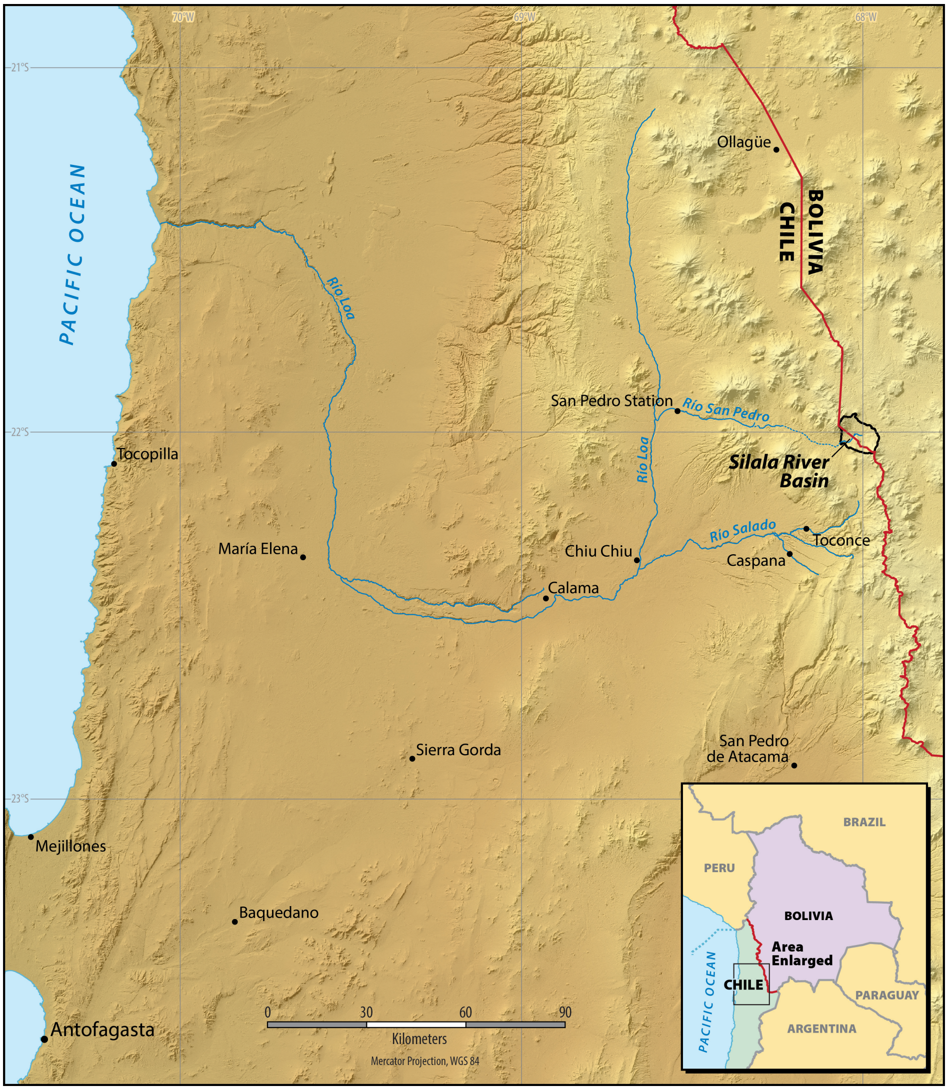

Figure 1. The Loa River and its main tributaries. **Exp. Rep. 1, Figure 1.**

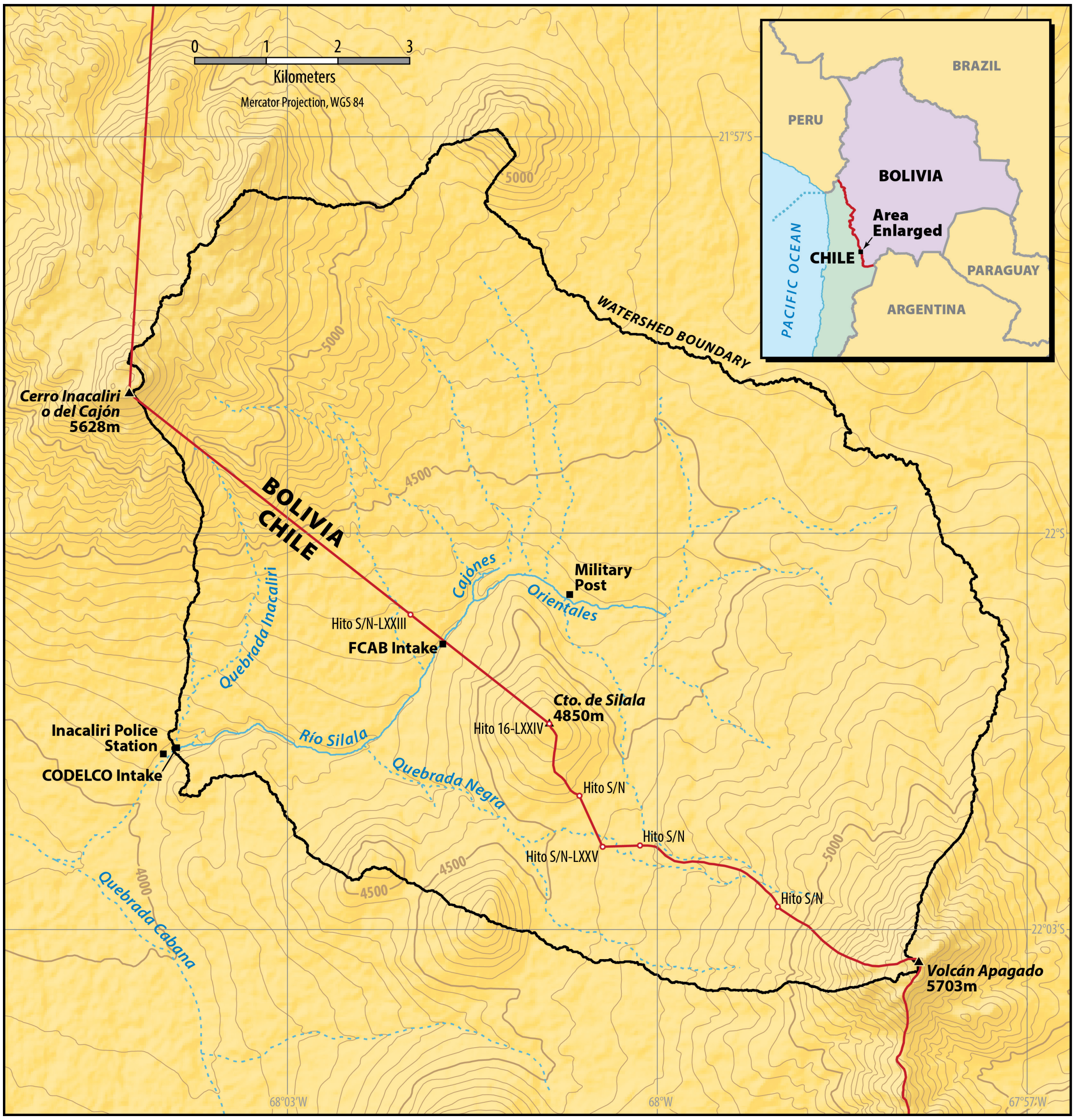

Figure 2. The Silala River basin. **Exp. Rep. 2, Figure 1-2.**

2.5. The Silala River flows from its sources for about 4 kilometres in Bolivia and a further 6 kilometres in Chile before joining the San Pedro River. It is on average one metre wide. Its flow when crossing the Chile-Bolivia boundary is an average of 170 l/s.[13] In Chile, downstream of the international boundary, the river interacts with several groundwater sources and gains additional flow of approximately 124 l/s.[14] The Silala is thus a small river, but has an importance far beyond its size due to its location in a highly arid region.

2.6. The entire course of the Silala River, from its headwaters in Bolivia at the Cajones and Orientales wetlands, across the international boundary into Chile up to the Inacaliri Police Station, is shown on satellite image Figure 3. In Bolivian territory, the Silala River becomes entrenched and carves a ravine into the existing bedrock of several metres deep, appearing as a clear-cut incision in the arid Altiplano landscape (Figures 3 and 4). The Silala River ravine crosses the international boundary, from Bolivia into Chile (Figures 3 and 5). In Chile, the Silala River continues its course through its natural ravine, supporting wetland vegetation (waiya grass) along its river banks (Figure 6). Despite the aridity of the Atacama Desert, there is significant annual precipitation in the Silala River area, mainly from January to March. Most recently, on 7 June 2017, a heavy snowstorm hit the area and left the Silala River ravine covered in snow (Figure 7).

[13] **Exp. Rep. 1**, p. 23.

[14] **Exp. Rep. 1**, p. 44.

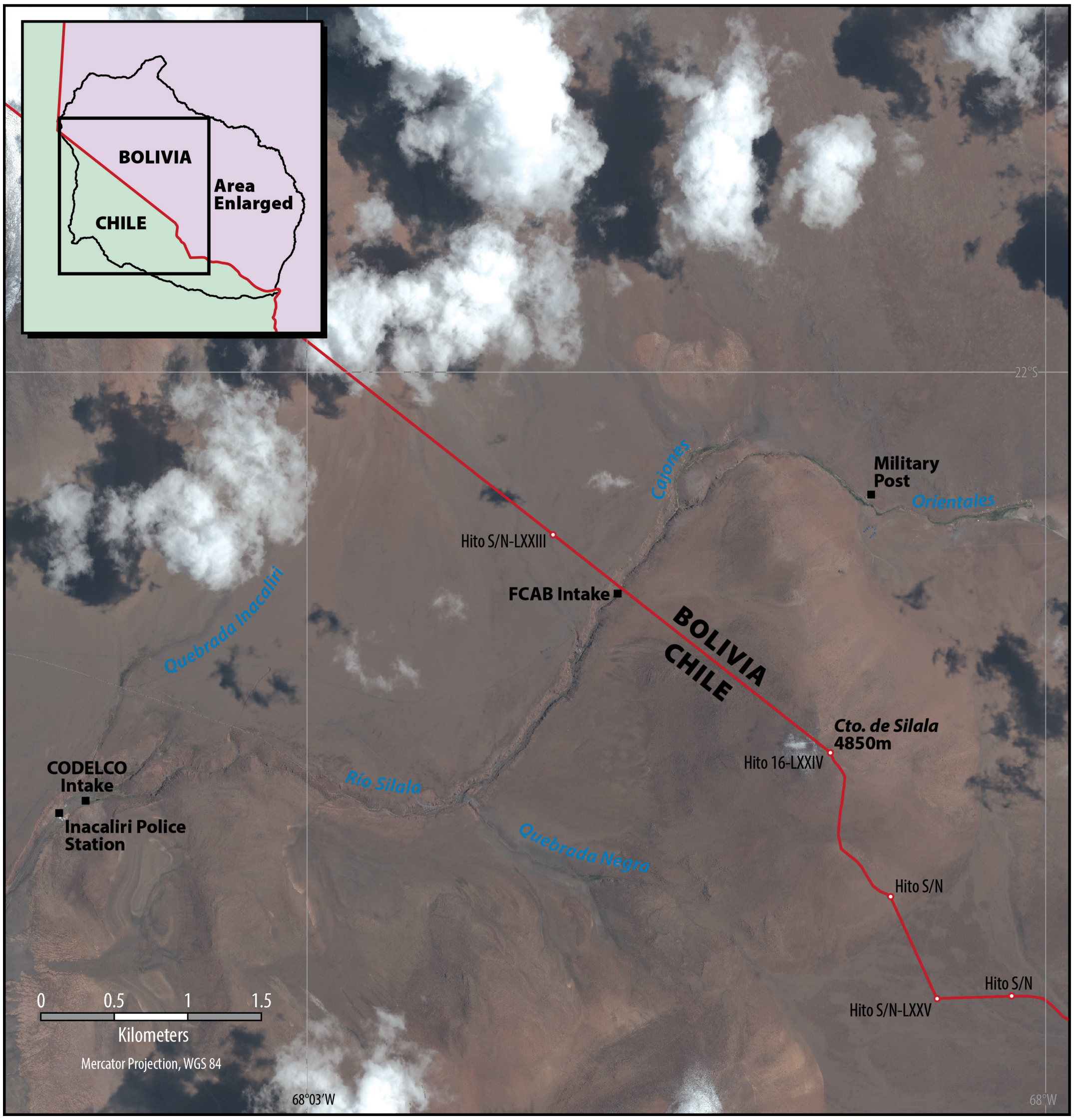

Figure 3. Satellite image provided by the Pléiades Satellite, 19 January 2017.

Figure 4. View of the Silala River ravine from Cerrito de Silala looking towards Volcán Paniri, Chile, 2016.

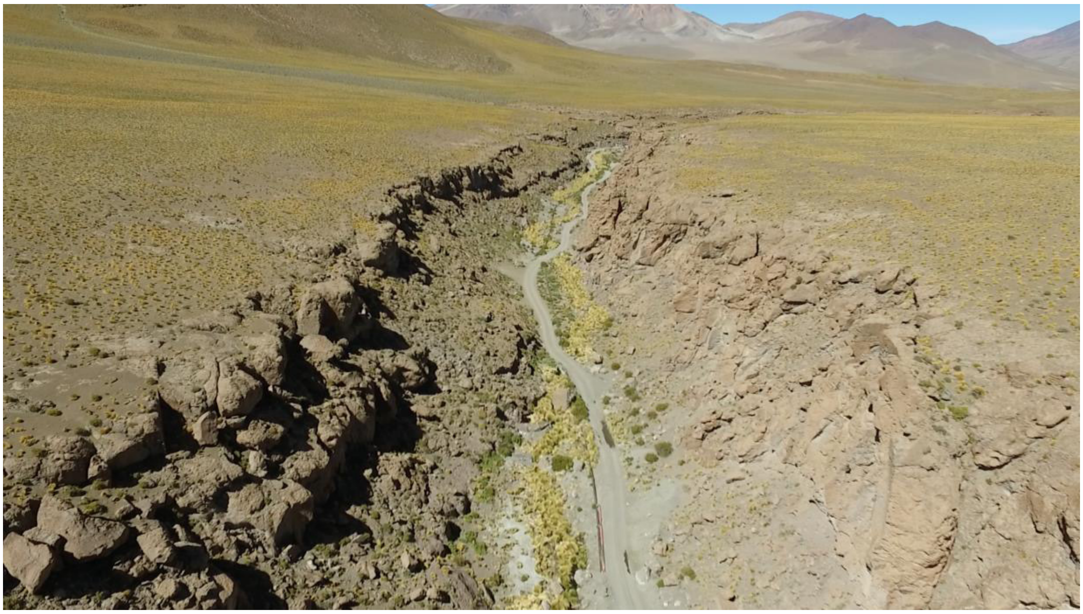

Figure 5. Aerial view of the Silala River ravine looking towards Chile, 2016.

Figure 6. The Silala River, November 2016.

Figure 7. The Silala River ravine covered in snow at the Chile-Bolivia boundary, June 2017.

2.7. The catchment area of the Silala River, i.e. the area where all surface water from rain, melting snow or ice drains to the outlet of the river under the force of gravity,[15] is 95.5 km^2, of which 69 km^2 is located in Bolivia.[16] The highest elevation in the Silala River basin is 5703 m.a.s.l. (Volcán Apagado).[17] As shown in Figure 8, the river is the natural drainage path of the topographic catchment area of the Silala River.

[15] The catchment is defined using a location on the river 4.9 km downstream of the Chile-Bolivia border, just below the Inacaliri Police Station, at 3948 m.a.s.l. **Exp. Rep. 1**, p. 11.

[16] **Exp. Rep. 1**, p. 11.

[17] **Exp. Rep. 1**, p. 11.

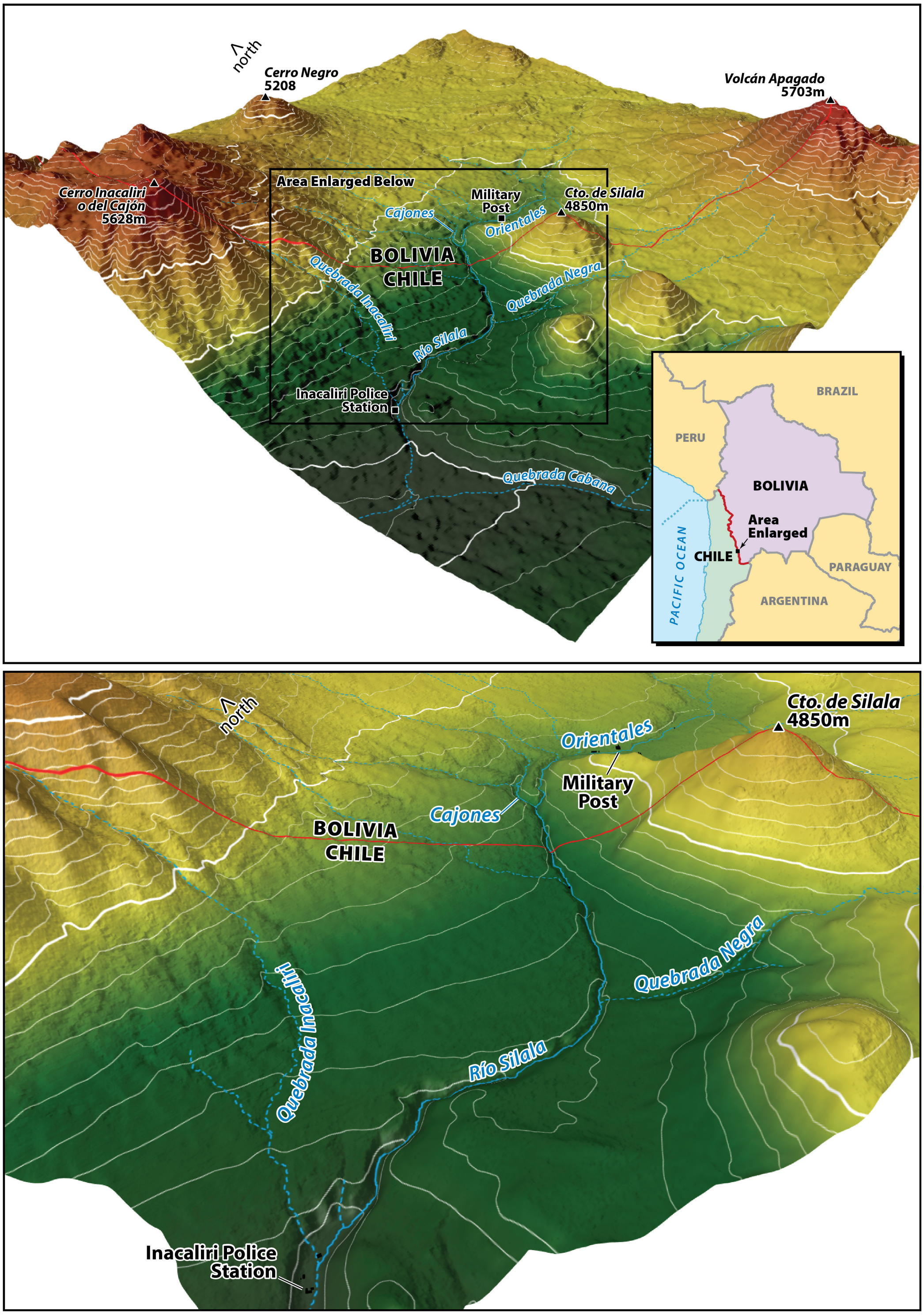

Figure 8. Contour lines of the terrain in the Silala River basin, as a 3D image.
Exp. Rep. 1, Figure 3.

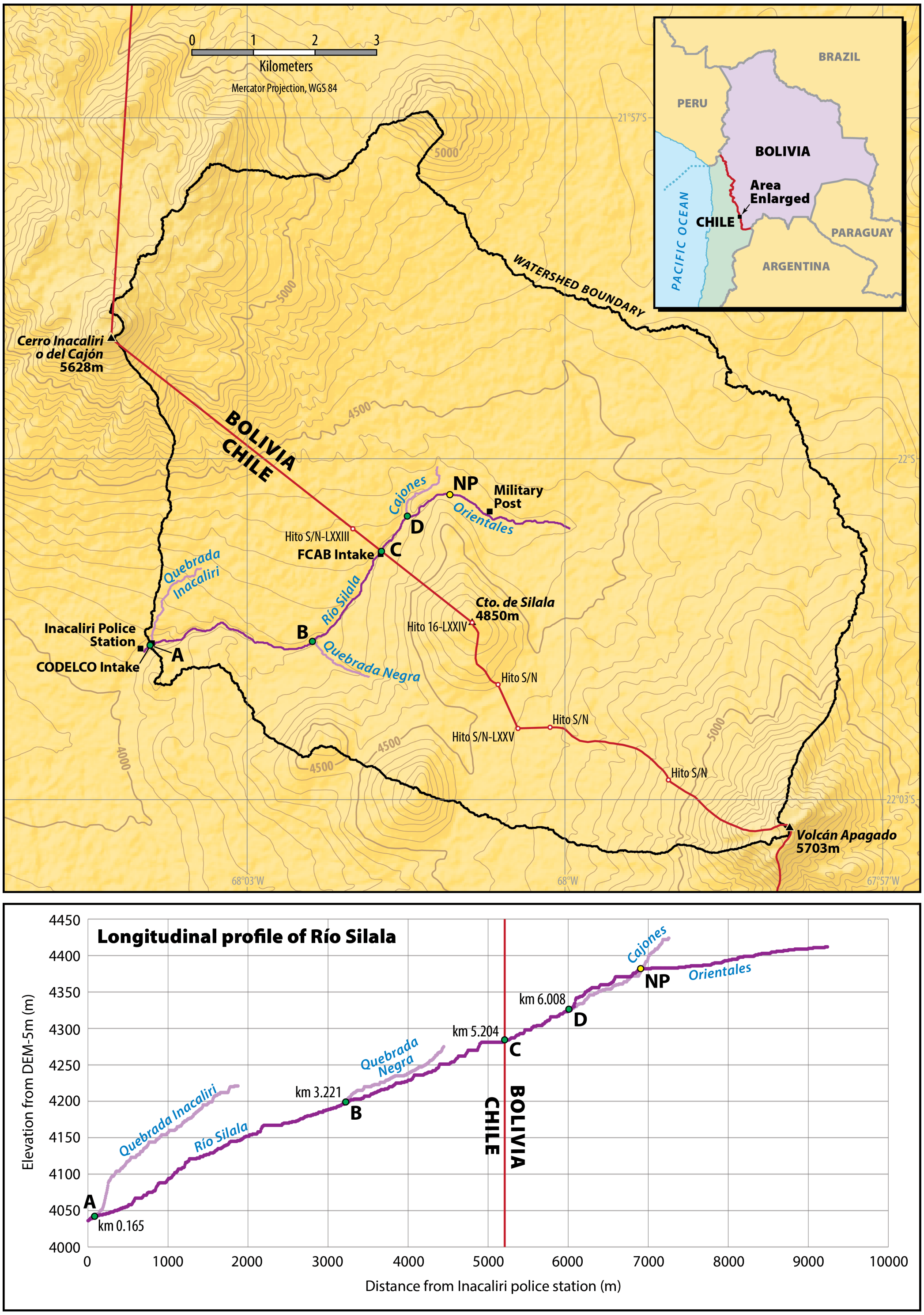

Figure 9. Longitudinal profile of the Silala River and main tributaries. **Exp. Rep. 1, Figure 4.**

2.8. The topographic gradient of the Silala River channel, from the Orientales and Cajones wetlands in Bolivia to its outlet in Chile, is continuous and amounts to a downhill slope of approximately 4-5% downstream from the wetlands, once the river enters into the ravine (Figure 9).[18] Hence, it is clear from the topography of the catchment area and the gradient of the river channel that the water that rises from springs in Bolivia cannot flow anywhere else but downhill into Chile.[19]

2.9. The geological history of the Silala River can be traced back to the period from about 5.8 to 2.6 million years ago, when volcanic activity created the first signs of the current topographic relief of the catchment area, including Cerro Inacaliri o del Cajón (Inacaliri hill or del Cajón, henceforth "Cerro Inacaliri"), Cerrito de Silala (Silala hillock) and Cerros de Silaguala (hills of Silaguala).[20] Between about 2.6 and 1.5 million years ago, there was fluvial activity more or less along the course of the current river, but this was truncated by a lava flow that erupted from Cerro Inacaliri, then an active volcano. This lava flow partially infilled the depression which is now home to the Orientales wetlands (the location of one of the two sets of springs from which the Silala River is formed) (Figure 10).[21]

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[18] **Exp. Rep. 1**, p. 14.

[19] **Exp. Rep. 1**, p. 7; **Exp. Rep. 2**, p. 47.

[20] **Exp. Rep. 2**, p. 19.

[21] **Exp. Rep. 2**, pp. 22-23.

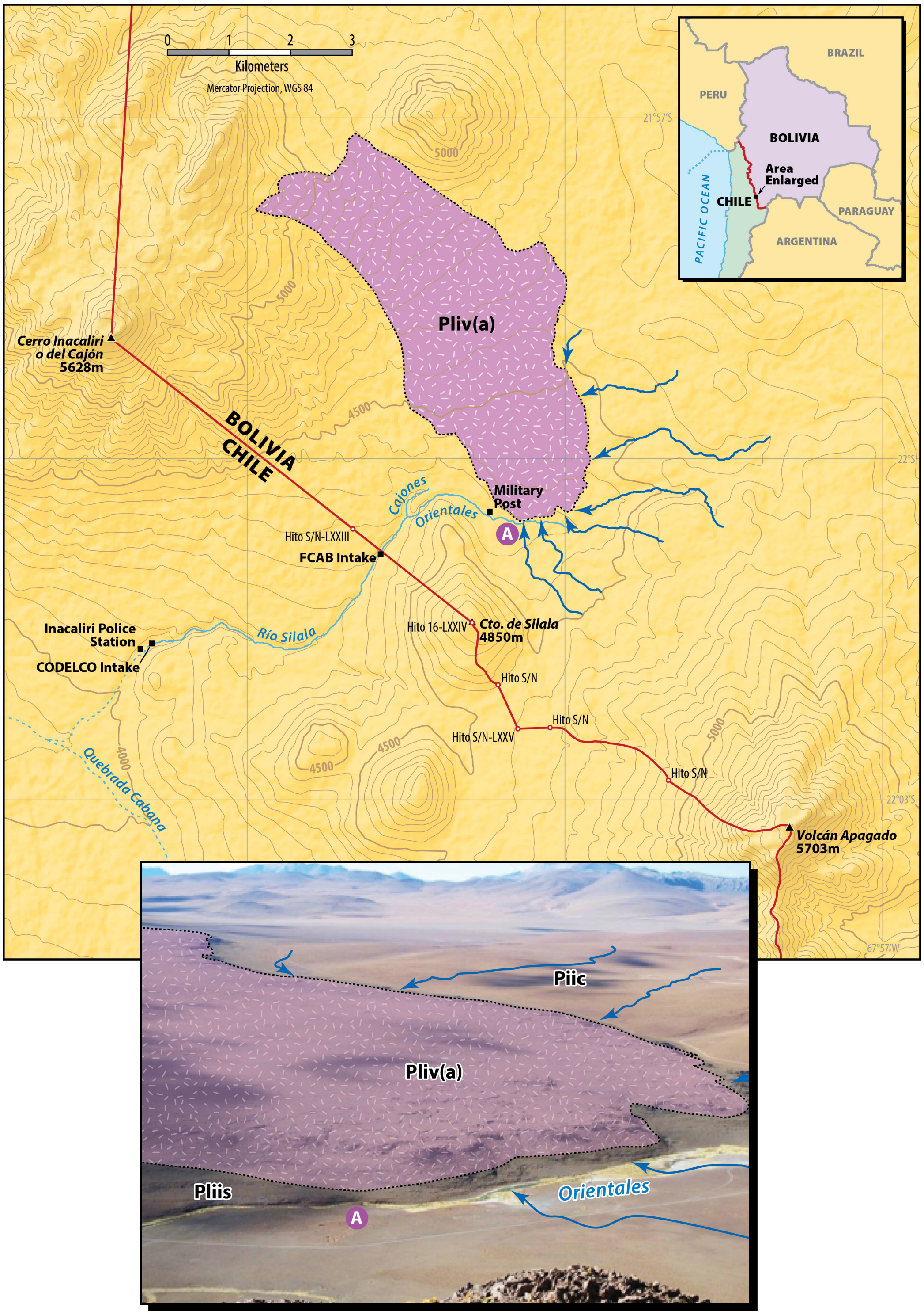

Figure 10. Lava flow Pliv(a) dated at approximately 1.5 Ma. **Exp. Rep. 2, Figure 4-4.**

2.10. The current Silala River ravine has been developing along its present course for at least 8400 years. This age is based on radiocarbon dating (8430-8350 years Before Present ("BP")) of organic material from sediment deposits that were sampled at sites in the ravine.[22]

2.11. Chile's experts have identified four periods of sediment deposition in the Silala River ravine, including evidence of wetland vegetation, followed by periods of fluvial erosion.[23] These natural cycles are associated with climate variability.[24] They have resulted in four river terraces that can be clearly distinguished along the river ravine and that can only be the result of fluvial activity (Figure 11).[25]

2.12. The course of the Silala River ravine is relatively winding and has a V-shape, typical of fluvial erosion. The ravine shows further commonplace fluvial features, such as potholes and *cavettos* in the walls of the ravine at different heights, indicating erosion at former water levels, normally on the outside of a bend.[26] All these features leave no room for doubt that the ravine was carved out by the river.[27]

[22] **Exp. Rep. 2**, p. 31.

[23] **Exp. Rep. 2**, pp. 31-32.

[24] **Exp. Rep. 2**, pp. 31-32.

[25] **Exp. Rep. 2**, p. 37.

[26] **Exp. Rep. 2**, p. 37.

[27] **Exp. Rep. 2**, p. 45.

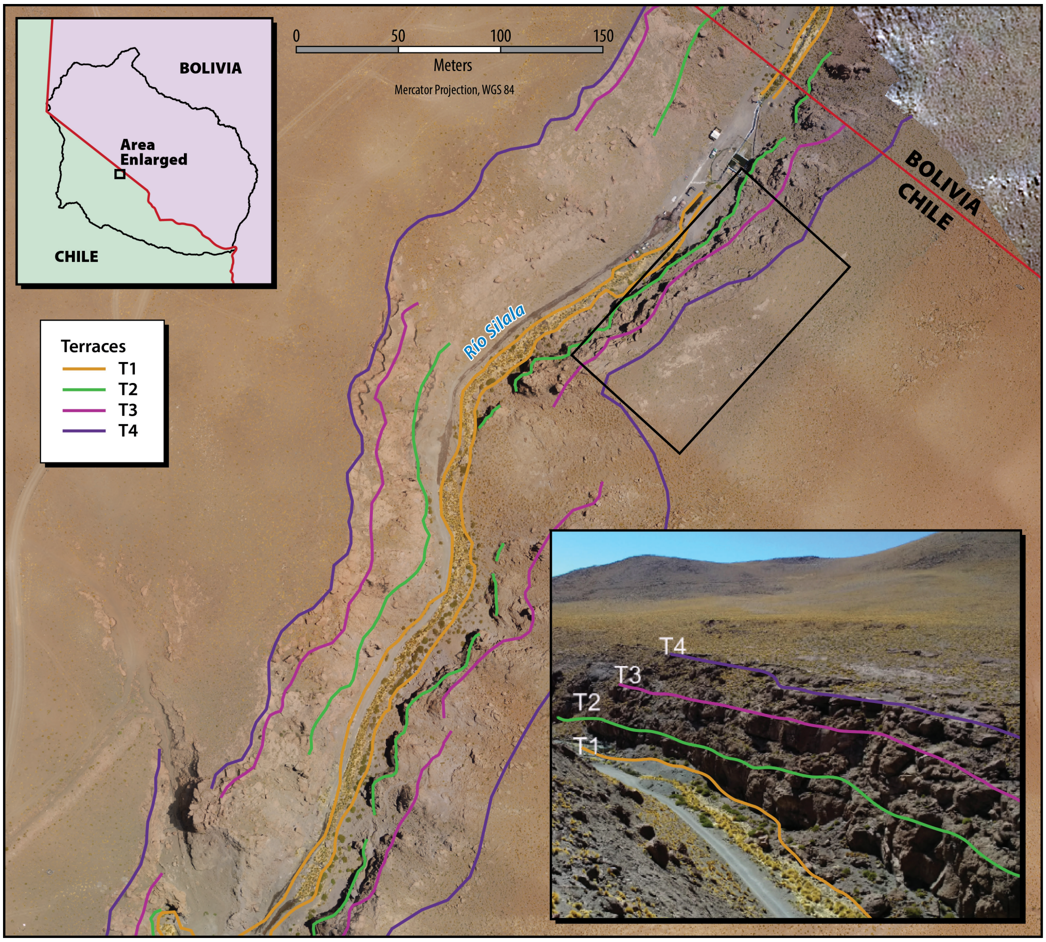

Figure 11. Identification of terraces in east slope of the Silala River ravine, 50 m southwest of the international boundary. **Exp. Rep. 2, Figure 5-3.**

2.13. The indigenous people of the Altiplano and Atacama Desert regions were nomadic and it is likely that the Silala River formed a route to and from the highlands, until at least the end of the nineteenth century. Archaeological evidence found during the 2016 research undertaken on the terraces along the Silala River ravine in Chile, includes pre-Columbian shelters, pottery and an arrowhead, confirming that the Silala River ravine has supported (probably temporary) human habitation, animal herding and possibly wild life hunting, for at least the last 1500 years (Figure 12).[28]

[28] **Exp. Rep. 2**, pp. 34-35.

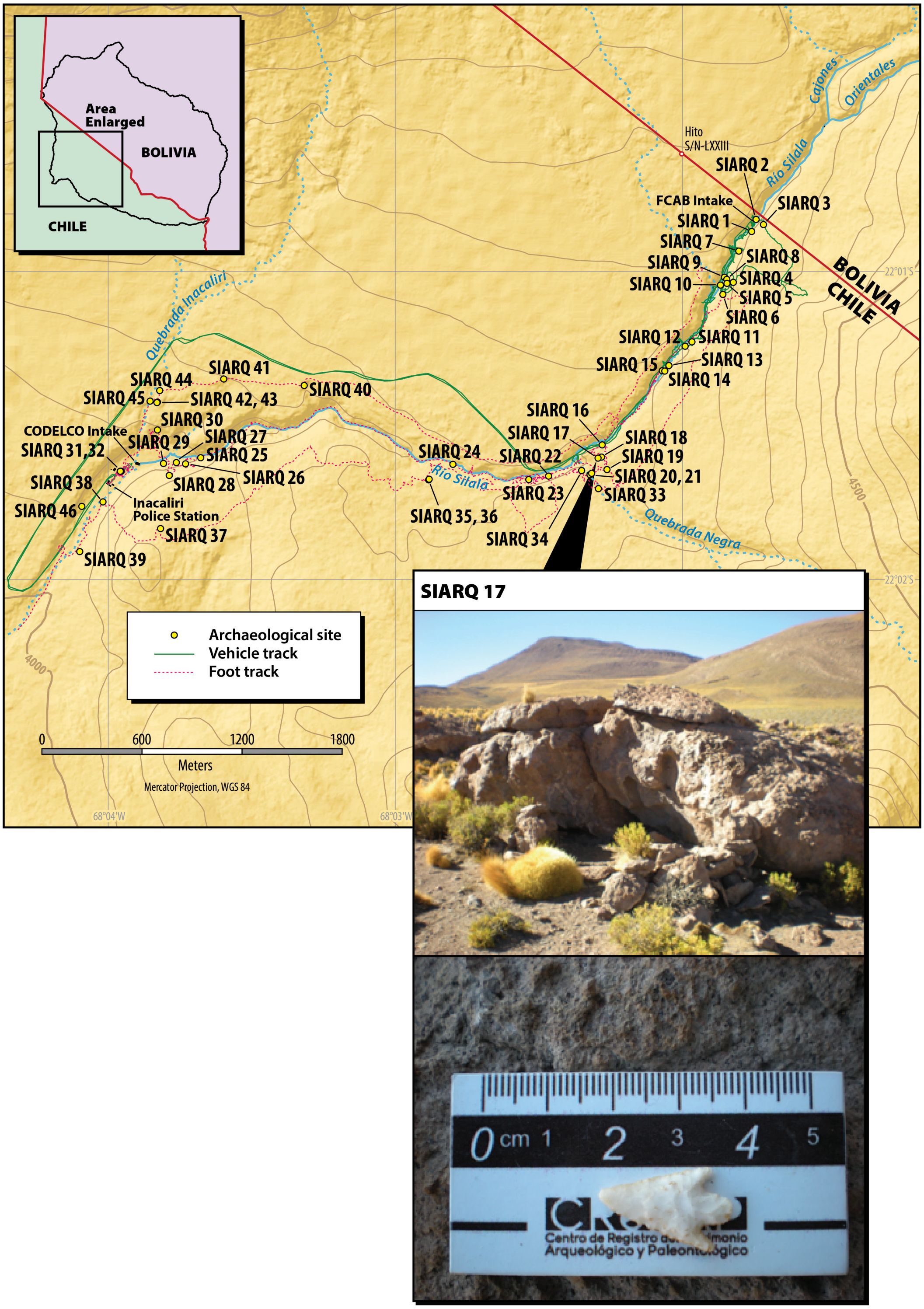

Figure 12. Archaeological sites identified in the Silala ravine and the Silala terraces, including site 17 with a photograph of the arrow head found. **Exp. Rep. 2, Figure 6-1.**

2.14. The Silala as of today remains a geomorphologically active river, meaning that it is not merely a conduit for water, but rather the processes of erosion and sediment transport that shaped the cross-border ravine are still active and ongoing.[29] The Silala is also a biologically active river, as it supports a healthy population of rainbow trout (an introduced species in Chile) and invertebrates.[30]

2.15. The surface flow of the Silala River interacts at various points with several groundwater systems. The Silala River receives its perennial flow from the groundwater springs in the Orientales and Cajones wetlands in Bolivia.[31] In Chile, it receives additional flow from springs that emerge from the walls of the cross-boundary ravine, of noticeably higher temperature than the Silala River water.[32] A deeper-lying aquifer contributes additional flow to the river near the junction of the Silala River and Quebrada (ravine) Negra, also of higher temperature,[33] whereas the Silala River loses some water to an underlying fluvial aquifer.[34] Environmental Isotope analyses show that most of the springs, and the deep groundwater aquifers, despite differences in chemical composition and age, are recharged at high altitude.[35]

2.16. Even though the Silala River is located in an arid region near the Atacama Desert, there is significant annual precipitation, mainly during the austral summer, from January to March. The annual average precipitation for the

[29] **Exp. Rep. 1**, p. 46.

[30] **Exp. Rep. 1**, p. 49.

[31] **Exp. Rep. 1**, p. 11.

[32] **Exp. Rep. 1**, pp. 40-41.

[33] **Exp. Rep. 1**, p. 43.

[34] **Exp. Rep. 1**, p. 44.

[35] **Exp. Rep. 1**, p. 43.

Silala River catchment area is 165 mm.[36] Temperatures can fall below freezing, even in summer; hence precipitation can take the form of rain at lower elevation and snow at higher elevation.[37] The surface material of the basin is highly permeable, allowing precipitation to infiltrate and recharge the groundwater system, rather than cause rapid runoff.[38] The high level of infiltration explains the relative constancy of the Silala River flow that has limited variability, confirming its groundwater dominated character.[39]

2.17. Chile's experts conclude, without any possible doubt, that the Silala is a system of surface waters and groundwaters, constituting by virtue of their physical relationship a unitary whole, flowing from Bolivia into Chile, following the natural gradient, into a common terminus.[40]

B. The water of the Silala River has been essential for modern habitation and development of the Antofagasta Region

2.18. The importance of the Silala River, despite its relatively modest length, size and flow, lies in its location in one of the driest deserts in the world and in the good quality of its water, which contains much lower concentrations of minerals and arsenic than many other watercourses in the Chilean Antofagasta Region.

2.19. During the larger part of the twentieth century, the Silala River supplied drinking water to, among others, the port city of Antofagasta and, as such, played an important role in sustaining the population and enabling the

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[36] **Exp. Rep. 1**, p. 27.

[37] **Exp. Rep. 1**, p. 30.

[38] **Exp. Rep. 1**, p. 38.

[39] **Exp. Rep. 1**, p. 23.

[40] **Exp. Rep. 1**, p. 49; **Exp. Rep. 2**, p. 47.

development of that city and the region. Until 2010, some of the water of the Silala was still used for human consumption by the towns of Sierra Gorda and Baquedano, located along the Antofagasta-La Paz railway.[41] As of today, a significant percentage (60%) of the waters of the Silala River that is extracted by Chilean State-owned mining company CODELCO is used for human consumption, in its Mining Divisions Radomiro Tomic, Ministro Hales and Chuquicamata, all in the Antofagasta Region.[42] This amounts to 30% of the total amount of water currently extracted from the Silala River.

2.20. In addition, the waters of the Silala River had industrial uses in the operation of the Antofagasta-La Paz railway until at least the late nineteen fifties, when diesel locomotives started to replace steam engines. Other past and present industrial uses include processing in the saltpetre and copper mining industry, both of which are vital to the economy of the Antofagasta Region.

2.21. Modern use of the waters of the Silala River started in 1906, when British company The Antofagasta (Chili) and Bolivia Railway Company (FCAB) acquired a concession for the use of its waters from the Chilean government.[43] Two years later, in 1908, FCAB also obtained a right of use from the Bolivian government.[44] In Chile, FCAB requested the use of the Silala to satisfy the need for potable water supply in Antofagasta; in Bolivia, the water was requested to supply the steam engines of the locomotives that operated the Antofagasta-La

[41] Notices of Termination of Water Supply by FCAB to the towns of Baquedano and Sierra Gorda, 5 October 2010. **CM Annexes 69.1 and 69.2.**

[42] Chilean Resolution N° 5.571, Director of the Antofagasta Health Service, 28 November 2002. **CM Annex 61.**

[43] Deed of Concession by the State of Chile of the Waters of the Siloli (N° 1.892) to The Antofagasta (Chili) and Bolivia Railway Company Limited, 31 July 1906. **CM Annex 55.**

[44] Deed of Concession by the State of Bolivia of the Waters of the Siloli (N° 48) to The Antofagasta (Chili) and Bolivia Railway Company Limited, 28 October 1908. **CM Annex 41.**

Paz railway. The history of the concessions will be told in further detail in section 4.B.3 below.

2.22. No waterworks or man-made channels existed in Bolivia or Chile when FCAB obtained the rights of use of the waters of the Silala River. FCAB built its first intake in 1909 on Bolivian territory, just below the confluence of the Cajones and Orientales ravines, at approximately 600 metres from the international boundary ("Intake N° 1"). In 1910, the pipeline from Intake N° 1 to FCAB's water reservoirs at San Pedro Station in Chile (the "San Pedro reservoirs"), some 60 kilometres away, was officially put into operation ("Pipeline N° 1"). The capacity of Pipeline N° 1 at the time was approximately 75 l/s.[45] In 1942, a second intake ("FCAB Intake") and pipeline ("Pipeline N° 2") were built in Chilean territory, at approximately 40 metres from the international boundary.[46]

2.23. At the San Pedro reservoirs, the water from the Silala River was mixed with water from other watercourses and connected with the existing pipeline to Antofagasta.[47] Since then and until now, the Silala River accounts for more than 80% of the total amount of water that is collected in the San Pedro reservoirs.

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[45] Robert H. Fox, The Waterworks Department of the Antofagasta (Chili) & Bolivia Railway Company, *South African Journal of Science*, 1922. **CM Annex 75.**

[46] Letter from the General Manager of FCAB in Chile to the Chairman of the Board of Directors of FCAB in London, 3 September 1942. **CM Annex 68.**

[47] Letter from the General Manager of FCAB in Chile to the Secretary of the Board of Directors of FCAB in London, 23 November 1910. **CM Annex 66.**

2.24. On 14 May 1997, Bolivia "reversed and annulled" FCAB's concession in Bolivia.[48] Since then, the FCAB Intake on Chilean territory is the only intake operated by FCAB at the Silala River.

2.25. In 1928, FCAB decided to construct open channels in Bolivia for sanitary reasons, to inhibit breeding of insects at the Silala River headwaters and avoid contamination of the potable water supply to Antofagasta. These channels run between the upper springs at Orientales and Intake N° 1, including a branch trench from the Cajones springs to Intake N° 1.[49]

2.26. The channels in Bolivia follow the natural drainage path and gradients of the river. Their construction following 17 years of uninterrupted use of the waters of the Silala River in Chile, demonstrates that the channels in Bolivia did not change the natural course of the river, nor "divert" the water of the Silala River from Bolivia into Chile. The waters of the Silala River have flowed and continue to flow naturally from Bolivian territory into Chile, before, after and independently of the construction of these channels.

2.27. Chile's experts estimate that the channels in Bolivia have had limited effect on the extent of the Orientales and Cajones wetlands in Bolivia, due to the shallow depth of the channels.[50] The channels have not been maintained since the termination of the Bolivian concession in 1997, until very recently.[51] So far as Chile's experts can discern, these variations in the maintenance regime have

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[48] Administrative Resolution Nº 71/97 by the Prefecture of the Department of Potosí, 14 May 1997. **CM Annex 46.**

[49] Letter from the General Manager of FCAB in Chile to the Secretary of the Board of Directors of FCAB in London, 27 January 1928. The channels were finished by June, see Letter dated 29 June 1928. **CM Annexes 67.1 and 67.2.**

[50] **Exp. Rep. 1**, pp. 36-37.

[51] Chile notes that very recently (2017) Bolivia has engaged in cutting and cleaning of the vegetation along the channels, as can be appreciated by visual inspection at the international boundary.

also not had any detectable effect on the wetland extent.[52] The effect of the channels on the cross-boundary flow, due to reduced evaporation in the wetlands, is therefore very limited and calculated to be less than 3.4 l/s or 2% of the annual average flow.[53]

2.28. In 1956, another intake further downstream was brought into use, by the Chile Exploration Company (Chilex, now Corporación Nacional del Cobre de Chile or CODELCO).[54] This intake (the "CODELCO Intake") is located approximately 5 kilometres downstream of the international boundary, near the junction of the Silala River and Quebrada Inacaliri, just upstream of the Inacaliri Police Station.

2.29. The currently in use intakes and pipelines of both FCAB and CODELCO are shown on Figure 13.

[52] **Exp. Rep. 1**, p. 37.

[53] **Exp. Rep. 1**, p. 36.

[54] CODELCO's rights to the water of the Silala River add up to 160 l/s. See Chilean Decree N° 1.324, 25 June 1958 for an initial 119 l/s, **CM Annex 56**; and Chilean Resolution N° 239, General Directorate of Water, 22 March 1990, for an additional 41 l/s. **CM Annex 59.** (CODELCO's rights are assigned to the Inacaliri River, which is the name of the Silala River downstream of the conjunction with Quebrada Inacaliri.)

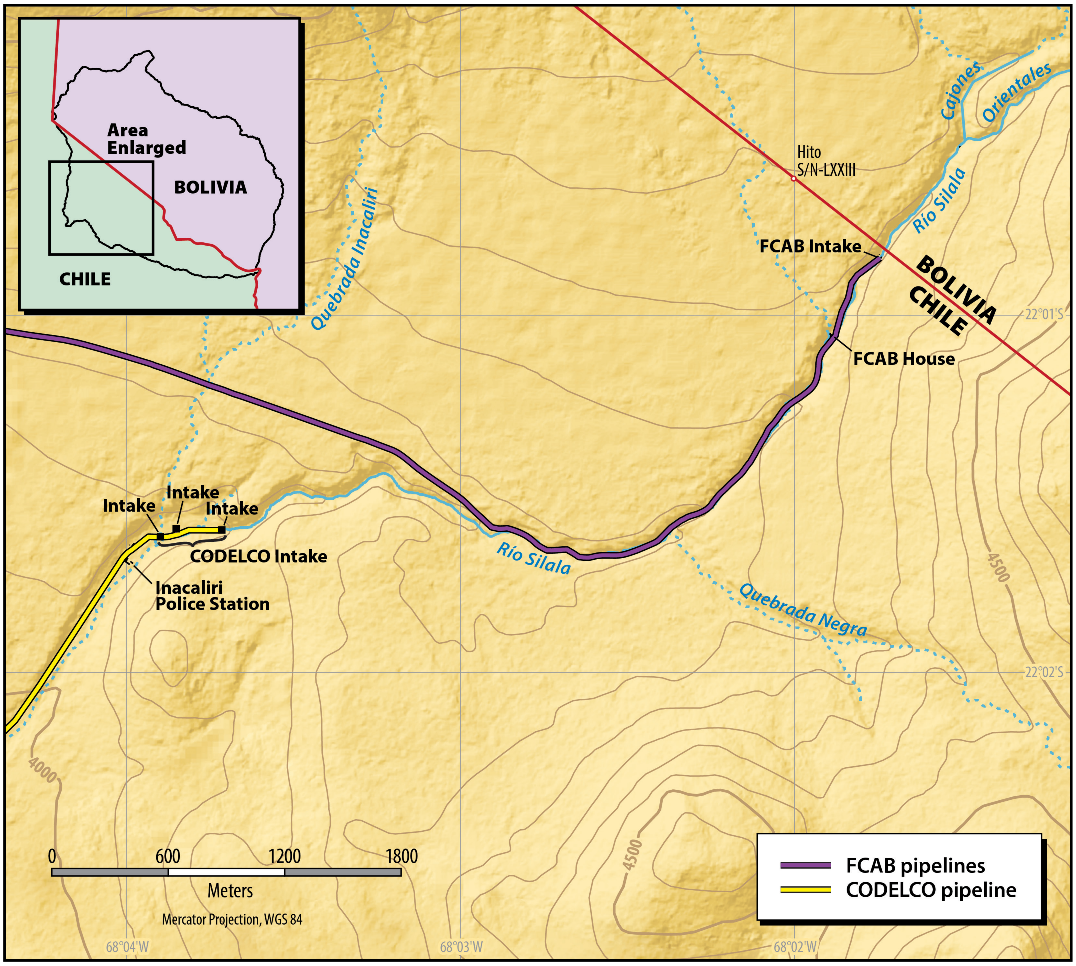

Figure 13. Current FCAB and CODELCO pipeline system used to collect Silala River waters.

2.30. Since then and as of today, of the average flow of 170 l/s that crosses from Bolivia into Chile, FCAB extracts an average of 125 l/s at the FCAB Intake near the international boundary, and CODELCO the remaining 45 l/s further downstream, at the CODELCO Intake.[55] In addition, CODELCO captures additional contributions from groundwater sources in Chile, downstream from the international boundary, extracting a total average amount of 140 l/s at the CODELCO Intake. Of the water extracted by CODELCO, 60% is used as drinking water in Mining Divisions Radomiro Tomic, Ministro Hales and Chuquicamata.[56] This means that, on average, 30% of the Silala water that is captured in Chile is currently used for human consumption.

2.31. The historic and current uses of the water of the Silala River confirm its importance for the livelihood and development of the Antofagasta Region. From the early twentieth century onwards, the waterworks, pipelines and infrastructure developed by FCAB allowed for the efficient use of its waters in Chile, initially for human consumption and railway operation, later increasingly for other industrial purposes. Since the late 1950s, additional resources from the Silala River have been extracted by mining company CODELCO, 60% of which is assigned to human consumption in its Mining Divisions in the Antofagasta Region. The waters of the Silala River are therefore of particular importance to Chile.

[55] Under the current Chilean Water Code, FCAB's rights under the 1906 Chilean concession are recognized as up to 237 l/s. See: Chilean Deed of Concession Regulating FCAB's Rights to the Silala under the 1981 Water Code, 22 January 1990. **CM Annex 58.** However, in 1989, FCAB and CODELCO agreed that FCAB's extraction activities would not affect CODELCO's entitlement to 160 l/s, see: Transaction Contract Celebrated Between CODELCO and FCAB, 6 November 1989. **CM Annex 74.** Since then, FCAB collects only 125 l/s on average, leaving the remainder of the cross-border flow to CODELCO.

[56] Chilean Resolution N° 5.571, Director of the Antofagasta Health Service, 28 November 2002. **CM Annex 61.**

CHAPTER 3
DEVELOPMENT OF THE DISPUTE

3.1. In this chapter, Chile will describe the development of the dispute between Bolivia and Chile on the nature and use of the Silala River. Section A will establish Bolivia's longstanding understanding of the international nature of the Silala River. Section B will describe how Bolivia suddenly and for the first time in 1999 denied the international nature of the Silala River, without any basis in science or international law. Section C will explain Chile's decision to submit this matter to the jurisdiction of the Court.

A. Bolivia's longstanding acknowledgment of the international nature of the Silala River system

3.2. For more than a century, Bolivia considered, as demonstrated by its public statements and other actions, the Silala to be an international watercourse, flowing along its natural course from Bolivia into Chile.

3.3. Bolivia's (entirely correct) understanding of the Silala River as a transboundary watercourse is evidenced by the Map appended to the 1904 Treaty of Peace and Amity between Bolivia and Chile, signed by the Bolivian Ambassador in Chile, Mr. Alberto Gutiérrez, and the Chilean Minister of Foreign Affairs, Mr. Emilio Bello Codesido. This Map depicts the Silala River crossing from Bolivia into Chile (Figure 14).

Figure 14. Map Appended to the Treaty of Peace and Amity, 20 October 1904. **CM Annex 82.**

3.4. This understanding is also evidenced by Bolivia's participation in joint demarcation and revision activities in the Silala River area, in 1906[57] and 1924,[58] as well as in subsequent revision and demarcation activities in the context of the Mixed Boundary Commission created by the two countries in 1942.[59]

[57] Chile-Bolivia Boundary Commission, Minutes of 23 March 1906, in: *Records of the Chile-Bolivia Boundary*, pp. 1-2. **CM Annex 6.** See also: Report signed by the Head of the Bolivian Demarcation Commission, Quintín Aramayo Ortíz, 14 August 1906, in: *Records of the Chile-Bolivia Boundary*, pp. 14-18. **CM Annex 40.**

[58] Report by Major Carlos Graña & C. on the Revision of the Boundary with Chile, La Paz, 20 June 1924. **CM Annex 43.** See also: Chile-Bolivia Mixed Revision and Replacement Commission, Minutes of 7 June 1924. **CM Annex 7.**

[59] See below chapter 4.B.2.

3.5. Indeed, as recently as May 1996, Bolivian Ambassador Teodosio Imaña Castro, then Chair of the Bolivian Boundary Commission and President of the Mixed Boundary Commission, confirmed that the Silala River flows naturally from Bolivia into Chile, following a consistently downhill course:

> "It rises from two main springs and receives additional waters from other minor springs. The narrow riverbed that is formed, called Silala, runs approximately two kilometers through Bolivian territory before it crosses the boundary at a point of the east-west slope of the glen between Cerro Inacaliri and Cerro Silala. <u>The inclination of the terrain has been established by experts to be around 30% [sic, more likely 3%], its river bed is narrow and its crystalline waters follow the course that, due to the force of gravity, goes downhill into Chilean territory</u>."[60] (emphasis added)

3.6. The evidence collected by Chile's experts, described in chapter 2, confirms the overall correctness of this statement by Bolivia.

3.7. There can be no doubt that the Silala River is a natural geographical feature that crosses the international boundary between Bolivia and Chile due to the force of gravity. There can also be no doubt that Bolivia has consistently acknowledged this fact of nature in its bilateral relations with Chile, from before the conclusion of the 1904 Treaty up until 1999, when it suddenly adopted the position that the Silala is not an international watercourse or even a river.

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[60] Presencia, "*Dialogue on Friday with Dr. Teodosio Imaña Castro*", La Paz, 31 May 1996. **CM Annex 71.**

B. The origin of the dispute: Bolivia's 1999 change of position regarding the international nature of the Silala River system

3.8. Abruptly, and for the first time, in a 1999 diplomatic note to Chile, Bolivia claimed the Silala as an exclusively Bolivian water resource. Contrary to all previous statements, and denying the obvious facts, Bolivia asserted in a one-paragraph statement that the Silala has no characteristics of a river at all:

> "The spring waters of the Silala, which are entirely located in Bolivian territory, have their origin in water holes (*ojos de agua*) from which surface flow emerges. This creates wetlands, from where the waters are caught and conducted by means of artificial works, generating <u>a system that lacks any characteristic of a river, let alone of an international river of a successive course</u>."[61] (emphasis added)

3.9. This unprecedented statement was made without the support of any legal reasoning and was not based on any scientific or other evidence.

3.10. Chile immediately issued a protest, stating its disagreement with Bolivia's abrupt and unilateral denial of objective facts and a century of practice. In its diplomatic note of 15 September 1999, basing itself on rules of general international law as well as sound scientific evidence, Chile stated that:

> "There is ample geographical, historical, cartographic and juridical background information, Chilean, Bolivian and bilateral, that constitutes undeniable sources of evidence. Said data necessarily leads to the conclusion that it [the Silala] is precisely a river, given its characteristics, that is a shared water resource having a successive course to which the general principles of international law must be applied, and by virtue of which Bolivia has the nature of an 'upstream country' and Chile of a 'downstream country' […]. Having a permanent natural runoff, its flow into Chilean territories, characterizes

[61] Note N° GMI-656/99 from the Ministry of Foreign Affairs of Bolivia to the General Consulate of Chile in La Paz, 3 September 1999. **CM Annex 27.**

> it [the Silala] as a binational river or a shared river. […]. Moreover, it should be noted that <u>until now the Bolivian Government had never officially denied the fact that the Silala is a river that naturally responds to the definition that international law gives for that purpose</u>."[62] (emphasis added)

3.11. Chile invited Bolivia:

> "…to continue discussing the topic through a constructive bilateral dialogue, based on an acknowledgement that it [the Silala] is a successive watercourse to which it is necessary to apply the principles recognized by the international community for the shared use of its waters."[63]

3.12. Bolivia nonetheless persisted in the adoption of its untenable position, replying to Chile as follows:

> "…the Ministry is convinced that the spring waters of the Silala, granted by the 1908 concession, do not constitute a river, let alone a 'binational river or shared waters', as there is no system that integrates the flowing water, the river bed and the banks, in order to respond to one of the universally accepted definitions of 'river'. There are no river banks because there is no natural flow of water that generates a river bed."[64]

3.13. Chile's continuing protests were expressed in diplomatic notes dated 14 October 1999 and 3 December 1999.[65]

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[62] Note N° 017550 from the Ministry of Foreign Affairs of Chile to the Ministry of Foreign Affairs of Bolivia, 15 September 1999. **CM Annex 28.**

[63] Note N° 017550 from the Ministry of Foreign Affairs of Chile to the Ministry of Foreign Affairs of Bolivia, 15 September 1999. **CM Annex 28.**

[64] Note N° GMI-815/99 from the Ministry of Foreign Affairs of Bolivia to the Ministry of Foreign Affairs of Chile, 16 November 1999. **CM Annex 29.**

[65] Note N° 1084/151 from the General Consulate of Chile in La Paz to the Ministry of Foreign Affairs of Bolivia, 14 October 1999 and Note N° 022314 from the Ministry of Foreign Affairs of Chile to the Ministry of Foreign Affairs of Bolivia, 3 December 1999. **CM Annexes 30.1 and 30.2.**

(a) In the note of 14 October 1999, Chile emphasized that:

> "[T]he existence of a sector of this hydrological basin in Chilean territory is very clear, since it would be impossible to maintain that a natural geographical feature ends in a political boundary; which in this sector is a straight line and not a watershed."[66]

(b) In its note of 3 December 1999, Chile once again stressed that its position was based on international law and incontrovertible evidence.[67]

3.14. On 25 April 2000, Bolivia granted the use of the waters of the Silala to the private Bolivian company DUCTEC S.R.L. for the duration of forty years. The concession authorized the commercialization or exportation of the waters for industrial use and human consumption, presumably to Chile, since the concession explicitly excluded their use for potable water and sewerage services in Bolivia without an additional public utility concession, as well as for mining activities by third parties in Bolivian territory.[68] In May 2000, DUCTEC attempted to invoice CODELCO and FCAB for their use of the waters of the Silala, ignoring the existing rights of both companies to the use of those waters on Chilean territory.[69]

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[66] Note N° 1084/151 from the General Consulate of Chile in La Paz to the Ministry of Foreign Affairs of Bolivia, 14 October 1999. **CM Annex 30.1.**

[67] Note N° 022314 from the Ministry of Foreign Affairs of Chile to the Ministry of Foreign Affairs of Bolivia, 3 December 1999. **CM Annex 30.2.**

[68] Concession Contract for the Use and Exploitation of the Springs of the Silala Between the Bolivian Superintendent of Basic Sanitation and DUCTEC S.R.L., 25 April 2000. **CM Annex 48.** DUCTEC's concession was terminated on 30 May 2003 due to the illegitimacy of the Concession Contract, see: Bolivian Administrative Resolution N° 75/2003 by the Superintendency of Basic Sanitation, 30 May 2003. **CM Annex 50.**

[69] Invoice Nº 003/00 from DUCTEC to CODELCO, 5 May 2000. **CM Annex 76.**

3.15. By diplomatic note of 27 April 2000, Chile formally objected to the concession of the waters of the Silala granted to DUCTEC on the ground that it disregarded the international nature of the Silala River and Chile's right to the utilization of its waters.[70] Moreover, Chile repeated its invitation to:

> "…begin as soon as possible a frank and in-depth bilateral dialogue that allows agreeing on a cooperation scheme and equitable use in the sincere interest of reaching an understanding about this shared water resource."[71]

3.16. Chile's efforts to maintain a collaborative relationship between co-riparian States resulted in the establishment of a joint technical commission.

3.17. In October 2000, Bolivian and Chilean technicians took ground-based measurements on both sides of the international boundary, as part of a joint field programme. It was agreed that each national technical team would take its own measurements in the other State's territory and exchange the results. Chile presented the results of its measurements of the entire course of the Silala River, in Bolivia and Chile, by diplomatic note of 19 December 2000.[72] By diplomatic note of 17 January 2001, Bolivia confirmed receipt, without expressing any kind of objection. Bolivia also presented its coordinates, but only from the Chilean side of the boundary.[73] The results of this field programme are reflected in the profile of the topographical gradient of the Silala River, from the Cajones and

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[70] Note N° 006738 from the Ministry of Foreign Affairs of Chile to the Ministry of Foreign Affairs of Bolivia, 27 April 2000. **CM Annex 31.**

[71] Note N° 006738 from the Ministry of Foreign Affairs Chile to the Ministry of Foreign Affairs of Bolivia, 27 April 2000. **CM Annex 31.**

[72] Note N° 74 from the Ministry of Foreign Affairs of Chile to the General Consulate of Bolivia in Santiago, 19 December 2000. **CM Annex 32.1.**

[73] Note N° CGB/19/2001 from the General Consulate of Bolivia in Santiago to the Ministry of Foreign Affairs of Chile, 17 January 2001. **CM Annex 32.2.** See also Note N° CGB/48/2001 from the General Consulate of Bolivia in Santiago to the Ministry of Foreign Affairs of Chile, 9 February 2001. **CM Annex 32.3.**

Orientales springs in Bolivia to the confluence with Quebrada Cabana in Chile, developed by Chile.[74]

3.18. In addition, both States agreed to carry out an aerial photographic flight over the area of the Silala River, on 15 November 2001, as a first step towards the development of a joint detailed cartography.[75] It was agreed that the necessary complementary field work would be carried out after the rainy season, which coincides with the austral summer, in March 2002.[76]

3.19. However, the work of this technical commission came to a halt when Bolivia, in an official press release of 26 February 2002, denied the transboundary nature of the Silala River. Bolivia threatened to cut off its flow into Chile or, in the alternative, to pursue litigation before an *ad hoc* Tribunal or this Court:

> "One course of action is to order the cut-off of the flow of the spring waters of the Silala, channeled by artificial means towards Chilean territory. The feasibility and the technical consequences of said course of action must be analyzed by the competent authorities on the matter and, depending on the decisions that are adopted, the Ministry of Foreign Affairs and Worship shall enforce the tasks that are of its competence.
>
> Given that our Government as well as the Chilean Government have not changed their respective positions, another course of action would

[74] Profile Silala River (undated, prepared by Chile in 2001). **CM Annex 32.4.**

[75] Note N° 973/224 from the General Consulate of Chile in La Paz to the Ministry of Foreign Affairs of Bolivia, 16 November 2001. **CM Annex 33.1.**

[76] Note N° VREC-185/2001-0020 from the Ministry of Foreign Affairs of Bolivia to the General Consulate of Chile in La Paz, 4 January 2002, and Note N° 019/05 from the General Consulate of Chile in La Paz to the Ministry of Foreign Affairs of Bolivia, 18 January 2002. **CM Annexes 33.2 and 33.3.**

> be to turn to arbitration before an ad hoc Court and before the International Court of Justice."[77]

3.20. In addition, this press release referred to an October 2001 report by the Bolivian Geological and Mining Survey (SERGEOMIN) on the Silala River basin. Without revealing the conclusions of this report, it was discredited by Bolivia as not representing "the official viewpoint of the National Government", going "beyond [SERGEOMIN's] sphere of competence as well as the scope of these studies, which are understood to be strictly technical in nature", and not bearing the approval of the Ministry of Foreign Affairs.[78] As of today, Chile has had no access to this SERGEOMIN report, which was never made public.

3.21. Chile rejected this further and once more unexpected turn of events, reminding Bolivia of the progress achieved by the technical commission:

> "[H]aving commenced activities aimed at making a cartography of the boundary area of the Silala River, and having completed the stage of an aerial photogrammetric flight in November of 2001, there still remains to carry out the corresponding geodesic ground support that by mutual consent is expected to be completed once the present rainy season is over.
>
> Thus, the Government of Chile expresses its rejection of all measures that could obstruct the flow of the waters of the Silala River to Chile, and points out in this respect the spirit of cooperation wherein the issue is being dealt with at a bilateral level."[79]

3.22. Discussions on the Silala River were resumed in 2004, within the framework of the Working Group on the Silala Issue, specifically created for this purpose. Again, both States agreed to carry out joint technical and scientific

[77] Press Release from the Ministry of Foreign Affairs of Bolivia, 26 February 2002. **CM Annex 49.**

[78] Press Release from the Ministry of Foreign Affairs of Bolivia, 26 February 2002. **CM Annex 49.**

[79] Press Release from the Ministry of Foreign Affairs of Chile, 4 March 2002. **CM Annex 60.**

studies to determine the nature, origin and flow of the waters of the Silala.[80] Chile has always been in favour of such joint studies in order to demonstrate the character of the Silala as a watercourse, or river, and the international nature of the Silala River by force of incontrovertible fact.

3.23. The Silala was also included on the XIII-Point Agenda adopted by Chile and Bolivia in July 2006, through the Working Group on Bilateral Affairs, which identified a list of issues on the bilateral agenda.[81] The issue of the Silala (and water resources generally) was included as Point VII.

3.24. In June 2008, the Working Group on the Silala Issue agreed to proceed with discussions on a preliminary agreement related to the "rational and sustainable management" of the waters of the Silala.[82] However, in July 2010, in the context of the Political Consultations Mechanism, i.e. the institutional framework in which the XIII-Point Agenda was discussed, Bolivia raised the issue of Chile's so-called "historic debt" for the past use of the waters of the Silala, brought forward by its constituents as a condition for such preliminary agreement.[83]

3.25. At the next meeting of the Working Group on the Silala Issue, in October 2010, Bolivia hardened its position and insisted on its alleged right to economic compensation for the past use of the waters of the Silala on Chilean territory, demanding the inclusion of an article in the draft preliminary agreement

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[80] Minutes of the First Meeting of the Bolivia-Chile Working Group on the Silala Issue, 6 May 2004. **CM Annex 21.**

[81] Minutes of the Second Meeting of the Bolivia-Chile Working Group on Bilateral Affairs, 17 July 2006. **CM Annex 22.**

[82] Minutes of the Third Meeting of the Bolivia-Chile Working Group on the Silala Issue, 10 June 2008. **CM Annex 23.**

[83] Minutes of the Twenty-Second Meeting of the Bolivia-Chile Political Consultation Mechanism, 14 July 2010. **CM Annex 24.**

that would define the amount and form of such compensation.[84] Such alleged right to compensation had never been among the scope and objectives of the draft preliminary agreement, was not based on scientific evidence and was not in accordance with the norms and principles of international law. This disconcerting contention was immediately rejected by Chile.[85] Bolivia's claim for compensation radically changed the terms of the conversations and made impossible any agreement between the Parties on the use of the waters of the Silala River. The Chile-Bolivia Working Group on the Silala Issue never met again.

C. Bolivia's position post-2010 and Chile's decision to submit the dispute on the international nature of the Silala River system to the Court

3.26. On 7 May 2012, Chile requested information on several projects in the Silala River area that had been announced by the Governor of the Department of Potosí, where the source of the Silala River in Bolivia is located, including the construction of a fish farm, a small dam and a mineral water bottling plant.[86] Bolivia failed to respond to Chile's request.

3.27. Chile repeated its request for information on 9 October 2012.[87] On 25 October 2012, Bolivia responded by denying that the Silala River is an international watercourse, and reaffirming its alleged full and exclusive rights over the use and exploitation of its waters.[88] A further exchange of diplomatic

[84] Press Release from the Ministry of Foreign Affairs of Bolivia, 1 October 2010. **CM Annex 52.**

[85] Press Release from the Ministry of Foreign Affairs of Bolivia, 1 October 2010. **CM Annex 52.**

[86] Note N° 199/39 from the General Consulate of Chile in La Paz to the Ministry of Foreign Affairs of Bolivia, 7 May 2012. **CM Annex 34.**

[87] Note N° 389/149 from the General Consulate of Chile in La Paz to the Ministry of Foreign Affairs of Bolivia, 9 October 2012. **CM Annex 35.**

[88] Note N° VRE-DGRB-UAM-020663/2012 from the Ministry of Foreign Affairs of Bolivia to the General Consulate of Chile in La Paz, 25 October 2012. **CM Annex 36.**

notes followed, in which Bolivia did not change its position, despite the absence of any scientific or other evidence in support of its claims.[89]

3.28. On 27 March 2014, Chile sent a diplomatic note repeating its continued interest and willingness to proceed with technical projects and mutual collaboration on the Silala River system.[90] Bolivia responded by insisting once more on its alleged full and exclusive rights over this common watercourse.[91]

3.29. During a press conference on 23 March 2016, on the occasion of Bolivia's annual Day of the Sea, the Bolivian President, Mr. Morales, stated that he had instructed the Strategic Maritime Vindication Office (DIREMAR) "to study the legal alternatives to undertake the defence of our water of the Silala before the competent international authorities."[92] According to President

[89] Note N° 586/206 from the General Consulate of Chile in La Paz to the Ministry of Foreign Affairs of Bolivia, 21 December 2012. **CM Annex 37.1.** Note N° VRE-DGLF-UMA-000715/2013 from the Ministry of Foreign Affairs of Bolivia to the General Consulate of Chile in La Paz, 17 January 2013. **CM Annex 37.2.** Note N° 003933 from the Ministry of Foreign Affairs of Chile to the General Consulate of Bolivia in Santiago, 9 April 2013. **CM Annex 37.3.** Note N° VRE-DGLF-UMA-008107/2013 from the Ministry of Foreign Affairs of Bolivia to the General Consulate of Chile in La Paz, 9 May 2013. **CM Annex 37.4.** Note N° 269/134 from the General Consulate of Chile in La Paz to the Ministry of Foreign Affairs of Bolivia, 25 September 2013. **CM Annex 37.5.** Note N° VRE-DGLF-UMA-017599/2013 from the Ministry of Foreign Affairs of Bolivia to the General Consulate of Chile in La Paz, 2 October 2013. **CM Annex 37.6.** Note N° 323/157 from the General Consulate of Chile in La Paz to the Ministry of Foreign Affairs of Bolivia, 29 October 2013. **CM Annex 37.7.** Note N° VRE-DGLF-UMA-020899/2013 from the Ministry of Foreign Affairs of Bolivia to the General Consulate of Chile in La Paz, 19 November 2013. **CM Annex 37.8.** Note N° 362/180 from the General Consulate of Chile in La Paz to the Ministry of Foreign Affairs of Bolivia, 28 November 2013. **CM Annex 37.9.** Note N° VRE-DGLF-UMA-022856/2013 from the Ministry of Foreign Affairs of Bolivia to the General Consulate of Chile in La Paz, 16 December 2013. **CM Annex 37.10.** Note N° 63/51 from the General Consulate of Chile in La Paz to the Ministry of Foreign Affairs of Bolivia, 12 February 2014. **CM Annex 37.11.** Note N° VRE-DGLFAIT-UAIT-Nv-7/2014 from the Ministry of Foreign Affairs of Bolivia to the General Consulate of Chile in La Paz, 19 February 2014. **CM Annex 37.12.**

[90] Note N° 96/72 from the Ministry of Foreign Affairs of Chile to the Ministry of Foreign Affairs of Bolivia, 27 March 2014. **CM Annex 38.1.**

[91] Note N° VRE-DGLFAIT-UAIT-Cs-136/2014 from the Ministry of Foreign Affairs of Bolivia to the General Consulate of Chile in La Paz, 10 April 2014. **CM Annex 38.2.**

[92] Prensa Palacio, "*President Morales Gives Instructions to Study Legal Alternatives to Defend Waters of the Silala*", La Paz, 23 March 2016, **CM Annex 72.1**; La Nación, "*Evo Morales*

Morales, the Silala is conducted to Chile by means of an artificial system of aqueducts:

> "Originating in the Bolivian Andean territory, the waters of the Silala spring have been supplying – without any compensation – several cities in northern Chile for more than 100 years and, due to a private law agreement, the watercourse was conducted to northern Chile by means of an artificial system of aqueducts. […] Each day, Chile makes an illegal and cunning use of that natural resource without compensating even a cent. This abusive and arbitrary behaviour that undermines our heritage cannot continue." [93]

3.30. Two days later, President Morales accused Chile of "stealing waters from the department of Potosí" and announced Bolivia's decision to present a claim before the International Court of Justice.[94] He also declared that the Silala "is not an international river but waters that spring from the wetlands of the department of Potosí"[95], suggesting an irreconcilable contradiction between a "river" and "springs" that is non-existent, because, as is well known, many rivers have their origin in springs.[96]

3.31. At a site visit to the Silala a few days later, he accused Chile of lying about the international nature of the Silala River.[97] Ten days after that, the

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Announces that Bolivia Will Seek Recourse to International Entities Concerning the Waters of the Silala", La Paz, 23 March 2016. **CM Annex 72.2.**

[93] Prensa Palacio, "*President Morales Gives Instructions to Study Legal Alternatives to Defend Waters of the Silala*", La Paz, 23 March 2016. **CM Annex 72.1.**

[94] Página Siete Digital, "*Bolivia Will Sue Chile over the Silala in The Hague*", La Paz, 26 March 2016. **CM Annex 72.3.**

[95] Página Siete Digital, "*Bolivia Will Sue Chile over the Silala in The Hague*", La Paz, 26 March 2016. **CM Annex 72.3.**

[96] **Exp. Rep. 1**, p. 7.

[97] Camiri.net, "*Evo Shows the World that the Waters of the Silala are Bolivian*", La Paz, 29 March 2016. **CM Annex 72.4.**

Bolivian Minister of Foreign Affairs, Mr. David Choquehuanca, announced that the preparation of the Silala case against Chile would take at least two years.[98]

3.32. The accusatory statements of President Morales in March 2016, together with Bolivia's declared decision to delay the judicial solution of this dispute for at least two years, recreated unnecessary tension regarding the status of the Silala River as an international watercourse and legal uncertainty between the two Parties in relation to their reciprocal rights and obligations regarding the uses of the waters of the Silala. Under these circumstances, Chile decided to request the Court's judgment on the nature of the Silala River as an international watercourse and of Chile's rights as a riparian State. Chile considers it critical to obtain a final judgment on matters that appear to Chile to be legally clear cut, but that nonetheless affect the legal certainty of the uses of the waters of the Silala in Chile, as well as the bilateral relations between Chile and Bolivia.

[98] La Razón, "*The Minister of Foreign Affairs Foresees Two Years to Prepare the Claim for the Silala*", La Paz, 8 April 2016. **CM Annex 73.**

CHAPTER 4
THE SILALA RIVER SYSTEM IS AN INTERNATIONAL WATERCOURSE UNDER INTERNATIONAL LAW

4.1. In the present chapter, Chile will show that, contrary to Bolivia's recent assertions, the Silala qualifies as an "international watercourse" as that term is defined in international law. Section A will establish how the concept of "international watercourse" is defined in international law and that the Silala River satisfies this definition. Section B will show that the conduct of the Parties confirms a longstanding and mutual acknowledgment of the existence of the Silala River as an international watercourse.

A. The Silala River system is an "International Watercourse" as that term is defined under international law

4.2. The International Law Commission (ILC) began working on the law of the non-navigational uses of international watercourses in 1974 and adopted a final set of draft articles on the topic in 1994.[99] In that same year, the General Assembly decided to convene negotiations for the elaboration of a framework convention on the law of the non-navigational uses of international watercourses on the basis of the 1994 ILC draft articles. The negotiations were open to all U.N. member states as well as states that are members of U.N. specialized agencies.[100] Thus, they were open to near-universal participation. These negotiations led to the adoption by the General Assembly on 21 May 1997 of the Convention on the Law of the Non-Navigational Uses of International

[99] *Yearbook of the International Law Commission*, 1994, vol. II (Part Two), p. 89, para. 222.

[100] UN General Assembly Resolution 49/52, 9 December 1994, U.N. Doc. A/RES/49/52, para. 3.

Watercourses ("UNWC" or "Convention").[101] The Convention follows closely the ILC's draft articles of 1994.[102]

4.3. From the beginning of its work on international watercourses over forty years ago, the ILC has given careful consideration to the definition of the term, "international watercourse." The first report of Richard D. Kearney, the ILC's first Special Rapporteur on the topic, was devoted largely to this question.[103] Kearney concluded that the scope of the term should be broad, encompassing "the non-navigational uses of international river basins."[104] The Commission's second Special Rapporteur, Stephen M. Schwebel, also found that a broad definition of "international watercourse" was appropriate.[105] In 1980, the ILC adopted a provisional indication of what was meant by the expressions "watercourse system" and "international watercourse system,"[106] which parallels closely the definition of "watercourse" in the 1997 UNWC.

[101] Convention on the Law of Non-Navigational Uses of International Watercourses, signed at New York on 21 May 1997, UN Doc. A/RES/51/229 (1997), entered into force 17 August 2014 (hereinafter "UNWC" or "Convention"). **CM Annex 5.**

[102] The "Statements of Understanding" adopted by the Working Group of the Whole, in which the Convention was negotiated, include the following: "Throughout the elaboration of the draft Convention, reference had been made to the commentaries to the draft articles prepared by the International Law Commission to clarify the contents of the articles." See: Statements of Understanding Pertaining to the Texts of the Draft Convention, Report of the Sixth Committee Convening as the Working Group of the Whole, UN Doc. A/51/869, 11 April 1997, para. 8.

[103] Richard D. Kearney, First Report on the Law of the Non-Navigational Uses of International Watercourses, *Yearbook of the International Law Commission*, 1976, vol. II (Part One), p. 184.

[104] Richard D. Kearney, First Report on the Law of the Non-Navigational Uses of International Watercourses, *Yearbook of the International Law Commission*, 1976, vol. II (Part One), p. 191, para. 49.

[105] Stephen M. Schwebel used the expression "international watercourse system" in his proposed Draft Articles. See: Stephen M. Schwebel, Second Report on the Law of the Non-Navigational Uses of International Watercourses, *Yearbook of the International Law Commission*, 1980, vol. II (Part One), p. 167, paras. 52-58.

[106] The ILC in 1980 adopted a "working hypothesis" concerning the meaning of that expression, which reads in part: "A watercourse system is formed of hydrographic components such as rivers, lakes, canals, glaciers and groundwater constituting by virtue of their physical relationship a unitary whole; thus, any use affecting waters in one part of the system may affect waters in

4.4. At its core, the definition of the term "watercourse" changed little throughout the Commission's work on the topic. As finally set out in Article 2 of the 1994 draft articles, the term is defined as follows:

> "'Watercourse' means a system of surface waters and groundwaters constituting by virtue of their physical relationship a unitary whole and normally flowing into a common terminus;" [107]

The term "international watercourse" is defined as "a watercourse, parts of which are situated in different States".[108] An indicative list of the components of a watercourses system is set out in the Commission's commentaries.[109] These definitions were carried over word-for-word into Article 2 of the 1997 UNWC.[110]

4.5. The provenance of the 1997 UNWC, as the product of painstaking work by the International Law Commission over a period of twenty years, gives it special status in international law as a codification of the rules of customary international law on the subject of international watercourses.

4.6. Indeed, a mere four months after the Convention was adopted by the General Assembly, it was referred to, and quoted from, in this Court's judgment in the *Gabčíkovo-Nagymaros Project* case.[111] In that case, the Court also referred to a State's "basic right to an equitable and reasonable sharing of the

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another part." An 'international watercourse system' is a watercourse system, components of which are situated in two or more States." *Yearbook of the International Law Commission*, 1982, vol. II (Part One), p. 68, para. 7.

[107] *Yearbook of the International Law Commission*, 1994, vol. II (Part Two), p. 90, para. 222, Art. 2(b).

[108] *Yearbook of the International Law Commission*, 1994, vol. II (Part Two), p. 90, para. 222, Art. 2(a).

[109] *Yearbook of the International Law Commission*, 1994, vol. II (Part Two), p. 90, para. 222, commentary to article 2(b), para. (4).

[110] 1997 UNWC, Art. 2(a) and (b). The order of the definitions is reversed in the Convention, "watercourse" being defined in Art. 2(a) and "international watercourse" in Art. 2(b).

[111] *Gabčíkovo-Nagymaros Project (Hungary/Slovakia), Judgment, I.C.J. Reports 1997*, p. 7, para. 147.

resources of an international watercourse,"[112] equitable and reasonable utilization being one of the cornerstones of the Convention.[113] Scholars agree on "the importance of the Convention […] as an authoritative instrument evidentiary of customary law."[114]

4.7. The UNWC may be taken as a reflection of certain core principles of customary international law relating to the non-navigational uses of international watercourses, including so far as concerns the definitions of "watercourse" and "international watercourse".

4.8. As to the Silala River, this satisfies the definition of "watercourse" under international law. Rising from springs and flowing on the surface of the land down a natural gradient,[115] it is manifestly a "system of surface waters and groundwaters." "[B]y virtue of their physical relationship" these surface and groundwaters may be said to "constitut[e] […] a unitary whole": without the springs, the surface flow originating in those springs would not exist.

4.9. The Silala River is an "international watercourse" because "parts of [it] are situated in different States", namely, Bolivia and Chile. It rises from springs located in Bolivia and flows down a natural slope across the border with Chile. The river has flowed downhill across what is now the border between Bolivia and Chile for at least 8400 years,[116] negating the curious suggestion that

[112] *Gabčíkovo-Nagymaros Project (Hungary/Slovakia), Judgment, I.C.J. Reports 1997*, p. 7, paras. 78 and 147, where the Court quotes from Art. 5(2), of the Convention, on equitable and reasonable participation.

[113] 1997 UNWC, Arts. 5 and 6. See also 1997 UNWC, Art. 7(2), providing further evidence of the central nature of equitable and reasonable utilization.

[114] Attila Tanzi and Maurizio Arcari, *The United Nations Convention on the Law of International Watercourses: A Framework for Sharing,* Kluwer Law International, 2001, p. 2.

[115] **Exp. Rep. 1**, p. 7.

[116] **Exp. Rep. 2**, p. 8.

the 1928 construction of channels in Bolivia is or ever has been responsible for its international character.

4.10. Therefore the Silala River system is an "international watercourse" as that expression is defined in the UNWC, a definition that has long been accepted by States and the International Law Commission as shown above.

B. The conduct of the Parties confirms the characterization of the Silala River system as an international watercourse under international law

4.11. As was demonstrated in chapter 2, and will now be addressed in more detail, over the course of more than a century, both States have consistently acknowledged the international status of the Silala River in a variety of international and domestic instruments as well as in their mutual relationship.

4.12. Such instruments include cartographic representations of the Silala River by both States (section 1); joint demarcation and revision activities in relation to the Silala River between 1904 and 2011 (section 2), and the concession of the use of the waters of the Silala River by both Chile and Bolivia, in 1906 and 1908, respectively (section 3). In addition, Bolivia has unilaterally acknowledged the existence of the Silala River in international and national instruments (section 4).

1. Chilean and Bolivian cartography confirm the nature of the Silala River as an international watercourse

4.13. Maps may provide valuable information on the existence and location of geographical and other features. As was recognized by the International Court of Justice in the *Kasikili/Sedudu Island* case, maps are of particular value when they are an integral part of an official text:

> "[M]aps merely constitute information which varies in accuracy from case to case; of themselves, and by virtue solely of their existence, they cannot constitute a territorial title, that is, a document endowed by international law with intrinsic legal force for the purpose of establishing territorial rights. Of course, in some cases maps may acquire such legal force, but where this is so the legal force does not arise solely from their intrinsic merits: <u>it is because such maps fall into the category of physical expressions of the will of the State or States concerned. This is the case, for example, when maps are annexed to an official text of which they form an integral part</u>."[117] (emphasis added)

4.14. The Eritrea-Ethiopia Boundary Commission also confirmed the binding effect of a map that is part of a treaty to the parties of that treaty.[118]

4.15. Such maps may provide conclusive evidence of the acceptance of a State of a later disputed geographical or other feature, as in the *Case concerning the Temple of Preah Vihear*, in which the Court stated that:

> "The Court […] considers that Thailand in 1908-1909 did accept the Annex I map as representing the outcome of the work of delimitation, and hence <u>recognized the line on that map as being the frontier line, the effect of which is to situate the Preah Vihear in Cambodian territory.</u> The Court considers further that, looked at as a whole, Thailand's <u>subsequent conduct confirms and bears out her original acceptance, and that Thailand's acts on the ground do not suffice to negative this</u>. Both Parties, by their conduct, recognized the line and thereby in effect agreed to regard it as being the frontier line."[119] (emphasis added)

4.16. The Arbitral Tribunal in the *Dispute between Chile and Argentina concerning the Beagle Channel* held that maps published *before* the conclusion

[117] *Kasikili/Sedudu Island (Botswana/Namibia), Judgment, I.C.J. Reports 1999*, p. 1045, para. 84.

[118] *Decision Regarding Delimitation of the Border Between the State of Eritrea and the Federal Democratic Republic of Ethiopia*, Award of 13 April 2002, Reports of International Arbitral Awards, Vol. XXV, para. 3.20: "As already noted, where a map is made part of a treaty then it shares the legal quality of the treaty and is binding on the parties."

[119] *Case concerning the Temple of Preah Vihear (Cambodia v. Thailand), Merits, Judgment of 15 June 1962: I.C.J. Reports 1962*, p. 6, pp. 32-33.

of a treaty may serve as evidence of "a situation of fact generally known at the time or within the actual, or to be presumed, knowledge of the negotiators".[120] It also held that maps published *after* the conclusion of a treaty may serve as evidence of the parties' understanding of the settlements agreed under that treaty, "and the degree to which the view now being asserted by [a] Party as the correct one is consistent with that which it appears formerly to have entertained".[121] More generally, the Arbitral Tribunal held that official maps are:

> "[G]ood evidence of the view the government took, or wished to be regarded as taking, at the date of publication; and it may, for that reason, assist, or, as the case may be, not assist, the contentions that such government advances in a subsequent litigation, or at a later date".[122]

4.17. Various cartographic representations before the 1904 Treaty, both Bolivian and Chilean, show the Silala River flowing from Bolivia into the territory then possessed by Chile as established under the 1884 Truce Pact signed between both States.[123] The temporary boundary agreed under the 1884 Truce Pact in this area was similar to the definitive boundary established under the 1904 Treaty. Hence, these early cartographic sources constitute strong evidence of the acknowledgment of both States of the transboundary nature of the Silala River, at

[120] *Dispute Between Argentina and Chile Concerning the Beagle Channel*, Award of 18 February 1977, Reports of International Arbitral Awards, Vol. XXI, para. 137.

[121] *Dispute Between Argentina and Chile Concerning the Beagle Channel*, Award of 18 February 1977, Reports of International Arbitral Awards, Vol. XXI, para. 137.

[122] *Dispute Between Argentina and Chile Concerning the Beagle Channel*, Award of 18 February 1977, Reports of International Arbitral Awards, Vol. XXI, para. 138.

[123] Truce Pact Between Bolivia and Chile, signed at Valparaíso on 4 April 1884. **CM Annex 1.** The boundary between Bolivia and Chile in the relevant area was defined under the Truce Pact as follows: "[A] straight line starting at Sapalegui, from the intersection with the demarcation separating them from the Republic of Argentina, to Volcán Llicancaur. From this point, it shall continue straight to the summit of the dormant Cabana volcano; from here, another straight line shall continue to the water source, which is found further south in the lake Ascotán…"

the time of the signing of the 1884 Truce Pact and again at the time of the signing of the 1904 Treaty.

4.18. The earliest known cartographic depiction of the Silala River dates from 1884, on the map of the Atacama Desert published by Chilean engineer and geographer Alejandro Bertrand (1854-1942). The Silala River, under its previous name Cajón, is there depicted as a tributary of the San Pedro River, entering from Bolivia into Chile (Figure 15).[124]

[124] The 1884 map was the result of two expeditions by Bertrand to the Atacama Desert, during the year 1880 and again in 1884. It was published together with Bertrand's "Treatise on the Mountain Ranges of the Atacama Desert" (*Memoria sobre las Cordilleras del Desierto de Atacama*), containing the logs of both expeditions and a critical analysis of previous publications and maps of the area.

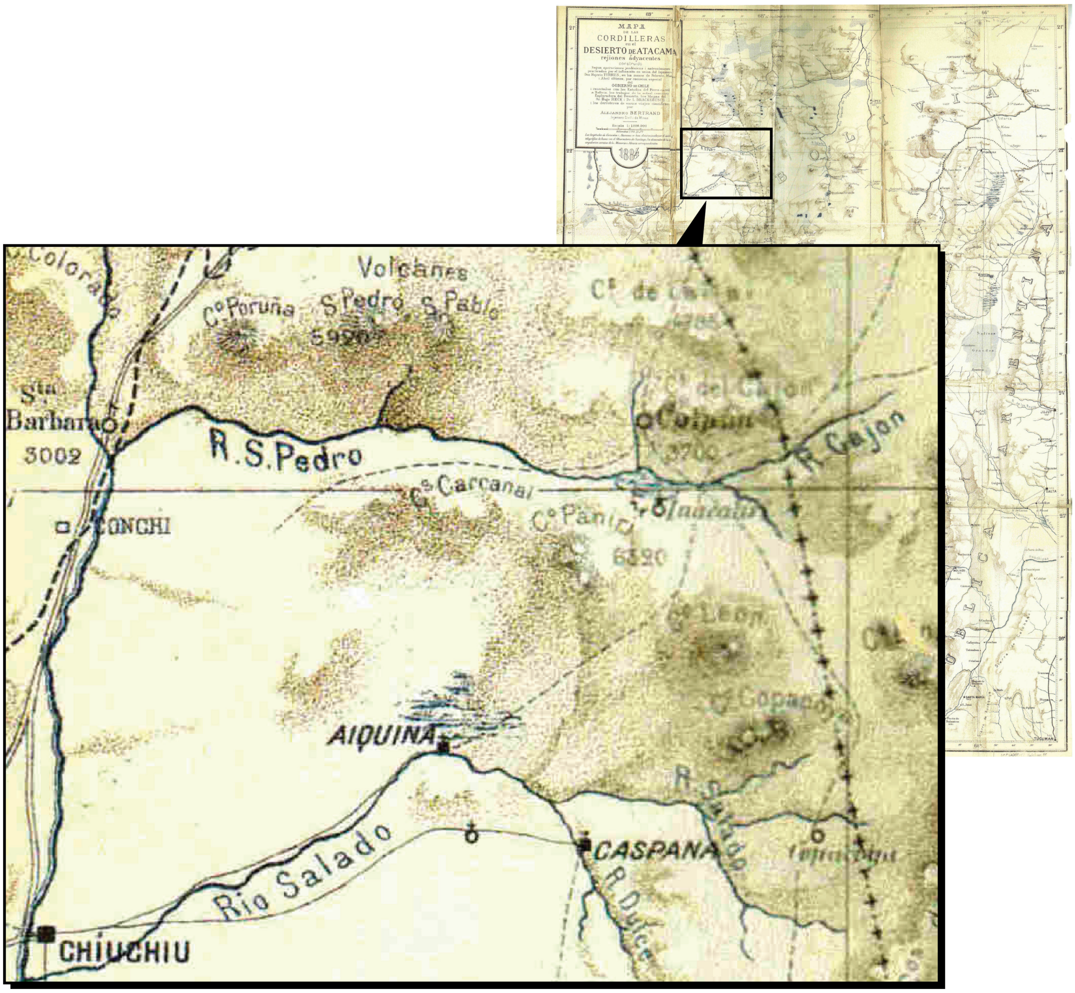

Figure 15. A. Bertrand, Map of the Mountain Ranges in the Atacama Desert and Adjacent Regions, 1884. **CM Annex 77.**

4.19. Another early representation of the Silala River, again under the name Cajón, can be found on the Map of the Republic of Argentina by German geologist and mineralogist Luis (Ludwig) Brackebusch (1849-1906) of 1891 (Figure 16).

Figure 16. L. Brackebusch, Map of the Republic of Argentina, 1891. **CM Annex 79.**

4.20. The Silala River is also depicted on the Chilean 1897 Map of the Province of Antofagasta, this time under the name of R.S. Pedro, crossing the temporary boundary under the 1884 Truce Pact (Figure 17).

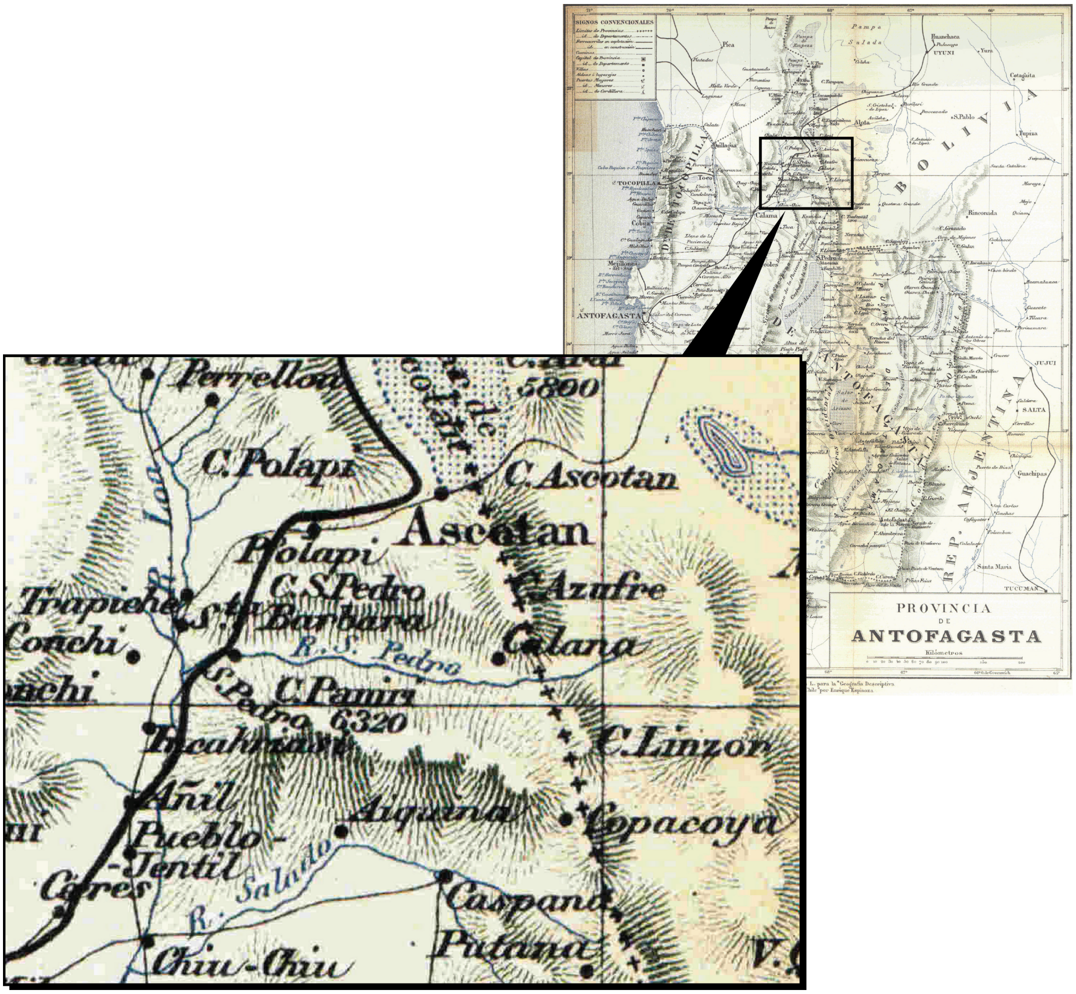

Figure 17. F. Fuentes, Map of the Province of Antofagasta, 1897. **CM Annex 80.**

4.21. An early Bolivian source for the location of the Silala River is the Geographic and Chorographic Map of the Republic of Bolivia of 1890, by Justo Leigue Moreno, Sergeant of the Republic of Bolivia. This map shows the watercourse on Bolivian territory, crossing the temporary boundary between Bolivia and Chile as established under the 1884 Truce Pact, and connecting to the San Pedro River on territory then possessed by Chile (Figure 18).

Figure 18. J. Leigue Moreno, Geographic and Chorographic Map, 1890. **CM Annex 78.**

4.22. Another Bolivian source which evidences its understanding of the transboundary nature of the Silala River prior to the 1904 Treaty is the 1901 Map of the Republic of Bolivia by Eduardo Idiaquez, ordered by President José Manuel Pando of Bolivia. It depicts the San Pedro River's origin in Bolivian territory, crossing the Chilean-Bolivian temporary boundary as established under the 1884 Truce Pact, corresponding geographically to what is known today as the Silala River (Figure 19).

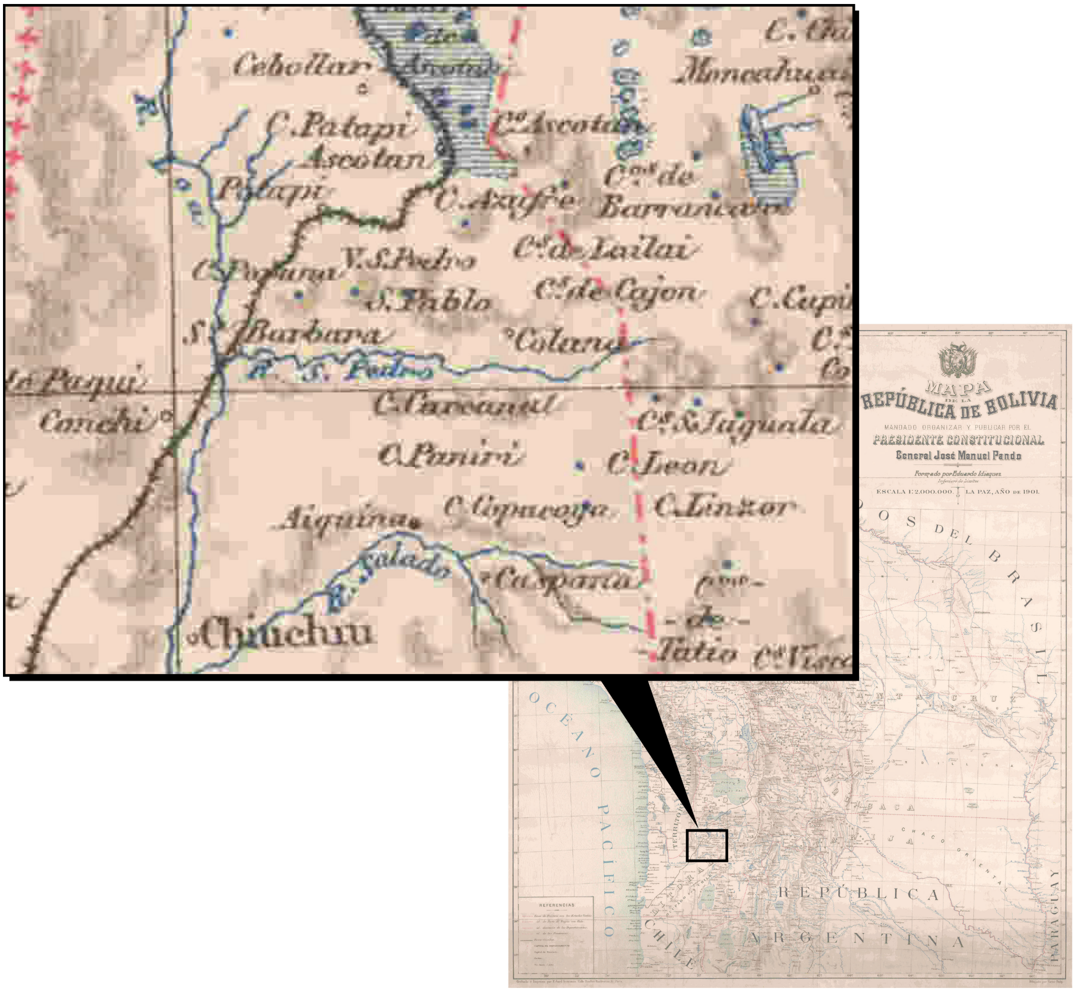

Figure 19. E. Idiaquez, Map of the Republic of Bolivia, 1901. **CM Annex 81.**

4.23. These early sources conclusively prove that both Chile and Bolivia recognized the existence of a shared watercourse crossing the temporary boundary as established under the 1884 Truce Pact, sometimes under a different name (Cajón or San Pedro) but always identifiable as what is now known as the Silala River.

4.24. The map appended to the 1904 Treaty of Peace and Amity provides further irrefutable evidence of Bolivia's and Chile's joint understanding of the transboundary nature of the Silala River. Both Map and Treaty were signed on 20 October 1904 by the highest Bolivian and Chilean authorities.[125] Article 2 of the 1904 Treaty establishes that the appended Map forms an integral part of the Treaty.[126]

4.25. The 1904 Treaty established the definitive international boundary between Chile and Bolivia and terminated the temporary regime defined under the 1884 Truce Pact. The appended Map, signed by Chilean Minister of Foreign Affairs, Mr. Emilio Bello Codesido, and the Bolivian Ambassador in Chile, Mr. Alberto Gutiérrez, depicts the Silala River (Río Silala), crossing the boundary between Bolivia and Chile amid point 16 (Cerrito de Silala) and point 17 (Cerro de Inacaliri o del Cajón) of that boundary (Figure 14).[127]

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[125] Treaty of Peace and Amity Between Bolivia and Chile, signed at Santiago on 20 October 1904. **CM Annex 2.** Map Appended to the Treaty of Peace and Amity, 20 October 1904. **CM Annex 82.**

[126] Treaty of Peace and Amity Between Bolivia and Chile, signed at Santiago on 20 October 1904. **CM Annex 2.**

[127] The boundary in the Silala area is indicated in the 1904 Treaty as follows: "from its northern peak (Apagado Volcano) (15) where it shall go by a spur towards the Silala Hillock (16), and thence in a straight line to Inacaliri or Cajón Hill (17)", see: Treaty of Peace and Amity Between Bolivia and Chile, signed at Santiago on 20 October 1904. **CM Annex 2.** On the Map appended to the 1904 Treaty, the numbers of these three points are displaced by one, Volcán Apagado appearing as N° 14 (instead of N° 15), Cerrito de Silala as N° 15 (instead of N° 16) and Cerro de Inacaliri o del Cajón as N° 16 (instead of N° 17). See Map Appended to the Treaty of Peace and Amity, 20 October 1904. **CM Annex 82.**

4.26. Following the 1904 Treaty, both Bolivia and Chile have confirmed the transboundary character of the Silala River by producing and publishing numerous official maps depicting the Silala River as an international watercourse.

4.27. Indeed, Bolivia's unconditional understanding and acceptance of the transboundary nature of the Silala River as represented on the Map appended to the 1904 Treaty is evidenced by a Bolivian map of 1905, elaborated immediately following the signing of the 1904 Treaty, "in accordance with official documents of the Ministry of Foreign Affairs studied with the competent collaboration of the eminent former Foreign Minister, the Honourable Mr. Eliodoro Villazon." This 1905 map depicts the San Pedro River, coinciding with the geographical features of the Silala River, crossing the now definitive Bolivia-Chile international boundary (Figure 20).

Figure 20. L. García Mesa, General Map of Bolivia, 1905. **CM Annex 83.**

4.28. Since then, Bolivia has depicted the geographical feature of the Silala River on official maps prepared by its Military Geographical Institute (Instituto Geográfico Militar or I.G.M.), such as the 1972 map of Cerrito de Silala (named "Cerro Silala Chico" by Bolivia), testifying to Bolivia's continued understanding of the transboundary nature of the Silala River (Figure 21).

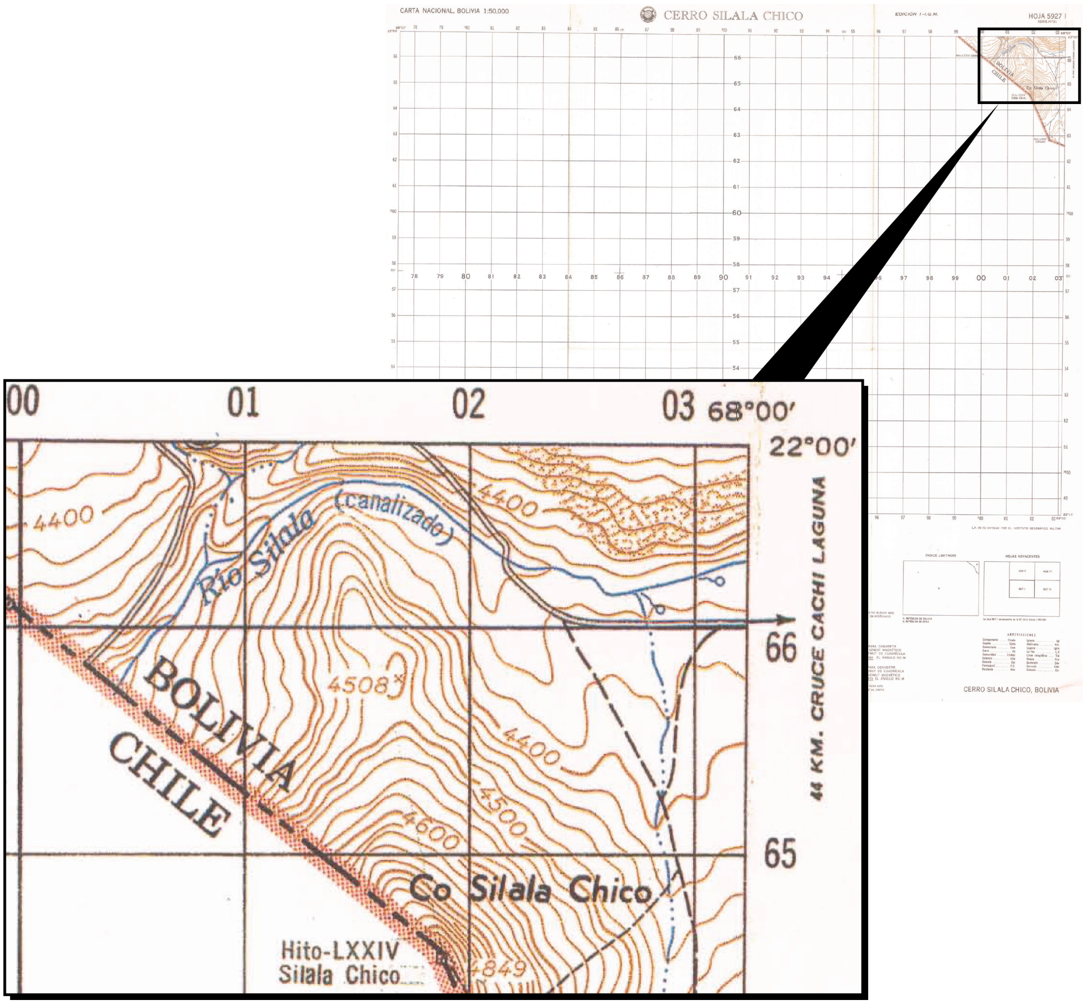

Figure 21. Bolivian Military Geographical Institute (I.G.M.), Cerro Silala Chico Sheet 5927 I Series H731, 1st ed., 1971. **CM Annex 87.**

4.29. Bolivia's most recent official map by I.G.M. that depicts the Silala as an international watercourse dates from 1997, only two years before its abrupt change of position on the nature of the Silala (Figure 22).

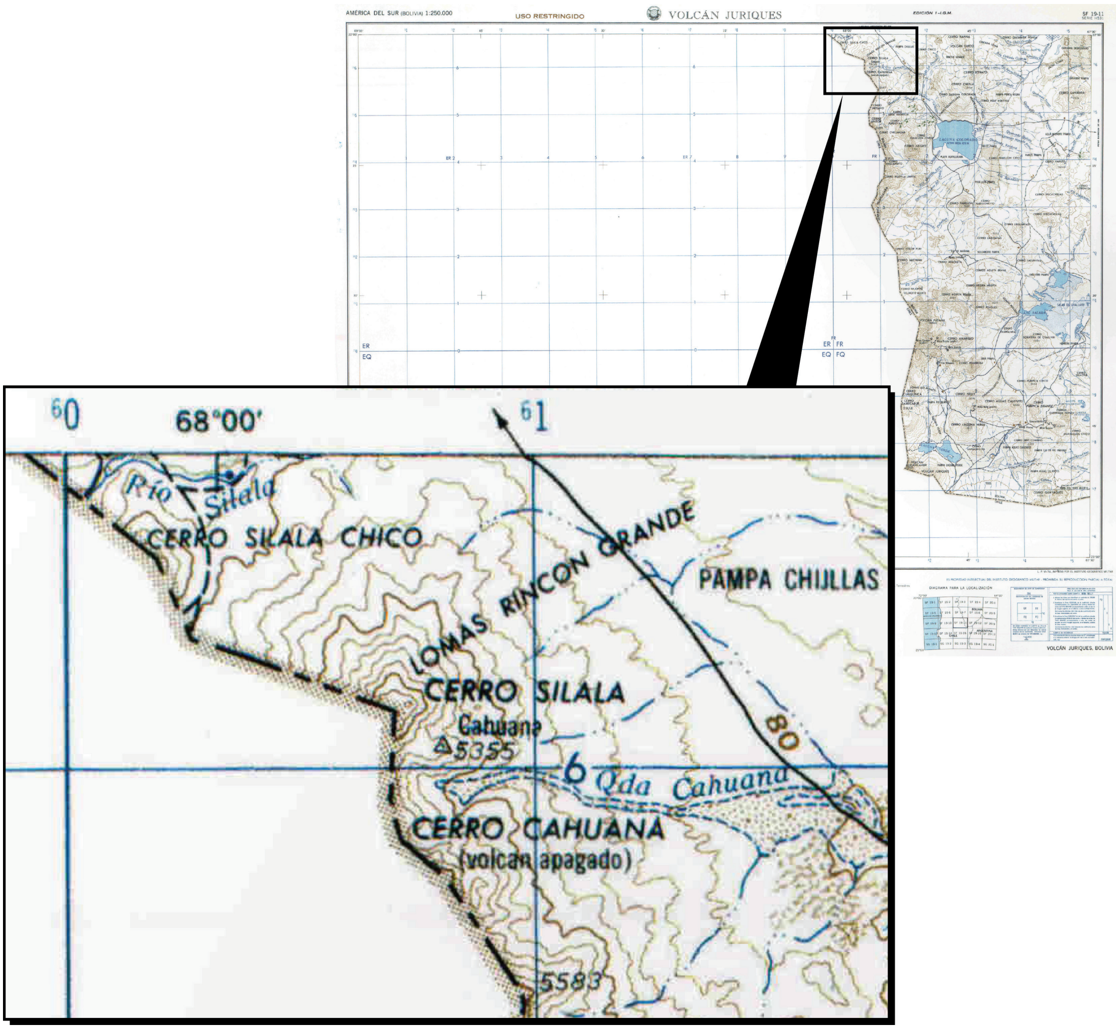

Figure 22. Bolivian Military Geographical Institute (I.G.M.), Map of South America (Bolivia) Volcán Juriques, 1st ed., reissued May 1997. **CM Annex 90.**

4.30. Also in 1997, the Bolivian Geology and Mining Survey SERGEOMIN reflected the transboundary nature of the Silala River on its Geological Map of Bolivia (Figure 23).

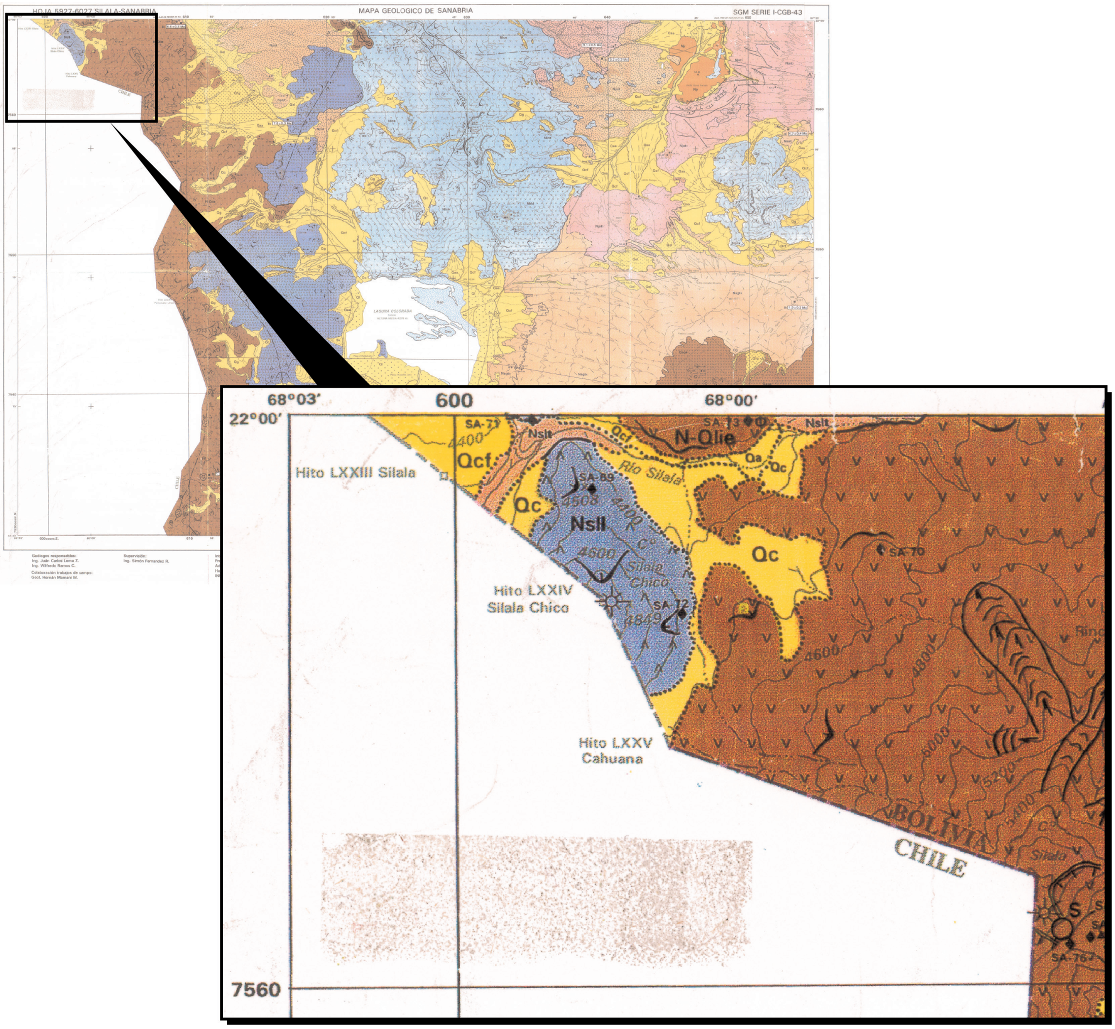

Figure 23. Bolivian Geology and Mining Survey (SERGEOMIN), Geological Map of Bolivia, Sheet 5927-6027 Silala-Sanabria, ed. March 1997. **CM Annex 89.**

4.31. On this map, SERGEOMIN classified deposits immediately north of the Silala River ravine as "Qcf", meaning Colluvial-fluvial deposits of the Pleistocene-Holocene Period.[128] This stands to confirm the fluvial origins of the Silala ravine by Bolivia's own most qualified technical authority. It also reconfirms the unfounded nature of Bolivia's change of position.

4.32. It is noteworthy that, on 27 April 1999, the Bolivian House of Deputies approved a proposal to instruct the Bolivian I.G.M. to modify its maps in which the Silala "mistakenly" appears as a river. It also accepted a proposal directed to the Executive, to instruct all divisions of the State to stop using the word "river" when referring to the Silala springs, "given that said confusion could bring serious problems to the national sovereignty".[129] The discussion in the Bolivian House of Deputies gave rise to a diplomatic note from Chile, confirming the status of the Silala River as an international watercourse.[130]

4.33. Chilean official maps published after the 1904 Treaty, as in 1907, 1910 and 2014, also depict the Silala River as a transboundary watercourse, originating in Bolivia and crossing the international boundary into Chile (Figures 24, 25 and 26).

[128] See for the definition of the Lithologic Descriptions, the upper right hand corner of the *Geological Map of Bolivia, Sheet 5927-6027 Silala-Sanabria,* ed. March 1997. **CM Annex 89.**

[129] Bolivian House of Deputies, Bulletin N° 308, 27 April 1999. **CM Annex 47.**

[130] Note N° 474/71 from the General Consulate of Chile in La Paz to the Ministry of Foreign Affairs of Bolivia, 20 May 1999. **CM Annex 26.**

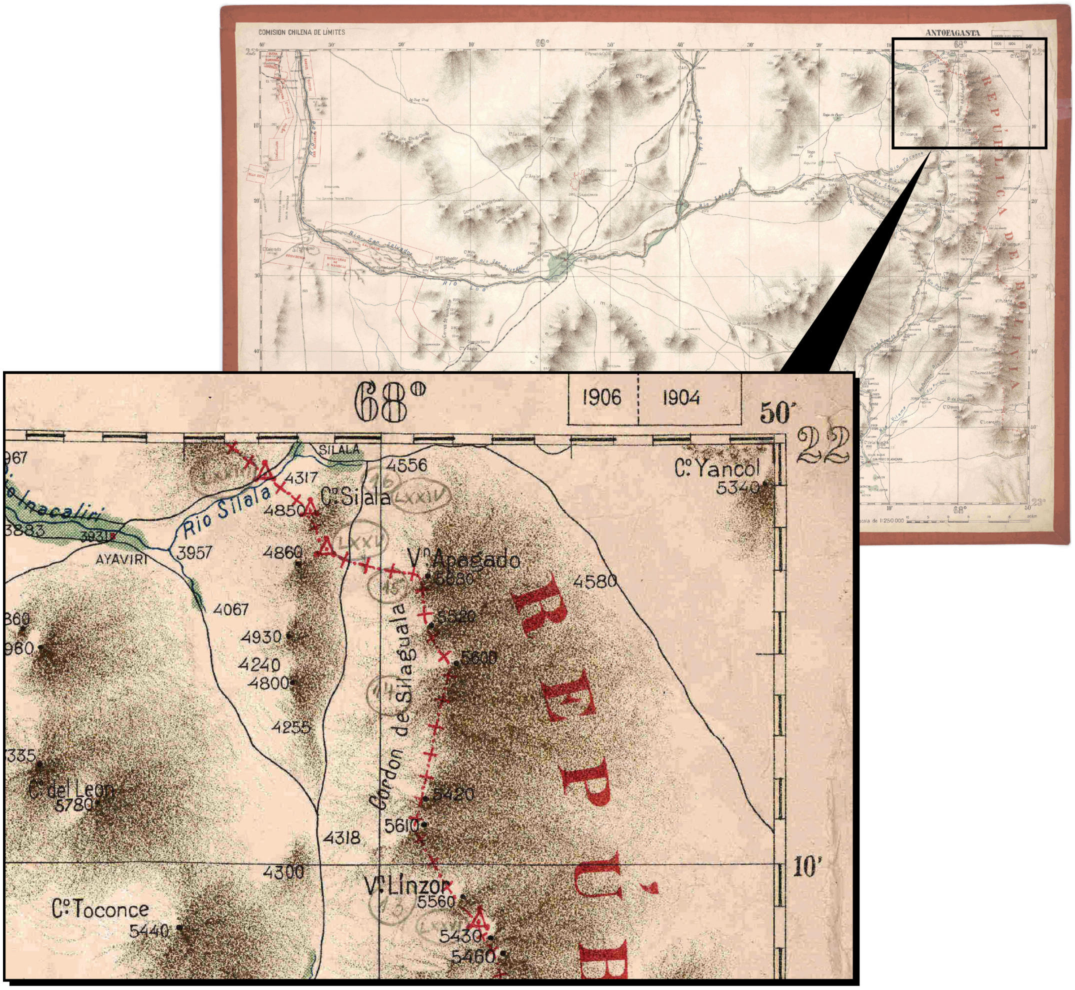

Figure 24. Chilean Boundary Commission, Antofagasta Sheet, 1907. **CM Annex 84.**

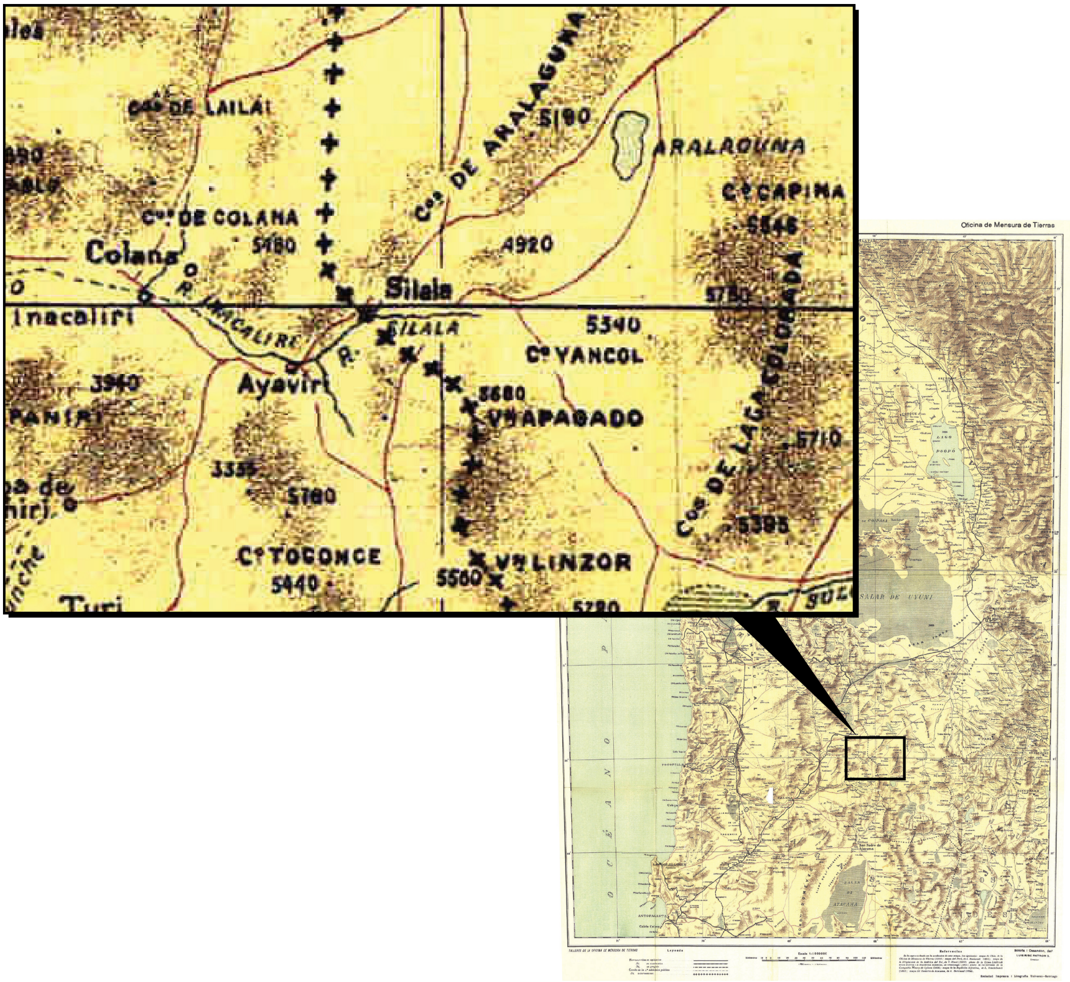

Figure 25. Land Measuring Office of Chile, Map (untitled), in: The Boundary Line with the Republic of Bolivia, 1910. **CM Annex 86.**

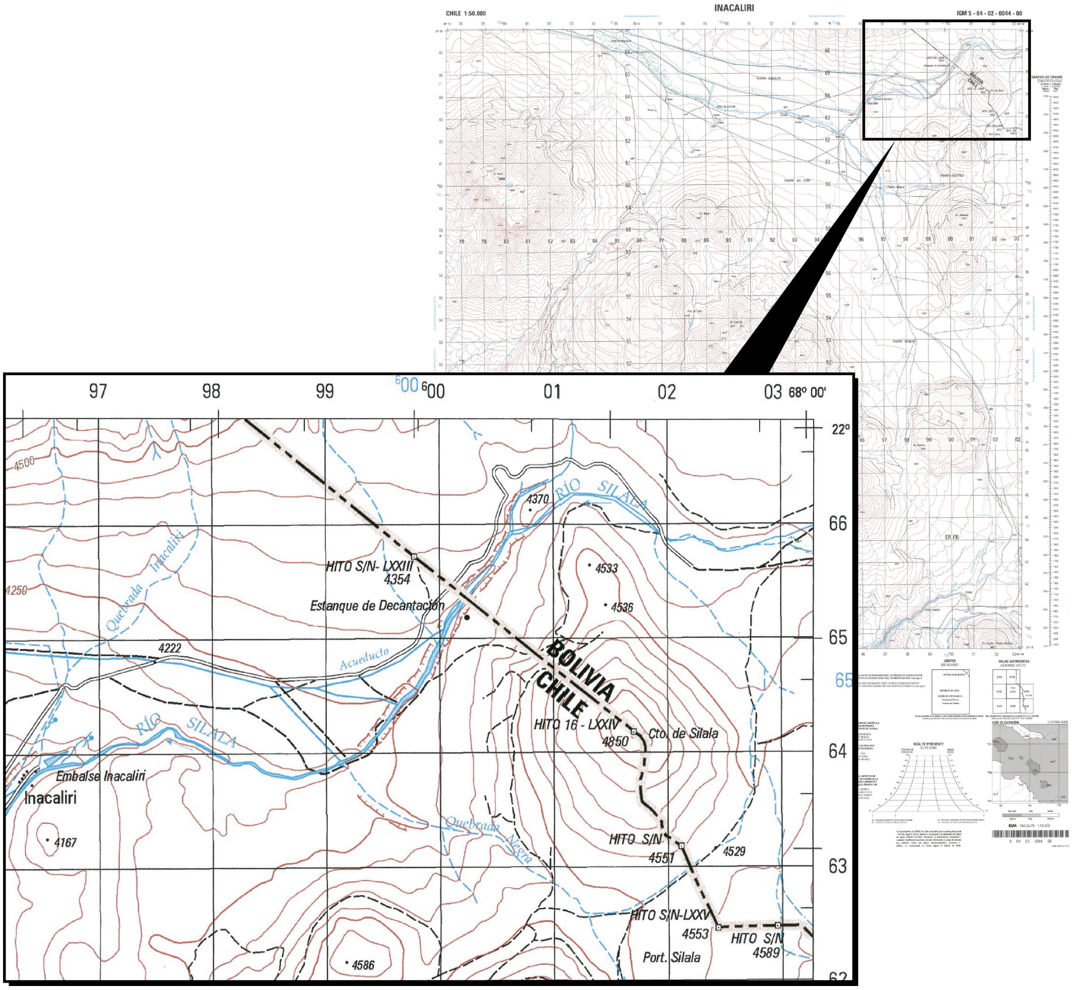

Figure 26. Chilean Military Geographical Institute (I.G.M.), Inacaliri Sheet, 3rd ed., 2014.
CM Annex 91.

4.34. A 1907 non-official Chilean map of the saltpetre region is also of particular interest, as it is based on recent measurements by the Chilean Boundary Office and prior to the putting into use of the Chilean and Bolivian FCAB concessions (Figure 27).

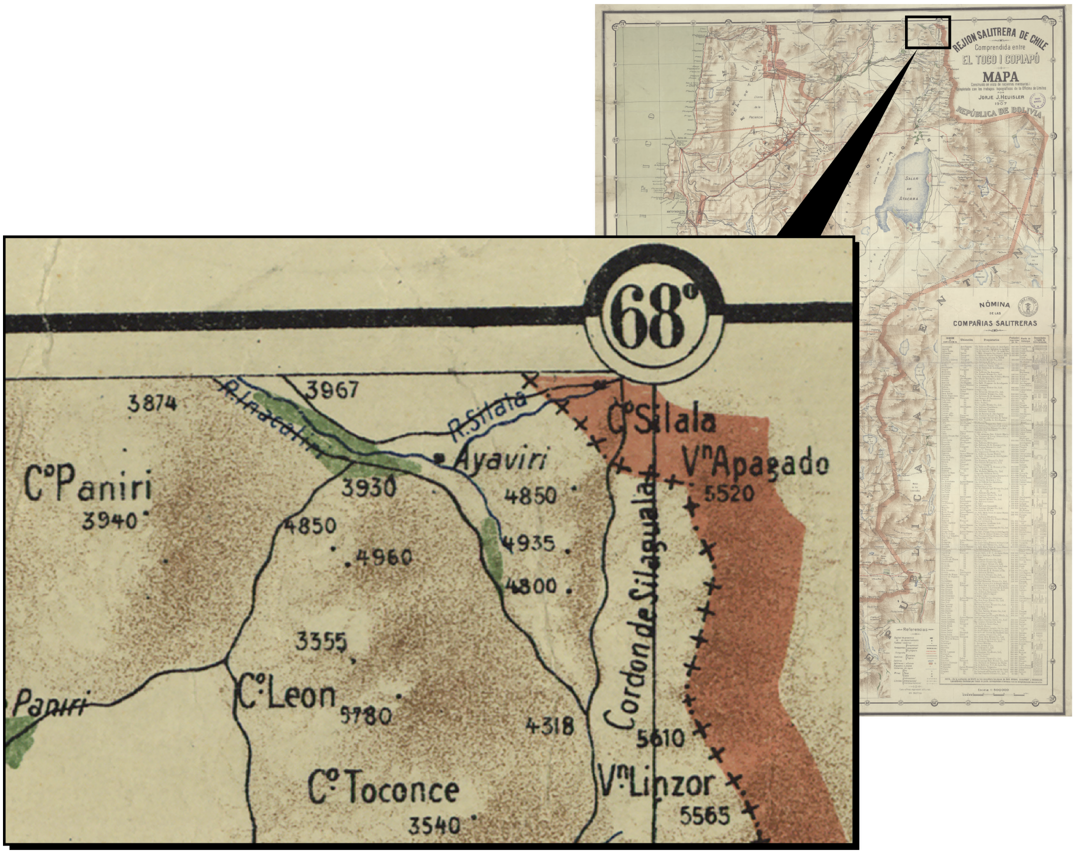

Figure 27. J. J. Heuisler, Map of the Saltpetre Region of Chile Comprised Between El Toco and Copiapó, 1907. **CM Annex 85.**

4.35. Therefore, the joint recognition (through the Map appended to the 1904 Treaty) is further confirmed by numerous official maps published by Bolivia and Chile after the 1904 Treaty that depict the Silala River as a transboundary watercourse, originating in Bolivia and flowing into Chile.

2. *All Mixed Commissions in charge of the demarcation and revision of the international boundary have acknowledged the nature of the Silala River as an international watercourse*

4.36. Following the signing of the 1904 Treaty, Bolivia has repeatedly acknowledged and confirmed the international status of the Silala River in the context of joint demarcation, revision and other activities in the area of the Silala River. Bolivia's delegations to these mixed commissions never called into question the nature of the Silala as an international watercourse.

4.37. In this respect it is recalled that, in *Armed Activities on the Territory of the Congo*, this Court has stressed that it will "prefer contemporaneous evidence from persons with direct knowledge" and that it will "give particular attention to reliable evidence acknowledging facts or conduct unfavourable to the State represented by the person making them."[131] Thus, the recognition and acknowledgment of the Silala River by Bolivia's own delegates to these mixed commissions are particularly weighty evidence of the status of the watercourse as a naturally flowing international watercourse.

4.38. It is also noted that a total of six boundary markers were jointly installed in the Silala River area, three in 1906 and an additional three in 1993.

4.39. The three 1906 boundary markers were defined and installed by the Mixed Demarcation Commission created to implement the boundary provisions established under the 1904 Treaty. One of these (N° S/N-LXXIII) was jointly identified as "At the Silala River" (*En el río Silala*).[132]

[131] *Armed Activities on the Territory of the Congo (Democratic Republic of the Congo v. Uganda), Judgment, I.C.J. Reports 2005*, p. 168, para. 61.

[132] Chile-Bolivia Boundary Commission, Minutes of 23 March 1906, in: *Records of the Chile-Bolivia Boundary*, pp. 1-2. **CM Annex 6.** Note that boundary marker N° S/N-LXXIII was not in

4.40. The three 1906 boundary markers were installed during a joint demarcation expedition, carried out between 28 May and 28 July 1906. On that occasion, the nature of the Silala as a river was confirmed in the field by Bolivian engineer Quintín Aramayo Ortíz, Head of the Bolivian Demarcation Commission, who made the following expedition log entries:

> "June 28. The temporary camp was moved to <u>the headwaters of the Silola [sic] River, while the main camp remained at the Silola River.</u>
>
> June 28. The next boundary marker was erected on Cerro Silola that is located on a straight line between Cerros Silola and the highest part of Cerro Inacaliri.
>
> June 29. The temporary camp is packed up to rejoin <u>the main camp at the Silola River</u>."[133] (emphasis added)

4.41. The location of the three 1906 boundary markers in relation to the Silala River can be seen on Figure 28 below.

fact located "at the Silala River" but on the plain to the north of the Silala ravine, to ensure its visibility.

[133] Report signed by the Head of the Bolivian Demarcation Commission, Quintín Aramayo Ortíz, 14 August 1906, in: *Records of the Chile-Bolivia Boundary*, pp. 14-18. **CM Annex 40.**

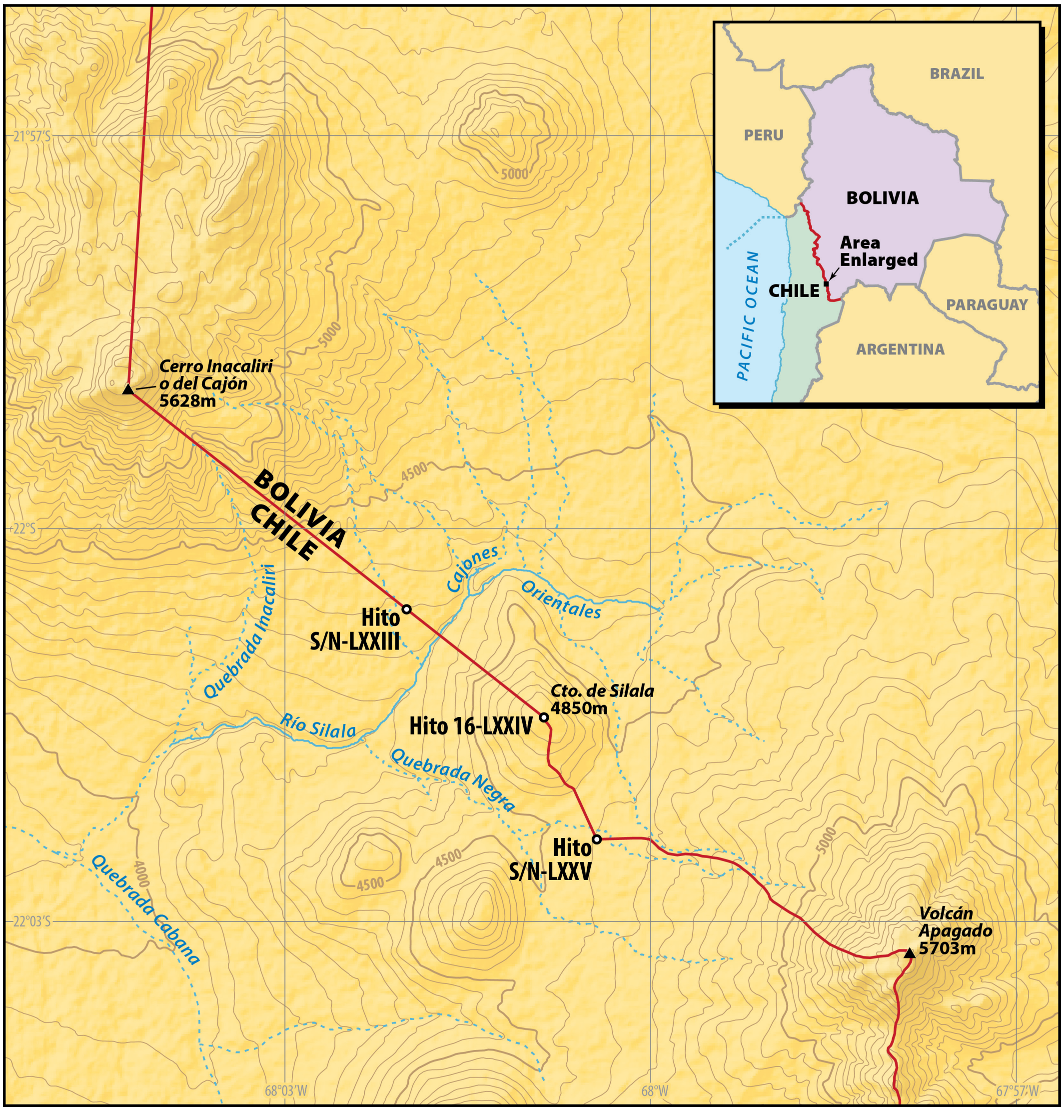

Figure 28. Location of the 1906 boundary markers in the Silala River area.

4.42. In 1924, the 1906 boundary markers at the Silala River were revisited for inspection by a Mixed Revision and Replacement Commission. Again, camp was made at the Silala River, as noted in the report of this activity by Major Carlos Graña, Head of the Bolivian Revision and Replacement Commission. Major Graña took issue with the name of the river established under the Treaty which, according to him, should have been "Siloli" and not

"Silala"; but at no point did he question its nature as a *river*, which was self-evident to him:

> "The Commissions immediately moved their camps to the Siloli River – not Silala as it is marked in the Treaty."[134]

4.43. In 1942, the Chile-Bolivia Mixed Boundary Commission ("Mixed Boundary Commission") was established under the Protocol on the Conservation of Boundary Markers (*Protocolo sobre Conservación de Hitos Fronterizos*).[135] The Mixed Boundary Commission has also on multiple occasions confirmed and acknowledged the existence of the Silala River as a stream that flows naturally from Bolivia into Chile.

4.44. In 1991-1992, the Mixed Boundary Commission adopted Monographs (*Monografías*) illustrating each of the three 1906 boundary markers in the Silala River area: Boundary Marker S/N LXXIII,[136] Boundary Marker 16-LXXIV[137] and Boundary Marker S/N-LXXV.[138] Each of these monographs contains a map that depicts the Silala River as a transboundary watercourse, as for instance in the Monograph of Boundary Marker S/N LXXIII (Figure 29).

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[134] Report by Major Carlos Graña & C. on the Revision of the Boundary with Chile, La Paz, 20 June 1924. **CM Annex 43.**

[135] Protocol on the Conservation of Boundary Markers Between Bolivia and Chile, signed at Santiago on 10 August 1942. **CM Annex 3.**

[136] Chile-Bolivia Mixed Boundary Commission, Monograph of Boundary Marker S/N-LXXIII, 20 August 1991. **CM Annex 9.** See for earlier revisions: Revision Minutes of Boundary Marker N° LXXIII, 23 September 1959, **CM Annex 8.1**; 17 September 1983, **CM Annex 8.2**; and 20 August 1991. **CM Annex 8.3.**

[137] Chile-Bolivia Mixed Boundary Commission, Monograph of Boundary Marker N° 16-LXXIV, 18 November 1992. **CM Annex 11.** See for earlier revisions: Revision Minutes of Boundary Marker N° LXXIV of 22 September 1959, **CM Annex 10.1**; 18 September 1983, **CM Annex 10.2**; and 18 November 1992. **CM Annex 10.3.**

[138] Chile-Bolivia Mixed Boundary Commission, Monograph of Boundary Marker S/N-LXXV, 20 August 1991. **CM Annex 13.** See for earlier revisions: Revision Minutes of Boundary Marker N° LXXV of 17 September 1983, **CM Annex 12.1**; and 20 August 1991. **CM Annex 12.2.**

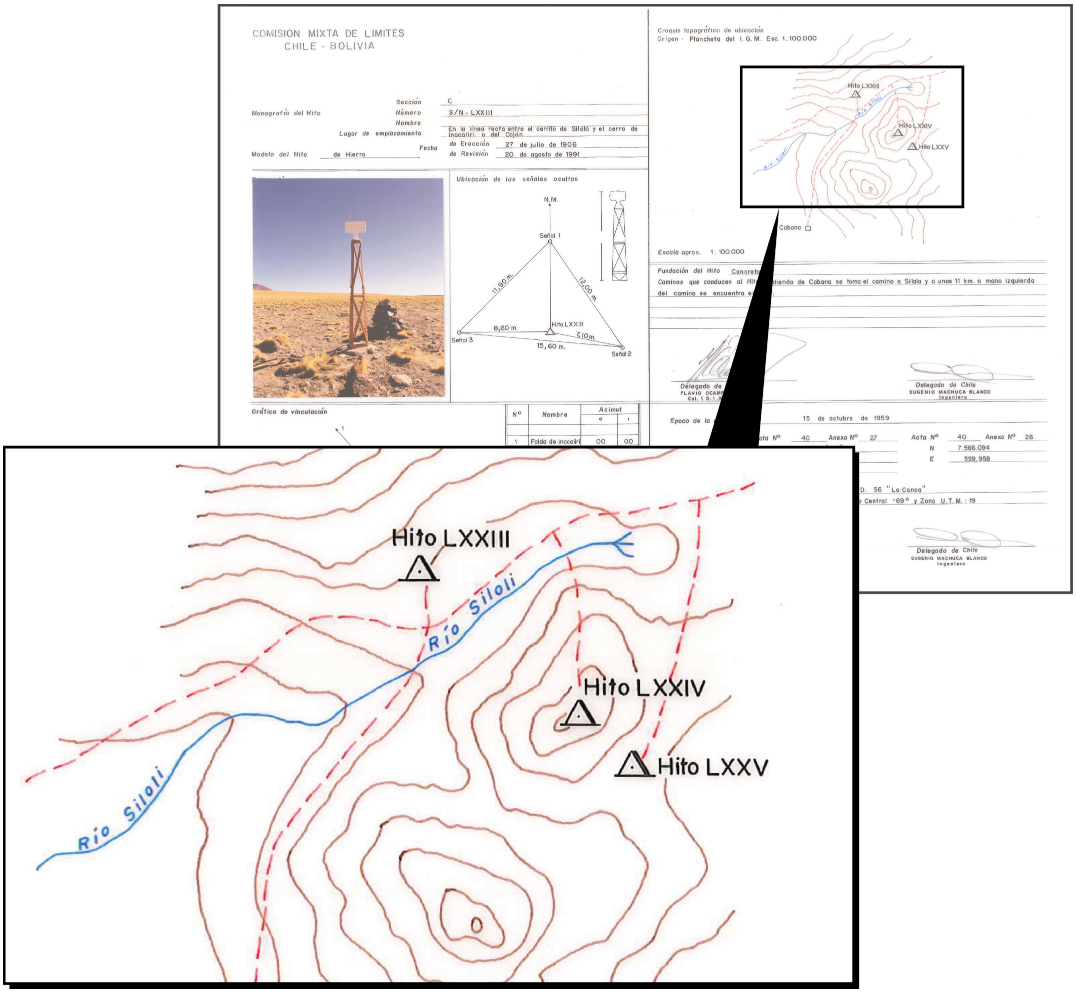

Figure 29. Monograph of Boundary Marker S/N-LXXIII, 20 August 1991. **CM Annex 9.**

4.45. Also in 1992, both States jointly adopted an official map of the Silala area, signed by the Bolivian and Chilean Heads and Delegates of the Mixed Boundary Commission. This map depicts the Silala River as a transboundary watercourse running from Bolivia into Chile, as is shown on Figure 30.[139]

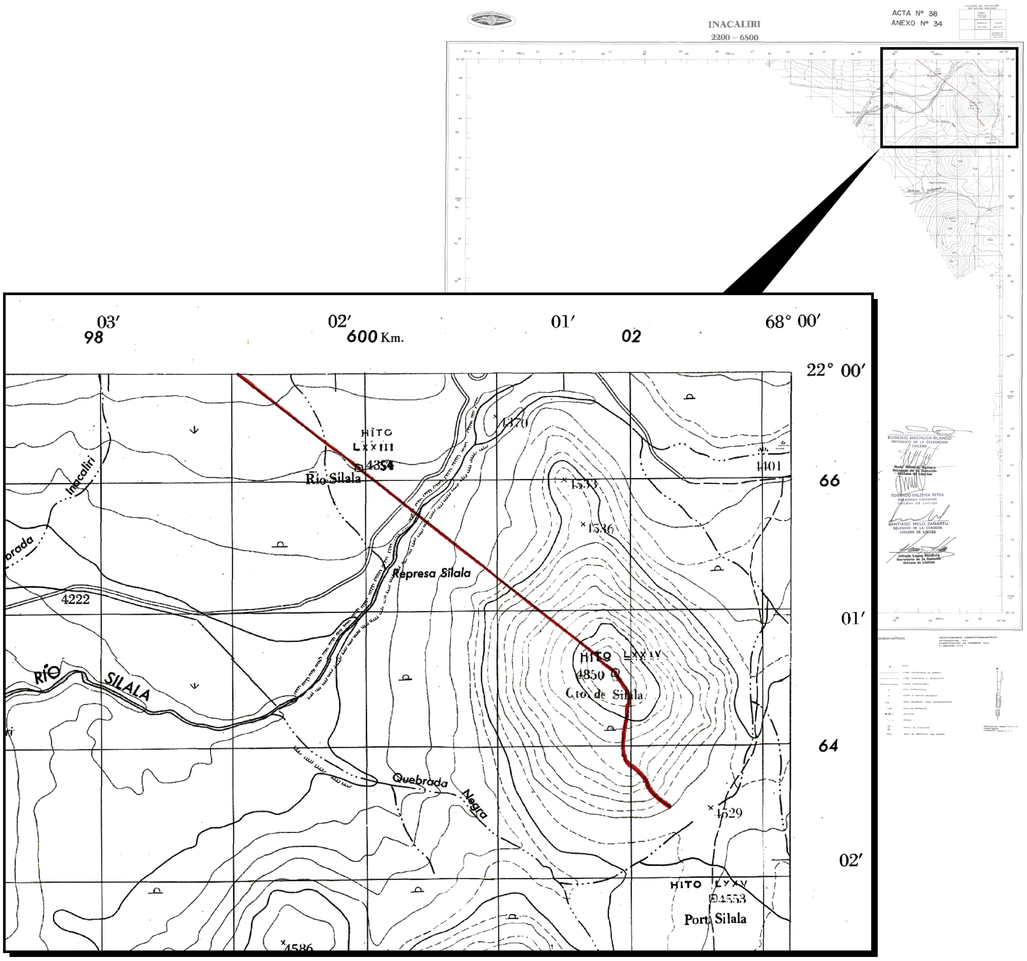

Figure 30. Chile-Bolivia Mixed Boundary Commission, Annex N° 34 to Minutes N° 38, 28 April 1992. **CM Annex 88.1**

[139] See also Chile-Bolivia Mixed Boundary Commission, Annex N° 34-A to Minutes N° 38, 28 April 1992. **CM Annex 88.2** The agreements reached in Minutes N° 38, including the map, were officially adopted by Bolivia and Chile through an exchange of the following instruments: Letter from the National Director of Borders and Boundaries of the State of Chile to the Chair of the National Commission of Sovereignty and Boundaries of Bolivia, 8 October 1992, and Letter from the Chair of the National Commission of Sovereignty and Boundaries of Bolivia to the General Consul of Chile in La Paz, 8 October 1992. **CM Annexes 25.1 and 25.2.**

4.46. The occasion of this map was the installation of three additional boundary markers in the Silala area between Volcán Apagado (point Nº 15 of the Treaty) and Boundary Marker N° S/N LXXIV (Cerrito de Silala), immediately south-east of the Silala River.[140] The Monograph of each of these three new boundary markers, jointly signed by the Bolivian and Chilean delegates of the Mixed Boundary Commission, contains an identical map of the area that again depicts the Silala River as a transboundary watercourse (Figure 31).[141]

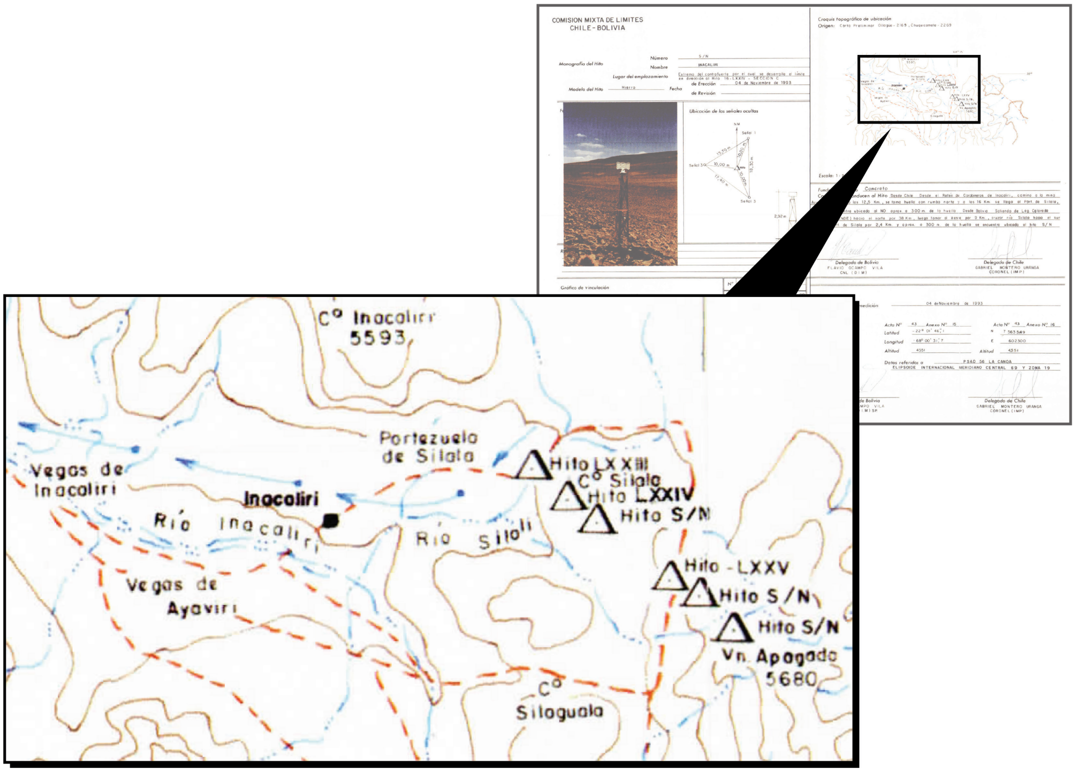

Figure 31. Monograph of Boundary Marker S/N Inacaliri, 4 November 1993. **CM Annex 15.1**.

[140] Chile-Bolivia Mixed Boundary Commission, Minutes N° 38, 28 April 1992. **CM Annex 14.**

[141] The new boundary markers were installed on 4 November 1993, see: Chile-Bolivia Mixed Boundary Commission, Monographs of Boundary Markers S/N Inacaliri, **CM Annex 15.1**; S/N Linzor (a), **CM Annex 15.2**; and S/N Linzor (b), **CM Annex 15.3.**

4.47. In consequence, the Mixed Boundary Commission has installed a total of six boundary markers in the Silala area, all of which are shown on Figure 32.

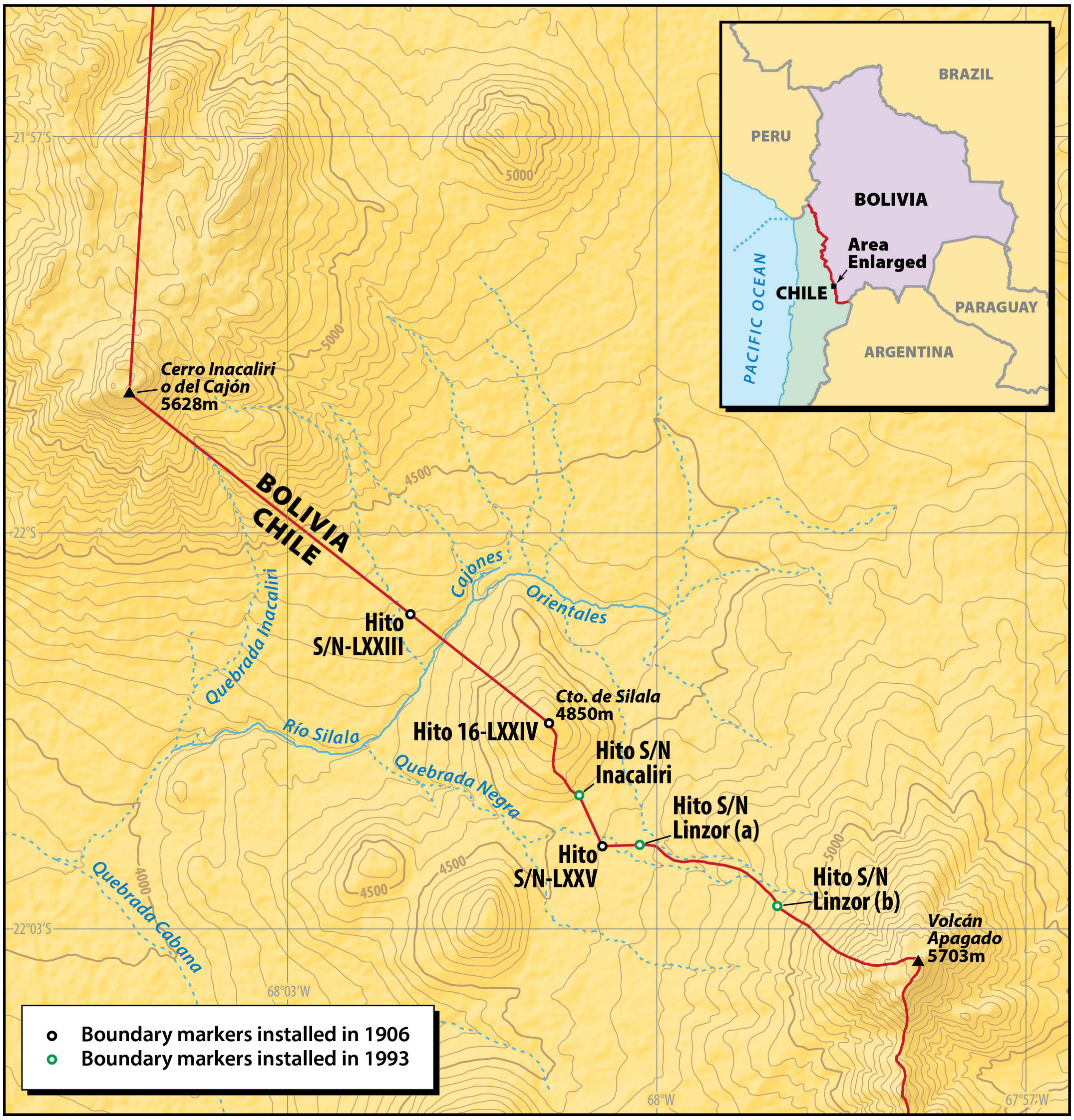

Figure 32. Location of the 1906 and 1993 boundary markers in the Silala River area.

4.48. Further, on 7 May 1996, the Bolivian boundary authorities issued an official press release, responding to certain allegations in the Bolivian press that waters from the Silala River had been artificially diverted to Chile. Bolivia rightly rejected such allegations and confirmed that the Silala is an international river:

> "Under instructions from the Honourable Minister of Foreign Affairs of the Republic, Dr. Antonio Araníbar Quiroga, the Chair of the National Commission of Sovereignty and Boundaries presented a technical report on the international nature of said river.
>
> The Silala is a river that has its origin in a spring at the foot of the hill of the same name, in Bolivian territory, after which it crosses into Chilean territory. In other words, Bolivia owns the upstream course of this river and Chile owns the downstream course."[142]

4.49. The Bolivian Minister of Foreign Affairs, Mr. Araníbar, visited the Silala on 18 May 1996. He confirmed first hand that the waters of the Silala are not diverted toward Chile and that the use of the waters and the construction of waterworks had been authorized by Bolivia.[143]

4.50. As noted earlier, the transboundary nature of the Silala River was also declared in plain terms by Bolivian Ambassador Teodosio Imaña Castro, then Chairman of the Bolivian Boundary Commission and President of the Mixed Boundary Commission, in an interview published on 31 May 1996. Mr. Imaña stressed that the Silala River naturally flows from Bolivia into Chile, following a consistently downhill course:

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[142] Press Release from the Ministry of Foreign Affairs of Bolivia, in: *El Diario*, La Paz, 7 May 1996. **CM Annex 45.**

[143] La Época, "*Bolivia Asks Chile for Compensation for Collecting the Waters of the Silala River*", La Paz, 21 May 1996. **CM Annex 70.**

"The Silala River is located in the province Sud Lípez of the Department of Potosí and belongs to the jurisdiction that in the beginnings of the century was called the Quetena Vice-Canton.

It rises from two main springs and receives additional waters from other minor springs. The narrow riverbed that is formed, called Silala, runs approximately two kilometers through Bolivian territory before it crosses the boundary at a point of the east-west slope of the glen between Cerro Inacaliri and Cerro Silala. The inclination of the terrain has been established by experts to be around 30% [sic, more likely 3%], its river bed is narrow and its crystalline waters follow the course that, due to the force of gravity, goes downhill into Chilean territory.

The Bolivian dominion and jurisdiction were exercised until 1879 by the rules of the Civil Code of Santa Cruz and the Law on Water Resources of 4 November 1874. There are references as to the calculation of the flow, which had been done in at least three opportunities: it is 0.4 cubic meters per second. On Chilean territory, it is a tributary of the San Pedro and Loa Rivers."[144]

4.51. A few months later, in October 1996, Bolivia's continued understanding of the Silala as a transboundary river was again evidenced when the Bolivian delegates of the Mixed Boundary Commission proposed the installation of another intermediate boundary marker in the area of the Silala River (*en el sector Río Silala*).[145]

4.52. This proposal was submitted to a Mixed Sub Commission, that recommended the installation of two intermediate boundary markers in the area, one of which was to be placed "on the bottom of the Silala River ravine" (*en el*

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[144] Presencia, "*Dialogue on Friday with Dr. Teodosio Imaña Castro*", La Paz, 31 May 1996. **CM Annex 71.**

[145] Chile-Bolivia Mixed Boundary Commission, Minutes N° 46, 21 April 1996, p. 27. **CM Annex 16.** The proposal to install an intermediate boundary marker between Boundary Markers LXXIII and LXXIV had been announced by Bolivia's Minister of Foreign Affairs Mr. Araníbar during his visit to the Silala River in May 1996: "to help determining the actual boundary point at the canyon (channel) through which the waters cross to Chile", see: La Época, "*Bolivia Asks Chile for Collecting for Catching the Waters of the Silala River*", La Paz, 21 May 1996. **CM Annex 70.**

fondo de la quebrada del Río Silala).[146] The installation of these two intermediate boundary markers was scheduled for 1999.[147] However, no field work was undertaken from 1999 onwards, for administrative reasons as alleged by Bolivia.[148]

4.53. In 2011, the Mixed Boundary Commission in session decided to reincorporate the annual work plan of 1999 in its yearly planning, including the installation of an intermediate boundary marker "in the ravine of the Silala River" (*en la Quebrada del Río Silala*).[149] The Mixed Boundary Commission has not convened since 2011. As of today, the installation of these two intermediate boundary markers in the Silala River area remains pending. But the Mixed Boundary Commission's recognition that the Silala is a river, and that it flows in its own ravine, is noteworthy.

4.54. During this 1996 to 2011 period in which these additional intermediate boundaries markers (one of which "in the ravine of the Silala River"[150]) were under consideration, the Bolivian delegates of the Mixed Boundary Commission never questioned the nature of the Silala River as a river

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[146] Chile-Bolivia Mixed Boundary Commission, Minutes N° 49, p. 5 and Minutes Nº 49, Annex Nº 2, 20 November 1998. **CM Annexes 17.1 and 17.2.**

[147] Chile-Bolivia Mixed Boundary Commission, Minutes N° 50, Annex Nº 5, 2 December 1998, p. 3: "at the bottom of the ravine of the Silala River and on the northern slope of Cerro Silala". **CM Annex 18.**

[148] Chile-Bolivia Mixed Boundary Commission, Minutes N° 51, 3 May 2001, p. 2 and Minutes N° 53, 28 October 2011, p. 10. **CM Annexes 19 and 20.1.**

[149] Chile-Bolivia Mixed Boundary Commission, Minutes N° 53, 28 October 2011, p. 6 under Point 8.5: "The Mixed Commission agreed to include in these Minutes as Annex N° 4 the 'Report on the Field Works to be considered in the Annual Task Planning' and that appears as Annex N° 5 of the Minutes N° 50". **CM Annex 20.1.** See for the 2011 Annual Task Planning, Minutes N° 53, Annex Nº 4, 28 October 2011. **CM Annex 20.2.**

[150] Chile-Bolivia Mixed Boundary Commission, Minutes N° 53, Annex Nº 4, 28 October 2011, p. 4. **CM Annex 20.2.**

or as a transboundary watercourse. On the contrary, they at all times referred to the Silala as a river running through its natural ravine (*quebrada*).[151]

4.55. The consistent practice of the technical authorities of Bolivia, who have always acknowledged and confirmed the nature of the Silala as a river that runs through a natural ravine and crosses the Bolivia-Chile international boundary, constitutes yet more incontrovertible evidence that Bolivia's 1999 abrupt denial of this fact is not based on any scientific evidence collected in the field, but is arbitrary and seems politically motivated.

3. Both Chile and Bolivia have exercised sovereignty over the waters of the Silala River by granting concessions relative to the use of the waters in Chile, in 1906 and in 1908, respectively

4.56. The transboundary nature of the Silala River is also plain from the fact that its waters were being used in Chilean territory prior to the construction of any waterworks in Bolivia. In fact, on 31 July 1906, Chile granted a concession for the use of the waters of the Silala River on its territory, to the British company The Antofagasta (Chili) and Bolivia Railway Company Limited (FCAB), for an indefinite period of time and for the purpose of increasing the flow of drinking water serving the Chilean port city Antofagasta.[152] At that time, there existed no works in either Bolivia or Chile relating to the watercourse.

[151] Chile-Bolivia Mixed Boundary Commission, Minutes N° 49, 20 November 1998, p. 5. **CM Annex 17.1**; Minutes N° 50, Annex Nº 5, 2 December 1998, p. 3. **CM Annex 18**; Minutes N° 53, Annex Nº 4, 28 October 2011, p. 4. **CM Annex 20.2.**

[152] Deed of Concession by the State of Chile of the Waters of the Siloli (N° 1.892) to The Antofagasta (Chili) and Bolivia Railway Company Limited, 31 July 1906. **CM Annex 55.** FCAB had obtained the right to provide potable water to Antofagasta in November 1888 from the mining company Compañía Huanchaca de Bolivia ("Huanchaca"), which had obtained its right from Chile under Chilean Law of 21 January 1888. **CM Annex 54.**

4.57. The waters of the Silala River on Chilean territory were first identified by FCAB in 1905 as a suitable source of drinking water, as appears from correspondence between the General Manager in Chile of FCAB and the Board of Directors of FCAB in London:

> "During my absence news was obtained of a large supply from a river (the Ciloli) [sic] also flowing into the San Pedro Salar where its waters disappear. Samples were taken from a point in this river called 'El Cajón' about 30 kilometres distant from the Colana springs (not from the source of the river which is much further away), and the quality, as per analysis enclosed, was found to be excellent. There is a large volume of water flowing down the river Ciloli [sic] which is probably the principal source of the San Pedro river."[153]

4.58. On 18 June 1906, Chile granted the concession to FCAB.[154] After that, FCAB considered also requesting a concession in Bolivia.[155]

4.59. On 7 September 1908, FCAB submitted its request for the waters of the Silala River to the Bolivian authorities. The concerned Bolivian authorities, i.e. the Deputy Prefect of Potosí, granted the concession on 21 September 1908, confirming that FCAB is "vested with the quality of true and

[153] Letter from the General Manager of FCAB in Chile to the Secretary of the Board of Directors of FCAB in London, 15 December 1905, p. 5. **CM Annex 63.**

[154] Deed of Concession by the State of Chile of the Waters of the Siloli (N° 1.892) to The Antofagasta (Chili) and Bolivia Railway Company Limited, 31 July 1906. **CM Annex 55.** The Chilean concession of the waters of the Silala was granted by the Intendant (*Intendente*) of Antofagasta, according to FCAB, because the Silala is a "stream" and not a "spring" under Chilean law and the concession of "streams" corresponded to the Intendant, see: Letter from the General Manager of FCAB in Chile to the Secretary of the Board of Directors of FCAB in London, 28 June 1906, p. 129. **CM Annex 64.**

[155] Letter from the General Manager of FCAB in Chile to the Secretary of the Board of Directors of FCAB in London, 28 June 1906, p. 129. **CM Annex 64.**

only holder of the concession and grantee of the use of the 'Sololi' [sic] waters, without there being any person who can claim a better right."[156]

4.60. FCAB built its first intake (Intake N° 1) on Bolivian territory, just below the confluence of the Cajones and Orientales ravines. In August 1910, FCAB requested and obtained permission from the Government of Bolivia to bring the necessary pipelines into Bolivian territory through Chilean territory, that being the shortest route.[157] Thus, the construction of intake and pipeline on Bolivian territory was expressly approved by the competent Bolivian authorities.

4.61. Seventeen years later, in 1928, the need arose to improve its installations and construct channels from the Orientales and Cajones wetlands to Intake N° 1, for sanitary reasons, to avoid contamination of the water with eggs of the green flies that were breeding in the vegetable growth around the Silala River.[158] These construction works were obviously known to Bolivia and not objected to. These channels did not change nor "divert" the course of the river into Chile. Bolivia's post-1999 position to the contrary is self-evidently untenable, as it ignores the natural topography. It is also misconceived, notably in the light of Bolivia's express authorization to FCAB in the 1908 Concession to construct waterworks in Bolivian territory.

[156] Deed of Concession by the State of Bolivia of the Waters of the Siloli (N° 48) to The Antofagasta (Chili) and Bolivia Railway Company Limited, 28 October 1908, p. 66. **CM Annex 41.**

[157] Request from FCAB to the Government of Bolivia, 3 August 1910, **CM Annex 65**; and Communication Nº 71 from the Government of Bolivia to The Antofagasta (Chili) and Bolivia Railway Company Limited, 9 August 1910. **CM Annex 42.**

[158] Letter from the General Manager of FCAB in Chile to the Secretary of the Board of Directors of FCAB in London, 27 January 1928, pp. 3-4. **CM Annex 67.1.**

4. Even after its abrupt change of position in 1999, Bolivia has continued to acknowledge the existence of the Silala River as an international watercourse

4.62. Even after its 1999 decision to deny the nature of the Silala as a river as somehow contrary to its origin in springs, Bolivia has continued to acknowledge the nature of the Silala River as a transboundary watercourse in bilateral, international and domestic contexts.

4.63. As demonstrated in preceding section 3, the Bolivian delegation to the Mixed Boundary Commission has always referred to the Silala as a transboundary river running through a natural ravine, including in the most recent session of the Mixed Boundary Commission, in 2011.

4.64. In its international relations, Bolivia as of today acknowledges the nature of the Silala as a *river* in the context of the Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention, 1971), to which Bolivia is a contracting State.[159] Even in this specific context related to wetlands, Bolivia repeatedly refers to the Silala as a *river* in its 2009 description of the Bolivian Ramsar Site "Los Lípez":

> "The Reserve borders to the northeast with the headwaters of the Silala River, located on the slopes of the hill by the same name, on the Bolivian-Chilean boundary line…"[160]

> "The area also has seasonal / intermittent / irregular rivers / streams / creeks (N) such as the rivers: Silala, Sulor, Quetena, and Khastor, among other."[161]

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[159] The Ramsar Convention entered into force in Bolivia on 27 October 1990, see: Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention), signed at Ramsar on 2 February 1971. Available at: http://www.ramsar.org/sites/default/files/documents/library/ scan_certified_e.pdf.

[160] Bolivian Information Sheet on Ramsar Wetlands – 2009-2012 Version, 4 May 2009, p. 2. **CM Annex 51.**

4.65. Bolivia's domestic legislation also recognizes the nature of the Silala as a *river*, regardless its origin in springs. Indeed, the Los Lípez Ramsar Site largely coincides with the Reserva Nacional de Fauna Andina Eduardo Abaroa, first created in 1973 by Bolivian Supreme Decree.[162] The area of this national reserve was modified in 1981, also by Bolivian Supreme Decree, and defined by reference to the "springs of the Silala River":

> "To the northwest, the headwaters of the Silala or Siloli River, located on the slopes of the hill by that same name, on the Bolivian-Chilean boundary line."[163]

4.66. Bolivia's multiple post-1999 acknowledgments of the Silala River as an international watercourse, both in its bilateral, international and domestic commitments and arrangements, underscore the futility of denying the simple fact of nature that the Silala is a watercourse that follows its natural course downhill, from Bolivia into Chile.

[161] Bolivian Information Sheet on Ramsar Wetlands – 2009-2012 Version, 4 May 2009, p. 9. **CM Annex 51.**

[162] Bolivian Supreme Decree N° 11.239, 13 December 1973. **CM Annex 44.1.**

[163] Bolivian Supreme Decree N° 18.313, 14 May 1981. **CM Annex 44.2.**

CHAPTER 5
THE LEGAL CONSEQUENCES OF THE STATUS OF THE SILALA RIVER SYSTEM AS AN INTERNATIONAL WATERCOURSE

5.1. In this final chapter, Chile will establish the legal consequences that follow from the status of the Silala River system as an international watercourse. Sections A and B of this chapter will establish and confirm Chile's right of equitable and reasonable utilization of the Silala waters. Section C will establish Bolivia's obligation to take all appropriate measures to prevent the causing of significant harm to Chile. In section D, Chile addresses Bolivia's persistent failure to inform Chile of its activities near the Silala River that may affect its waters or utilization in Chile.

A. Chile has a right to the equitable and reasonable utilization of the Silala River, as an international watercourse

5.2. As noted above, in 1999, Bolivia made the surprising claim that the Silala is not an international watercourse, contending that it is therefore entitled to the use of 100 per cent of its waters.[164] Bolivia had, it is recalled, never before questioned the international status of the river, nor claimed that its waters were exclusively Bolivian. Bolivia has now even gone so far as to contend that Chile owes it a "historic debt" for its past use of Silala waters.[165] Chile has shown in chapter 4 that the Silala is in fact and in law an international watercourse and that, for over a century, Bolivia consistently treated it as such in its practice.

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[164] See for Bolivia's first statement of its sudden change of position: Note N° GMI-656/99 from the Ministry of Foreign Affairs of Bolivia to the General Consulate of Chile in La Paz, 3 September 1999. **CM Annex 27.**

[165] Press Release from the Ministry of Foreign Affairs of Bolivia, 1 October 2010. **CM Annex 52.** See also: Prensa Palacio, "*President Morales Gives Instructions to Study Legal Alternatives to Defend Waters of the Silala*", La Paz, 23 March 2016. **CM Annex 72.1.**

5.3. The Silala's status as an international watercourse gives rise to certain rights and obligations of the States sharing it. These rights and obligations derive from the fact that, as this Court and its predecessor have found, there is a community of interest among riparian States in an international watercourse.[166] In accordance with the principle of equitable and reasonable utilization, Chile has the right to utilize the waters of the Silala and to be free from significant harm caused by Bolivia. Chile also has corresponding obligations owed to Bolivia. Bolivia has the same rights, as well as corresponding obligations owed to Chile. The Court has made clear that a State may not "unilaterally assum[e] control of a shared resource, and thereby depriv[e] [another State] of its right to an equitable and reasonable share of the natural resources of the [shared resource]."[167] Yet Bolivia is precisely purporting to assert such rights of control with respect to the Silala River.

5.4. The Court also stated in the *Gabčíkovo-Nagymaros Project* case that States have a "basic right to an equitable and reasonable sharing of the resources of an international watercourse."[168] This statement may be taken as recognition by the Court that the right, and corresponding obligation, of equitable and reasonable utilization form part of customary international law. The customary nature of the right/obligation is signaled by the fact that the 1977 Treaty concerning the construction and operation of the *Gabčíkovo-Nagymaros* system of locks involved in the *Gabčíkovo-Nagymaros case* made no mention of equitable and reasonable utilization or sharing of the resources of an international watercourse. The Court nonetheless found that the basic right/obligation existed, leaving customary international law as its only source. Likewise, the Court also referred to equitable and reasonable utilization in its judgment in the *Pulp Mills*

[166] *Gabčíkovo-Nagymaros Project (Hungary/Slovakia), I.C.J. Reports 1997*, p. 7, para. 85.

[167] *Gabčíkovo-Nagymaros Project (Hungary/Slovakia), I.C.J. Reports 1997*, p. 7, para. 85.

[168] *Gabčíkovo-Nagymaros Project (Hungary/Slovakia), I.C.J. Reports 1997*, p. 7, para. 78.

case, notwithstanding the absence of any reference to the same in the treaty there at issue.[169]

5.5. Therefore, once the Silala River is held to be an international watercourse, shared by Bolivia and Chile, each of those States has this "basic right" and obligation of equitable and reasonable utilization of its waters.

5.6. Moreover, equitable and reasonable utilization and participation form a cornerstone of the UNWC. The Convention, whose negotiation was based upon twenty years' work by the International Law Commission, as noted in chapter 4 above, lays down equitable and reasonable utilization and participation as its first "general principle."[170]

B. Chile's use of the waters of the Silala River system is consistent with the obligation of equitable and reasonable utilization

5.7. Despite Chile's use of the waters of the Silala River without objection by Bolivia for over a century, Bolivia now claims that it is entitled to the use of 100 per cent of those waters.[171] That Chile has a right to the equitable and reasonable use of the waters of the Silala River under customary international law is, however, evident from the authorities reviewed in section A above. This section will demonstrate that Chile's use of Silala waters has been, and remains, equitable and reasonable.

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[169] *Pulp Mills on the River Uruguay (Argentina v. Uruguay), Judgment, I.C.J. Reports 2010,* p. 14, paras. 177 and 266.

[170] UNWC, Art. 5, the first article in Part II of the Convention, General Principles.

[171] Note Nº VRE-DGLFAIT-UAIT-Cs-136/2014 from the Ministry of Foreign Affairs of Bolivia to the General Consulate of Chile in La Paz, 10 April 2014. **CM Annex 38.2.** See also, Prensa Palacio, "*President Morales Gives Instructions to Study Legal Alternatives to Defend Waters of the Silala*", La Paz, 23 March 2016. **CM Annex 72.1.**

5.8. The situation before the Court is that, as between the two States sharing the Silala River system, Chile has been, and remains, the only one that has made a significant use of the waters of the Silala River.[172] Further, Chile's utilization of Silala waters has always been, and without doubt remains, equitable and reasonable vis-à-vis Bolivia.

5.9. It is evident from the text adopted at Articles 5 and 6 of the UNWC that the standard of equitable and reasonable utilization is correctly regarded as a flexible standard that must be adapted to fit the facts and circumstances of each case. Article 5 of the UNWC provides as follows:

> "Article 5. Equitable and reasonable utilization and participation
>
> 1. Watercourse States shall in their respective territories utilize an international watercourse in an equitable and reasonable manner. In particular, an international watercourse shall be used and developed by watercourse States with a view to attaining optimal and sustainable utilization thereof and benefits therefrom, taking into account the interests of the watercourse States concerned, consistent with adequate protection of the watercourse.
>
> 2. Watercourse States shall participate in the use, development and protection of an international watercourse in an equitable and reasonable manner. Such participation includes both the right to utilize the watercourse and the duty to cooperate in the protection and development thereof, as provided in the present Convention."

5.10. Equitable and reasonable utilization must then be assessed in light of all the relevant circumstances. Article 6 of the UNWC contains an indicative, non-exhaustive list of factors to be taken into account in determining that

[172] This is subject to the qualification that Bolivia has recently constructed certain projects near the headwaters of the Silala River system, referred to in section C below, which appear to use and presumably affect Silala waters to some extent.

utilization is equitable and reasonable.[173] An application of these factors to the present case leaves no doubt that Chile's use of the Silala River waters is, and has been, equitable and reasonable.

5.11. As to the use by Chile, it has relied and still relies on the waters of the Silala for various municipal, industrial and mining uses, developed over the course of more than a century. Among other users, the Chilean port city of Antofagasta and the towns of Sierra Gorda and Baquedano, at different times in the past and until as recent as 2010, used the water of the Silala River collected by FCAB for human consumption.[174] A significant part of the waters collected by CODELCO is still used today for human consumption in its Mining Divisions. [175] Past industrial uses included the Antofagasta-La Paz railway service, operated by

[173] UNWC, Art. 6 provides the factors relevant to an equitable and reasonable utilization, as follows:

"1. Utilization of an international watercourse in an equitable and reasonable manner within the meaning of article 5 requires taking into account all relevant factors and circumstances, including:

(a) Geographic, hydrographic, hydrological, climatic, ecological and other factors of a natural character;

(b) The social and economic needs of the watercourse States concerned;

(c) The population dependent on the watercourse in each watercourse State;

(d) The effects of the use or uses of the watercourses in one watercourse State on other watercourse States;

(e) Existing and potential uses of the watercourse;

(f) Conservation, protection, development and economy of use of the water resources of the watercourse and the costs of measures taken to that effect;

(g) The availability of alternatives, of comparable value, to a particular planned or existing use.

2. In the application of Article 5 or paragraph 1 of this article, watercourse States concerned shall, when the need arises, enter into consultations in a spirit of cooperation.

3. The weight to be given to each factor is to be determined by its importance in comparison with that of other relevant factors. In determining what is a reasonable and equitable use, all relevant factors are to be considered together and a conclusion reached on the basis of the whole."

[174] Notices of Termination of Water Supply by FCAB to the towns of Sierra Gorda and Baquedano in the Municipality of Sierra Gorda, 5 October 2010. **CM Annexes 69.1 and 69.2.**

[175] Chilean Resolution Nº 5.571, Director of the Antofagasta Health Service, 28 November 2002. **CM Annex 61.**

FCAB, and current mining uses include that of CODELCO. The extremely arid conditions in the region make the waters of the Silala River of significant importance for all of these uses.

5.12. As to the use by Bolivia, there has been virtually none - at least in Bolivian territory. Bolivia has granted concessions with respect to use of the water in Chile, first in the 1908 concession to FCAB and, later, in the 1999 concession to DUCTEC, that was terminated in 2003. To Chile's knowledge, no concessions remain operative today.

5.13. In the absence of countervailing uses in Bolivia, it inevitably follows that all use by Chile, as downstream riparian State, of the 170 l/s flow of the Silala River that crosses the international boundary from Bolivia into Chile, has been, and cannot but be, equitable and reasonable vis-à-vis Bolivia.

C. Bolivia is under an obligation to take all appropriate measures to prevent the causing of significant harm to Chile

5.14. States sharing an international watercourse are under an obligation to take all appropriate measures to prevent the causing of significant harm to other watercourse States. This rule of international law is enshrined in Article 7 of the UNWC.

5.15. In the *Border Activities/San Juan River Cases* this Court has reiterated that, under customary international law, "[a] State is . . . obliged to use all the means at its disposal in order to avoid activities which take place in its territory, or in any area under its jurisdiction, causing significant damage to the environment of another State."[176] In *Pulp Mills* case the Court noted that "the

[176] *Certain Activities Carried out by Nicaragua in the Border Area/Construction of a Road in Costa Rica Along the San Juan River (Costa Rica v. Nicaragua/Nicaragua v. Costa Rica), Judgment, I.C.J. Reports 2015*, para. 118. See also *Pulp Mills on the River Uruguay (Argentina v.*

principle of prevention, as a customary rule, has its origins in the due diligence that is required of a State in its territory. It is 'every State's obligation not to allow knowingly its territory to be used for acts contrary to the rights of other States' (*Corfu Channel (United Kingdom v. Albania), Merits, Judgment, I.C.J. Reports 1949*, p. 4, p. 22)."[177]

5.16. In making use of the waters of the Silala River before they cross the border, or in carrying out activities which may affect the quality of the waters, Bolivia has to take measures which will as far as possible eliminate the risk of pollution or water abstraction rendering the waters of the Silala River unfit for use in Chile, or causing any other kind of harm in Chile.

5.17. Chile does not ask the Court to specify precisely what measures Bolivia must take in order to give full effect to article 7 of the UNWC. Rather, it asks the court to reaffirm that Bolivia has an obligation to take all appropriate measures to prevent and control pollution and other forms of harm to Chile resulting from activities in the vicinity of the Silala River.

Uruguay), Judgment, I.C.J. Reports 2010, p. 14, para. 101; *Legality of the Threat or Use of Nuclear Weapons, Advisory Opinion, ICJ Reports 1996*, p. 226, para. 29; *Responsibilities and obligations of States with respect to activities in the Area, Advisory Opinion*, 1 February 2011, ITLOS Reports 2011, p. 10, paras. 110-150; *Arbitration Regarding the Iron Rhine ("Izjeren Rijn") Railway Between the Kingdom of Belgium and the Kingdom of the Netherlands*, Award of 24 May 2005, Reports of International Arbitral Awards, Vol. XXVII, para. 59; *The Islamic Republic of Pakistan v. The Republic of India, P.C.A. Case Nº 2011-01*, Partial Award, 18 February 2013, para. 451 and Final Award, 20 December 2013, para. 112.

[177] *Pulp Mills on the River Uruguay (Argentina v. Uruguay), Judgment, I.C.J. Reports 2010,* p. 14, para. 101.

D. Bolivia has persistently failed to inform Chile of activities within its jurisdiction which may affect the waters of the Silala River or their utilization by Chile

5.18. As noted above in chapter 3.C, Chile has on several occasions sought information from Bolivia about activities in the area adjacent to the headwaters of the Silala River.

5.19. On 7 May 2012, Chile requested information on several projects in the Silala area that had been announced by the Governor of the Department of Potosí, including the construction of a fish farm, a weir, and a mineral water bottling plant. That request was made by Chile, in order to ensure preservation of its rights, as a riparian State, to the utilization of the Silala waters and the prevention of harm.[178] Bolivia did not respond to Chile's request.

5.20. Chile repeated its request for information on 9 October 2012.[179] On 25 October 2012, Bolivia responded by denying that Chile has any right to the utilization of the waters of the Silala which, according to Bolivia, was not considered to be an international river.[180] This has remained Bolivia's declared position during further exchanges of diplomatic notes and remains its position as of today.[181] It is a position that stands in stark contrast to the general obligation to

[178] Note N° 199/39 from the General Consulate of Chile in La Paz to the Ministry of Foreign Affairs of Bolivia, 7 May 2012. **CM Annex 34.**

[179] Note N° 389/149 from the General Consulate of Chile in La Paz to the Ministry of Foreign Affairs of Bolivia, 9 October 2012. **CM Annex 35.**

[180] Note N° VRE-DGRB-UAM-020663/2012 from the Ministry of Foreign Affairs of Bolivia to the General Consulate of Chile in La Paz, 25 October 2012. **CM Annex 36.**

[181] For the exchanges of diplomatic notes up to April 2014, see **CM Annexes 37 and 38.**

cooperate under international law[182] and also to the obligation to exercise due diligence to prevent the causing of transboundary harm.[183]

5.21. Most recently, on 7 February 2017, Chile requested information on the use of the waters of the Silala River and installation of sanitary treatment systems related to the recent construction of ten houses near the Bolivian Military Post.[184] Since activities in Chile rely on the quality of Silala River water, Chile has an important interest in the question of whether recent installations in the vicinity of the Silala headwaters in Bolivia may affect the quality of its waters. On 24 March 2017, Bolivia responded to the effect that it would inform Chile, "as soon as the requested information is available".[185] On 26 May 2017, Bolivia informed Chile that the houses built are not inhabited and therefore, it was said, do not constitute a risk. With regard to the Military Post, Bolivia stated that appropriate measures have been provided, that the use of the waters is minimal, and that the disposal thereof is controlled through a system of basic sanitation.[186]

5.22. A response of this kind, made without provision of any technical details and pre-supposing that housing constructed will not sooner or later be used for habitation, could not be sufficient answer to the questions legitimately posed by Chile. It constitutes another example of Bolivia's persistent failure to inform or consult Chile with respect to activities it has undertaken in the area around the headwaters of the Silala River.

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[182] See, e.g., UNWC, Article 8.

[183] See, e.g., *Pulp Mills on the River Uruguay (Argentina v. Uruguay), Judgment, I.C.J. Reports 2010*, p. 14.

[184] Note N° 29/17 from the General Consulate of Chile in La Paz to the Ministry of Foreign Affairs of Bolivia, 7 February 2017. **CM Annex 39.1.**

[185] Note VRE-Cs-47/2017 from the Ministry of Foreign Affairs of Bolivia to the General Consulate of Chile in La Paz, 24 March 2017. **CM Annex 39.2.**

[186] Note VRE-Cs-117/2017 from the Ministry of Foreign Affairs of Bolivia to the General Consulate of Chile in La Paz, 25 May 2017. **CM Annex 39.3.**

5.23. These failures to inform and consult are based on Bolivia's (new) refusal to recognise that the Silala is an international watercourse,[187] despite the fact that it manifestly rises in Bolivia and flows naturally downhill, across the border into Chile, due to the force of gravity. There can be no basis for refusing to recognize what is self-evident, and likewise so far as concerns the refusal to recognize the legal corollary that the Parties have a common interest in the optimal and sustainable management of the shared resource.

5.24. Article 8(1) of the UNWC provides that "Watercourse States shall cooperate on the basis of sovereign equality, territorial integrity, mutual benefit and good faith in order to attain optimal utilization and adequate protection of an international watercourse." The ILC commentary to Article 8 draws attention to the large number of treaties, declarations and resolutions of intergovernmental organisations which emphasise the importance of cooperation in the utilization of international watercourses.[188]

5.25. Consistent with the principle reflected in Article 8 of the UNWC, this Court has recognised that transboundary cooperation is the foundation for managing the risks of environmental damage and common utilization of shared water resources arising out of the use of an international watercourse.[189]

[187] Bolivia insists that "it does not share the denomination of 'Silala River system' used by the Chilean Government when referring to the waters of the Silala springs", see: Note VRE-Cs-117/2017 from the Ministry of Foreign Affairs of Bolivia to the General Consulate of Chile in La Paz, 25 May 2017. **CM Annex 39.3.**

[188] *Yearbook of the International Law Commission*, 1994, vol. II (Part Two), p. 106, paras. (3) - (5).

[189] *Pulp Mills on the River Uruguay (Argentina v. Uruguay), Judgment, I.C.J. Reports 2010*, p. 14, para. 77: "The Court observes that it is by co-operating that the States concerned can jointly manage the risks of damage to the environment that might be created by the plans initiated by one or other of them, so as to prevent the damage in question, through the performance of both the procedural and the substantive obligations laid down by the 1975 Statute." See also *Gabčíkovo-Nagymaros Project (Hungary/Slovakia), Judgment, I.C.J. Reports 1997*, p. 7, para. 147.

Cooperation is also required by the obligation of equitable and reasonable use, discussed in sections A and B of the present chapter.

5.26. Nonetheless, as set out in greater detail in chapter 3 above, Bolivia has recently adopted the position that the Silala is not an international watercourse and that it therefore has no obligation to co-operate with Chile in managing and utilizing its waters. In particular, Bolivia has neither notified nor consulted Chile when undertaking activities that may affect the equitable use and preservation of the waters of the Silala.

5.27. The duty to notify and consult with respect to any activity which may affect an international watercourse or other watercourse States is set out in detail in articles 11 to 18 of the UNWC. Article 11 provides that "Watercourse States shall exchange information and consult each other and, if necessary, negotiate on the possible effects of planned measures on the condition of an international watercourse."[190] The ILC commentary notes that the expression *possible effects,* "includes all potential effects of planned measures, whether adverse or beneficial."[191]

5.28. Article 12 of the UNWC sets out a more detailed prescription for planned measures which may have adverse effects on other States.[192] It requires timely notification to be given before the planned measures are implemented or permitted. The ILC Commentary draws attention to the practice of States, and the large number of treaty provisions and declarations or resolutions of

[190] UNWC, Article 11.

[191] *Yearbook of the International Law Commission*, 1994, vol. II (Part Two), p. 111, commentary to article 11, para. (3).

[192] UNWC, Article 12 provides: "Before a watercourse State implements or permits the implementation of planned measures which may have a significant adverse effect upon other watercourse States, it shall provide those States with timely notification thereof. Such notification shall be accompanied by available technical data and information, including the results of any environmental impact assessment, in order to enable the notified States to evaluate the possible effects of the planned measures."

intergovernmental organisations which affirm the need for prior notification and consultation.[193]

5.29. In the *Pulp Mills* case, the Court noted that "the obligation to notify is therefore an essential part of the process leading the parties to consult in order to assess the risks of the plan and to negotiate possible changes which may eliminate those risks or minimize their effects."[194] The Court regarded these procedural rules as part of the obligation of prevention.[195] While the Court made this statement in the context of the obligations under the 1975 Statute of the River Uruguay, the same obligation to notify is reflected in Article 12 of the UNWC and is part of general international law. In the *Pulp Mills* case, the Court also held that in general international law the parties had a duty to cooperate in good faith.[196]

5.30. It is not for Bolivia alone to decide whether there is any risk for Chile arising from activities which may affect the waters of the Silala. In the *Lac Lanoux* arbitration, the arbitral tribunal observed:

> "A State wishing to do that which will affect an international watercourse cannot decide whether another state's interests will be

[193] *Yearbook of the International Law Commission*, 1994, vol. II (Part Two), pp. 112-3, commentary to article 12, paras. (6) to (13). See also U.N. Environment Programme, U.N. Conference on the Human Environment: Rio Declaration on Environment and Development, U.N. Doc. A/CONF.151/26, 1992, Principle 19.

[194] *Pulp Mills on the River Uruguay (Argentina v. Uruguay), Judgment, I.C.J. Reports 2010*, p. 14, para. 115.

[195] *Pulp Mills on the River Uruguay (Argentina v. Uruguay), Judgment, I.C.J. Reports 2010*, p. 14, paras. 101 and 102.

[196] *Pulp Mills on the River Uruguay (Argentina v. Uruguay), Judgment, I.C.J. Reports 2010*, p. 14, paras. 101, 145 and 146. See also para. 81: "The Court considers that the procedural obligations of informing, notifying and negotiating constitute an appropriate means, accepted by the Parties, of achieving the objective which they set themselves in Article 1 of the 1975 Statute. These obligations are all the more vital when a shared resource is at issue, as in the case of the River Uruguay, which can only be protected through close and continuous co-operation between the riparian States."

> affected; the other State is sole judge of that and has the right to information on the proposals."[197]

5.31. By its persistent failure to notify and consult, or to respond to Chile's legitimate requests for information in a substantive manner, Bolivia has afforded Chile no opportunity to make representations or to determine the appropriate measures to prevent or mitigate whatever risk it may face from Bolivian use of the waters of the Silala River or from Bolivian activities adjacent to those waters. That failure is based on Bolivia's current refusal to recognise (i) that the Silala River is an international watercourse and (ii) the ensuing obligations that derive from being a riparian of an international watercourse.

5.32. By its repeated failure to respond to requests from Chile for information, Bolivia is in breach of its obligation under international law to notify and consult Chile with respect to activities that may affect the waters of the Silala River or the use thereof by Chile.

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[197] *Affaire du Lac Lanoux (Spain v. France)*, Award of 16 November 1957, Reports of International Arbitral Awards, Vol. XI, para. 21. Original in French: "L'Etat exposé à subir les répercussions des travaux entrepris par un Etat limitrophe est seul juge de ses intérêts, et si ce dernier n'en a pas pris l'initiative, on ne saurait méconnaître à l'autre le droit d'exiger notification des travaux ou concessions qui sont l'objet d'un projet."

CHAPTER 6
REMEDIES SOUGHT

6.1. As follows from the rule of customary international law reflected in Article 35 of the ILC's 2001 Articles on State Responsibility:

> "A State responsible for an internationally wrongful act is under an obligation to make restitution, that is, to re-establish the situation which existed before the wrongful act was committed, provided and to the extent that restitution:
>
> (*a*) is not materially impossible;
>
> (*b*) does not involve a burden out of all proportion to the benefit deriving from restitution instead of compensation."

6.2. As noted in the Commentary to Article 35, an international court or tribunal can, by determining the legal position with binding force for the parties, award what amounts to restitution.[198] As matters now stand, Chile considers that its rights as the downstream riparian with respect to an international watercourse, the Silala River, will be adequately protected by a series of declaratory orders from the Court, determining the legal position with binding force as between Chile and Bolivia.

6.3. First, and most obviously, Chile seeks a declaration that the Silala River is indeed – as is manifest – an international watercourse. That declaration is needed given Bolivia's current refusal to accept what it once accepted with no difficulty at all.

[198] *Yearbook of the International Law Commission,* 2001, vol. II (Part Two), p. 97, commentary to Article 35, para. (5), referring to *Legal Status of Eastern Greenland, Judgment Nº 53, 1933, P.C.I.J., Series A/B*, p. 22, p. 75, and *Free Zones of Upper Savoy and the District of Gex, Judgment Nº 46, 1932, P.C.I.J., Series A/B*, p. 96, p. 172.

6.4. Secondly, Chile seeks declarations as to the important rights that follow inevitably from the Silala River's status as an international watercourse, including in particular Chile's right to equitable and reasonable utilization and Bolivia's obligations with respect to not causing harm and with respect to cooperation, including notification and consultation. The declarations sought are needed given that Bolivia is currently denying the existence of Chile's rights and of Bolivia's related obligations.

6.5. Thirdly, consistent with chapter 5.B above, Chile seeks a declaration that its current use of the Silala River waters is equitable and reasonable. In this respect, it is emphasised that Chile does not seek to obtain any pre-judgment as to what future use of the Silala River may be equitable and reasonable and likewise does not seek in any way to freeze further development and use of the waters so far as concerns either State. It is accepted that what is equitable and reasonable may change over time, and the only declaration sought concerns Chile's current usage.

6.6. Finally, consistent with chapter 5.D above, Chile seeks a declaration with respect to breach by Bolivia of its obligations of notification and consultation.

6.7. Accordingly, the Court is requested to judge and declare as set out in the Submissions below.

SUBMISSIONS

Chile therefore requests the Court to adjudge and declare that:

(a) The Silala River system, together with the subterranean portions of its system, is an international watercourse, the use of which is governed by customary international law;

(b) Chile is entitled to the equitable and reasonable utilization of the waters of the Silala River system in accordance with customary international law;

(c) Under the standard of equitable and reasonable utilization, Chile is entitled to its current use of the waters of the Silala River;

(d) Bolivia has an obligation to take all appropriate measures to prevent and control pollution and other forms of harm to Chile resulting from its activities in the vicinity of the Silala River;

(e) Bolivia has an obligation to cooperate and to provide Chile with timely notification of planned measures which may have an adverse effect on shared water resources, to exchange data and information and to conduct where appropriate an environmental impact assessment, in order to enable Chile to evaluate the possible effects of such planned measures. Obligations that Bolivia has breached so far as concerns its obligation to notify and consult Chile with respect to activities that may affect the waters of the Silala River or the utilization thereof by Chile.

Ximena Fuentes T.
Agent of the Republic of Chile
3 July 2017

Expert Report 1

Wheater, H.S. and Peach, D.W., *The Silala River Today – Functioning of the Fluvial System*

THE SILALA RIVER TODAY – FUNCTIONING OF THE FLUVIAL SYSTEM

Drs. Howard Wheater and Denis Peach

May, 2017

ABOUT THE AUTHORS

Dr. Howard Wheater

Dr. Howard Wheater is Canada Excellence Research Chair in Water Security, Director of the Global Institute for Water Security at the University of Saskatchewan, and Distinguished Research Fellow and Emeritus Professor of Hydrology at Imperial College London. A leading expert in hydrological science and modelling, he has published more than 200 refereed articles and 6 books. He is a Fellow of the Royal Academy of Engineering and the American Geophysical Union and winner of the Prince Sultan bin Abdulaziz International Prize for Water. He has initiated and led national and international research programmes in the UK and Canada, and has advised states, provinces and national governments on flood, water resource and water quality issues. He represented Hungary and Argentina at the International Court of Justice, and recently sat on an International Court of Arbitration concerning the Indus Waters Treaty. He was, until 2014, vice-chair of the World Climate Research Programme's Global Energy and Water Cycle Exchange (GEWEX) project and leads UNESCO's GWADI arid zone water program. In Canada, he leads the Changing Cold Regions Network, focused on the analysis and prediction of hydrological change in western Canada, and the Global Water Futures Program, focused on managing water futures in Canada and other cold regions where global warming is changing landscapes, ecosystems, and the water environment. His role as Chair of the Council of Canadian Academies Expert Panel on Sustainable Management of Water in the Agricultural Landscapes of Canada saw release of a report in February 2013 entitled Water and Agriculture in Canada: Towards Sustainable Management of Water Resources.

Dr. Denis Peach

Dr. Denis Peach spent nine years as the Manager of the British Geological Survey (BGS) Groundwater Programme, then 6 years as BGS Chief Scientist. He is a hydrogeologist with broad scientific interests and 44 years of experience, which includes work for a UK water authority, overseas work in tropical hydrogeological environments, small island hydrogeology and work for international consultants in arid zone hydrogeology. His particular scientific interests include groundwater modelling which he developed in BGS, arid zone hydrogeology, Chalk and Karst hydrogeology. He has been a Vice President of the Geological Society of London (GSL), is a Visiting Professor at Imperial College, London and University of Birmingham and he has given the Ineson Distinguished lecture at the GSL. He currently carries out research with BGS and Imperial College and provides advice to the University of Saskatchewan and UK engineering consultants.

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DGA	–	Dirección General de Aguas (General Directorate of Water).
ET_r	–	Evaporation rate.
FCAB	–	The Antofagasta (Chili) and Bolivia Railway Company Ltd.
MQI	–	Morphological Quality Index.
NDVI	–	Normalized Difference Vegetation Index.
UNWC	–	United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses.

1 INTRODUCTION

1.1 Experts' Terms of Reference

In the context of the dispute between the Republic of Chile and the Plurinational State of Bolivia concerning the status and use of the waters of the Silala, to be heard before the International Court of Justice, the Republic of Chile has requested our independent expert opinion, as follows:

> "Questions for Dr. Howard Wheater, as a hydrological engineer:
>
> (i) Do the waters of the Silala constitute a system of surface waters and groundwaters constituting by virtue of their physical relationship a unitary whole and normally flowing into a common terminus, parts of which are situated in different states? If yes, what do you consider to be the natural direction of flow?
>
> (ii) Insofar as you consider that there is currently an active fluvial system in the Silala catchment, what is the evidence that establishes this in your view?
>
> (iii) What, if anything, is the effect of the channeling of the flow on Bolivian territory on the watercourse that enters from Bolivia into Chile?
>
> Questions for Dr. Denis Peach, as a hydrogeologist:
>
> (i) Do the waters of the Silala constitute a system of surface waters and groundwaters constituting, by virtue of their physical relationship a unitary whole and normally flowing into a common terminus parts of which are situated in Bolivia and Chile? If yes, what do you consider to be the natural direction of flow?
>
> (ii) What geological, geomorphological and/or other events formed the Silala ravine as it exists today?
>
> (iii) Does the geological, geomorphological and other evidence point to the historical existence of a fluvial system in the Silala catchment?"

In this joint report we address the three questions to Wheater, including the Peach response to the common question (i). A separate report (Peach and Wheater, 2017) addresses the historical evolution of the Silala, i.e. questions (ii) and (iii) to Peach, as above.

1.2 Background to the report

In May 2016, Dr. Wheater visited the Silala River at the request of the Republic of Chile and advised that, in his professional opinion, the Silala River was, without doubt, an international watercourse in his understanding of that term.[1] While inspection of maps, images, flow data and the site visit was sufficient to confirm this view, he recommended that Chile seek additional expert opinion from a hydrogeologist, and commission scientific studies, to better understand the geological and geomorphological evolution of the river and its current functioning, including surface water-groundwater interactions. Dr. Peach was subsequently invited to offer his opinion and advice, and a Chilean team of scientific experts was put in place, led by Dr. José Muñoz, Civil Engineer and Professor at the Faculty of Civil Engineering at the Pontificia Universidad Católica de Chile. This team, working under the leadership of Dr. Muñoz, and the technical direction of Drs. Wheater and Peach, has carried out a set of intensive observational and monitoring studies, which are ongoing. Detailed results of these studies to date are presented in a set of technical reports, appended hereto as Annexes I-X. In this report we summarize the key findings of these technical reports for the benefit of the Court, and our joint opinion.

[1] We note that the flows in the Silala River are relatively small, so that the terms 'stream' and 'river' could equally be considered appropriate.

1.3 Structure of the report

In **section 2** we present a summary of our findings. In **section 3** the current understanding of the hydrology of the river is presented, structured as follows: 3.1 location and topography; 3.2 history of water use and development; 3.3 discharge at the international border; 3.4 climate, precipitation and temperature; 3.5 evaporation; 3.6 hydrological processes and hydrogeological functioning; 3.7 geomorphology and fluvial habitats. A concluding discussion is presented in **section 4**. While this co-authored report reflects our joint opinion, Wheater is the lead author of the report, except for the hydrogeology section 3.6 whose lead author is Peach.

2 SUMMARY OF FINDINGS

The Convention on the Law of the Non-Navigational Uses of International Watercourses, signed in New York on 21 May 1997 and entered into force on 17 August 2014 (the "UNWC"), defines a watercourse as "a system of surface waters and groundwaters constituting by virtue of their physical relationship a unitary whole and normally flowing into a common terminus", and an international watercourse as "a watercourse, parts of which are situated in different states".

We show below that:

- The topography of the Silala River catchment area is such that natural drainage from an area of approximately 69.0 km^2 in Bolivia flows across the international border between Bolivia and Chile.
- In our accompanying report (Peach and Wheater, 2017) we present geological and geomorphological evidence that shows that the river has shaped a ravine, which crosses the current border; sediment dating shows

that the Silala River has flowed through this ravine, which begins on Bolivian territory, for over 8400 years.

- The river flow at the border is perennial and has been measured by Chile since 2001. It shows the characteristics of a groundwater-dominated river, i.e. a relatively constant base flow rate with limited contributions to flow from rapid runoff from storm events. The average flow for the period 2001-2015 is 170 litres per second.
- The river is currently geomorphologically and biologically active. The processes of geomorphology that shaped the cross-border ravine are still active, and the river has a healthy population of fish and invertebrates.
- While the source areas for the perennial flow at the border lie in two major sets of groundwater springs in Bolivia (the water sources for the Orientales and Cajones wetlands) the river interacts with groundwater throughout its subsequent course. Numerous springs contribute additional flow to the river; in particular this is evident in the cross-border ravine where they can be seen emerging from the face of the ravine at higher elevations than the stream bed, and joining the main river. In addition, the flowing river loses water through its bed to a shallow underlying groundwater aquifer.
- There are at least three types of groundwater aquifer systems: i) shallow aquifers in alluvial sediments drain the hillslopes in Bolivia and Chile, generating the spring flows discussed above; ii) immediately below the river bed a shallow aquifer, in the unconsolidated sediments laid down by the river, receives water as leakage from the river bed; iii) deeper underlying aquifers have been proven to exist, between depths of 15-20 m to over 100 m. The first two of these groundwater systems are interpreted

as cross-border aquifers.[2] The deep groundwater systems are likely to be a substantial water resource, although at present of unknown spatial extent.

- The river is located in an arid region, with average annual precipitation of approximately 165 mm. Precipitation recharges the groundwater aquifers, and hence the springs that feed the river; as noted above, contributions to river flow from rapid runoff from storm events are relatively limited. Our estimate of the annual water balance shows that of the 165 mm of precipitation, 87 mm is lost to evaporation and 78 mm is discharged as river flow (i.e. 170 litres per second) at the border. Due to topographic constraints, the only possible flow path for this water is across the border in the present flowing channel.

- Evaporation is generally limited by the available precipitation; however, in the Bolivian wetland source areas for the perennial river flow, groundwater springs provide water that can support wetland evaporation at a much higher rate, determined by atmospheric demand and the state of the vegetation. Our best estimate is that the annual evaporation from the Bolivian wetlands is the equivalent of an average flow of 1.3 litres per second, or 0.7% of the flow at the border; a more conservative (i.e. higher) estimate is 3.4 litres per second, or 2% of the flow at the border.

- There has, we understand, been a history of the use of the waters of the Silala River, through concessions awarded to a British company, The Antofagasta (Chili) and Bolivia Railway Company Ltd. (FCAB), by the Chilean government in 1906, and by the Bolivian government in 1908.

[2] Water chemical and isotope data indicate that the recharge of the springs can be differentiated. The springs feeding the upper reaches of the river immediately downstream of the border are recharged by high elevation precipitation to aquifer storage where the groundwater may spend decades before emerging from the springs mixed with more recent recharge. The springs on the northern flank of the ravine downstream of Quebrada Negra appear to be recharged more locally and have a shorter aquifer residence time.

FCAB subsequently built small structures to divert part of the river flow into a pipeline, one in Bolivia (in 1909-1910), and one in Chile (in 1942). In 1928, as we understand it, some development of the river channel took place due to concerns for water quality and the fact that the wetland vegetation provided a breeding ground for an insect population. Earth channels of the order of 0.6 x 0.6 m cross-section were constructed and subsequently lined with stone. They thus act as drains and are able to receive water from the wetland soils (and to release water back to riparian soils). These constructed channels followed the natural drainage path and gradients of the river and have not affected the flow path across the border. In 1997, Bolivia revoked the FCAB concession for withdrawals from Bolivian territory; we understand that maintenance of the constructed channels in Bolivia ceased, until recently.

- While active, the channel works are likely to have reduced the extent of surface water in the wetlands and hence reduced the direct loss of water to evaporation, although effects on wetland vegetation are likely to have been minimal.[3] Any resulting reduction in evaporation would potentially provide additional water for surface discharge, including cross-border flows. No impact of canalization on the wetland extent has been detectable from the available data,[4] and any changes to evaporation would be, at most, a small fraction of the total wetland evaporation, which, as noted above, is estimated to have a maximum effect equivalent, on average, to 2% of the trans-border flow.

[3] Given the shallow depth of the channels, soil water would remain readily available to the vegetation.

[4] Over the period 1987 to 2016 we see no long term trend in wetland extent, despite our understanding that the channels had variable maintenance. The major response is of marked seasonal and inter-annual variability.

We address in summary, the three questions posed to us by Chile. Further detail is provided in the full report that follows:

(i) Do the waters of the Silala constitute a system of surface waters and groundwaters constituting by virtue of their physical relationship a unitary whole and normally flowing into a common terminus, parts of which are situated in different states? If yes, what do you consider to be the natural direction of flow?

The Silala River is typical of a groundwater-fed river.[5] The perennial river flows originate in groundwater springs in Bolivia at more than 4323 metres above sea level (m.a.s.l.), but the river interacts with groundwater along its flow path. It receives substantial inputs from groundwater springs that emerge from the wall of a ravine that crosses the international border (at approximately 4277 m.a.s.l.), and loses water from the flowing channel to an underlying fluvial aquifer. Deeper groundwater systems have also been identified; at present, one of these contributes flow to the river in Chile via an artesian discharge. The topography of the basin is such that natural drainage will flow from Bolivia to Chile. The difference in elevation between the spring sources in Bolivia and the river channel at the border is more than 45 metres, and the gradient of the natural river channel is relatively steep (approximately 4-5%). In the vicinity of the border, the river channel flows within a ravine that has been created by fluvial processes. The ravine provides evidence that a river has flowed across what is now the international border, at this location, for more than 8350 years. We conclude that the river is indeed a unified system of surface waters and groundwaters, and that the natural direction of flow is across the international border, from Bolivia to Chile. The "common terminus" element is also satisfied, by the discharge of Silala

[5] Many major rivers originate in perennial or ephemeral groundwater springs. The River Thames (UK) is a notable example (British Geological Survey, 1996).

waters into the San Pedro River, and ultimately via the Loa River into the Pacific Ocean.

(ii) Insofar as you consider that there is currently an active fluvial system in the Silala catchment, what is the evidence that establishes this in your view?

The dating of fluvial sediments from several sequences in the ravine that crosses the border provides clear evidence that the ravine has been carved by fluvial processes over a period of more than 8350 years, up to the present day. The current fluvial system continues to be geomorphologically active; we have observed size-selective transport of fine and coarse sediments and bed armouring, and the current channel morphology of steps and pools is consistent with that needed to transport the current flow and sediment loads. The river also maintains flourishing populations of fish and invertebrates, an indicator of aquatic ecosystem health.

(iii) What, if anything, is the effect of the channeling of the flow on Bolivian territory on the watercourse that enters from Bolivia into Chile?

The channeling of flow on Bolivian territory has not influenced the river flow direction, which follows the natural topographic gradients. Flow across the border in the present ravine has occurred for at least the last 8350 years and long predated the concessions to FCAB and the later construction of a system of small channels. The channels may have had a minor effect in reducing the extent of the wetlands in Bolivia, and decreasing the occurrence of surface water in those wetlands. However, our calculations show that even under the most conservative assumptions, evaporation from these wetlands is a small component of the water balance (equivalent on average to 2% of the river flow at the border). So, minor changes to what is a small element of the catchment water balance would in our opinion have had no significant effect on flows at the border. Further, the channels, as we understand, have (until very recently) not been maintained since 1997, and we see no evidence of a change in flow regime at the border. In fact, satellite data shows the wetland extent to be dominated by large natural seasonal and inter-annual variability.

We conclude, from our expert point of view that the Silala River is without doubt "a system of surface waters and groundwaters constituting by virtue of their physical relationship a unitary whole and normally flowing into a common terminus", and that it is "a watercourse, parts of which are situated in different states".

3 THE SILALA RIVER

3.1 Silala River – Location and topography

In this section we introduce the basin location and topography, showing that any natural drainage from the headwaters in Bolivia will drain into Chile, through a natural ravine that crosses the border.

The Silala River originates in Bolivia and flows to the Antofagasta Region of Chile (Figure 1). It is one of the main tributaries of the San Pedro River. This, in turn, is a tributary of the Loa River, the longest river in Chile (440 km long) and the main watercourse in the Atacama Desert, discharging into the Pacific Ocean.

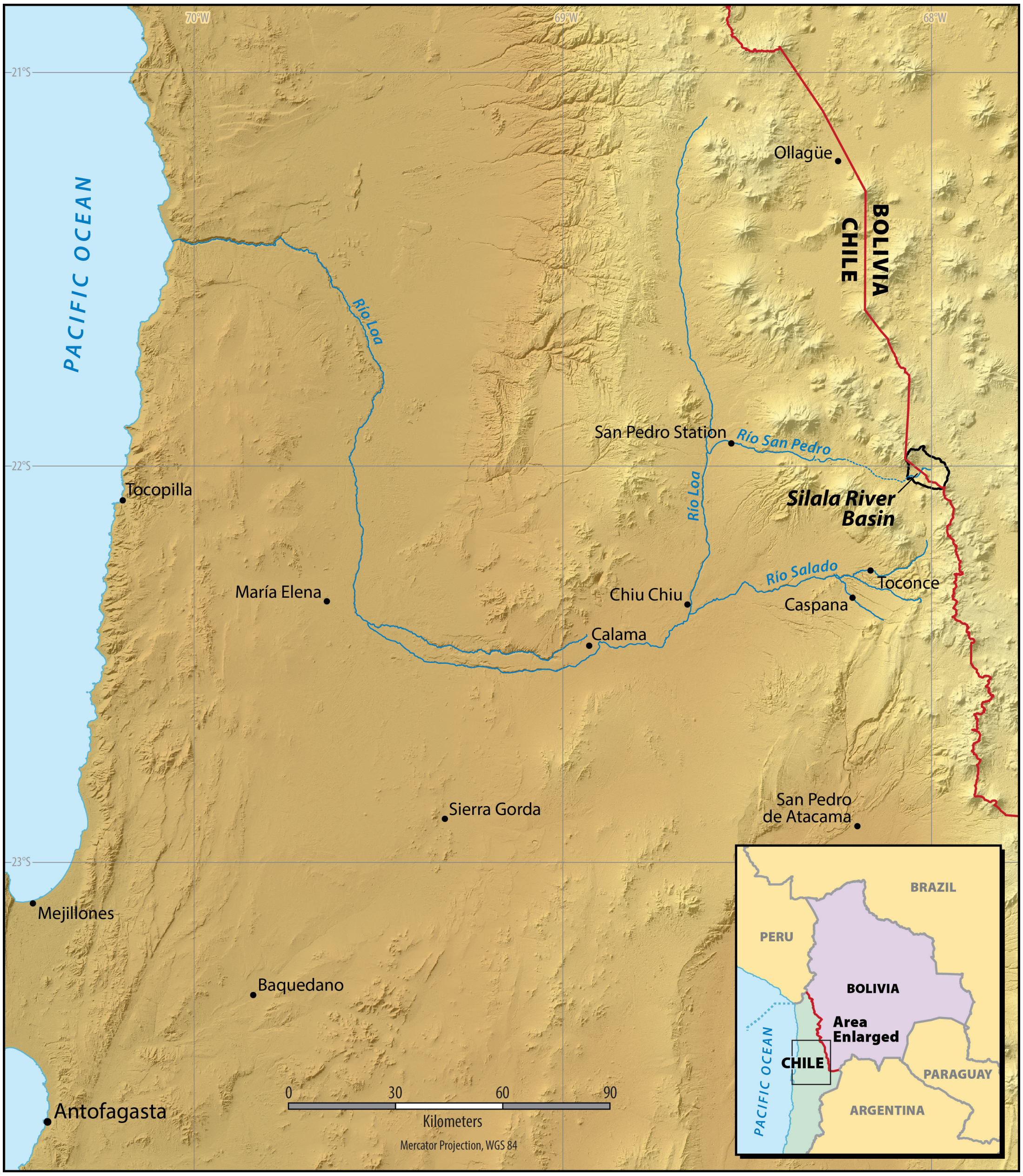

Figure 1. The Loa River system, including the Silala River basin.

A river is commonly defined by its topographic catchment area, i.e. the area draining to a given point on the river channel.[6] In the case of the Silala River, different maps and data products produce differences of detail in the definition of the topographic catchment (see Alcayaga, 2017, for a full analysis); we use a recent high resolution (5m) satellite-derived digital elevation map (DEM) to illustrate the topography. Figure 2 shows this catchment area and key features of the river network. The perennial sources of the river are multiple springs, which create two major wetland areas in Bolivia, namely the Cajones and Orientales wetlands.

We define the catchment using a location on the river 4.9 km downstream of the Chile-Bolivia border,[7] which gives a catchment area of 95.5 km^2, of which 69.0 km^2 is in Bolivian territory. The highest elevations in the basin reach 5703 m.a.s.l. (Volcán Apagado), and the elevation of the basin outlet is 3948 m.a.s.l.; most of the basin lies above 4000 m.a.s.l.

Figure 3 shows the contours of the catchment topography, from Alcayaga (2017). These show that natural runoff will drain to the river network and across the international border.

[6] Precipitation falling on the topographic catchment area and draining under the force of gravity, either as overland flow or shallow subsurface flow, will follow the topographic gradients to the river. However, where groundwater contributes discharge to a river, the area recharging the groundwater aquifer may differ from the topographic catchment.

[7] UTM coordinates are 596,453 E; 7,563,039 N, datum WGS84-19S.

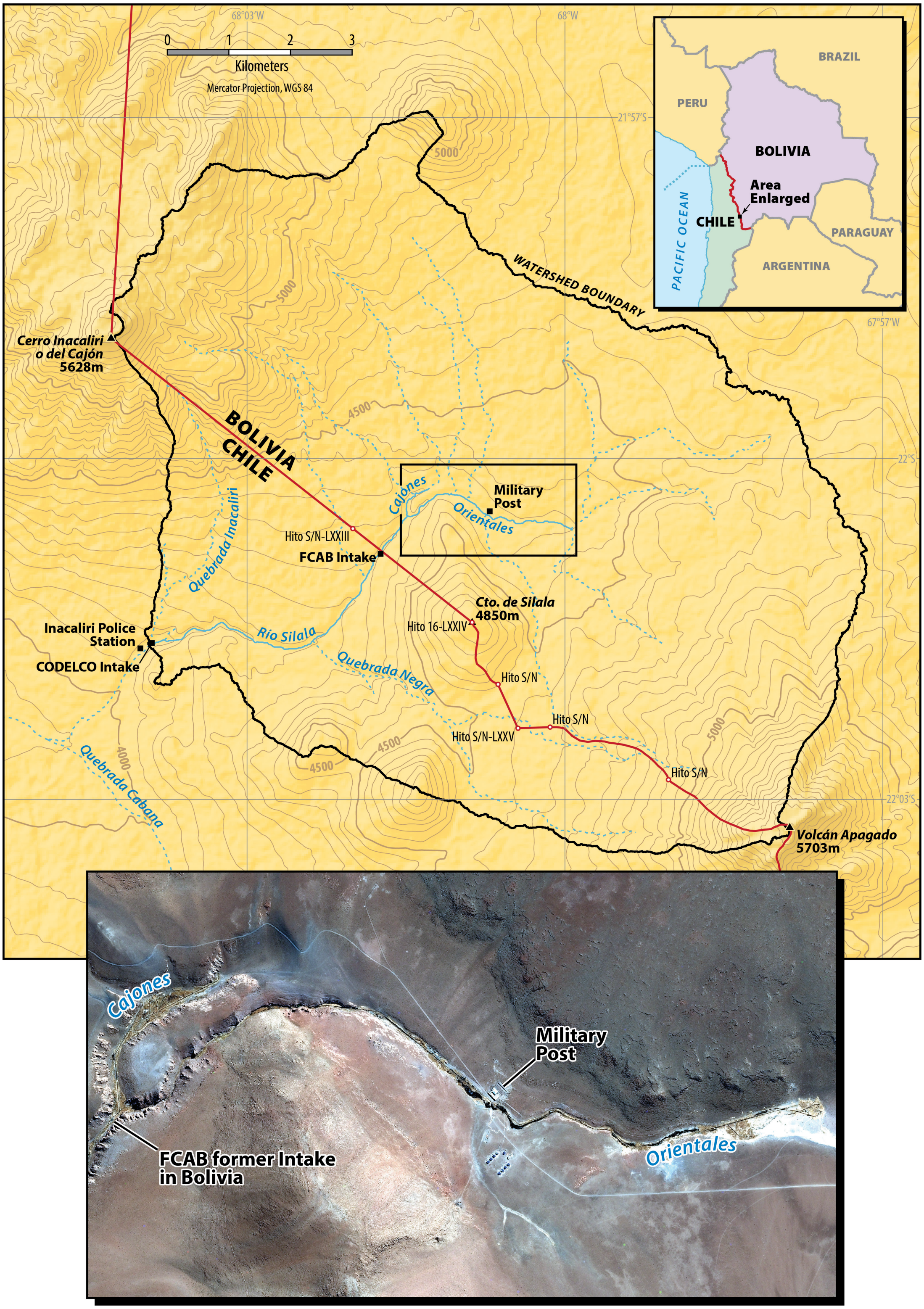

Figure 2. Drainage network of the Silala River basin, the Cajones and Orientales wetlands and other key features of the river network (Muñoz et al., 2017).

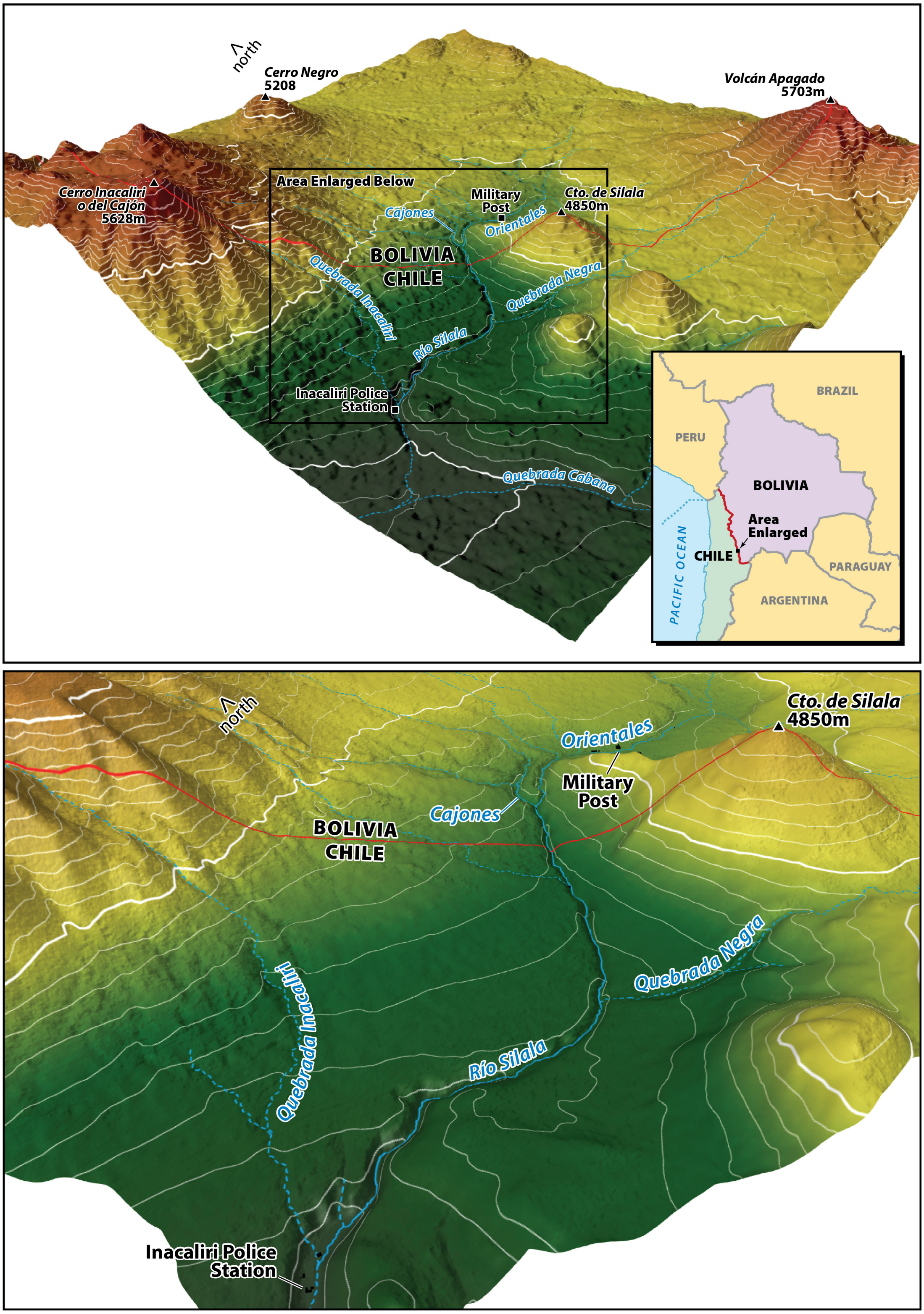

Figure 3. Contour lines of the terrain in the Silala River basin, as a 3D image (Alcayaga, 2017).

Figure 4 shows the gradient of the river channel, from the sources of perennial flow in the Orientales and Cajones wetlands in Bolivia, across the international border, to the catchment outlet. While this profile is derived from the DEM-5m, it is also consistent with ground-based measurements made by Chile as part of a joint field programme with Bolivian technicians in 2000 (see Alcayaga, 2017, for the comparison). It can be seen that the natural drainage path of the river system flows from Bolivia to Chile, and that the river slopes, downstream of the wetlands, are relatively steep (approximately 4-5%).

Images of the basin are shown in Figure 5. A distinct and important feature of the drainage network is that downstream of the perennial sources in Bolivia, the river flows through a natural ravine (Figure 5A), which can also be seen on the topographic map of Figure 3. Peach and Wheater (2017) show that this ravine has been formed over at least 8 millennia by the river; we note here that the ravine constrains the river to flow across the border, and we note below that the river continues to be geomorphologically-active.

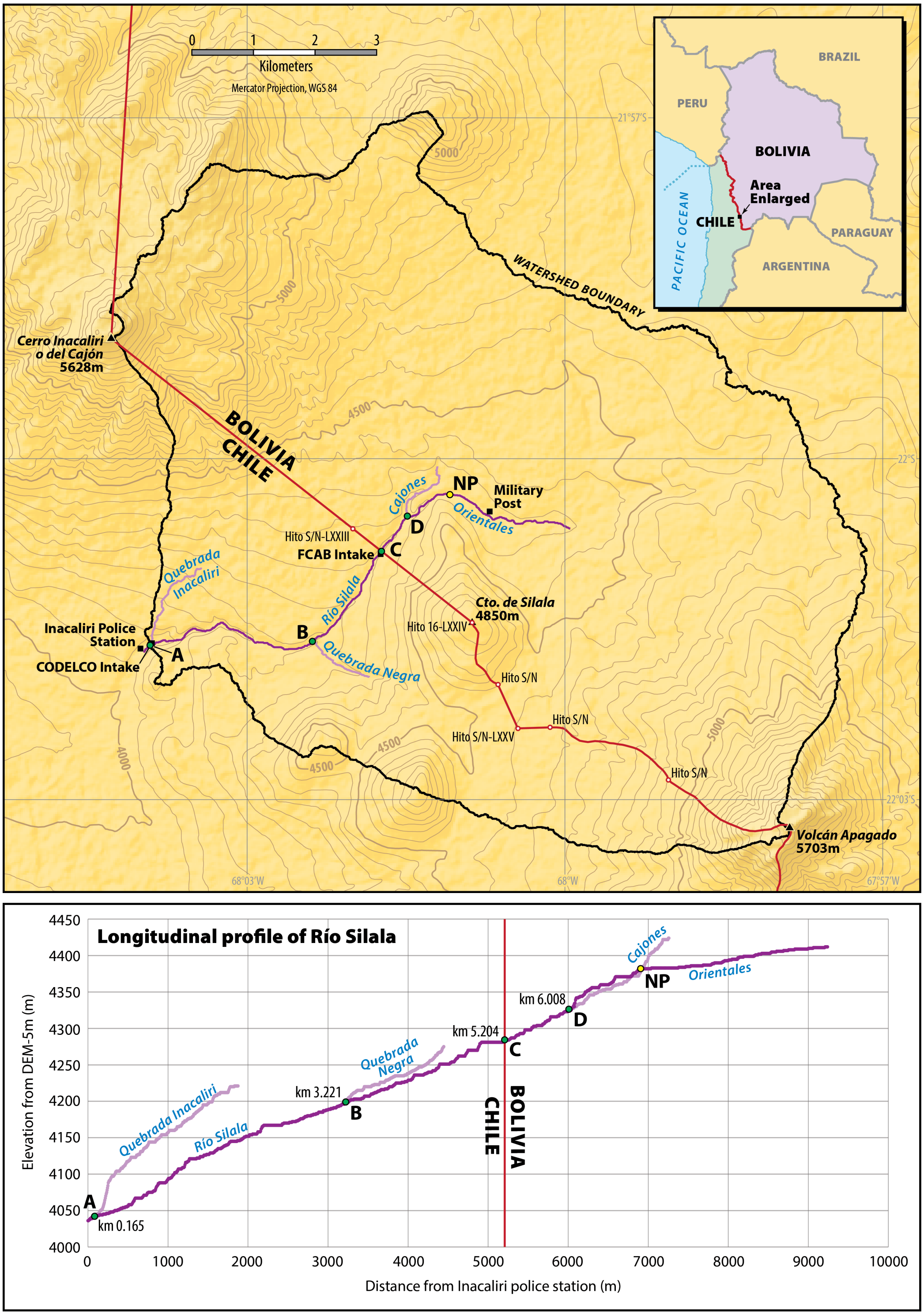

Figure 4. Longitudinal profile of the Silala River and main tributaries, extracted from the DEM-5m (Alcayaga, 2017).

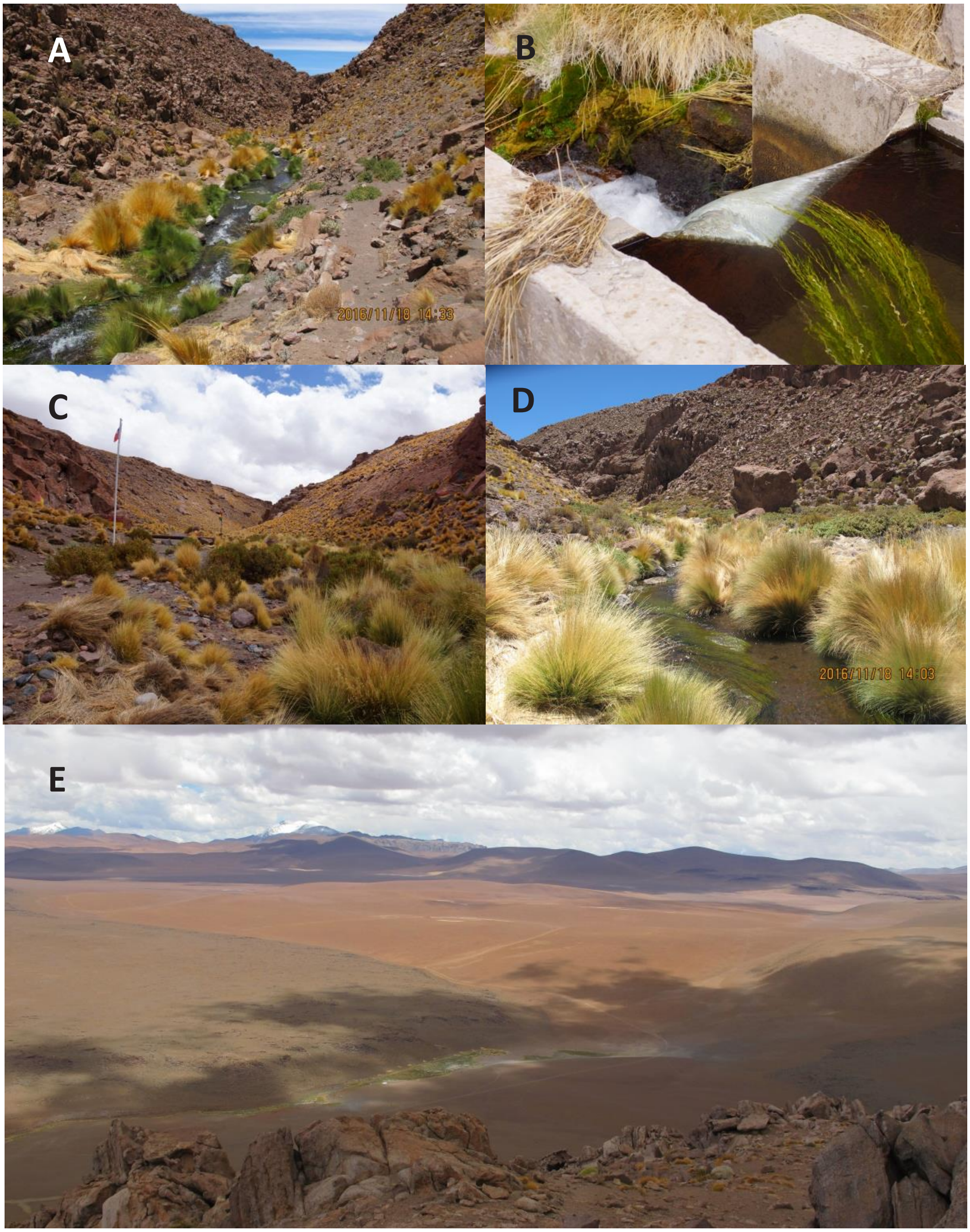

Figure 5. Photographs of the Silala River basin. A) Silala River. B) River flow gauge station at the Silala River. C) Chile-Bolivia international border where the Silala River flows. D) Riparian wetlands of the Silala River. E) View of Orientales wetlands (Bolivian territory) from the Chilean side of the boundary on the Cerrito de Silala (Muñoz et al., 2017).

3.2 Silala River – History of water use and development

As appears from Muñoz et al. (2017), water concessions were granted to a British company (FCAB) by Chile in 1906 and by Bolivia in 1908, and minor works were constructed in 1909-10 to allow river water to be diverted in Bolivia into a pipeline to supply the city of Antofagasta. In 1928 small earth channels were constructed in Bolivia to protect water quality and minimize insect pests. In 1942, a second diversion structure and pipeline was constructed in Chile. In 1997, Bolivia revoked the concession and channel maintenance ceased, until very recently. FCAB continues to abstract water from the Silala River in Chilean territory. Since 1954 a further withdrawal of water, by the mining company CODELCO, has taken place downstream of the FCAB sites.

In the hyper-arid region of the Atacama Desert, the Silala River is a precious water resource. There has therefore been, as we understand it, a long-standing interest in the use of the waters of the Silala to support local communities and their economic development. Muñoz et al. (2017) summarize the history of the water concessions in the basin. They report that in 1906, a concession was granted by Chile to a British company, The Antofagasta (Chili) and Bolivia Railway Company Ltd. (FCAB), to use the waters of the Silala for an indefinite period of time to supply drinking water for Antofagasta. Two years later, in 1908, FCAB also secured the rights to use the waters of the Silala from the Bolivian government.

During the period 1909-1910, the first civil engineering works were put in place in Bolivia and in Chile for the intake and transportation of the water of the Silala River. Figure 6 shows the location of the former FCAB intake in Bolivia, which was built in 1910 to raise water levels and thereby facilitate flow diversion into a pipeline, while still allowing river flows to pass downstream. A second FCAB intake and pipeline was constructed on Chilean territory in 1942, and continues to operate up to the present day.

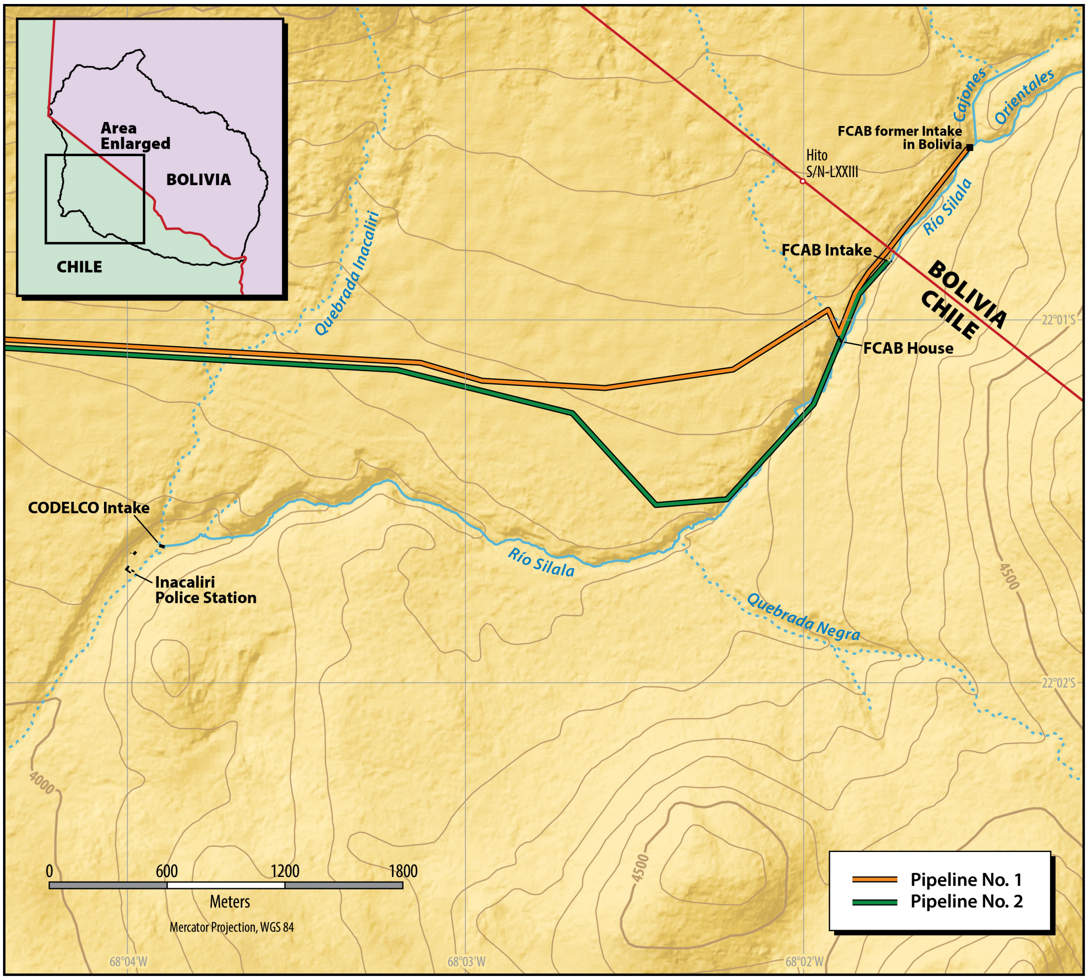

Figure 6. FCAB former Intake in Bolivia, FCAB Intake in Chile and pipelines constructed and used by FCAB. The FCAB former Intake in Bolivia and Pipeline N°1 (orange line) conducted water from Bolivian Territory to the FCAB reservoirs at San Pedro Station (and on to Antofagasta). FCAB Intake and Pipeline N°2 (green line) conducted water from Chilean territory, also to the San Pedro reservoirs (Muñoz et al., 2017).

Figure 6 also shows the location of a further withdrawal of water, downstream of the FCAB intakes, which was initiated in 1956 by the mining company CODELCO to support domestic water uses for around 12,000 inhabitants of the Chuquicamata copper mine.

Nearly two decades after the original FCAB intake system began operation, in 1928, there were concerns about water quality (presumably due to sediments in the river), and the fact that the vegetation in the riparian wetlands was supporting breeding grounds for insects. As a result, FCAB designed a system of small (0.6m x 0.6m) channels for the Bolivian Orientales and Cajones wetlands, which were constructed as earth channels, lined with stone (Figure 7).

The aim seems to have been to formalize the natural channel system to minimize erosion and to drain standing water. We note that the channels would be acting as drains, allowing ingress and loss of water to the adjacent soils, and that the limited depth of the constructed channels would have a minor effect in reducing groundwater levels, and hence on wetland vegetation.

In 1997, Bolivia revoked FCAB's concession for the use of the waters of the Silala in Bolivian territory, and FCAB has continued to abstract water from its intake on Chilean territory, at approximately 40-50 m from the border. The current engineered system is shown in Figure 8. Approximately 126 litres per second are currently withdrawn by FCAB (see Suárez et al., 2017, Figure 5-3). CODELCO currently has rights to use up to 160 litres per second.

At some point, FCAB installed a series of small weirs in the channel downstream of the border, presumably to allow for flow measurements. Their locations are shown in Figure 9, together with a photograph of one of the weirs.

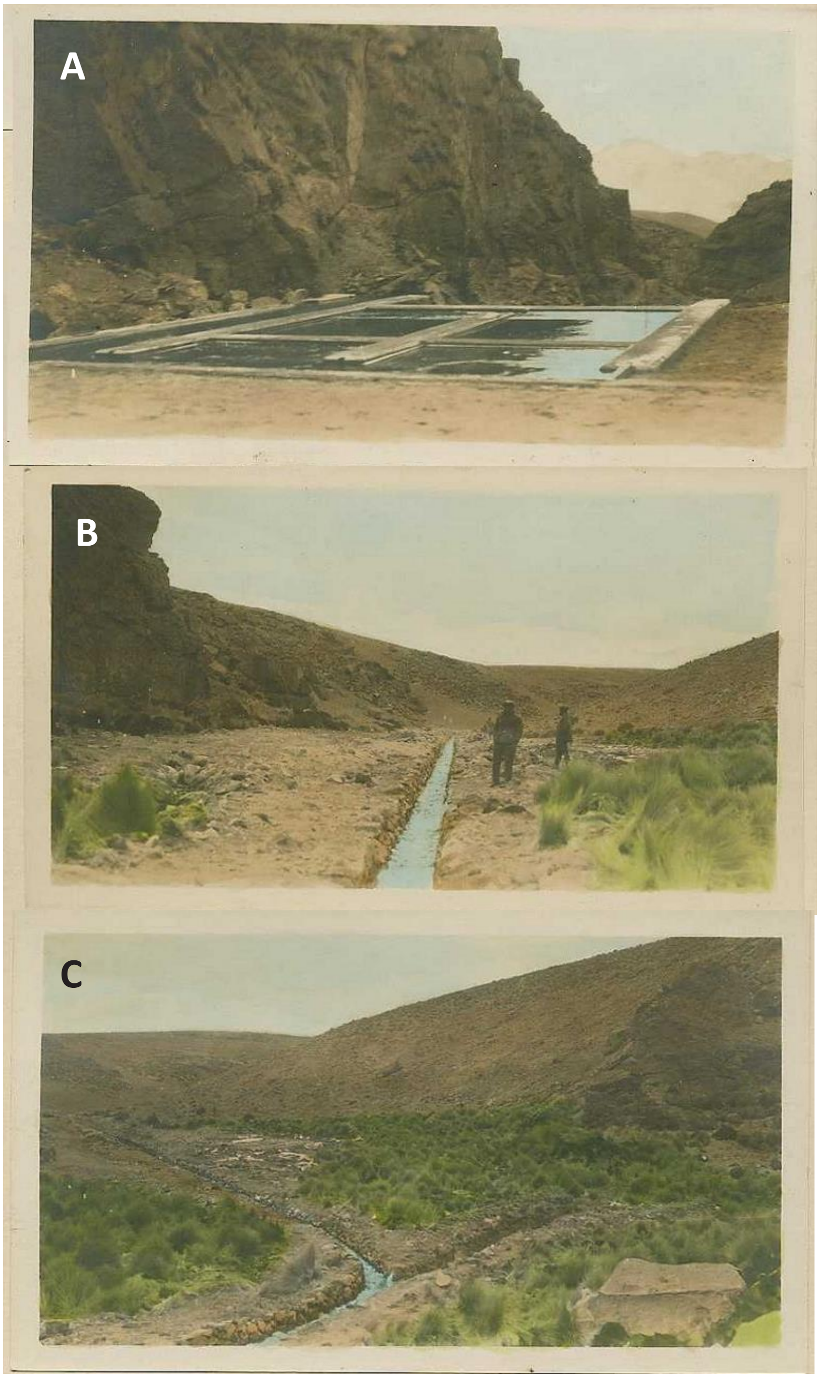

Figure 7. Channels and impoundment probably constructed in 1928 on Bolivian territory. a) Bolivia impoundment looking down the valley (towards Chile). b) Cajones main channel looking upstream c) Junction of the channels that come from the Cajones and Orientales wetlands (Photographs provided by FCAB, taken in Bolivian territory, undated).

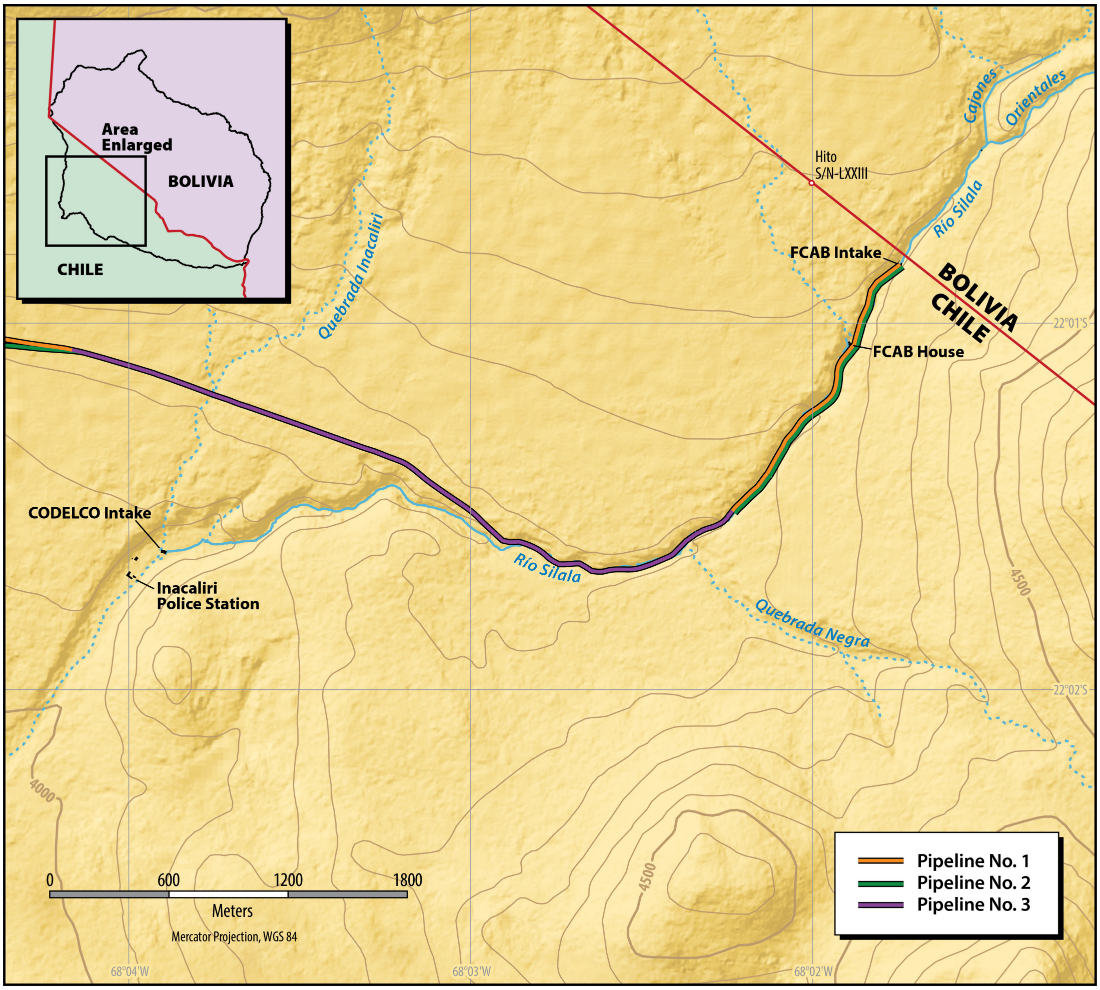

Figure 8. Current FCAB system (constructed in ~ 1997) used to transport water from the Silala River to the San Pedro reservoirs. The water is collected from the FCAB Intake and transported using two pipelines (Pipelines N°1 and N°2), which are combined in a single pipe (Pipeline N°3) before rejoining the pre-existing two pipes (Pipelines N°1 and N°2) (Muñoz et al., 2017).

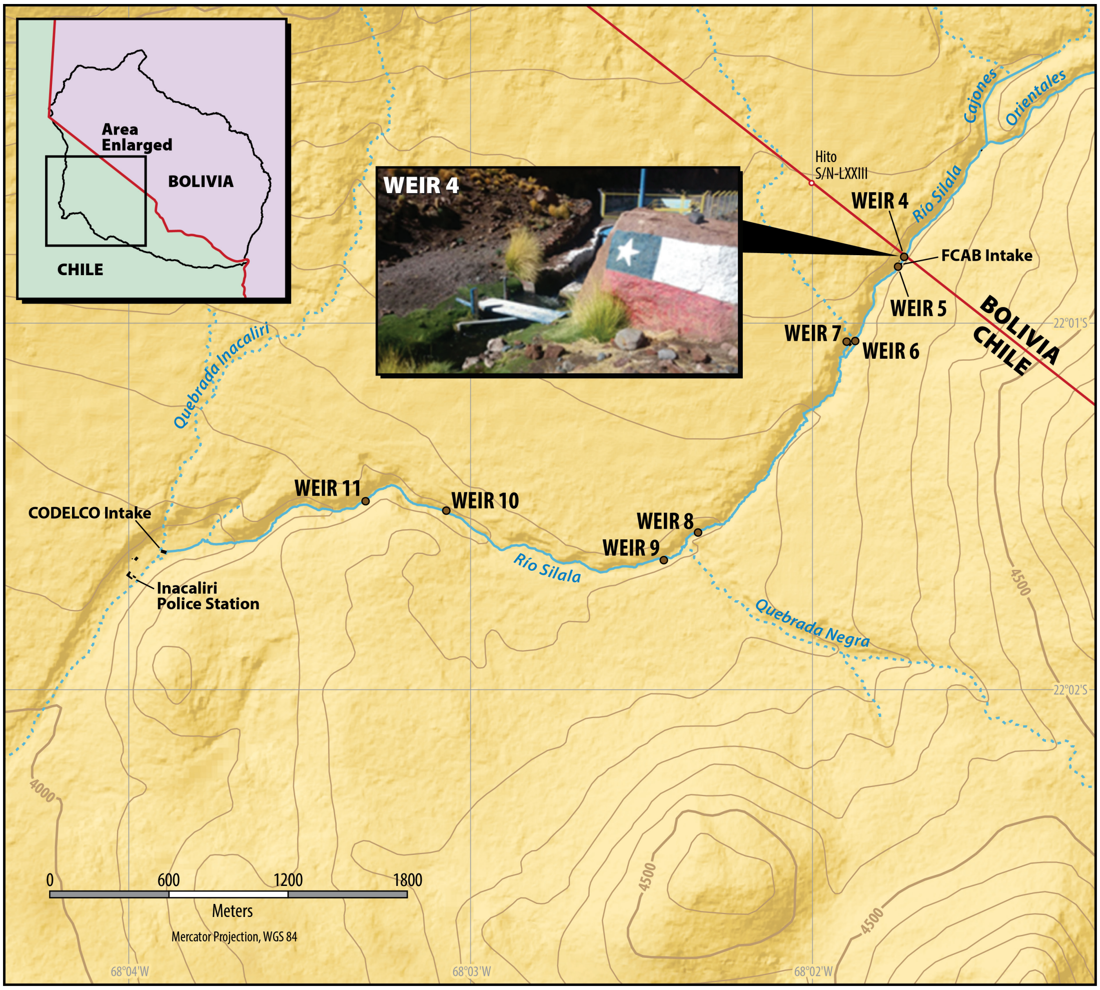

Figure 9. FCAB weirs used to measure flow in the Silala River basin (Muñoz et al., 2017).

3.3 Silala River – Discharge at the international border

In this section we present Chile's measurements of transboundary river discharge, showing that the Silala River has a perennial flow across the border of approximately 170 litres per second (0.17 cubic metres per second). The flow time-series is relatively constant, showing limited response to individual events, characteristic of a river dominated by groundwater sources.

A flow gauge (known as Río Silala antes de Bocatoma FCAB, and here designated "DGA Fluviometric Station") is located in the Silala River just downstream of the international border (Figure 10), installed and maintained by the Dirección General de Aguas of Chile – General Directorate of Water (DGA). Data are published in the national archive on the DGA web-site,[8] and are available from 2001, but with some missing records (e.g. in the periods 2008-2009 and 2012-2015).

Figure 11 shows the annual flow series, and Figure 12 the monthly data (Muñoz et al., 2017). The annual average flow over this period is 170 litres per second (0.17 cubic metres per second), with a maximum of 200 and minimum of 150 l/s. The relatively small variability observed in the flow data at these timescales is a general characteristic of a river in which flow is dominated by contributions from groundwater.[9] Calculation of a 'Baseflow Index' suggests that 92% of the river flow is from groundwater sources.

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[8] http://snia.dga.cl/BNAConsultas/reportes

[9] In catchments where rapid responses from overland flow and lateral subsurface flow are dominant, the hydrographic is much more dynamic, with marked event response and seasonal variability.

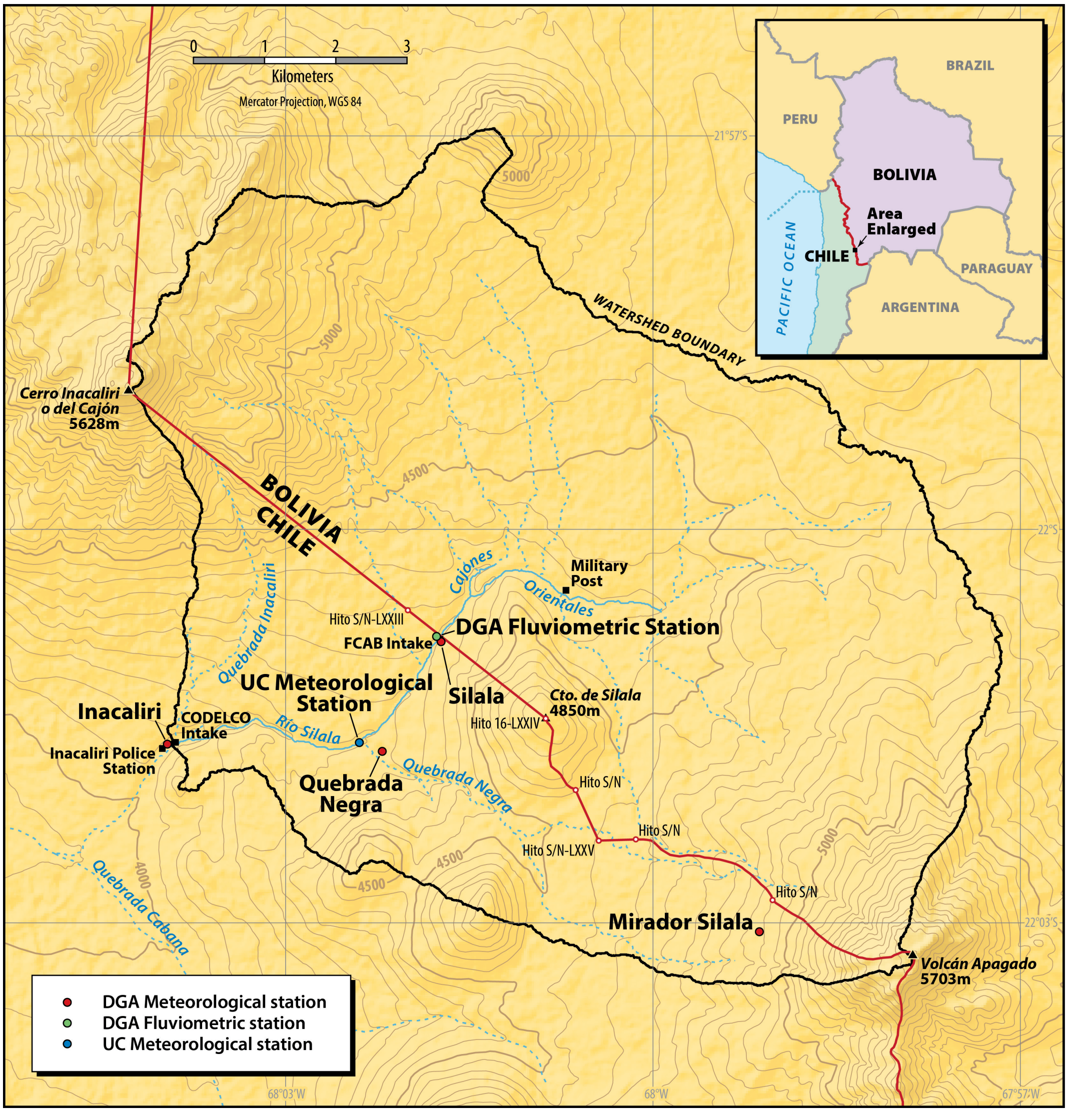

Figure 10. Location of monitoring stations in the Silala River basin.

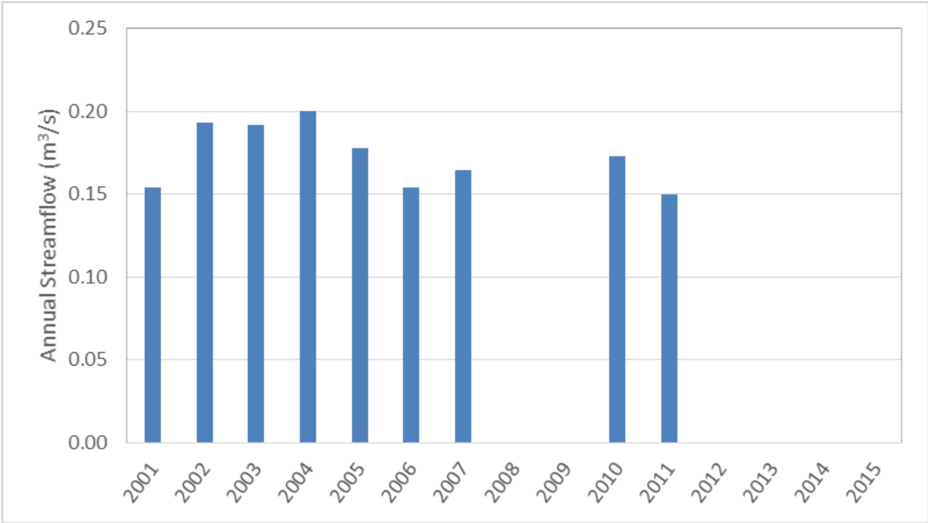

Figure 11. Annual streamflow at the DGA Fluviometric Station flow gauge, from 2001 to 2015 (Muñoz et al., 2017).

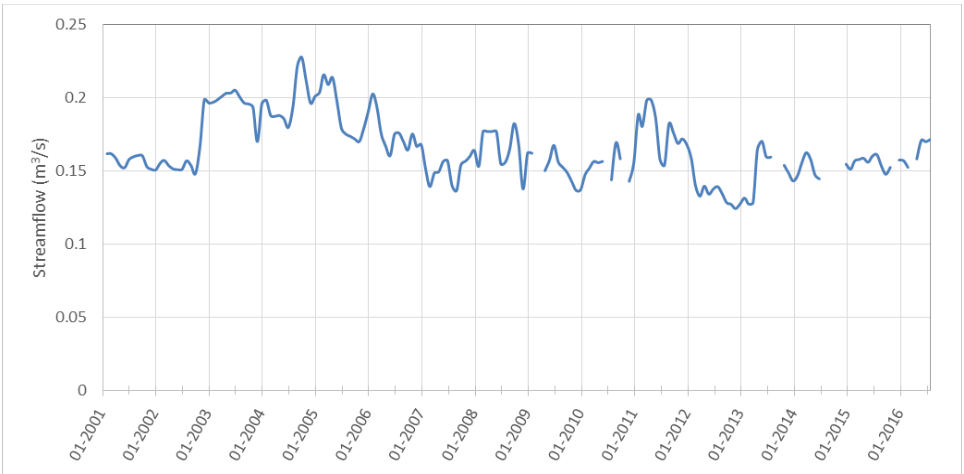

Figure 12. Monthly streamflow at the DGA Fluviometric Station flow gauge, from 2001 to 2016 (Muñoz et al., 2017).

It should be noted that there are difficulties in measuring flow due to the extreme climate conditions and remoteness of the basin. Instrumentation can be damaged by freezing conditions; frequent maintenance is needed but difficult to provide for this remote location. Freezing conditions also influence the accuracy of the data. In a conventional installation, a 'stilling well' (a vertical tube, connected to the river) would be used to measure water level, to damp rapid fluctuations in river water surface elevation, but this would be subject to freezing at this location. And partial freezing of the channel, due to ice build-up from the banks, will affect the relationship between water level (stage) and discharge that is used to calculate flow rates. Given these site limitations, the data can be considered a reliable indicator of the perennial flow from this groundwater-dominated river, but absolute discharge values will be subject to greater error than at a more conventional flow gauging situation.

3.4 Silala River – Climate, precipitation and temperature

In this section, we summarize the climate of the basin. Precipitation occurs mainly in summer, and annual precipitation shows a strong increase with elevation. Using local measurements of precipitation and a regional relationship with elevation, we estimate the annual average precipitation over the basin to be 165 mm. This is the precipitation that drives the hydrological functioning of the river system, providing recharge to the groundwater systems as well as rapid streamflow response to rainfall events. We note that temperatures can fall below freezing, even in summer.

A detailed discussion of the climatology of the region, and the sources of precipitation, is presented in Muñoz et al. (2017). We note that precipitation falls mainly in the summer months, associated with convective activity, and that there is high inter-annual variability of precipitation, influenced by El Niño effects on large scale atmospheric circulation. An important regional feature is the strong relationship between precipitation and elevation, shown in Figure 13. Within the Silala basin, there are two raingauges with historical records, Inacaliri (4040 m elevation, 29 years of daily data) and Silala (4305 m elevation, 9 years of daily data), (see Figure 10 for their location). These are located near the basin outlet, i.e. at relatively low elevations. The correlation between these and similar gauges in the region has been used to estimate the mean annual precipitation for these sites as 119 mm (over 34 years, 1969-2016) and 99 mm (over 28 years, 1977-2016), respectively (detailed in Muñoz et al., 2017).

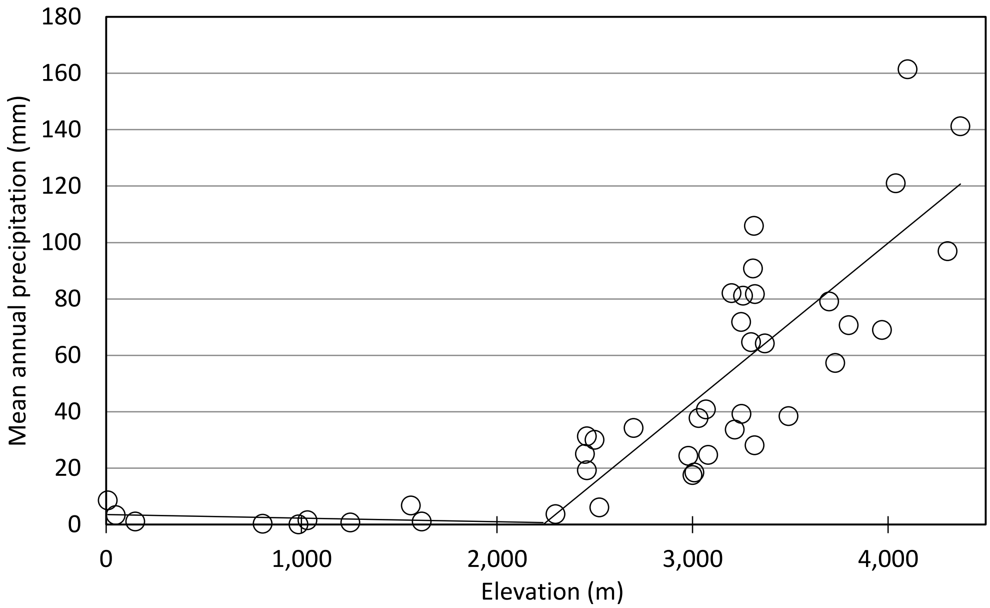

Figure 13. Regional precipitation as a function of elevation (Muñoz et al., 2017).

These lower elevation local data can be combined with the regional relationship with elevation shown in Figure 13 to derive estimates of the spatial distribution of precipitation over the basin as a whole, shown in the contours of annual precipitation (isohyets) in Figure 14. The annual average for the Silala catchment thus obtained is 165 mm.

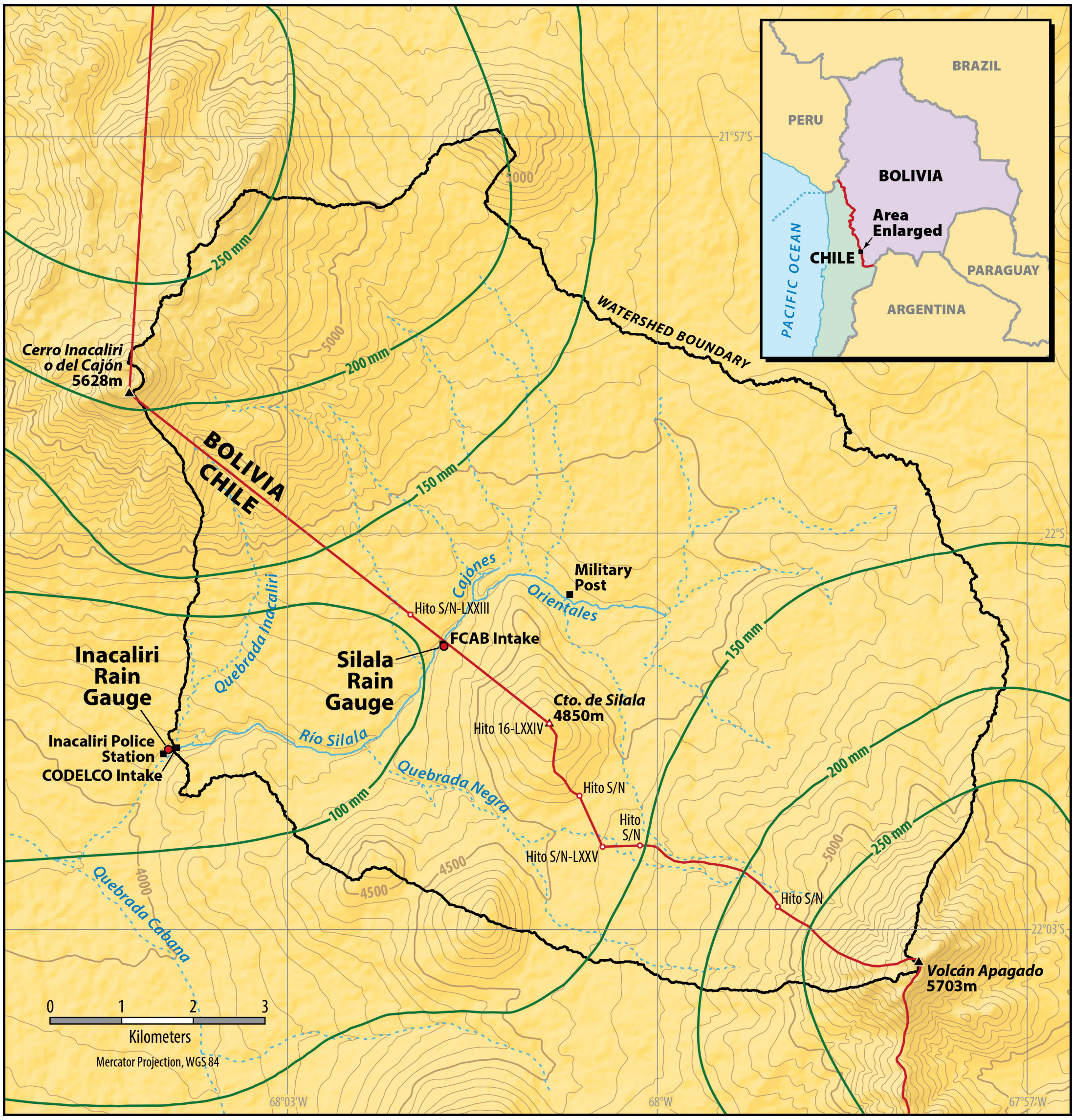

Figure 14. Average annual precipitation over the Silala catchment area (Muñoz et al., 2017).

The distribution of monthly precipitation is given in Table 1, which shows that precipitation mainly occurs in the summer months of January to March. This precipitation is caused dominantly by convective activity, and daily totals can therefore be quite high, e.g. 15-20 mm.

GAUGE	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
MEAN	0.2	0.5	6.1	32.1	36.0	17.0	1.3	0.9	1.1	0.7	1.5	1.3	99
MAX	5.4	14.9	47.1	121.2	217.1	83.2	14.3	13.8	13.5	9.8	16.3	14.4	
MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
STAN.DEV	0.9	2.5	10.3	36.0	47.6	21.5	3.3	2.6	2.9	2.3	4.0	3.3	

Table 1. Average mean, maximum, minimum and standard deviation of the monthly precipitation measured at the Silala gauge (1978-2016 – infilled data) (mm) (Muñoz et al., 2017).

The pattern of daily precipitation for the Silala gauge is shown in Figure 15.

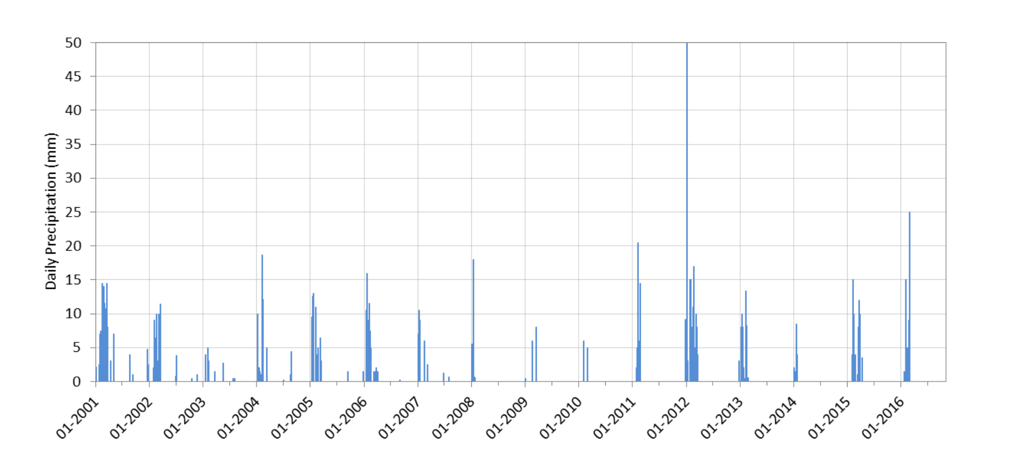

Figure 15. Daily precipitation, Silala gauge (mm) (2001-2016) (Muñoz et al., 2017).

Historical measurements of temperature are available from the Inacaliri gauge (Figure 10), which gives a mean annual temperature of 5.3 ^{o}C. However, there is a strong regional relationship of decreasing temperature with elevation (4.6 ^{o}C/km), shown in Figure 16. There is also a strong seasonal cycle of temperature, shown for Inacaliri in Table 2. To provide higher temporal resolution local data, we installed a weather station (UC Meteorological station, Figure 10) in November 2016. Figure 17 shows selected examples of the diurnal variability from the period November 2016 to January 2017. An important point is that even in summer, night time temperatures at this low elevation site fall below freezing. Recalling the decrease of temperature with elevation, and its seasonality, it can be concluded that freezing conditions commonly occur in the basin. While summer precipitation falls mainly as rain at lower elevations, it can fall as snow at higher elevation.

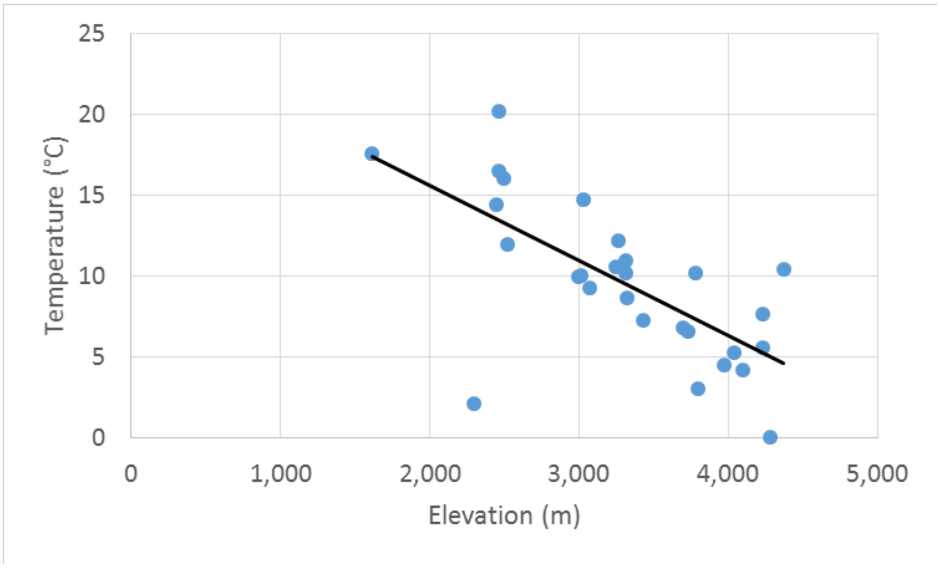

Figure 16. Regional relationship between mean annual temperature and elevation (Muñoz et al., 2017).

GAUGE	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
MEAN	5.3	6.6	7.9	8.3	8.4	8.6	6.4	3.9	2.1	1.8	2.7	3.7
MAX	10.3	9.1	9.7	9.8	10.5	12.2	8.6	7.7	5.8	4.8	5.6	6.3
MIN	2.5	4.8	6.2	5.6	6.3	6.3	4.2	1.7	-0.7	-0.8	1.0	1.4
STAN.DEV	1.8	1.2	0.9	1.0	1.1	1.5	1.1	1.5	1.7	1.3	1.1	1.3

Table 2. Monthly mean temperature at the Inacaliri gauge (°C) (1969-1992).

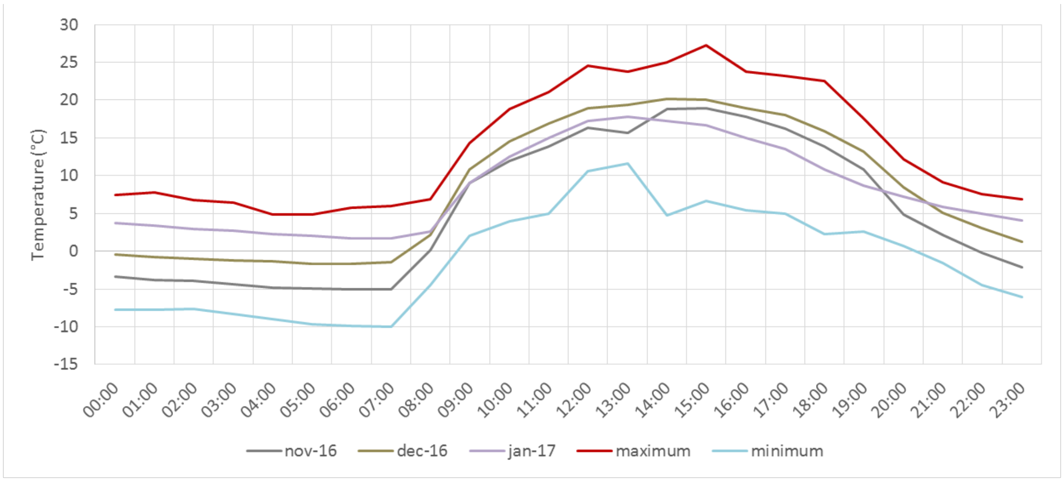

Figure 17. Hourly temperatures for selected months, as well as overall maximum and minimum temperatures at the UC Meteorological Station gauge (Muñoz et al., 2017).

3.5 Silala River – Evaporation

For most of the basin area, evaporation is limited by the precipitation. Our estimate of the average annual water balance shows that of the 165 mm of precipitation, 87 mm is lost to evaporation and 78 mm is discharged as river flow (i.e. 170 litres per second) at the border. However for wetland areas, where springs provide water to support wetland evaporation, higher evaporation rates may occur. Using remote sensing data we calculate the area of wetlands, and estimate that the associated wetland evaporation is equivalent to 0.7% of the average flow at the border. An alternative upper bound estimate of evaporation yields a figure equivalent to 2% of the average flow at the border. Anthropogenic effects on the wetlands, due to the small channels discussed above, are unlikely to affect wetland evaporation significantly, but could reduce the area of surface water. But given that the total effect of wetland evaporation is small, any reduction would be expected to have a negligible effect on Silala River flows from Bolivia to Chile.

Precipitation over the topographic catchment area is the primary input of water to the Silala River.[10] Some of the precipitated water can be lost to the atmosphere by evaporation, including sublimation of snow. The difference between precipitation and evaporation will be water that moves through the basin on varying timescales and is ultimately discharged as surface flow or groundwater discharge. The water balance for the basin can be defined, for a given time period (normally 1 year), as:

Equation 1[11]: precipitation - evaporation = discharge + change in storage

Having estimated average precipitation input to the Silala River basin as 165 mm/year, and measured the average discharge as 170 litres per second at the border (equivalent to 78 mm/year for the corresponding catchment area), the evaporation losses from the basin in Bolivia can be estimated as 87 mm/year. This assumes that inter-annual changes in water storage within the basin, for example water in transit through groundwater aquifers, will be small.

In those areas where water is readily available to support evaporation, i.e. the Bolivian Orientales and Cajones wetlands, which are maintained by flow from groundwater springs, and similar wetland and riparian areas downstream, higher evaporation rates may occur, but over relatively limited areas. Suárez, Muñoz et al. (2017) used historical satellite NDVI (Normalized Difference Vegetation Index) images from Alcayaga (2017) (see Figure 18 for examples) to identify the spatial extent of the wetland areas, including the Cajones and Orientales wetlands in Bolivia. These are marked by high seasonal variability, likely due to the

[10] Precipitation falling outside the topographic catchment area may contribute to groundwater if an aquifer extends beyond the topographic boundary.

[11] Precipitation and evaporation are normally described as a depth (mm) of water over a given time period, considered to apply over the area of the basin. Discharge is normally defined as a volume flow rate at the basin outlet (for example litres per second or cubic metres per second). In equation 1 we require consistent units. We can divide the discharge rate by the basin area to give the flow in mm over a given time period. Alternatively, we can consider evaporation and precipitation (in mm) to apply to a given area over a given time period, and hence calculate these terms in the units of discharge.

seasonality of precipitation and vegetation activity, with a maximum extent in the period January to March of approximately 0.16 km^2, and a minimum in winter of approximately 0.011 km^2 (Table 3).

Using a method developed for arid and semi-arid areas to estimate evaporation loss from riparian vegetation using NDVI data, the evaporation losses from the wetland areas were estimated. The average evaporation rates (ET_r) were highest for February (Table 4), at 3.9 mm/day. If this value is multiplied by the area of the wetland to give the volume of water lost per day, and then converted to equivalent units of flow, this corresponds to a rate of 5.9 litres per second (l/s) or 3.3% of the monthly flow at the border. Over a whole year, the average evaporation is 1.4 mm/day, which corresponds to 1.3 l/s, or 0.7% of the average flow. Hence if the wetland evaporation loss were not to occur, there could potentially be a small additional river flow, with a monthly maximum value of 5.9 l/s and an annual average of 1.3 l/s, or 0.7% of the Silala discharge at the border.

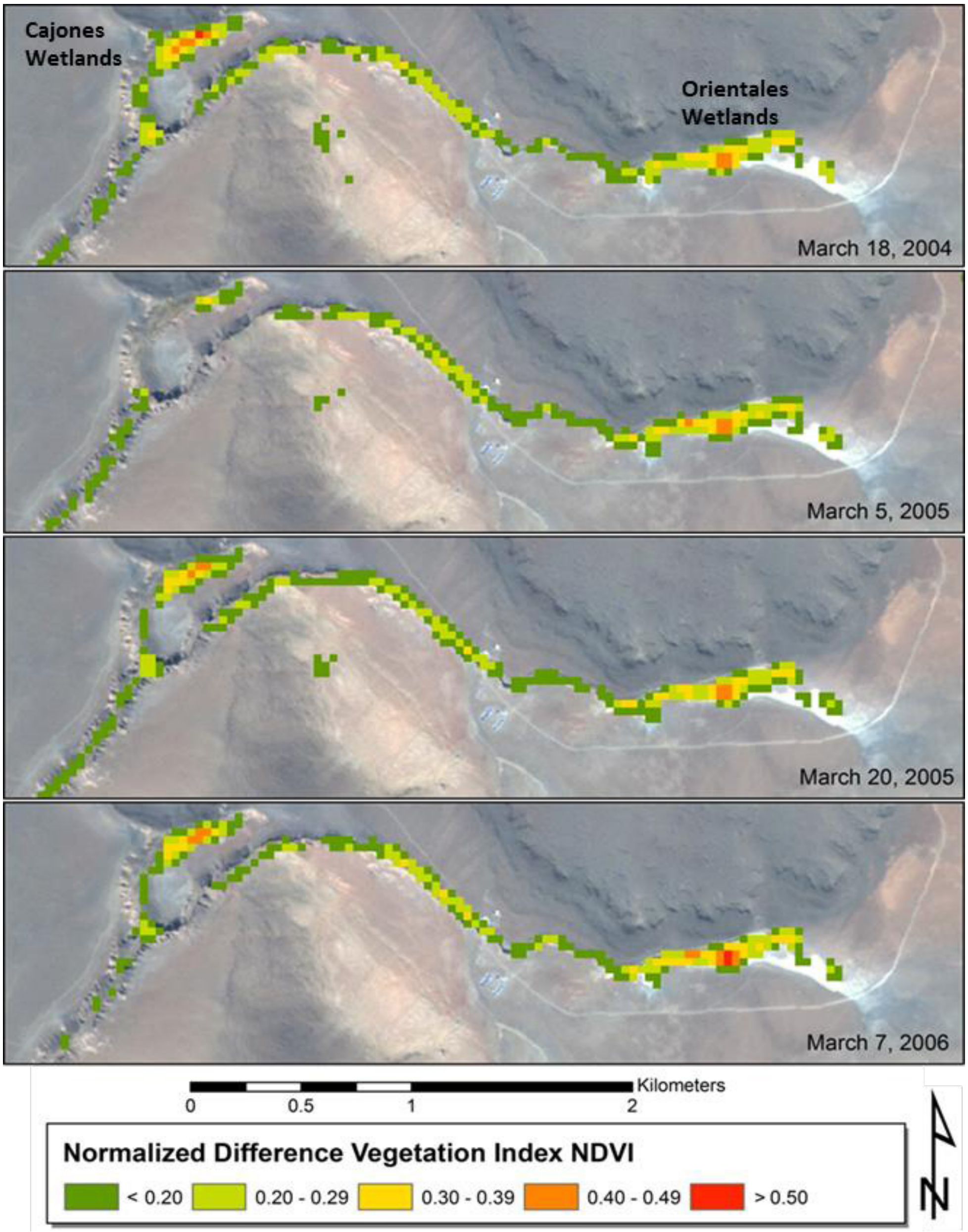

Figure 18. Examples of the NDVI images for the main wetlands in the Silala River basin. The wetlands shown are the Orientales and Cajones that are located in Bolivian territory (Alcayaga, 2017).

Surface (km^2) per NDVI Values Range								
Month	≤ 0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	> 0.6	Total
January	0.781	0.102	0.042	0.014	0.006	0.001	0.000	0.165
February	0.799	0.068	0.051	0.022	0.006	0.003	0.000	0.147
March	0.793	0.090	0.041	0.016	0.005	0.001	0.000	0.153
April	0.891	0.039	0.013	0.004	0.000	0.000	0.000	0.055
May	0.920	0.025	0.002	0.000	0.000	0.000	0.000	0.027
June	0.932	0.013	0.001	0.000	0.000	0.000	0.000	0.014
July	0.936	0.010	0.000	0.000	0.000	0.000	0.000	0.010
August	0.938	0.008	0.000	0.000	0.000	0.000	0.000	0.008
September	0.932	0.014	0.000	0.000	0.000	0.000	0.000	0.014
October	0.923	0.023	0.001	0.000	0.000	0.000	0.000	0.023
November	0.932	0.011	0.004	0.000	0.000	0.000	0.000	0.015
December	0.909	0.027	0.011	0.001	0.000	0.000	0.000	0.038
Average	0.890	0.036	0.014	0.005	0.001	0.000	0.000	0.056
Maximum	0.938	0.102	0.051	0.022	0.006	0.003	0.000	0.165
Minimum	0.781	0.008	0.000	0.000	0.000	0.000	0.000	0.008
Stand. Dev.	0.062	0.033	0.019	0.008	0.003	0.001	0.000	0.062

Table 3. Monthly average wetland area (km^2) as estimated using the NDVI (Alcayaga, 2017).

Month	METHOD					Average	Percentage of stream discharge
	Penman-Monteith	Turc	Priestley-Taylor	Taylor-de Bruin	Jensen-Haise		
	ET_r (l/s)						
Jan	4.1	3.1	3.6	4.4	3.3	3.7	2.1
Feb	5.8	5.3	6.0	6.8	5.7	5.9	3.3
Mar	3.1	2.2	2.3	2.9	2.3	2.6	1.5
Apr	0.8	0.6	0.6	0.8	0.6	0.7	0.4
May	0.3	0.2	0.2	0.2	0.2	0.2	0.1
Jun	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Jul	0.1	0.1	0.0	0.1	0.1	0.1	0.0
Aug	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Sep	0.2	0.1	0.1	0.2	0.1	0.2	0.1
Oct	0.3	0.2	0.3	0.4	0.3	0.3	0.2
Nov	0.5	0.4	0.4	0.5	0.3	0.4	0.2
Dec	1.0	0.7	0.7	0.9	0.7	0.8	0.5
Annual	1.4	1.1	1.2	1.4	1.1	1.2	0.7

Table 4. Average monthly ET_r, expressed as an equivalent streamflow (l/s) using the Groeneveld et al. (2007) method combined with five different methods for potential evaporation estimation, and the percentage of the monthly and yearly streamflow of the mean of all methods (Suárez, Muñoz et al., 2017).

Recognizing that these calculations are subject to high uncertainty, Suárez, Muñoz et al. (2017) made an assumption that evaporation from the wetlands occurred at the potential evapotranspiration rate to give an upper bound estimate. This is an idealized estimate of the evaporation that could occur from a vegetated surface, actively growing, and not short of water. In this case, the highest rate of loss in January is equivalent to a discharge of 11.5 litres per second, or 6.5% of the flow at the border. The average annual rate of loss corresponds to 3.4 l/s, or 2% of the average flow. Thus even under this assumption the conclusion remains that the evaporation from the wetlands is a relatively minor component of the Silala River basin water balance.

As discussed in section 3.7 below, and noted above, some channelization of the river channels was carried out in 1928, apparently to protect water quality and inhibit the breeding of insects. It could reasonably be expected that the channelization may have had some very limited effect on the areas of surface water in the wetlands, although effects on wetland vegetation are likely to have been very limited, given the shallow depth of the channels.[12] We understand that maintenance ceased in 1997 and was only very recently reinstated. Observed wetland extent is marked by strong seasonal and inter-annual variability (Figure 19), and no effect of these anthropogenic activities has been detectable in the recent record. In any case, given the small relative magnitudes of evaporation loss from the wetlands as noted above, it is clear that this management is likely to have had no significant effect on the Silala River flows at the international border.

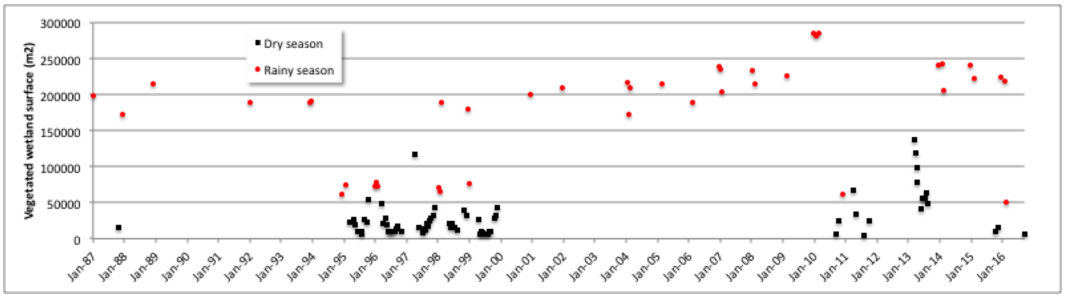

Figure 19. Time series for Cajones and Orientales vegetated area from Landsat imagery, based on NDVI values greater than 0.1 (Alcayaga, 2017).

3.6 Silala River – Hydrological processes and hydrogeological functioning

Much of surface geology of the basin is permeable; precipitation will therefore infiltrate the surface and recharge groundwater. Rapid runoff from storm events is limited and will most likely occur where saturated areas are present, for example at the spring-fed wetlands and riparian wetland areas. Groundwater discharges at springs in Bolivia provide the perennial sources of the Silala River

[12] Water tables will have been reduced by a maximum of 0.5 m adjacent to the channels, an effect that decreases with distance from the channels. Thus soil moisture levels can readily be maintained by capillary action, providing plentiful water for plant transpiration.

flow, but substantial groundwater inflows are also observed downstream, in particular in multiple springs that emerge from the walls of the cross-border ravine. There are at least three types of groundwater system – shallow perched aquifers that discharge as springs, a fluvial aquifer that underlies the river and receives water from the river channel, and deeper groundwater aquifers that have been intercepted by several boreholes, including one that encountered artesian groundwater and discharges into the river in Chile.

A summary of the geology of the Silala River catchment is presented in Peach and Wheater (2017) and the detailed results of their geological mapping programme are presented by SERNAGEOMIN (2017).

Infiltration experiments reported by Arcadis (2017) show that in general, infiltration capacities of the surface materials are high, commonly of the order of 1 m/day, which far exceeds the normal intensities of precipitation (15-20 mm per day). We can conclude that infiltration is the dominant surface hydrological process, with only very limited contributions of rapid runoff from overland flow during intense storms, which is consistent with the river flow observations. Subsurface processes are predominant, although we note that spring flows support wetland areas, which can then generate rapid event response due to rainfall falling on saturated areas.

Integrating the geological mapping with evidence from hydrogeological investigations (Arcadis, 2017) and detailed studies of stream-aquifer interactions using heat-based methods (Suárez et al., 2017) leads to the conclusion that there are three major types of aquifer that are active in the Silala River catchment. They are depicted in longitudinal catchment cross-section and transverse cross-section in Figures 20 and 21.

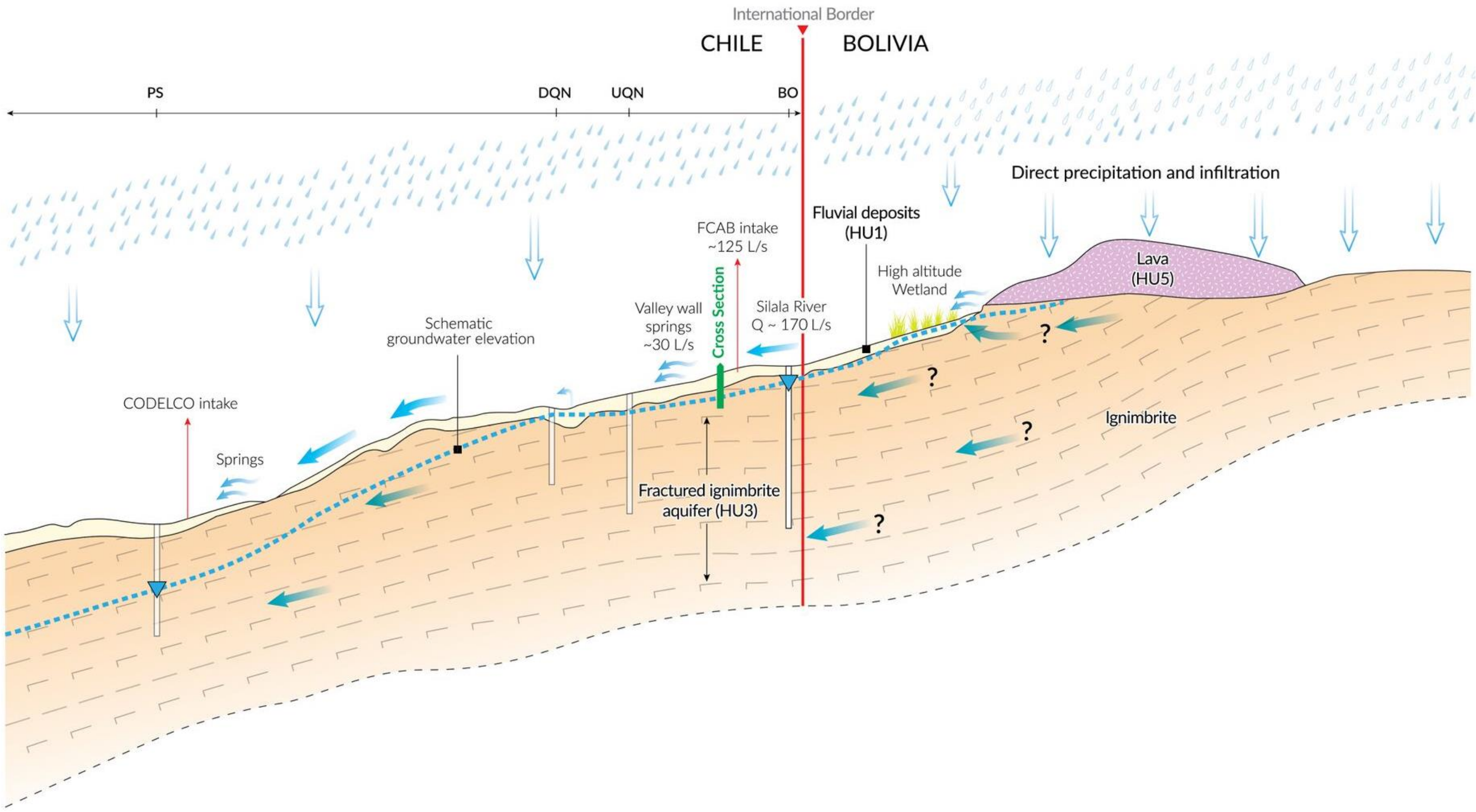

Figure 20. Hydrogeological conceptual model – longitudinal catchment cross-section (Arcadis, 2017).

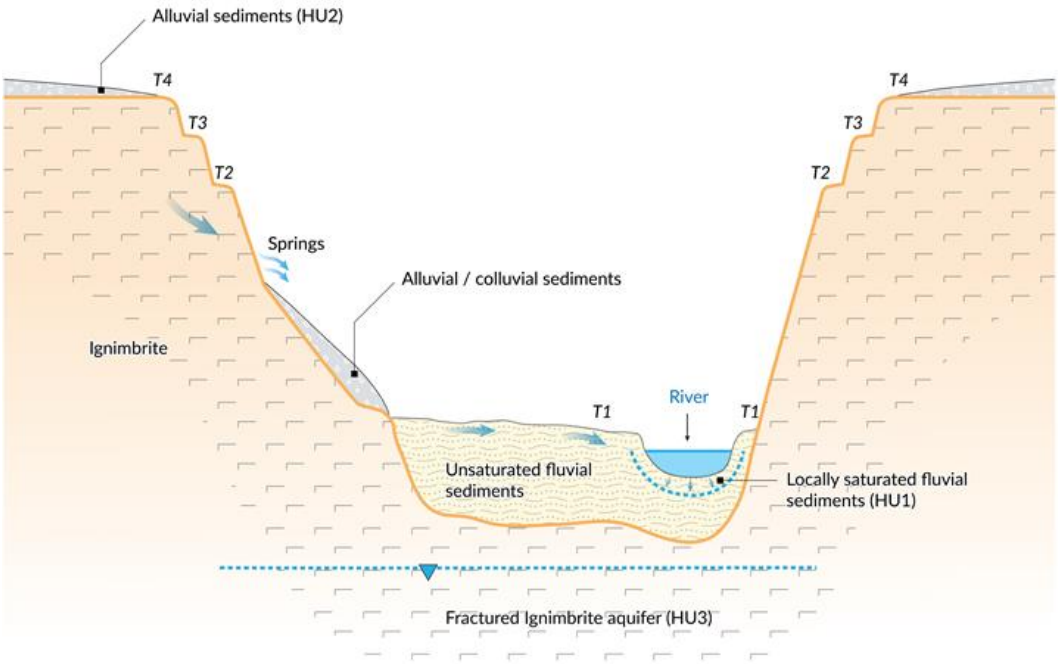

Figure 21. Hydrogeological conceptual model – ravine springs and stream aquifer interactions (Arcadis, 2017).

For much of the Silala River downstream of the international border the river bed overlies several metres of sediments, which form an alluvial aquifer. Suárez et al. (2017) showed that, at five points along the profile that he studied, the river loses water through the river bed to the sediments beneath. In other places it has been shown by drilling boreholes that the water level in the fluvial sediment lies well below the river bed (Arcadis, 2017), so it appears that the permeability in the fluvial deposits is vertically and laterally very variable, leading to variable saturation and perching of water tables[13] (Figures 20 and 21).

Numerous springs can be seen to issue from the walls of the ravine (Arcadis, 2017) especially in the region between the international border and the junction of the river with Quebrada Negra (Figure 22). These springs often emerge from high

[13] i.e. water tables at various elevations, supported by zones of low permeability.

in the sides of the ravine or from the alluvial deposits overlying the solid geology on the flanks of hills to either side of the ravine. The spring waters have a distinctly higher temperature than the Silala River water (Suárez et al., 2017). Use of a fibre-optic cable, laid along the river, showed the ingress of the warmer water from the springs at the base of the ravine (Suárez et al., 2017) (Figures 20 and 21). A low resistivity zone above the bedrock in the alluvial deposits was detected during geophysical surveys (Arcadis, 2017), which has been interpreted to represent perching of groundwater, which flows downgradient towards the Silala River ravine and issues from springs. This spring water is likely to be a mix of old and new recharge from these aquifers.

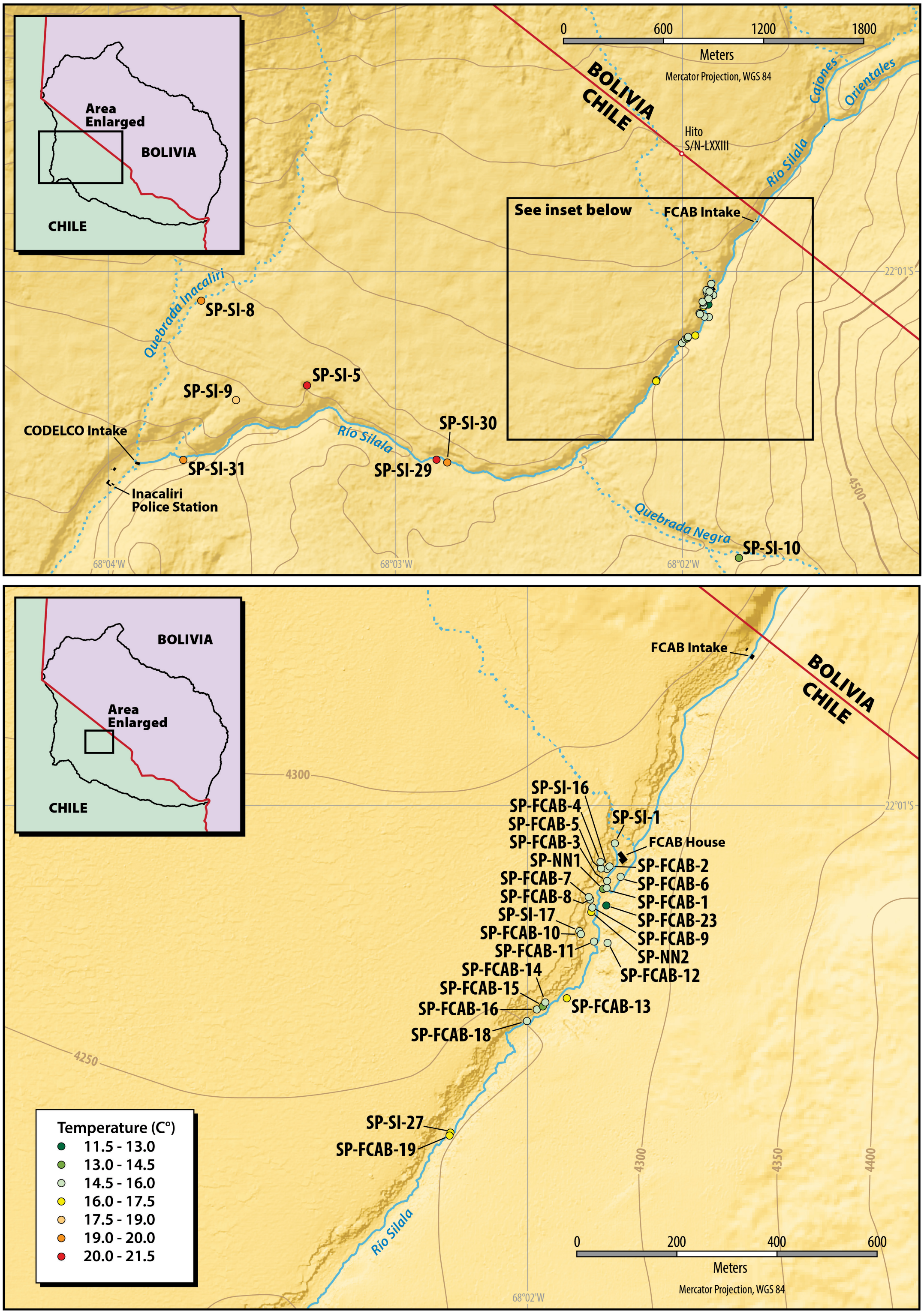

Figure 22. Spring locations downstream of the border with the temperature distribution. Red are the hottest samples and green are the coolest (Arcadis, 2017).

Underlying the Silala River in Chile at depth is a confined aquifer system.[14] This aquifer has been drilled and pump tested (Arcadis, 2017) and is located within the Cabana and Silala Ignimbrites (Peach and Wheater, 2017; Arcadis, 2017; SERNAGEOMIN, 2017). The Cabana and Silala Ignimbrites are basal rocks beneath the Silala ravine that were emplaced by explosive volcanic eruptions extruding flows of rock fragments, molten rock droplets and hot gases, which flowed down the existing topographic gradient at great speed. This deep aquifer system provides water of different chemical quality (Herrera and Aravena, 2017) and much higher temperature (Suárez et al., 2017) than the waters of the springs mentioned above, but was still recharged at high altitude. Chemical composition and radiocarbon analyses indicate that its residence time in the aquifer is much greater than the spring waters described above. It is believed that a deep aquifer was intercepted by an exploratory well drilled in 1995, which, because of the artesian pressure, continues to discharge a substantial amount of water to the stream and increased river temperatures by up to 9 ^{o}C (Suárez et al., 2017). It is interpreted from drilling and pumping test results (Arcadis, 2017) that the combined Silala and Cabana Ignimbrites form a laterally and vertically heterogeneous aquifer system which is confined at depth beneath the Silala River and our current understanding is that it does not interact with the river downstream of the international border except in the case of the artesian borehole mentioned above. The degree of heterogeneity may result in very poor lateral and vertical hydraulic connections within the system, so that hydrological responses at one site may or may not be felt at another. It seems likely that this aquifer system underlies much of the Silala catchment.

In the headwaters of the Silala River many springs supply the Cajones and Orientales wetlands. The Silala Ignimbrite outcrops at surface along the river

[14] A confined aquifer is one containing groundwater that is under pressure exceeding atmospheric pressure. The recharge area to a confined aquifer is at some distance and is unconfined but at higher elevation than the confined aquifer.

ravine and at the Orientales wetlands in Bolivia. The older and lower Cabana Ignimbrite outcrops further northeast in Bolivia. The precise sources of the perennial springs in Bolivia remain uncertain, given the lack of available geological, hydrogeological and water quality data. However, it seems likely that the source of the springs is the alluvial deposits on the slopes of the surrounding hills, which is consistent with the topographic analysis of Alcayaga (2017), who showed that these springs are coincident with locations of strong topographic convergence. An important additional influence is likely to be the extensive andesitic lava flow which truncates the ancient drainage system, as discussed in Peach and Wheater (2017).

Detailed data from fibre-optic cable monitoring and point temperature measurements beneath the river bed together with flow monitoring at weirs (Suárez et al., 2017) enabled the net contributions from groundwater to be quantified for the reach investigated (Figure 23). 35.9 l/s of water were contributed from the springs in the walls of the ravine, 3.3 l/s flows from the river bed to the underlying fluvial aquifer, and 91.6 l/s is contributed from the deep artesian source.

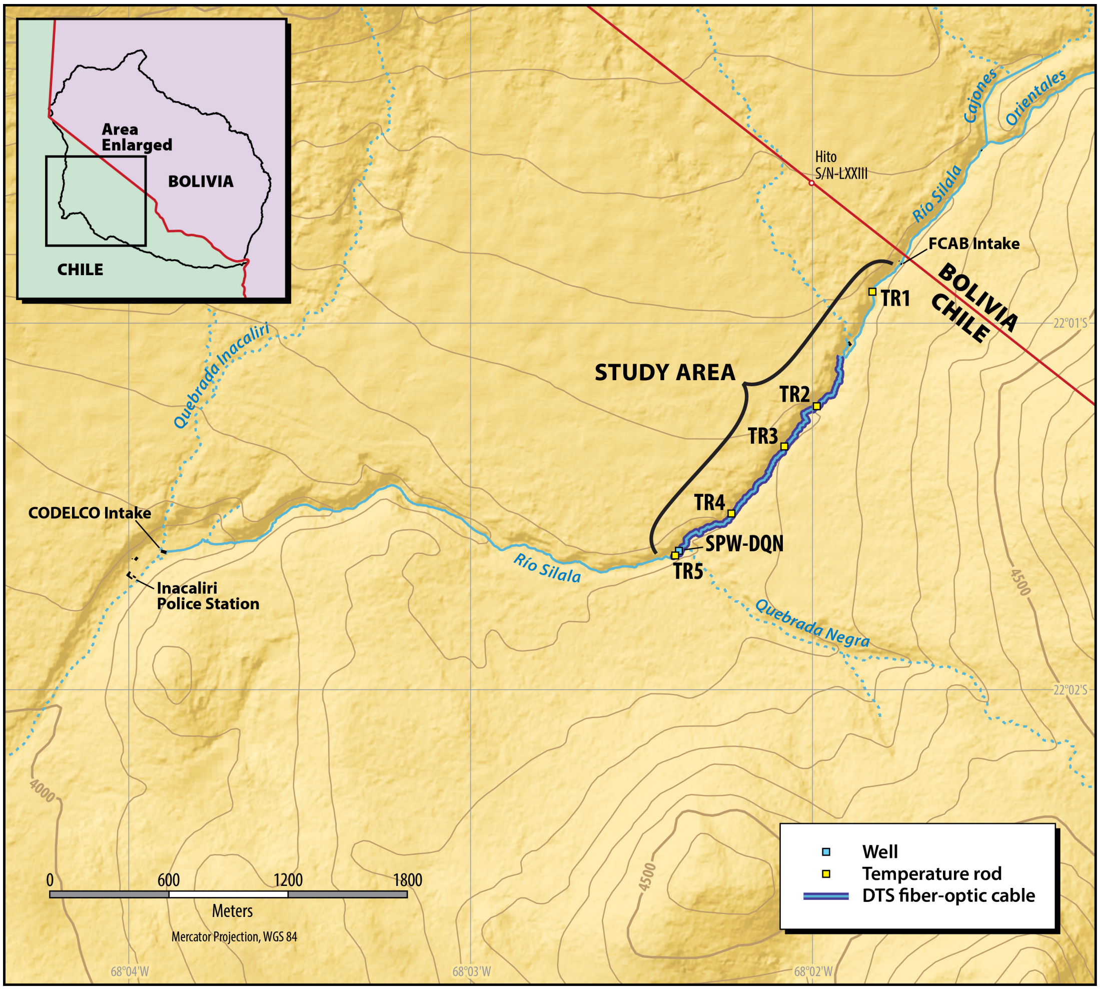

Figure 23. River reach where the interactions between groundwater and surface waters were investigated (Suárez et al., 2017).

In summary, it is clear that the river is largely fed by groundwater. It interacts over much of its flowing length with at least 2 distinct groundwater systems, and receives water at one location from a third, deep aquifer.

3.7 Silala River – Geomorphology and fluvial habitats

Our studies have shown that the river is currently geomorphologically active, with size-selective transport of fine and coarse sediments, and an armoured bed. It has the morphological and bed characteristics that can be expected from a perennial *river with this flow and sediment regime, has a good status as defined by an international Morphological Quality Index, and supports a healthy fish population.*

While the UNWC's definition of "watercourse" refers to a system of surface waters and groundwaters, for geomorphologists an important question is whether a river is not merely a conduit for water, but is also geomorphologically-active. Peach and Wheater (2017) present the fluvial history of the Silala River, demonstrating that its current ravine has been carved out by fluvial processes over at least the last 8000 years or more. Mao (2017) reports a series of experiments to investigate the current state of geomorphological activity. Field surveys of sediment transport were carried out in two river reaches, using marked sediments (coloured and with PIT (Passive Integrated Transponder) tags) and sediment traps. Figures 24a and b show that fine and coarse sediments are moved by the flow, with size-selective flow transport, and Mao concludes that the characteristics of the bed sediments are consistent with an armoured bed typical of perennial rivers. The river cascade step/pool morphology is that expected in an alluvial river with the slopes, sediment load and lateral confinement experienced by the Silala River. Using an internationally accepted Morphological Quality Index (MQI), the river is classified as in 'good' status. A healthy population of rainbow trout, with a wide range of sizes and weights, demonstrates that the general state of the river, with respect to perennial flows, water quantity and quality, and the availability of food, is sufficient to sustain a healthy fish population (Figure 25).

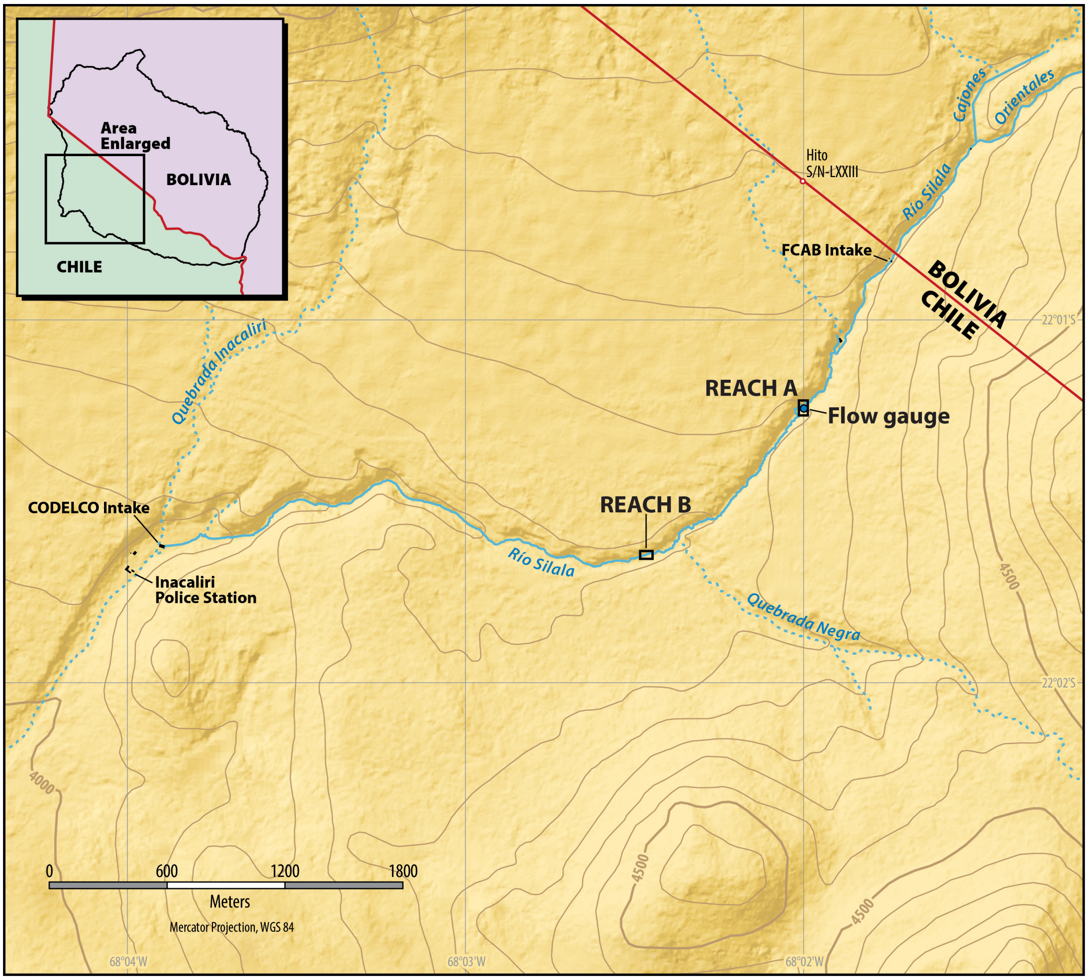

Figure 24a. Location of study reaches of Mao (2017).

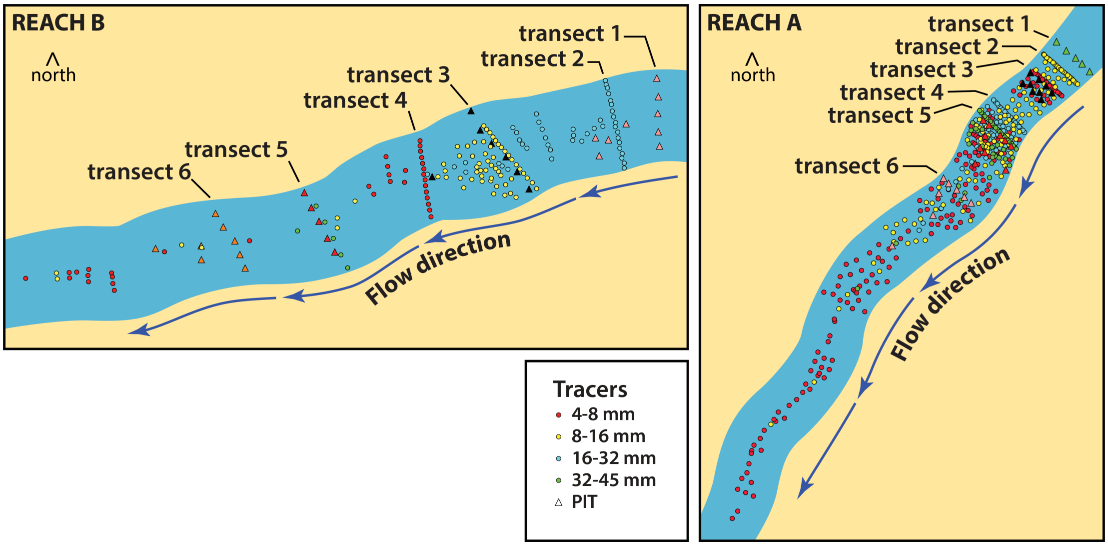

Figure 24b. Results from sediment tracing: reaches A (right) and B (left) (Mao, 2017).

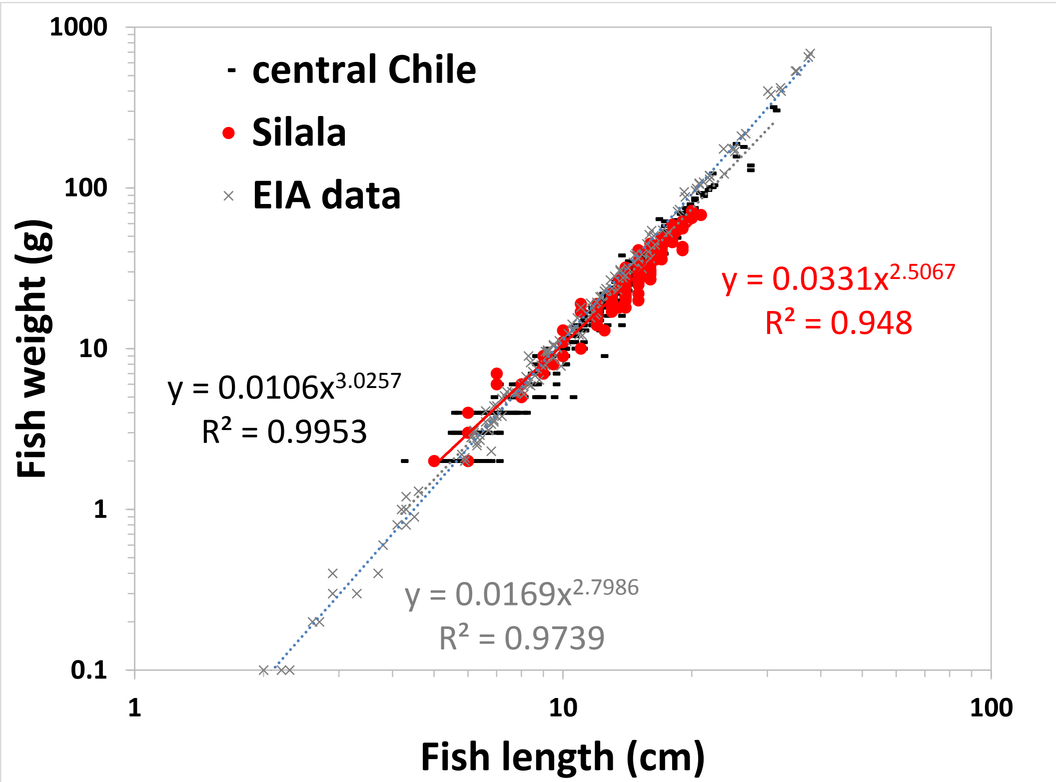

Figure 25. Length-to-weight relationship for rainbow trout captured in the Silala River and other rivers of Central Chile (Mao, 2017).

4 CONCLUDING DISCUSSION

The status of the waters of the Silala River can be determined based on the following four basic facts:

Firstly, the topography of the Silala River catchment area is such that natural drainage from an area of approximately 69.0 km^2 in Bolivia flows across the international border between Bolivia and Chile.

Secondly, the river flow at the border, currently approximately 170 litres per second, is a perennial flow that follows the natural drainage path.

Thirdly, in our accompanying report (Peach and Wheater, 2017) we show that the Silala River has flowed through a ravine, which crosses the current border, for over 8400 years.

Fourthly, while the source areas for the perennial flow at the border lie in two major sets of groundwater springs in Bolivia (the water sources for the Orientales and Cajones wetlands), the river interacts with groundwater throughout its subsequent course.

This is, from our expert point of view, "a system of surface waters and groundwaters constituting by virtue of their physical relationship a unitary whole and normally flowing into a common terminus".

We also show that the river is currently geomorphologically and biologically active. The processes of geomorphology that shaped the cross-border ravine are still active, and the river has a healthy population of fish and invertebrates.

One further factor to note is that in the history of the use of the waters of the Silala River, concessions were awarded to a British company, The Antofagasta (Chili) and Bolivia Railway Company Ltd. (FCAB), by the Chilean government in 1906, and by the Bolivian government in 1908. FCAB subsequently built small structures to divert part of the river flow into a pipeline (in Bolivia in 1909-1910, and in Chile in 1942). Nearly two decades after abstractions commenced, in 1928, some small-scale channelization of the river took place due to concerns for water quality and the fact that the wetland vegetation provided a breeding ground for an insect population.

We have shown, in Peach and Wheater (2017), that cross-border flows have a very long history, exceeding 8400 years for the river in its present ravine, and we also note that the concessions to FCAB for water use precede the channelization by nearly two decades. Nevertheless, we understand that concerns have been raised about the effect of these constructed channels. Our analysis shows that they follow the natural drainage path and gradients of the river and have not significantly affected the flow path across the border. We estimate that the evaporation from the Bolivian wetland evaporation is at most the equivalent of 2% of the average flow at the border (our best estimate is 0.7%). Any impact of canalization on the wetland extent is undetectable from the available remotely sensed data, but could only be, at most, a small fraction of that amount.

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Expert Report 2

Peach, D.W. and Wheater, H.S., *The Evolution of the Silala River, Catchment and Ravine*

THE EVOLUTION OF THE SILALA RIVER, CATCHMENT AND RAVINE

Drs. Denis Peach and Howard Wheater

May, 2017

ABOUT THE AUTHORS

Dr. Denis Peach

Dr. Denis Peach spent nine years as the Manager of the British Geological Survey (BGS) Groundwater Programme, then 6 years as BGS Chief Scientist. He is a hydrogeologist with broad scientific interests and 44 years of experience which includes work for a UK water authority, overseas work in tropical hydrogeological environments, small island hydrogeology and work for international consultants in arid zone hydrogeology. His particular scientific interests include groundwater modelling which he developed in BGS, arid zone hydrogeology, Chalk and Karst hydrogeology. He has been a Vice President of the Geological Society of London (GSL), is a Visiting Professor at Imperial College, London and University of Birmingham and he has given the Ineson Distinguished lecture at the GSL. He currently carries out research with BGS and Imperial College and provides advice to the University of Saskatchewan and UK engineering consultants.

Dr. Howard Wheater

Dr. Howard Wheater is Canada Excellence Research Chair in Water Security, Director of the Global Institute for Water Security at the University of Saskatchewan, and Distinguished Research Fellow and Emeritus Professor of Hydrology at Imperial College London. A leading expert in hydrological science and modelling, he has published more than 200 refereed articles and 6 books. He is a Fellow of the Royal Academy of Engineering and the American Geophysical Union and winner of the Prince Sultan bin Abdulaziz International Prize for Water. He has initiated and led national and international research programmes in the UK and Canada, and has advised states, provinces and national governments on flood, water resource and water quality issues. He represented Hungary and Argentina at the International Court of Justice, and recently sat on an International Court of Arbitration concerning the Indus Waters Treaty. He was, until 2014, vice-chair of the World Climate Research Programme's Global Energy and Water Cycle Exchange (GEWEX) project and leads UNESCO's GWADI arid zone water program. In Canada, he leads the Changing Cold Regions Network, focused on the analysis and prediction of hydrological change in western Canada, and the Global Water Futures Program, focused on managing water futures in Canada and other cold regions where global warming is changing landscapes, ecosystems, and the water environment. His role as Chair of the Council of Canadian Academies Expert Panel on Sustainable Management of Water in the Agricultural Landscapes of Canada saw release of a report in February 2013 entitled Water and Agriculture in Canada: Towards Sustainable Management of Water Resources.

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BP – Before Present

ca. – about or approximately

ky – thousand years

Ma – Million years before present

m.a.s.l.– metres above sea level

1. INTRODUCTION

1.1 Experts' Terms of Reference

In the context of the dispute between the Republic of Chile and the Plurinational State of Bolivia concerning the status and use of the waters of the Silala, to be heard before the International Court of Justice, the Republic of Chile has requested our independent expert opinion, as follows:

> "Questions for Dr. Howard Wheater, as a hydrological engineer:
>
> (i) Do the waters of the Silala constitute a system of surface waters and groundwaters constituting by virtue of their physical relationship a unitary whole and normally flowing into a common terminus, parts of which are situated in different states? If yes, what do you consider to be the natural direction of flow?
>
> (ii) Insofar as you consider that there is currently an active fluvial system in the Silala catchment, what is the evidence that establishes this in your view?
>
> (iii) What, if anything, is the effect of the channeling of the flow on Bolivian territory on the watercourse that enters from Bolivia into Chile?
>
> Questions for Dr. Denis Peach, as a hydrogeologist:
>
> (i) Do the waters of the Silala constitute a system of surface waters and groundwaters constituting by virtue of their physical relationship a unitary whole and normally flowing into a common terminus, parts of which are situated in Bolivia and Chile? If yes, what do you consider to be the natural direction of flow?
>
> (ii) What geological, geomorphological and/or other events formed the Silala ravine as it exists today?
>
> (iii) Does the geological, geomorphological and other evidence point to the historical existence of a fluvial system in the Silala catchment?"

This report addresses questions (ii) and (iii), to Peach.

1.2 Background to the report

In May 2016, Dr. Wheater visited the Silala River at the request of the Republic of Chile and advised that, in his professional opinion, the Silala River was, without doubt, an international watercourse in his understanding of that term.[1] While inspection of maps, images, flow data and the site visit was sufficient to confirm this view, he recommended that Chile seek additional expert opinion from a hydrogeologist, and commission scientific studies, to better understand the geological and geomorphological evolution of the river and its current functioning, including surface water-groundwater interactions. Dr. Peach was subsequently invited to offer his professional opinion and advice, and after inspection of maps, images, flow data, hydrogeological and geological data and reports gave advice on the development of the programme of monitoring and investigation. A Chilean team of scientific experts was put in place, led by Dr. José Muñoz, Civil Engineer and Professor at the Faculty of Civil Engineering at the Pontificia Universidad Católica de Chile. This team, working under the leadership of Dr. Muñoz, and the technical direction of Drs. Wheater and Peach, has carried out a set of intensive observational and monitoring studies, which are ongoing. After his visit to the Silala River and ongoing investigations in October 2016, Dr. Peach confirmed his view that the Silala River was indeed an international watercourse. Detailed results of the studies to date are presented in a set of technical reports, appended hereto as Annexes I-X. In this report, we summarize the key findings of these technical reports, for the benefit of the Court, and present our joint opinion.

[1] We note that the flows in the Silala River are relatively small, so that the terms 'stream' and 'river' could equally be considered appropriate.

1.3 Structure of the report

Section 1 describes the background to the report, its structure and the location of the Silala River, ravine and catchment area. **Section 2** briefly summarizes the major findings of this report. **Section 3** provides a description of the geological evolution of the Silala River, its ravine and catchment area. **Section 4** describes in summary the geology of the Silala River catchment upon which the narrative of the evolution of the Silala catchment is based. **Section 5** examines the development of the modern ravine and the sediments found in the ravine over approximately the last 8-12000 years. **Section 6** briefly outlines the archaeological evidence for the occupation of the Silala River environs by humans. **Section 7** assesses the evidence, relevance and importance of the fluvial, glacial and aeolian processes of erosion and deposition in the Silala River catchment. **Section 8** draws some conclusions and answers the questions:

a) What geological, geomorphological and/or other events formed the Silala ravine as it exists today?

b) Does the geological, geomorphological and other evidence point to the historical existence of a fluvial system in the Silala catchment?

The report will explain a) how the Silala River, catchment and ravine evolved over geological time and b) its more recent history as it evolved to become the landscape feature it is today.

While this report represents our joint opinion, the lead author on each of the sections has been Dr. Denis Peach.

1.4 The Silala River - location

The Silala River originates in Bolivia and flows towards the Antofagasta Region of Chile. It is one of the main tributaries of the San Pedro River. This, in turn, is a tributary of the Loa River, the longest river in Chile (440 km long) and the main watercourse in the Atacama Desert region, discharging into the Pacific Ocean (Figure 1-1).

Figure 1-1. The Loa River and its main tributaries.

A river is commonly defined by its topographic catchment area, i.e. the area draining to a given point on the river channel.[2] We define the catchment using a location on the river 4.9 km downstream of the Chile-Bolivia border,[3] which gives a catchment area of 95.5 km^2. Figure 1-2 shows this catchment area and key features of the river network. The contours and river network clearly show drainage to the south west from Bolivia across the international border into Chile (Alcayaga, 2017) – see also section 8 below. We note that the river originates in groundwater springs at the Cajones and Orientales wetlands in Bolivia, which are the source of its perennial flow at the international border. Shortly after the Orientales wetland springs the river enters a ravine before being joined by the discharge from the Cajones springs. From this junction it flows within the ravine across the international border (Figure 1-3). This report explains the geological history of the catchment and its effect in shaping the current landscape and geology. It then focusses on the origins and evolution of the ravine, including evidence of human habitation.

[2] Precipitation falling on the topographic catchment area and draining under the force of gravity, either as overland flow or shallow subsurface flow, will follow the topographic gradients to the river. However, where groundwater contributes discharge to a river, the area recharging the groundwater aquifer may differ from the topographic catchment and the groundwater flow directions may not always follow the topographic gradients.

[3] UTM coordinates are 596,453 E; 7,563,039 N, datum WGS84-19S.

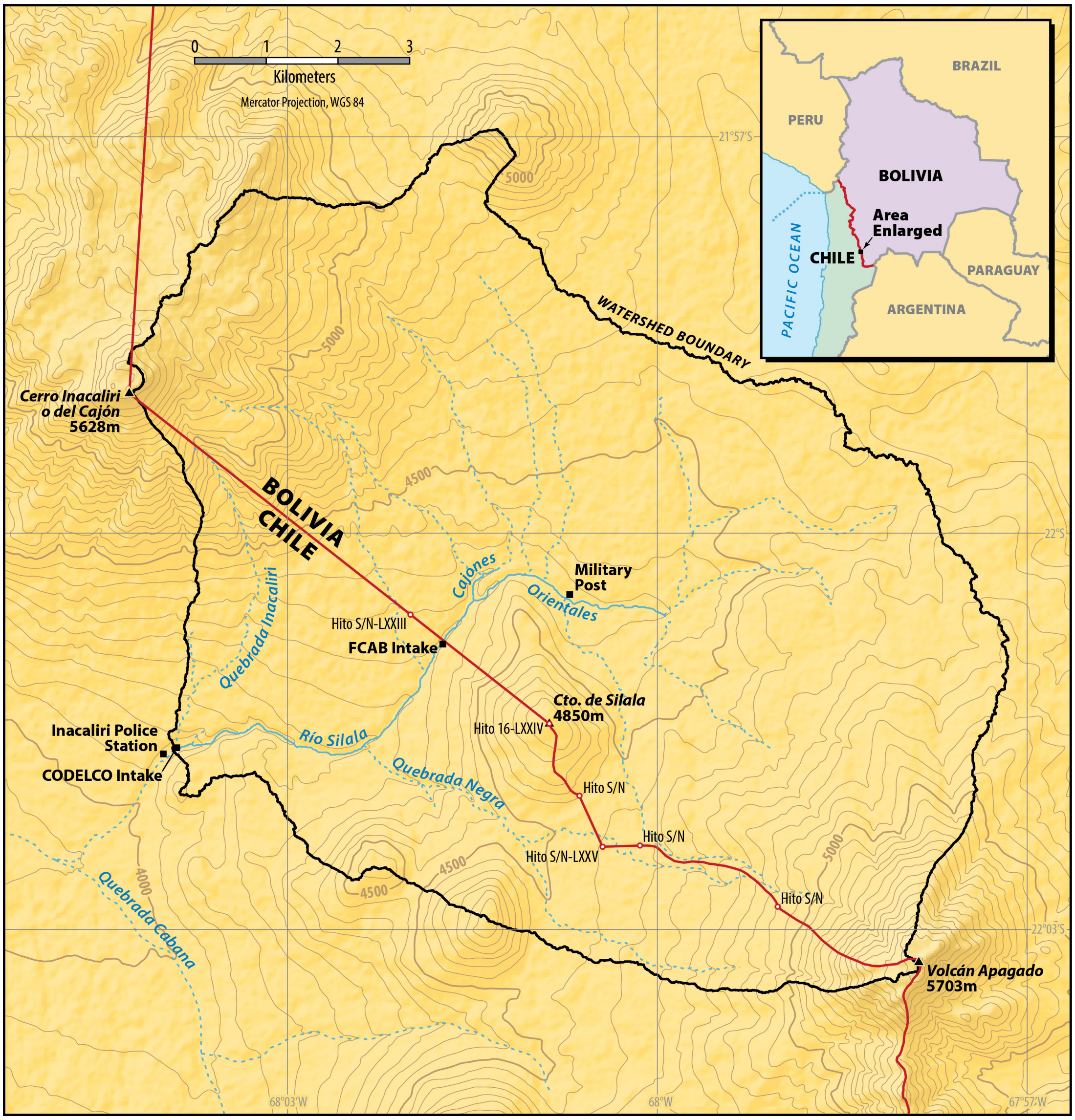


Figure 1-2. The Silala River (perennial drainage solid blue and ephemeral streams in dotted blue lines) and catchment area (outlined in black), showing some of the main physiographic features in and around the catchment.

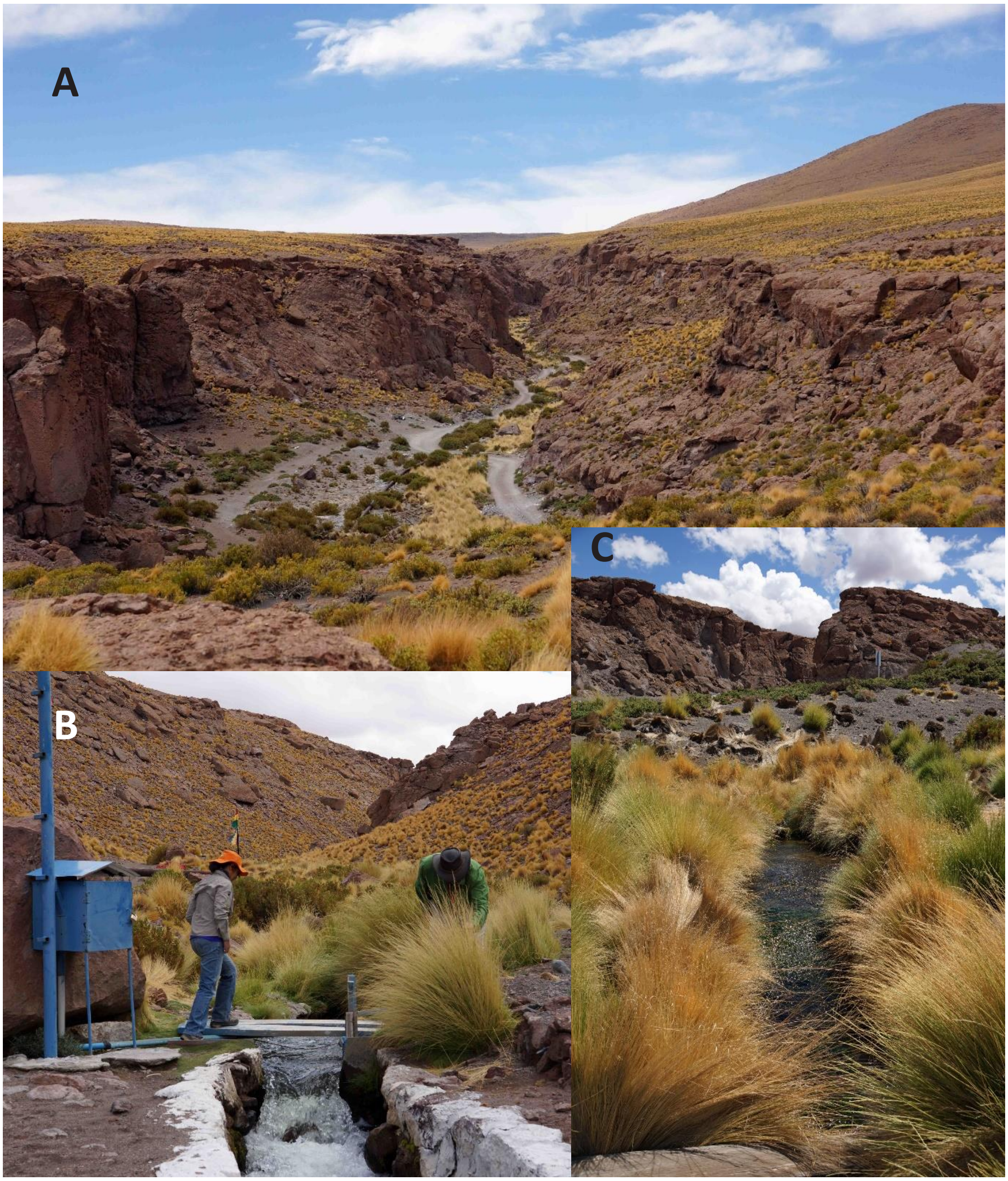


Figure 1-3. Various views of the Silala River and ravine. A) View of the Silala River (hidden by vegetation) ravine looking upstream from a position above the junction with the tributary Quebrada Negra. B) Silala River at the DGA Fluviometric Station near the international border looking upstream. C) View looking upstream at the junction with Quebrada Negra.

2. SUMMARY OF FINDINGS

Detailed mapping of the geology of the Silala River catchment and environs, investigation of the sediments found in the Silala River ravine, identification of archaeological sites along the ravine and observation of the evidence for different types of geological processes of sedimentary deposition and erosion have led to an understanding of the evolution of the landscape and morphology of the Silala River catchment and its ravine over the last approximately 6 million years.

We demonstrate that:

1) There was fluvial activity along a previous valley more or less aligned with the present course of the Silala River as early as 1-2 million years ago. These dates were constrained by radiometric dates from volcanic rocks above and below these early fluvial sediments. These sediments were deposited in a valley which was later infilled by volcanic deposits.

2) The incision of the current Silala River ravine began before about 8400 years Before Present (BP) and probably as early as 11-12000 years BP. The modern Silala River ravine has been developing along its present course for over about 8400 years. Over this period, the river has deposited sediments (and supported vegetation) and then eroded them at least four times. This has resulted in four identifiable terraces and four different sequences of sediment accumulation.

3) The periods of deposition and erosion were caused by climatic regime changes that resulted in changes in groundwater level. Falls in groundwater levels would have changed the flow regime of the river and caused death of wetland vegetation and subsequent high flows would have caused erosion and incision of the ravine; rises would have promoted wetland vegetation growth and the trapping of sediment as water flowed downstream.

4) Considerable evidence for fluvial erosion and sediment deposition has been found and documented in the Silala ravine. Evidence for wind erosion and minor accumulations of wind-blown sands was found in the ravine, but the impact of the wind erosion on the development of the ravine is marginal.

5) While glacial action played a role in the development of the landscape at high elevations, no evidence of glacial action or deposits was found below 4400 m.a.s.l. The formation of the ravine (at approximately 4000-4300m elevation) was not caused by glacial erosion.

6) Archaeological evidence shows that the Silala River and ravine was a place frequented by humans from 1500 years ago and probably earlier. This was very likely to be due to the presence of reliable water and associated food resources.

We address in summary, the two questions posed to us by Chile, as defined above. Further detail is provided in the full report that follows:

ii) What geological, geomorphological and/or other events formed the Silala ravine as it exists today?

During the period from about 6 million years ago to about 1.5 million years ago, the area now occupied by the catchment of the Silala River was subject to episodes of volcanism associated with the collision of the oceanic tectonic plate to the west (beneath the Pacific Ocean) and the South American continental tectonic plate. This has resulted in volcanic activity that has shaped the landscape, including the building of the Cerro Inacaliri o del Cajón (henceforth Cerro Inacaliri), Cerrito de Silala and the Volcán Apagado, which are all dominant features of the catchment morphology (Figure 1-2). The basal rocks beneath the Silala ravine are called ignimbrites and were emplaced by explosive volcanic eruptions extruding flows of rock fragments, molten rock droplets and hot gases, which flowed down the existing topographic gradient at great speed. The first of these (Cabana Ignimbrite) was a very extensive and voluminous event affecting a large area of the Altiplano. This was followed by a first period of fluvial activity which eroded a valley in the ignimbrite and left fluvial sediments. On top of these early (between approximately 2.6 and 1.5 million years ago) fluvial deposits a further ignimbrite (Silala Ignimbrite) was deposited, probably filling the valley. Subsequently further volcanism led to a massive lava flow erupted from the Inacaliri volcano, now called Cerro Inacaliri, (1.48 million years ago) which flowed into the headwater area of the Silala River. This lava flow truncated the then-existing drainage network of the Silala River. There appears to have been a hiatus in volcanic activity in the catchment after 1.48 Ma and the next major events to impact the catchment morphology were associated with the glaciation of the high peaks, above 4400 m.a.s.l. There is no evidence of glacial erosion or glacial deposits to be found at the level of the current Silala River ravine or in the ravine. The cutting of the ravine, as we know it today, began in the period 12000-8400 years ago. Radio-carbon dating has shown that there are sediments deposited by the current Silala River system in the ravine that are over about 8400 years old. The river began cutting the ravine before that, probably as a result of the melting of the glaciers about 12000 years ago that caused significant runoff and increased flow in the river, and continues in a cycle of erosion and deposition in response to climatic regime changes.

iii) Does the geological, geomorphological and other evidence point to the historical existence of a fluvial system in the Silala catchment?

Sediments deposited by fluvial systems were laid down over about 1.5 million years ago, as evidenced by fluvial deposits found on top of the first (Cabana) ignimbrite and beneath the second (Silala) ignimbrite. About 1.48 million years ago the lava flow from the Inacaliri volcano flowed into the area now occupied by the Orientales wetland in Bolivia (after the deposition of the Silala Ignimbrite) and truncated the then-existing drainage system. There are four sequences of sediments in the current Silala ravine. The oldest dates for organic material from these fluvial sediments have been found to be approximately 8400 old and the youngest dates have given ages in the late twentieth century, demonstrating the current fluvial system to have been active for at least about 8400 years and that the cycle of erosion and deposition continues into modern times. Features of fluvial erosion are common in the sides of the ravine. There are four water-cut river terrace surfaces and four sedimentary sequences of deposits several metres thick. These deposits include sands, gravels, silts and organic remains of wetlands. The sides of the ravine contain some wind erosional features and there are some windblown sand deposits to be found, but these are minor features, and would have had no significant impact on the ravine formation. Archaeological surveys have found artefacts and shelters or temporary dwellings along the course of the river, mainly on the upper three terraces. These testify to the human use of the river and its course over the past at least 1500 years. There is no doubt that the geological, geomorphological and other evidence points definitively to the historical existence of a fluvial system in the Silala catchment. The modern ravine, created by fluvial action, has existed for more than 8 millennia.

3. THE EVOLUTION OF THE SILALA RIVER, RAVINE AND CATCHMENT OVER GEOLOGICAL TIME

In this section, we explain the evolution of the Silala River, catchment and ravine; how it has come to its present form and geography. We track the major geological events that have shaped the Silala River catchment and its ravine over geological time from about 6 million years ago to the present. We find that there was fluvial deposition in the catchment between about 2.6 and 1.5 million years ago and a *river system existed over 1.48 Ma ago in the headwater area of the current Silala River system that was truncated by a lava flow. We demonstrate that the cutting of the current ravine by the Silala River began before about 8400 years ago and the cycle of erosion and deposition continues today.*

The Silala River basin geology was formed by a series of volcanic, tectonic (structural movements) and sedimentary events and processes that have taken place over the last 5-6 million years (SERNAGEOMIN, 2017; Latorre and Frugone, 2017; Arcadis, 2017).

The history of the development of the Silala River catchment begins about 5.8 Ma (Million years before present) and continues to the present day. The basic geology that the Silala River ravine was cut into was already formed by the end of the last Ice Age, approximately 12 ky BP (thousand years before present). The cutting of the Silala River ravine began in the period 8.5 – 12 ky BP and the cycles of deposition and erosion which characterise the morphology and sedimentary infill found in the ravine are ongoing today (Latorre and Frugone, 2017; SERNAGEOMIN, 2017).

The consolidated geology of the Silala River catchment is dominated by the presence of volcanic rocks, as is much of the Altiplano. This volcanism and the high mountain range of the Andes have been caused by the collision of two tectonic plates. The oceanic plate in the west (under the Pacific Ocean) is sliding beneath the South American continental plate, because it is denser, being made of basic rocks, like basalt. When these rocks melt as they get pushed deeper into the earth's crust, they become less dense and rise upwards into the continental plate which is lighter and made of more acidic rocks like granite. The rising "magma" sometimes reaches the land surface and a volcano is the result. If the composition of the rocks is acidic the volcanoes tend to be very explosive and throw ash and molten rock into the atmosphere; this type of process can result in pyroclastic flows. Pyroclastic flows consist of droplets of molten rock and fragments of rock and ash, supported and fluidized by hot gases so they flow like a liquid. They have high temperatures, over 350 degrees Celsius and more, and flow down the topographic gradient at speeds of up to and sometimes over 100 km/hour. When these flows cool, and consolidate, the rock they form is called ignimbrite.

The radiometric ages of the rocks found in the Silala catchment indicate at least two major volcanic events, the oldest, dated from about 5.8 Ma, continued until about 2.6 Ma, and was a long period of dominantly acidic volcanism that included the emplacement of volcanoes, domes, volcanic vents and the extrusion of lavas (Figure 3-1 Panel 1). During this period of extensive volcanic activity, a very large eruption in the east resulted in the deposition of an ignimbrite, in this case named the Cabana Ignimbrite, which has been dated in the Silala catchment at approximately 4.12 Ma (Figure 3-1 Panel 2). This represents part of a voluminous, explosive and extensive volcanic eruption or series of eruptions that affected this area of the Altiplano (SERNAGEOMIN, 2017). After this, various volcanoes and volcanic vents were established through and on top of the Cabana Ignimbrite. The volcanic activity continued and led to the first development of the Inacaliri volcano. The products of eruptions from these volcanoes were mainly lava flows and lava domes. This created the oldest positive relief in the area (e.g. Cerro Inacaliri and Cerrito de Silala). Subsequently during the late Pliocene and early Pleistocene (about 2.6 Ma - 1.5 Ma) local compressive tectonic deformation resulted in faulting which exposed and tilted the Cabana Ignimbrite deposits (Figure 3-1 Panel 3). Dated during this period there is evidence of fluvial erosion and deposition, including silt and sand deposits, which are found in the vicinity of the Inacaliri Police Station (Figure 1-2), and debris and mud flow deposits, found at depth in borehole cores at a location a few metres downstream of the international border beneath the Silala River ravine. These deposits can be thought of as the first phase of the Silala River development, which might be called the proto-Silala River (Figure 3-1 Panel 4, Silala 1) (SERNAGEOMIN, 2017).

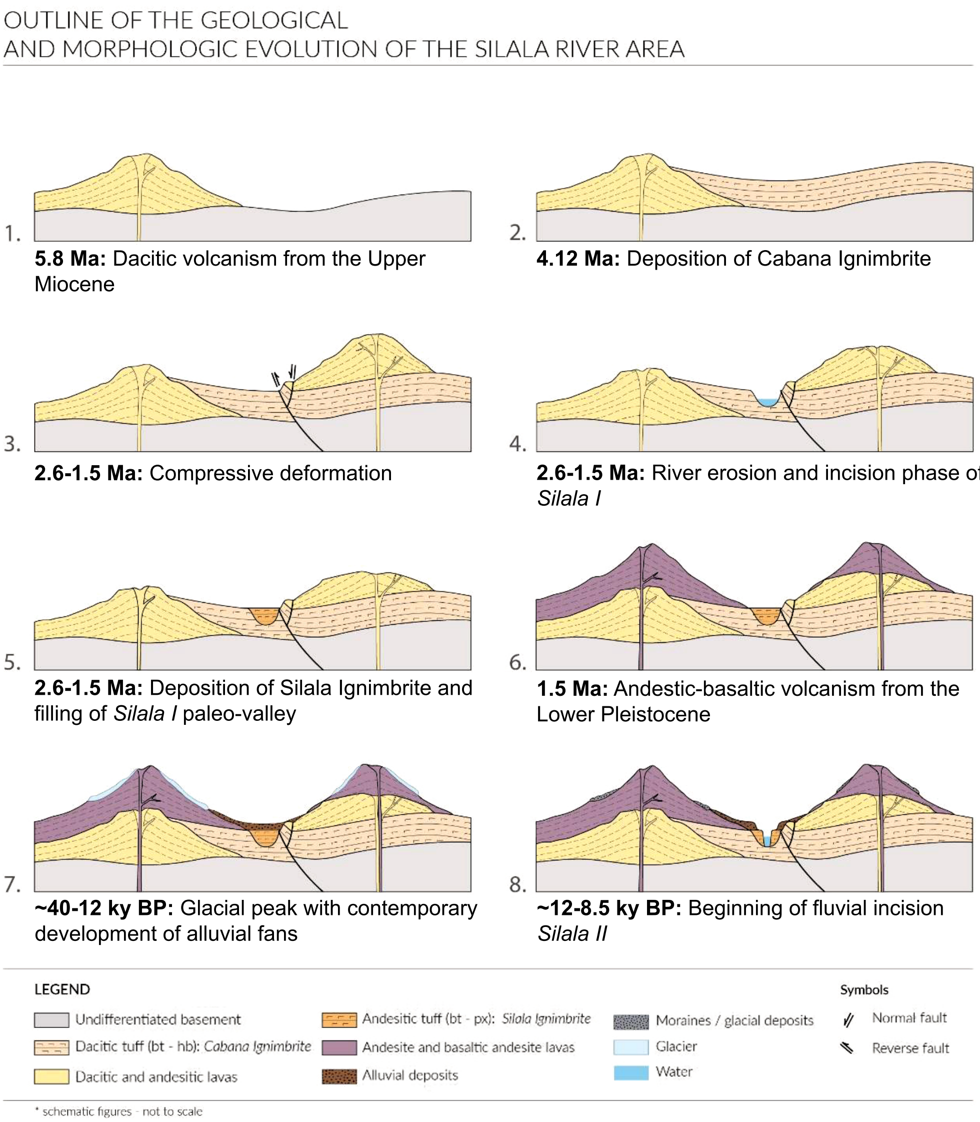


Figure 3-1. A schematic outline of the geological and geomorphological evolution of the Silala River, ravine and catchment (SERNAGEOMIN, 2017).

In the palaeo-valley of the proto-Silala (constrained by the hills of Inacaliri, Silala and Volcán Apagado) in the same period a further less extensive ignimbrite, named the Silala Ignimbrite, was deposited as a result of a pyroclastic flow moving down the proto-Silala valley. This ignimbrite thins to the west so is interpreted as originating in the east in what is now Bolivia, but is likely to have more or less filled the valley. Pyroclastic flows by their nature, molten droplets of rock or rock fragments supported by hot gases, would have flowed at great speed following the topographic gradient from its origins down the relatively newly formed proto-Silala River valley (Figure 3-1 Panel 5).

After this, further volcanic activity resulted in the formation of new volcanic edifices on the Inacaliri and Apagado volcanoes and in the deposition of an extensive lava flow on the eastern side of the Inacaliri volcano. This flowed into the headwaters of the proto-Silala River, truncating a previously established drainage system (Figure 3-1 Panel 6) (SERNAGEOMIN, 2017).

Following the extrusion of this lava flow there appears to have been a hiatus in volcanic and sedimentary activity in the catchment as there are no outcrops of deposits that can be dated younger than 1.48 Ma until the late Pleistocene (about 40-12 ky BP) was reached. During this period, the last glacial maximum of the most recent Ice Age occurred. The glaciers that occupied and cut valleys in the highest hills in the area finally began to retreat about 11-12 ky BP. Evidence for the existence of glaciers is provided by what are called end and lateral moraine deposits left by the erosive action of the ice. These are found at levels of above approximately 4400 m.a.s.l. on the side of Cerro Inacaliri. Alluvial fan deposits can be found interdigitating with the glacial moraine downslope on the hillside (Figure 3-1 Panel 7). These were formed contemporaneously as a result of the outwash from the melting of the glaciers. About 11.5 ky ago the last evidence of volcanic activity can be found in thin deposits of volcanic ash from an eruption of the San Pedro volcano (20 km east of Inacaliri Police Station) (SERNAGEOMIN, 2017).

After this the “modern” geomorphology of the Silala River, its deposits and ravine began to be established (Figure 3-1 Panel 8). Radiocarbon dates indicate that the Silala River has been active since before about 8.4 ky BP (Latorre and Frugone, 2017). The fluvial activity of this second phase of Silala River development has seen both erosive and depositional periods and has left as evidence four mapped river terraces (erosional features) and with four different sedimentary depositional units (see Figure 3-2) (Latorre and Frugone, 2017). Organic materials from these sedimentary sequences have been dated using carbon-14 techniques. These provide a record of sedimentary depositional and erosional activity from over 8400 years ago through to very recent times in the late twentieth century.

There is also archaeological evidence to indicate that the Silala River and its ravine have been at least the temporary home to pre-Columbian and more recent human communities, thus supporting the notion that the Silala River was a suitable water source to sustain life, support animal herding and perhaps fish and other wildlife (McRostie, 2017). This evidence includes notable pre-Columbian sites with artefacts (including an arrowhead) and temporary stone structures built into caves and *cavettos* in the wall of the ravine on the upper three terraces. An apparent strong relationship between archaeological sites and the existence of palaeo-wetlands demonstrates a link between water and biotic resources for at least the last 1500 years.

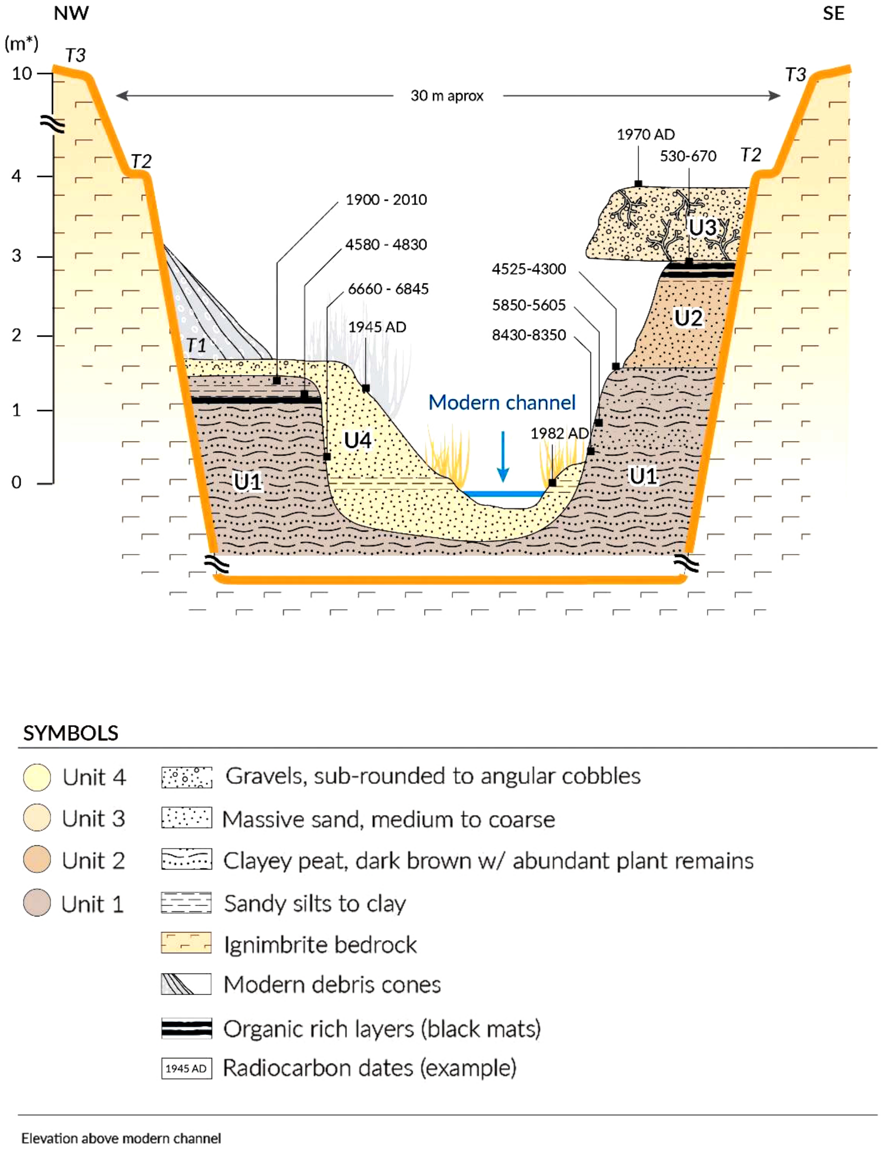


Figure 3-2. Sedimentary infill of the current Silala River ravine in four units together with the associated terraces T1, T2 and T3. T4 is higher and not shown on this figure. Dates are given as years before present unless marked AD (Latorre and Frugone, 2017).

4. THE GEOLOGY OF THE SILALA RIVER, RAVINE AND CATCHMENT, TO THE END OF THE PLEISTOCENE (12- 11000 YEARS BP)

In this section, we describe the geology of the Silala catchment up to about 11-12000 years ago beginning with the oldest deposits and describing the rocks in age order. This information provides the basis for understanding the morphology of the catchment and the course of the river and its ravine.

At a regional scale, in an area approximately 10-20 km around the Silala River catchment, it is possible to identify a series of volcanic processes and episodic events that have taken place over the course of the last 12 Ma (SERNAGEOMIN, 2017). Some of the oldest rocks that are exposed in this region include sequences of ignimbrites.

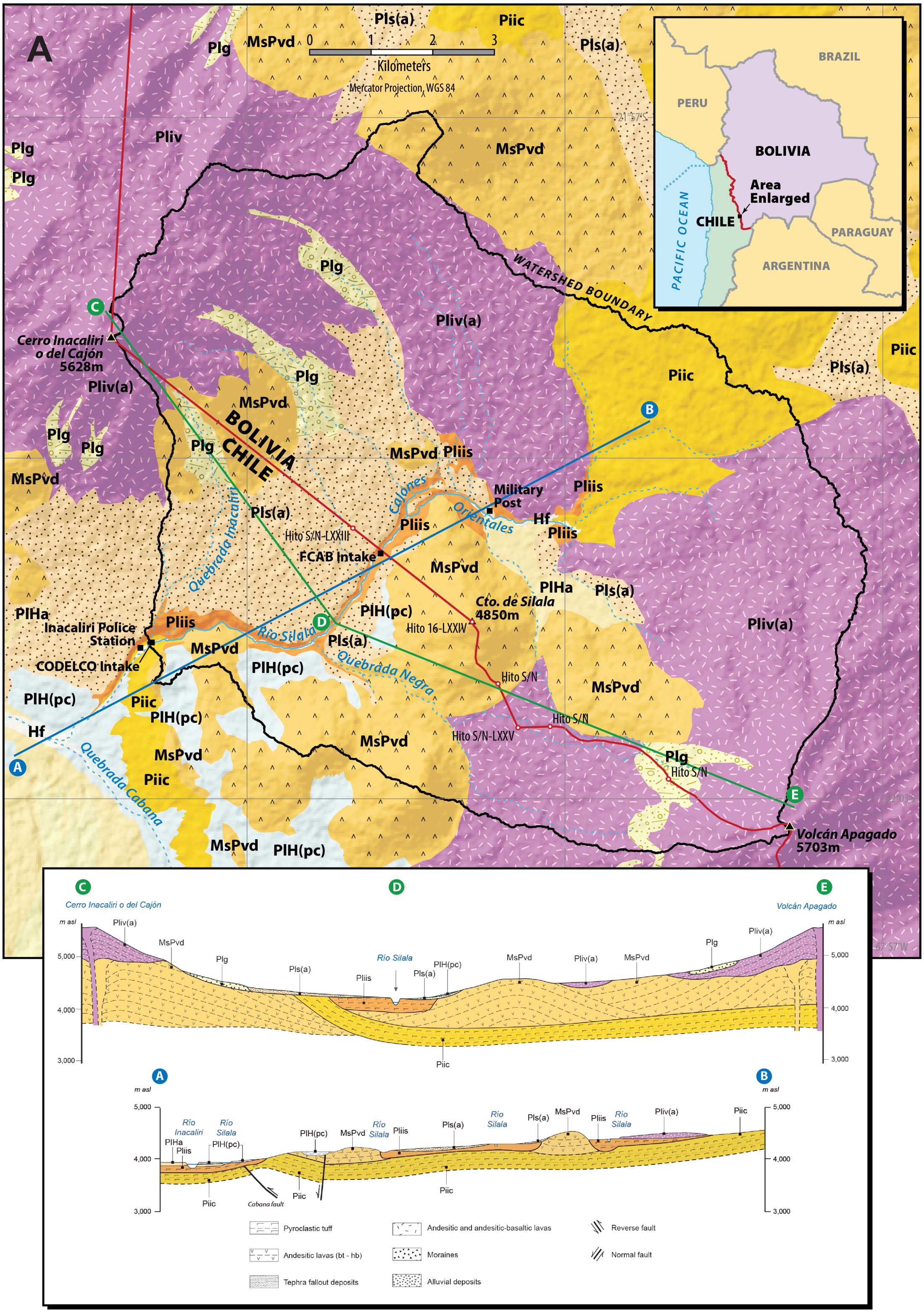
As part of the studies and investigations referred to in section 1.1, geological mapping and rock dating studies were carried out by the Chilean National Geology and Mining Service, SERNAGEOMIN.

The rocks that can be found outcropping in the Silala River catchment are shown on the geological map reproduced in Figure 4-1 (SERNAGEOMIN, 2017). Their disposition tends to be centred around the Inacaliri and Apagado volcanoes. To some extent the rocks “radiate” from these volcanic centres because they mostly originated from them.

Figure 4-1 also displays two cross-sections, one approximately in the direction of the Silala River and the other from the Cerro Inacaliri to the Volcán Apagado across the Silala River at a point just upstream of the confluence with the Quebrada Negra (an ephemeral tributary shown in Figure 1-2) (SERNAGEOMIN, 2017). These show the disposition of the various rock deposits with depth, to give an impression of the three-dimensional nature of the earth beneath the area of what is now the Silala River catchment.

The stratigraphic positions of the various deposits and their radiometric ages, where known, are shown on Figure 4-2 (SERNAGEOMIN, 2017 and Arcadis, 2017). This is a schematic diagram to visualise the order of the deposits from the earliest at the bottom to the most recent at the top, called the stratigraphy, with the exception of the sediments found close to or in the Silala River ravine; these are recent (<12000 years old) and they are positioned schematically as they occur in the ravine (as if the right hand side of the diagram constitutes the wall of the ravine) and in relation to the erosion terraces cut by the Silala River into the sides of the ravine.

In the period ca. 5.8-2.6 Ma, a series of volcanic rocks, delineated as Volcanic Sequences from the Upper Miocene - Pliocene (MsPvd) on Figure 4-1, including volcanic cones, lava domes, lava flows and autoclastic breccias, were emplaced. Their composition is acidic in this case (called dacitic) and they outcrop in the northern and southern edges of the Silala River basin. During this period of extensive volcanic activity, the Cabana Ignimbrite (designated Piic) was deposited by a massive and very voluminous pyroclastic flow. These are the oldest rocks found in the Silala ravine at 4.12±0.08 Ma. The deposit thins to the west and was probably erupted from a very large volcano to the east of where the international border can be found today. Although the deposit thins to the west it probably covers quite a large area in the Altiplano (10s of km^2). The Cabana Ignimbrite has been interpreted as outcropping in Bolivian territory, since rocks having a similar stratigraphic position have been found and mapped there (SERNAGEOMIN, 2017). These are covered by Silala Ignimbrite and more basic (intermediate, called andesitic) lava flows dated at 1.48±0.02 Ma (SERNAGEOMIN, 2017). The lava domes and volcanic cones/vents of the Volcanic Sequences from the Upper Miocene – Pliocene (ca. 5.8-2.6 Ma) provided the first signs of the topographic relief of the catchment that can be seen today (the beginnings of the Cerro Inacaliri, Cerrito de Silala and Cerros de Silaguala).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CHILE
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Military Post
Hito S/N-LXXIII
FCAB Intake
Cto. de Silala 4850m
Hito 16-LXXIV
Inacaliri Police Station
CODELCO Intake
Hito S/N
Hito S/N-LXXV
Volcán Apagado 5703m
Quebrada Inacaliri
Río Silala
Quebrada Negra
Quebrada Cabana
Cajones
Orientales
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Reverse fault
Normal fault
Cabana fault

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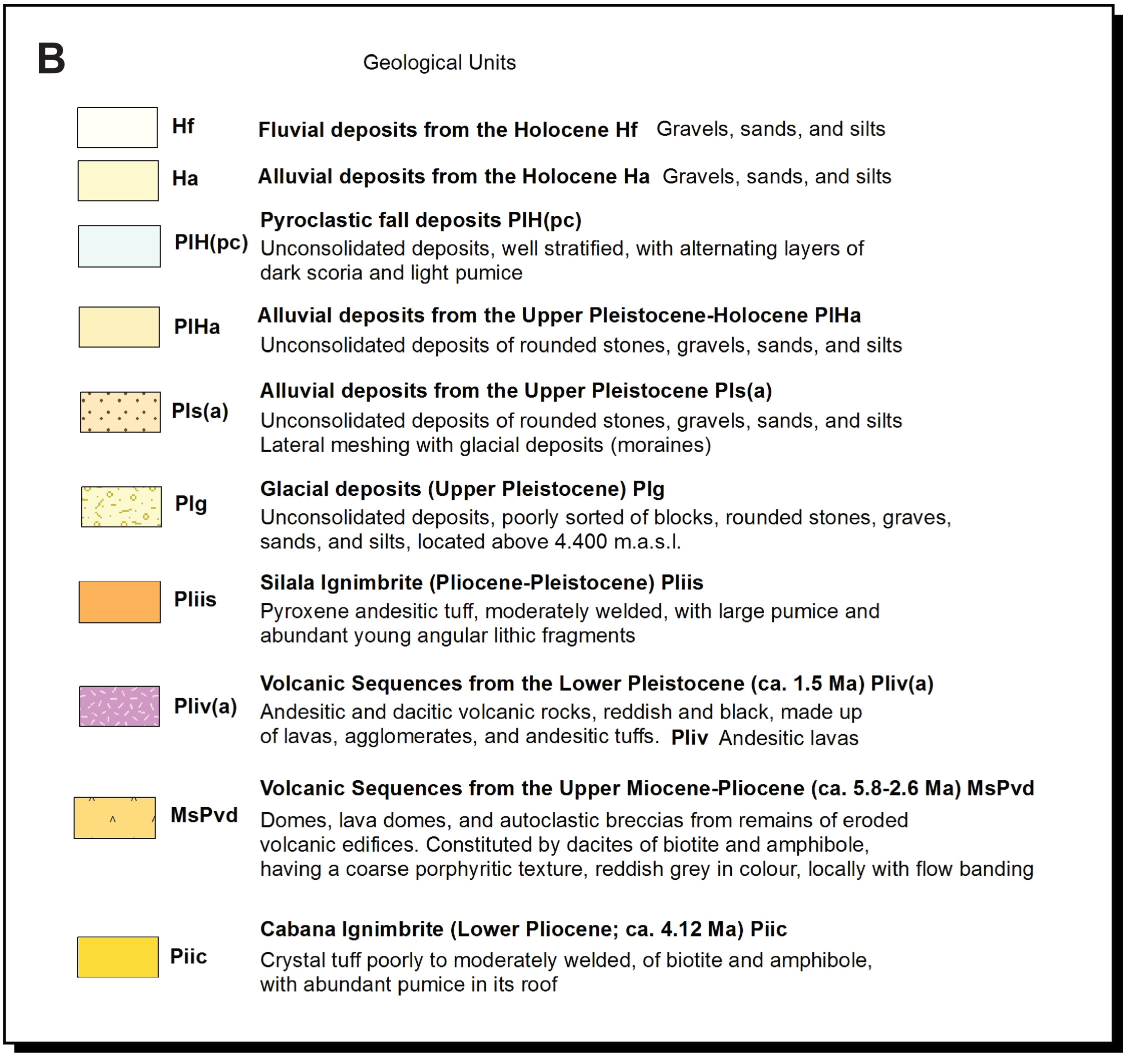


Figure 4-1. Geology of the Silala River basin. (A) Geological map and cross-sections, (B) Legend of geological units (SERNAGEOMIN, 2017).

Alluvial Deposits (these are not found on Figure 4-1, because the outcrop is very small), dating from the period ca. 2.5-1.5 Ma (Upper Pliocene - Lower Pleistocene), can be identified as a thin sedimentary fluvial deposit, located in a manner that indicates a gap in deposition (unconformably) overlying the Cabana Ignimbrite, but in conformable contact beneath the Silala Ignimbrite. Outcrops of this unit are exposed 600 m south of the Inacaliri Police Station and it can be found in the core of the cored borehole (CB-BO) drilled close to the international border (SERNAGEOMIN, 2017 and Arcadis, 2017). These deposits provide the earliest recognizable sedimentary rocks deposited by fluvial activity in the Silala catchment.

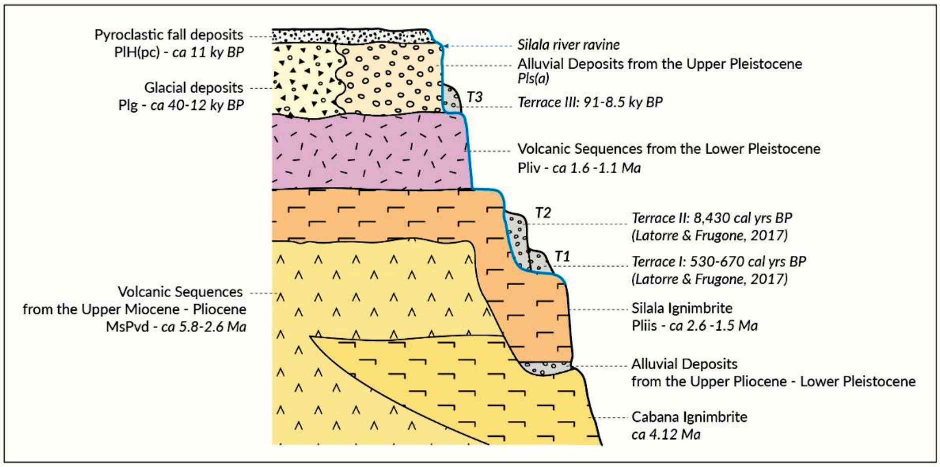


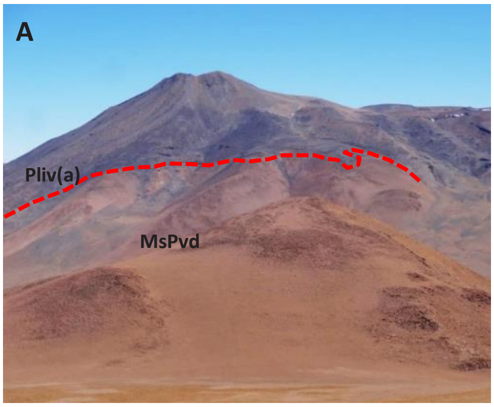
Figure 4-2. The Stratigraphy of the Silala catchment (SERNAGEOMIN, 2017 and Arcadis, 2017).

In the period ca. 2.6 – 1.5 Ma (Upper Pliocene – Lower Pleistocene) the Silala Ignimbrite (Pliis) was deposited by a pyroclastic flow. It has an intermediate composition (between basic and acidic, called andesitic) that outcrops along the course of the Silala River and is exposed in the sides and sometimes the base of the ravine. It lies, unconformably, on top of the Cabana Ignimbrite (Piic) and lava flows from the Volcanic Sequences from the Upper Miocene - Pliocene (MPsvd). At its base there is evidence, see above, of fluvial deposition.

The Volcanic Sequences from the Lower Pleistocene (Pliv (a)) comprise a group of volcanic edifices and well preserved lava flows having largely intermediate (andesitic) composition which are exposed as the volcanic cone of the Cerro

Inacaliri, the Volcán Apagado and its extension into Bolivian territory, and a vast andesitic lava flow, aged 1.48 Ma, that partially fills up the depression where the headwater springs of Silala River and Orientales wetlands can be found (Figures 4-3 and 4-4).

The volcanic edifices of this unit are located on the remains of lesser edifices and domes from the earlier Upper Miocene - Pliocene (MPsvd) volcanics, as is clearly visible in the middle part of the south slope of the Cerro Inacaliri (Figure 4-3). At the wetland springs of the Silala River (in Bolivian territory), there is a large lava flow overlying the Silala Ignimbrite. This lava flow partially fills the shallow depression where the source springs of the Silala River are found at the Orientales wetland (Figures 4-3 and 4-4). This lava flow clearly truncates an ancient drainage system that must therefore pre-date the lava flow, i.e. older than 1.48 Ma, but younger than the underlying Silala Ignimbrite. Since we have no radiometric date for the Silala Ignimbrite, all we can say is that the drainage system is about 1.5 Ma and probably somewhat older.



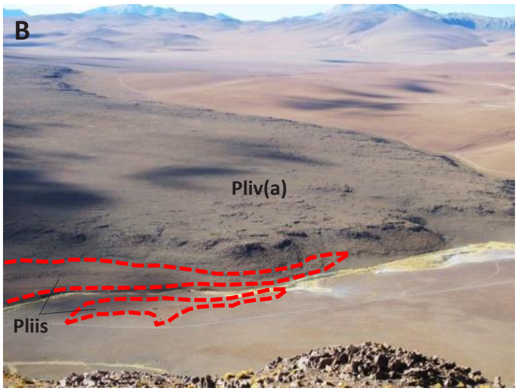


Figure 4-3. Volcanic edifices and lava flows of the Lower Pleistocene. (A) Construction of the andesitic volcanic cone of the Cerro Inacaliri (Pliv(a)) on remains of dacitic domes from the Upper Miocene - Pliocene (MsPvd) (view to the northwest); (B) Andesitic lava flow that partially fills the depression where the source springs of the Silala River (Orientales wetland), deposited on the Silala Ignimbrite (Pliis) in Bolivian territory (view to the northeast) (SERNAGEOMIN, 2017).

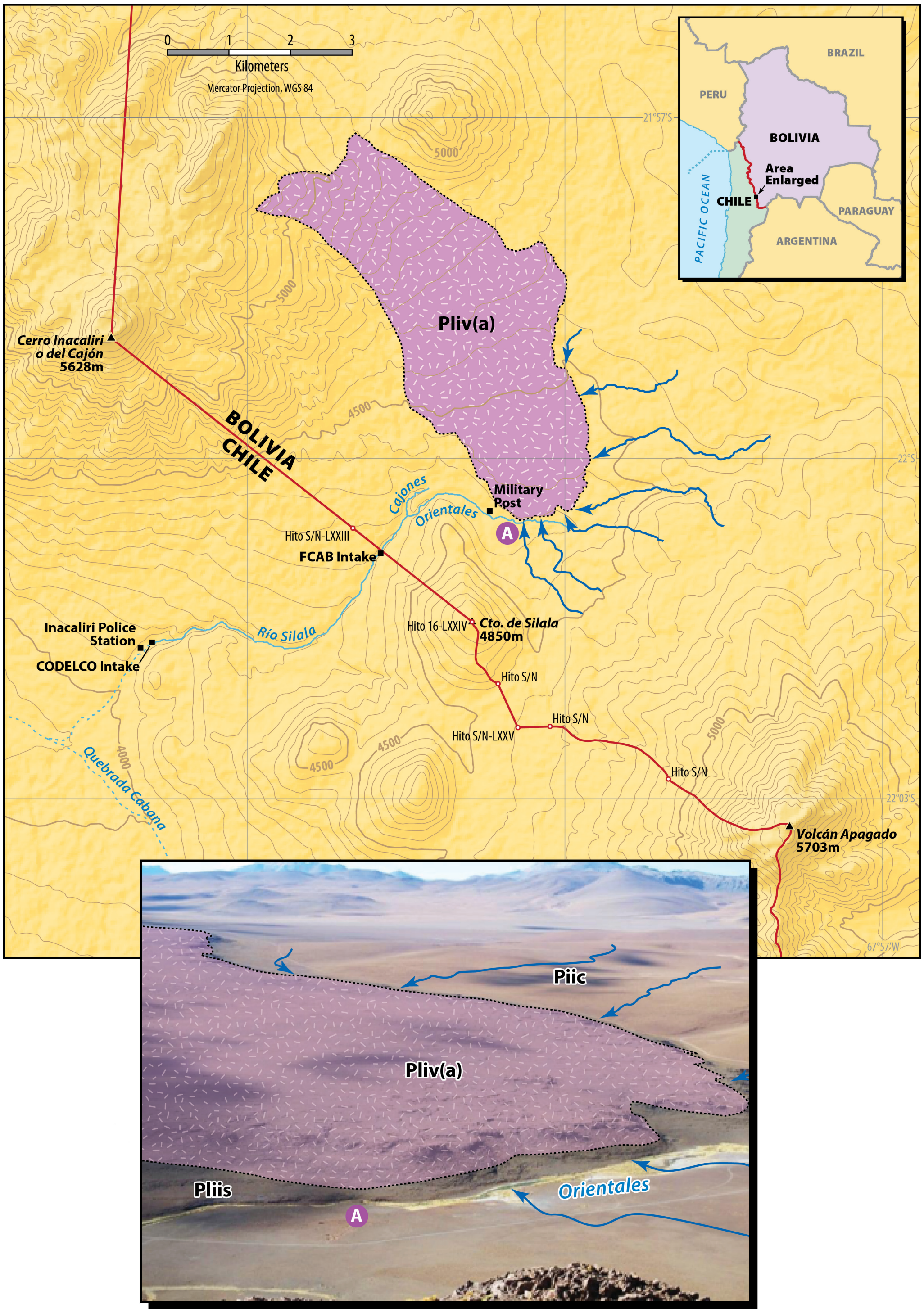


Figure 4-4. Lava flow Pliv(a) dated at 1.48 Ma truncates a palaeo-drainage system with flow to the west and that converges towards the headwater of the present Silala River indicating the existence of 'Silala palaeo-valley' in the Lower Pleistocene. (SERNAGEOMIN, 2017).

The Glacial Deposits (Plg) (Upper Pleistocene) (ca. 40-12 ky BP) that can be found in the Silala River basin are confined to the south, southwestern, and southeastern slopes of the Cerro Inacaliri (Figures 4-1 and 4-5), and to the northwest end of the Volcán Apagado ridge. They comprise well-preserved terminal and lateral moraines (till) that are associated with small glacial valleys. On the northern slope of the Silala River basin, the morainic deposits extend from high elevation down to approximately 4400 m.a.s.l. (SERNAGEOMIN, 2017) (some 500m above the flowing river channel).

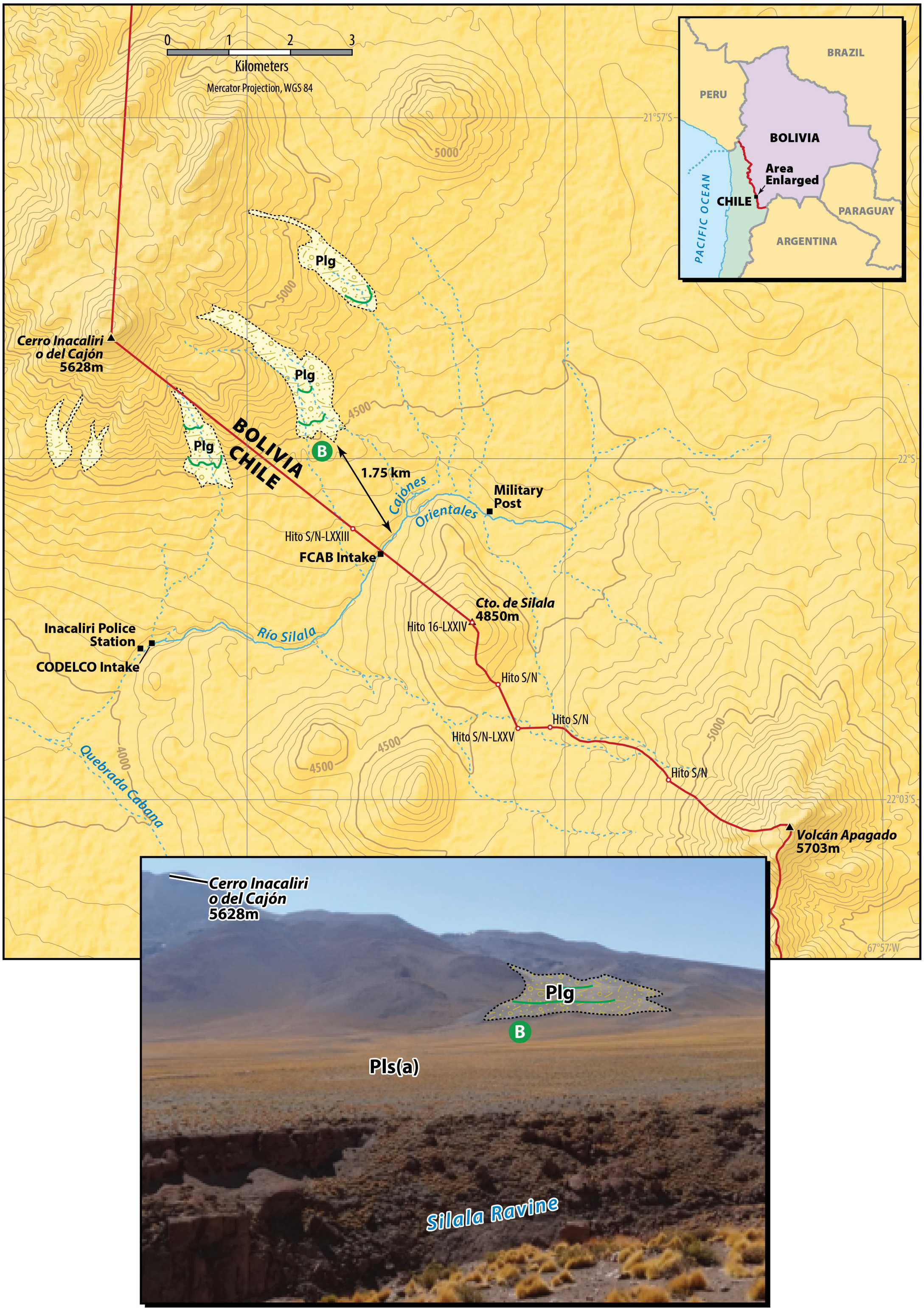


Figure 4-5. Glacial deposits on the northern slope of the Silala River basin. Two main phases of ice stabilization, represented by two terminal moraines ridges (green lines), are

attributed to the Upper Pleistocene (approximately 40-12 ky BP). The photo shows the flat surface of alluvial deposits (Pls(a)), the reach of the glaciers and their non-genetic relationship with the Silala River ravine. B represents location point on the map (SERNAGEOMIN, 2017).

Alluvial Deposits from the Upper Pleistocene (Pls(a)) are found interfingering with the higher Glacial Deposits (moraine). They comprise blocks, rounded stones, gravels, sands and silts, which are unconsolidated and exposed chiefly on the north slope of the Silala River basin. They are incised by the Alluvial Deposits from the Upper Pleistocene - Holocene (PlHa) and active lesser river beds (Figure 4-1). They are covered by Pyroclastic Fall Deposits PlH(pc) from the Upper Pleistocene (ca. ~11.5 ky BP).

The pyroclastic fall deposits are unconsolidated deposits, dark grey with thin strips of lighter colour, well stratified, and composed of ash, volcanic rock fragment including pumice. They are primarily located in the central and south-central parts of the Silala catchment and were deposited on top of the Alluvial Deposits from the Upper Pleistocene Pls(a) and have also been eroded by the later Alluvial Deposits from the Upper Pleistocene - Holocene (PlHa).

Alluvial Deposits from the Upper Pleistocene - Holocene (PlHa) consist of unconsolidated deposits of rounded stones, gravels, sands and silts, and are found exposed in the central and southwest parts of the Silala catchment. These deposits cut off and partially cover the Alluvial Deposits from the Upper Pleistocene (Pls(a)) and the Pyroclastic Fall Deposits (PlH(pc)). They have been eroded by alluvial systems from the Holocene (Ha) (Figure 4-1).

Examination of the geology of the Silala catchment (SERNAGEOMIN, 2017) including the ravine and at depth through borehole investigations (Arcadis, 2017) has found that the first fluvial activity more or less along the course of the current river occurred between about 2.6 and 1.5 Ma ago. The resulting fluvial deposits were covered by the Silala Ignimbrite (Figure 3-1 Panel 5) but a further drainage network developed subsequently and this was truncated 1.48 Ma ago when a lava flow (Figures 4-3 and 4-4) of that age partially infilled the depression which now is home to the Orientales wetlands. We turn, below, to the subsequent development of the river system.

5. THE DEVELOPMENT OF THE SILALA RIVER AND RAVINE OVER THE LAST 11-12000 YEARS (LATORRE AND FRUGONE, 2017)

This section explores the sedimentary deposits and erosional terrace features of the Silala River ravine to establish their origins and age. Our findings indicate that the ravine has been carved over the past 11-12000 years, and that radiocarbon dating shows that wetlands existed within the ravine about 8400 years ago. Sedimentation began earlier than this and the carving of the bedrock to form the ravine must have occurred even earlier, probably closer to 12000 years ago.

Detailed investigations into the sedimentary history of the Silala ravine were carried out by Latorre and Frugone in 2016 and early 2017. These investigations included detailed logging and description of the sedimentary sequences found in the ravine, including excavation of trial pits in the ravine sediments and subsequent sampling of plant and other organic matter for carbon-14 dating.

Investigations by trial pitting in the area at the junction of the Silala River and the Quebrada Negra and at another site close to boreholes drilled upstream of Quebrada Negra (Arcadis, 2017) revealed four sedimentary depositional units within the Silala River ravine. The sediments found in the Silala ravine and deposited by the Silala River include sands, silts, gravels with up to cobble-sized clasts and organic carbon-14 datable matter, including peat, black organic mats (from ancient wetlands), roots and other plant matter and organic remains. By understanding the relationships between one more or less continuous conformable sequence of sediments and the other sequences, and constraining the ages of parts of these sedimentary sequences, a picture of the development over time of the river, its ravine, and the vegetation and the climate of the times of deposition has been built. This development of the river, its ravine and the fluvial sediments found in the ravine has been summarised in Figures 5-1, 5-2 and 3-2.

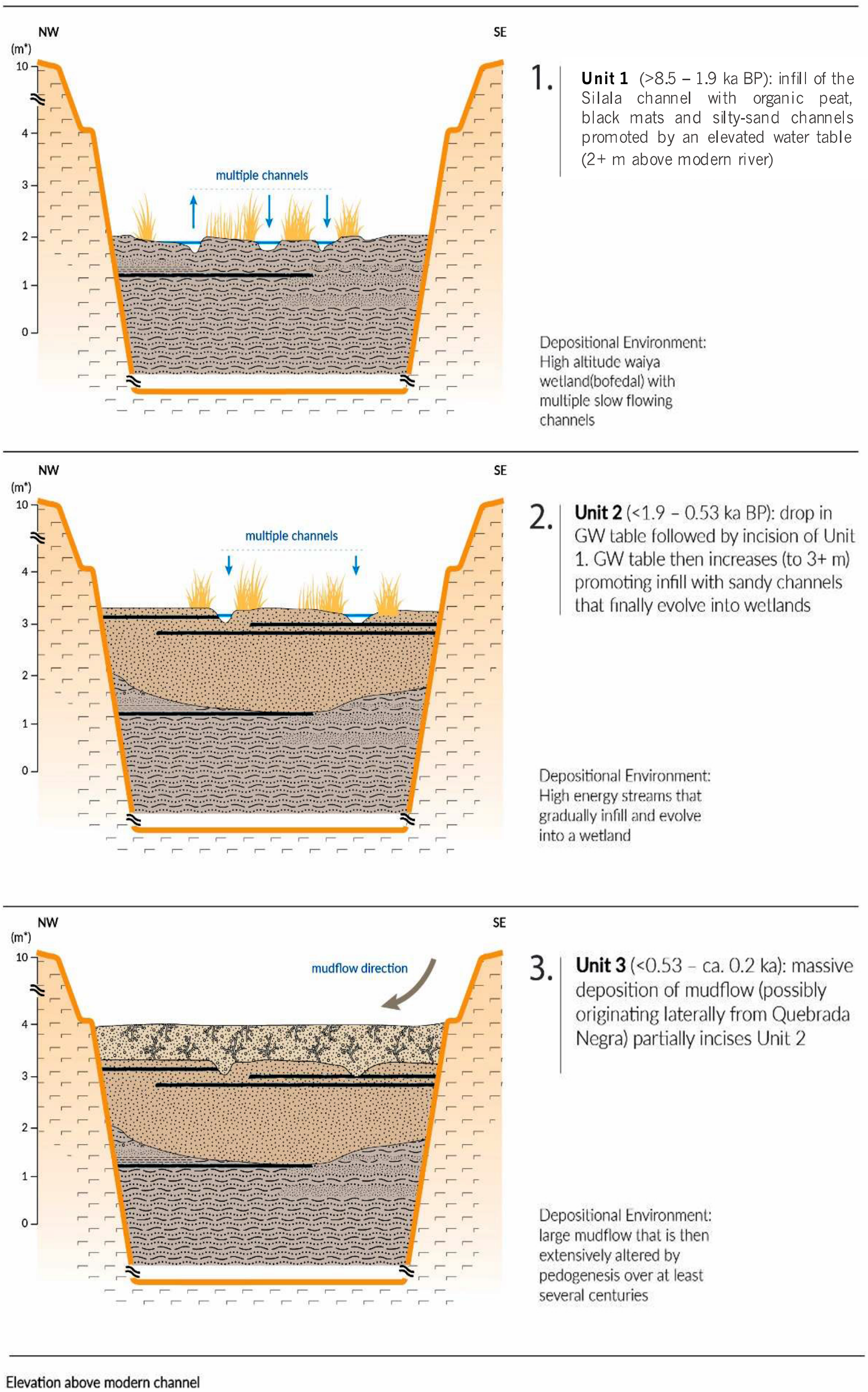


Figure 5-1. Schematic diagram showing the fluvial deposition of Units 1, 2 and 3 (Latorre and Frugone, 2017).

Before these fluvial sediments were deposited, the ravine had been cut into the Silala Ignimbrite rock, which forms the volcanic bedrock beneath them. This clearly must have occurred before the earliest dated organics from Unit 1 sediments, which gives an age of 8430-8350 years BP (Latorre and Frugone, 2017). From this we can conclude that the ravine was incised before this. It is logical to think that the incision of the ravine would have been because of the melting of ice caps on the surrounding mountains and dormant volcanoes since this would have produced large run-off events and deposited the alluvial fan/outwash sands and gravels. Thus, it is highly likely that the modern Silala River ravine has existed from 11-12000 years BP. Although the earliest date obtained from organic samples from depositional Unit 1 was 8430 – 8350 years BP, the sample was not from the base of the unit, so the age of the earliest sediments must have been deposited about 8400 years BP or earlier (see Figure 5-1 Panel 1 and Figure 3-2).

The most recent dates from this sedimentary unit (Unit 1) correspond to 1900 – 2010 years BP (Latorre and Frugone, 2017), so deposition appears to have been more or less continuous for at least 6000 years, meaning that the Silala River was an active river with wetland type vegetation, since there are several beds with organic matter (peats, “black organic mats” and other vegetation) which testify to this.

This depositional phase was followed by a period of erosion, probably promoted by a fall in groundwater levels (see Latorre and Frugone, 2017). Such a fall, perhaps by over 1 metre, would have caused the wetland vegetation to die and no longer hold the unconsolidated sediments together, thus allowing erosion during occasional flood events. Such events occur in these desert climatic regimes, which have highly variable wet season rainfall, and would have had the power to rapidly erode unconsolidated sediments and incise into the Unit 1 deposits. Unit 2 was deposited between about 1900 and 530 years BP, after a rise in water table due to a climate regime change which introduced wetter times (Figure 5-1 Panel 2). Deposition of Unit 2 was interrupted by a massive mudflow deposited laterally from the Quebrada Negra and partially eroding Unit 2. This is shown schematically in Figure 5-1 Panel 3. The origins of the mudflow are unknown, but it appears to have flowed down the Quebrada Negra from the direction of the Volcán Apagado.

The next identifiable period was one of considerable erosion. Figure 5-2 shows the erosion of Units 2 and 3 and partial erosion of Unit 1 in the period between ca. 200 years BP and recent times. Subsequently this incision was filled with sediments, named Unit 4, for a period from the beginning of the nineteenth century.

Further erosion has occurred much more recently, to remove some of Unit 4. A prolonged reduction in rainfall in the twentieth century appears to have led to a reduction in groundwater levels leading to vegetation die off and erosion. Occasional extreme flood events are likely to have caused the incision of the current river bed into the Unit 4 sediments (see Figure 5-2).

Figure 3-2 summarises these events, and gives radiocarbon dates of the samples and their relative stratigraphic position in the various sedimentary units. This schematic section also labels the associated terrace features 1, 2, and 3. Terrace 4 is higher still and not included on the schematic section, but can be seen on the photograph on Figure 5-3.

It is clear that fluvial erosion and sediment deposition along the course of the Silala River has been ongoing for at least 8400 years and the formation of the ravine may have begun as early as 11-12000 BP. The regime of wetland development, sediment deposition and erosional incision has a cyclical history which is over about 8400 years old and still continues today.

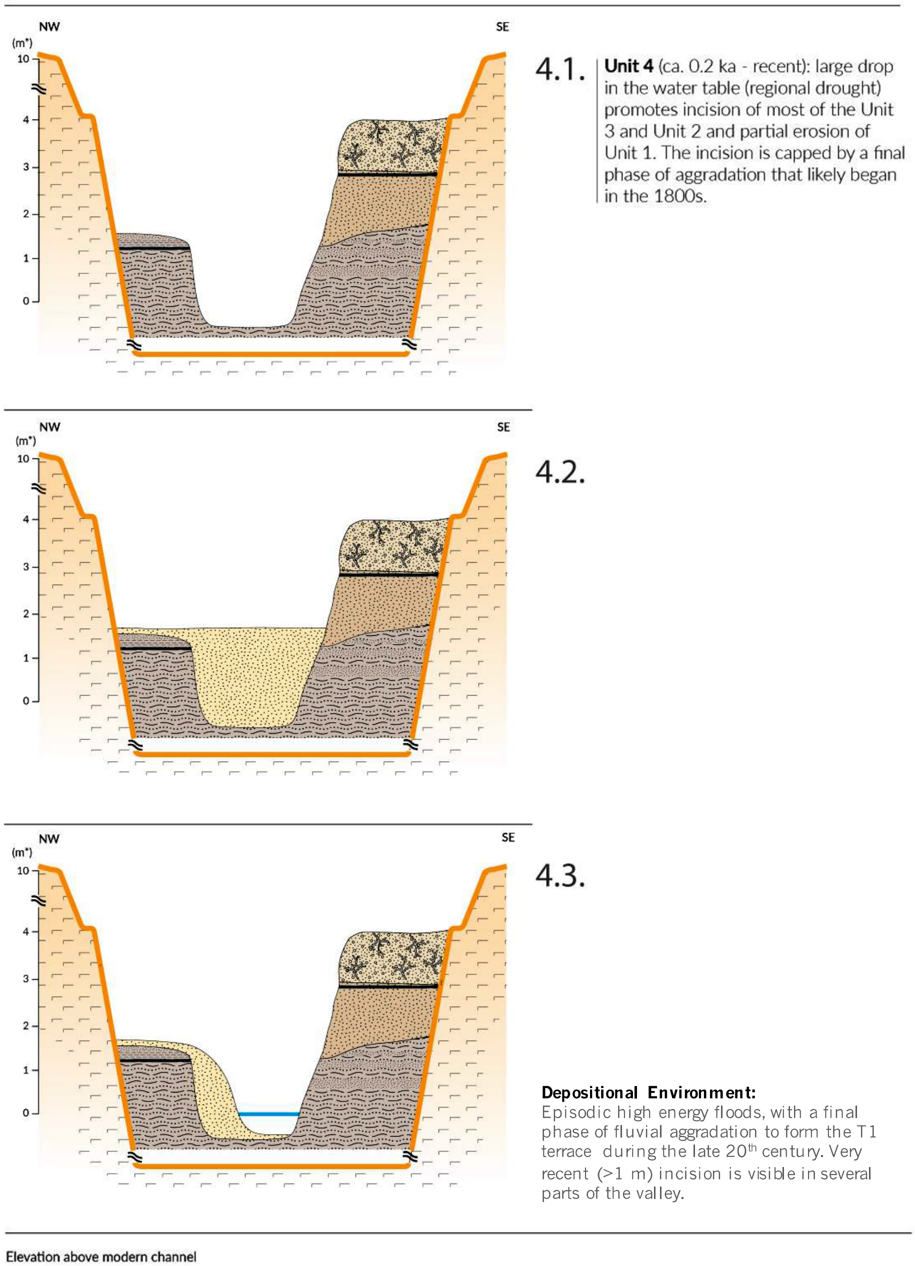


Figure 5-2. Erosion of Units 3 and 2 (4.1) and deposition of Unit 4 (4.2) then recent erosion of Unit 4 (4.3) (Latorre and Frugone, 2017).

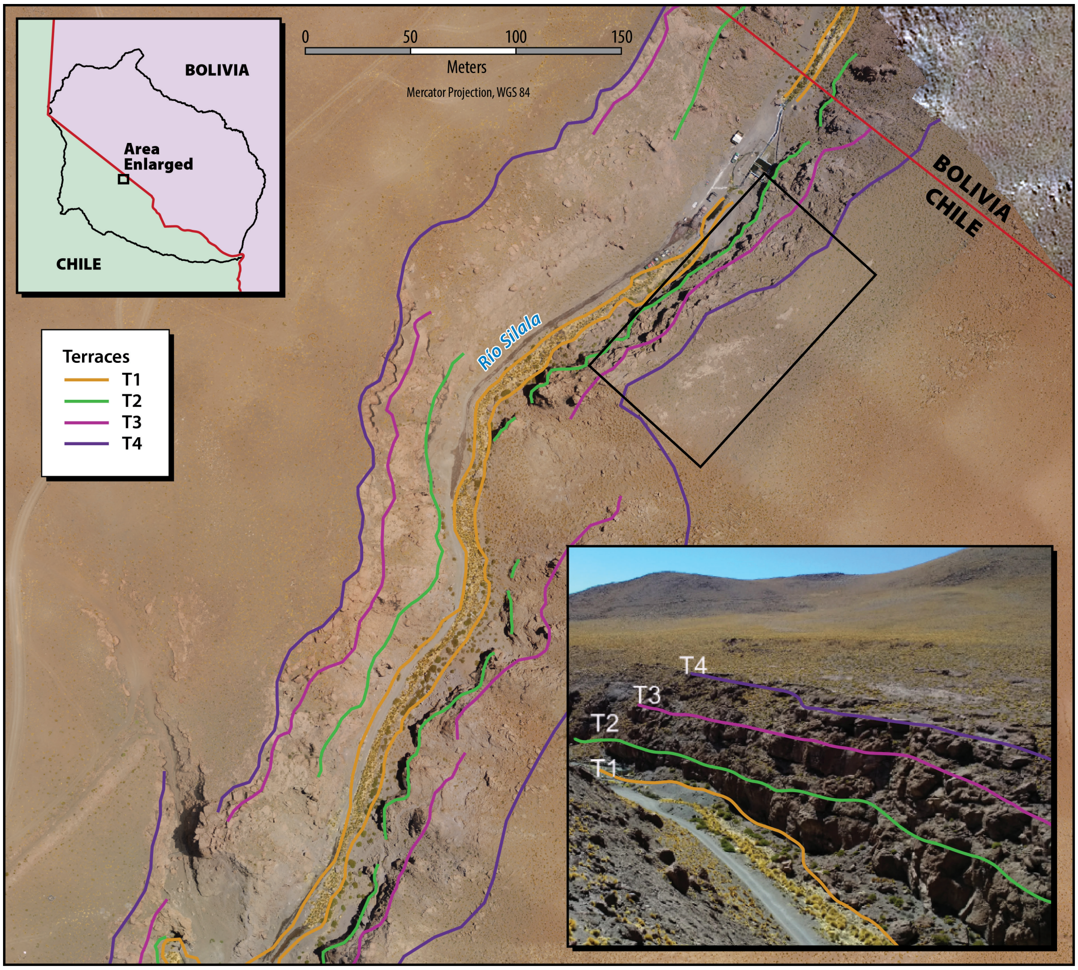


Figure 5-3. Identification of terraces in east slope of the Silala River ravine, 50 m southwest of the international border (Arcadis, 2017).

6. EVIDENCE OF HUMAN ACTIVITY IN THE ENVIRONS OF THE SILALA RIVER AND RAVINE (MCROSTIE, 2017)

In this section, we introduce briefly the archaeological evidence of the use and occupation of the Silala River and its ravine by human communities at over the last 1500 years.

Stone dwellings and shelters, often built into caves and *cavetto* fluvial features found in the walls of the ravine on the terraces of the Silala River, provide evidence of human activity and habitation along the Silala River, likely on a temporary basis. The indigenous peoples of the Altiplano and Atacama Desert regions were nomadic and herded animals, hunted and may have fished in the Silala River. It appears that the Silala River formed a route to and from the highlands.

The presence of the water resources of the Silala would have attracted nomads and communities and it seems likely that the Silala was on migratory routes in some of these times. There are sites with examples of pottery and an arrow head of apparent Pre-Columbian age (probably from 1500 years BP) was found on one terrace. The sites of archaeological interest identified in a 2016 survey are shown on Figure 6-1 (McRostie, 2017).

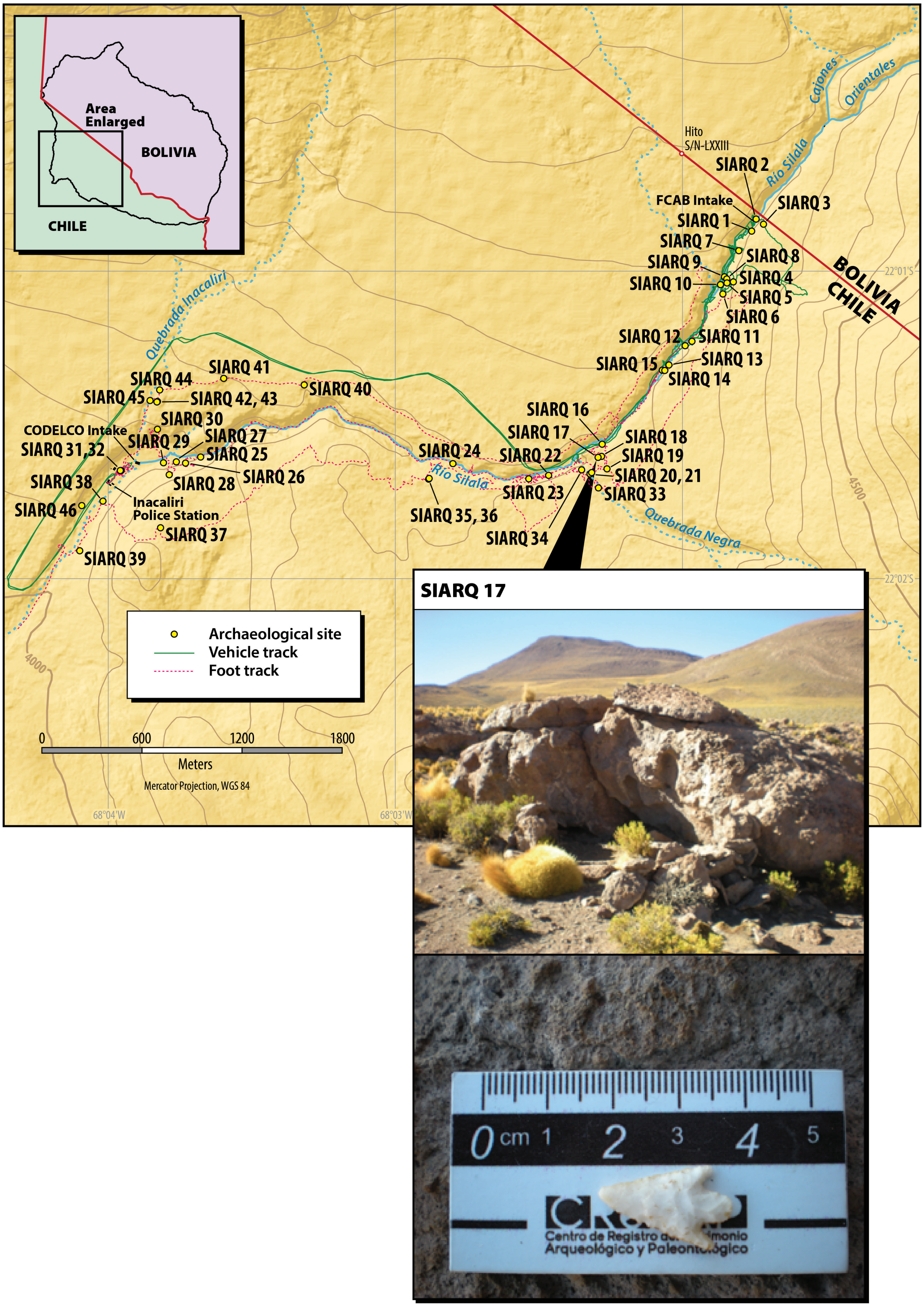


Figure 6-1. Archaeological sites identified in the Silala ravine and the Silala terraces, including site 17 with a photograph of the arrow head found (McRostie, 2017).

7. FLUVIAL, GLACIAL AND AEOLIAN PROCESSES OF EROSION AND DEPOSITION IN THE SILALA RIVER RAVINE

Here we examine the evidence for different geological processes to establish those of greatest importance in the formation of the Silala River ravine. We show that the overwhelmingly dominant processes that resulted in the carving of the ravine and the deposition of the sediments found in the ravine are fluvial.

There is such considerable geological evidence to be found in the Silala River ravine and environs that there is no doubt that the origins of the ravine and the terraces mentioned in section 5 can be interpreted as being attributed to the fluvial activity of the river.

The course of the Silala River ravine is relatively winding, and has a typical V-shaped or asymmetric section, with one sloping side (<45°) and a sub-vertical side, that is interpreted as being caused by whether the slope is on the inside (<45°) or outside (sub-vertical) of bends in the river course (Figure 7-1B).

Other fluvial features such as potholes and *cavettos* (SERNAGEOMIN, 2017) are commonplace along the various terraces and in the wall of the ravine at a variety of levels, indicating previous river bed levels and erosion at the water level, normally on the outside of a bend. Examples of these features can be found on Figures 7-2 and 7-3.

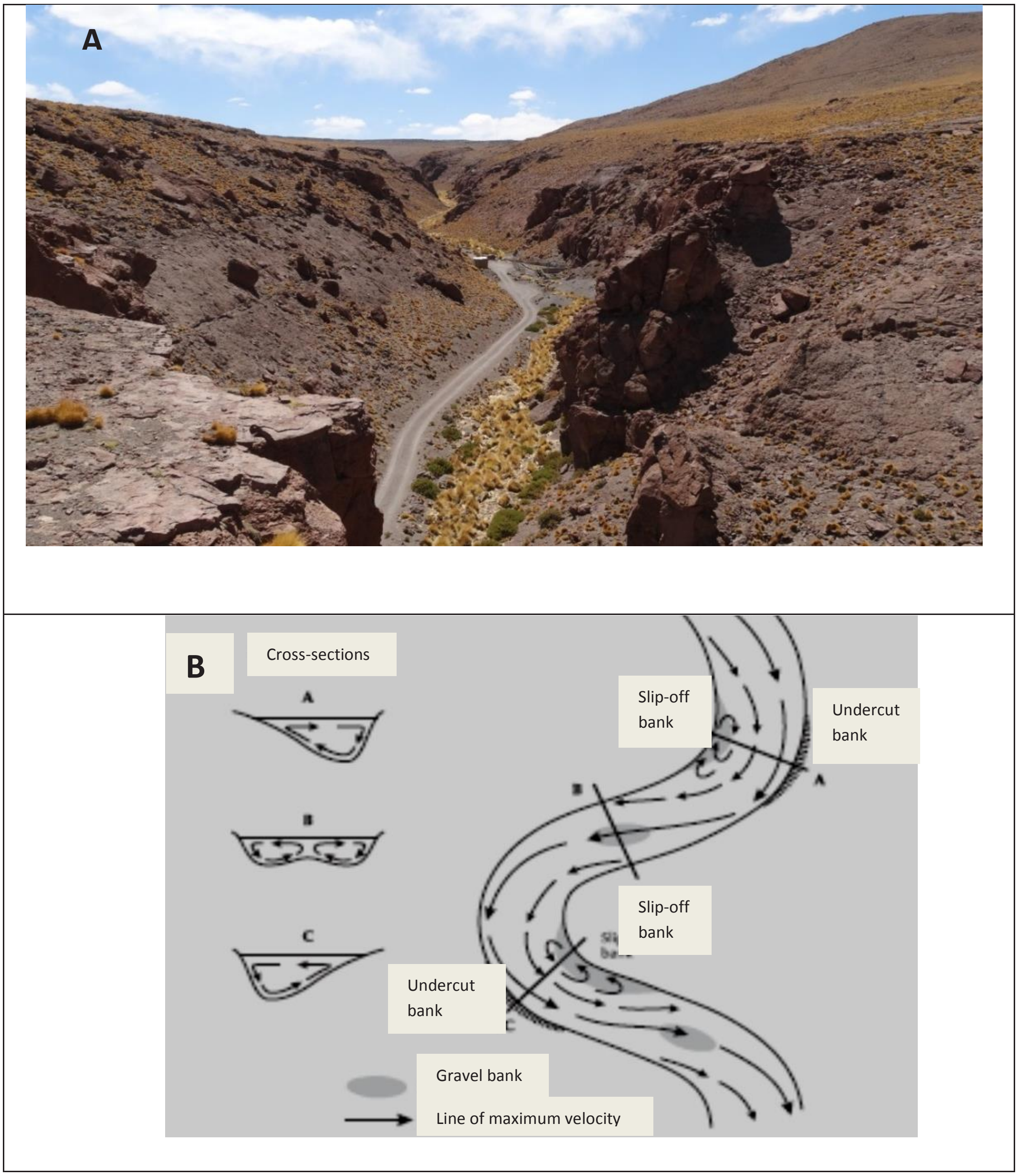


Figure 7-1. View along the Silala River ravine (A), with mixed profile, whether V-shaped or asymmetric having sloped sides, corresponding to the inner course or side of the river, and the subvertical side corresponding to the external course or side of the river (view to the east). (B), conceptual model of water flow in a winding river (SERNAGEOMIN, 2017).

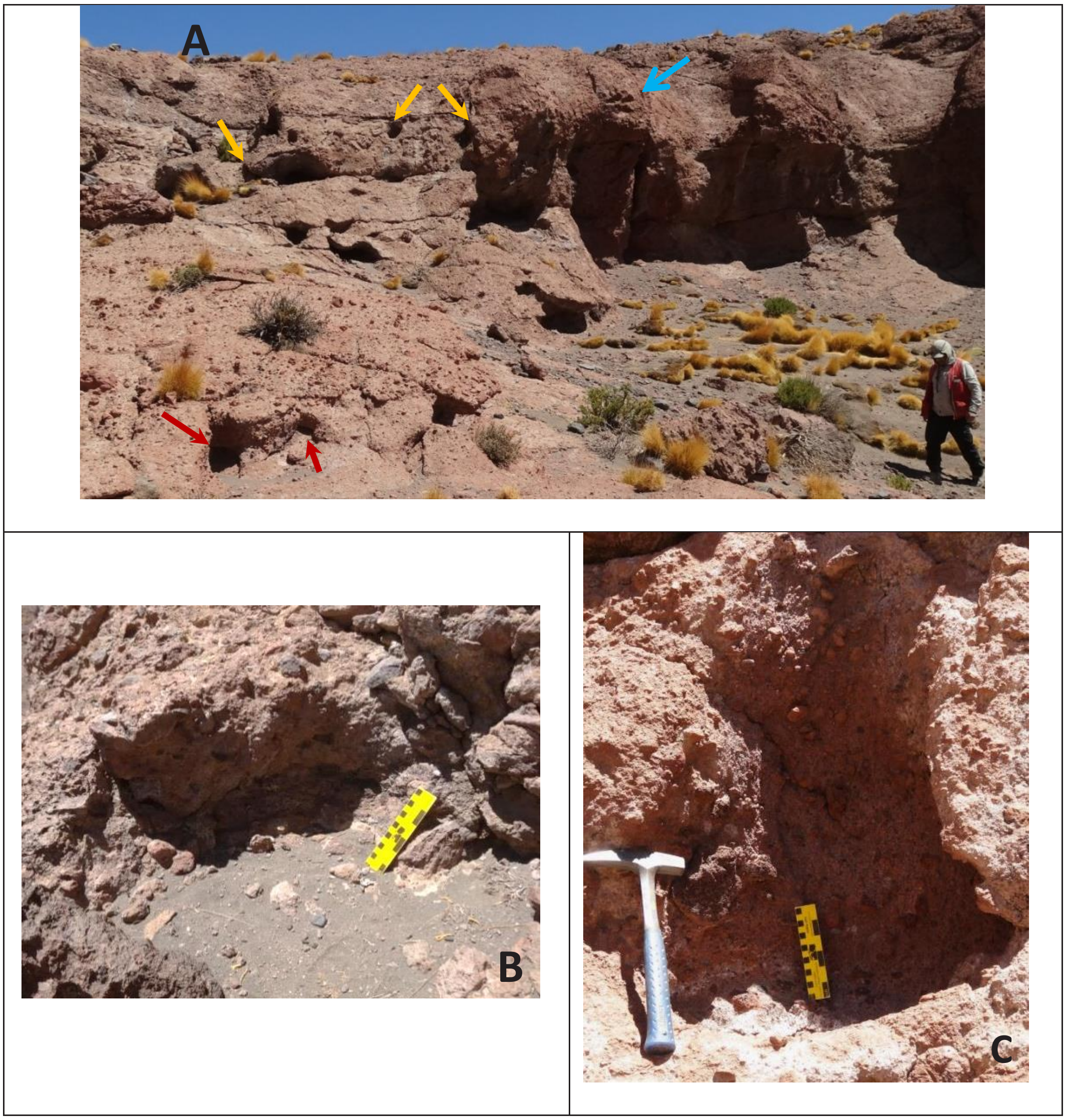


Figure 7-2. Erosional pothole forms carved out in the highest terrace of the Silala River ravine. (A) Creation of closed, lateral potholes (orange arrows), coalescent lateral potholes (blue arrow), and open potholes in a palaeo-channel[4] bed (red arrows); (B) Detail of a pothole located in the bottom of a previous channel location; (C) Detail of a closed, lateral pothole in the walls of the escarpment; note the differential circular erosion towards the bottom of the cavity, caused by a smaller lithic fragments in the Silala Ignimbrite (scale in cm) (SERNAGEOMIN, 2017).

[4] A river channel in an earlier landscape.

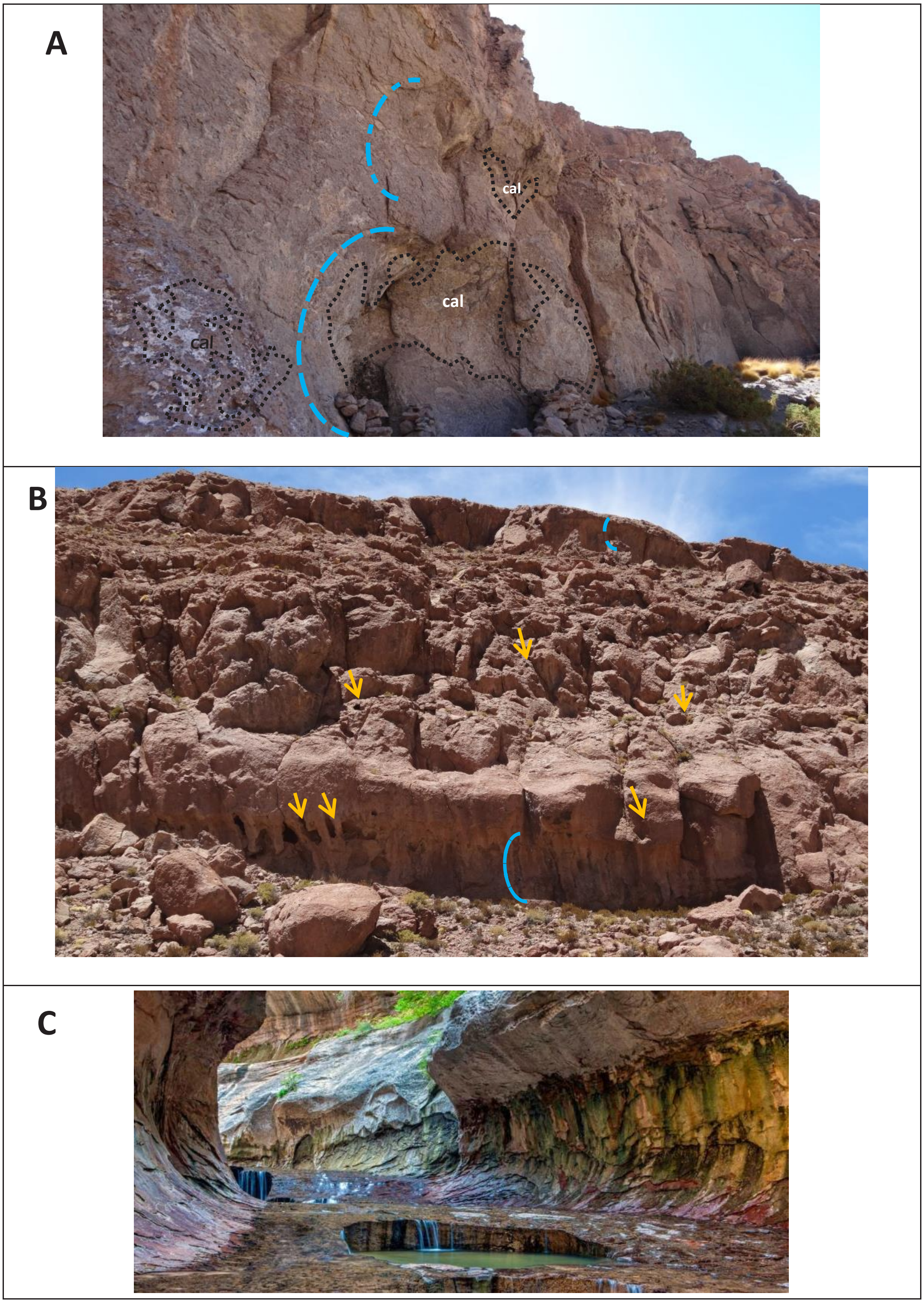


Figure 7-3. Concave hanging formations or cavettos due to river erosion. (A) Midcourse of the Silala River (between Inacaliri Police Station and the international border) with

creation of cavettos or alcoves (blue lines) on top of the present surface of the river bed, associated with caliche (calcrete) impregnations (lime) on the north slope of the ravine. (B) A few hundred metres upstream of Inacaliri Police Station, on the south slope of the ravine, shows the development of at least two well preserved cavettos (blue lines), associated to closed lateral potholes and open bottom potholes (orange arrows). (C) Present-day example of the formation of cavettos in the Fairy Pool River, Scotland (SERNAGEOMIN, 2017).

No evidence of glacial erosion or sediment deposition was found during surveys in the Silala ravine, in Chilean territory. Glacial deposits that were identified and mapped were found at higher levels on the side of the Cerro Inacaliri at about 4400 m.a.s.l. and even higher on the flanks of the Volcán Apagado, i.e. several hundred metres higher than the elevations of the stream channel and ravine. See section 4 above.

Strong winds are common all year round in the Silala catchment, but the effects of these on the local geomorphology appear to be very marginal compared to those of fluvial activity outlined above. The erosional forms that can be seen include small pillars or arcs, usually associated with surfaces with small impact holes and abraded surfaces (Figure 7-4). The winds transport fine sand, often of black basaltic composition, which accumulates in areas where it gets trapped on the various terraces. No examples of major wind-eroded features were found in surveys of the Silala River ravine.

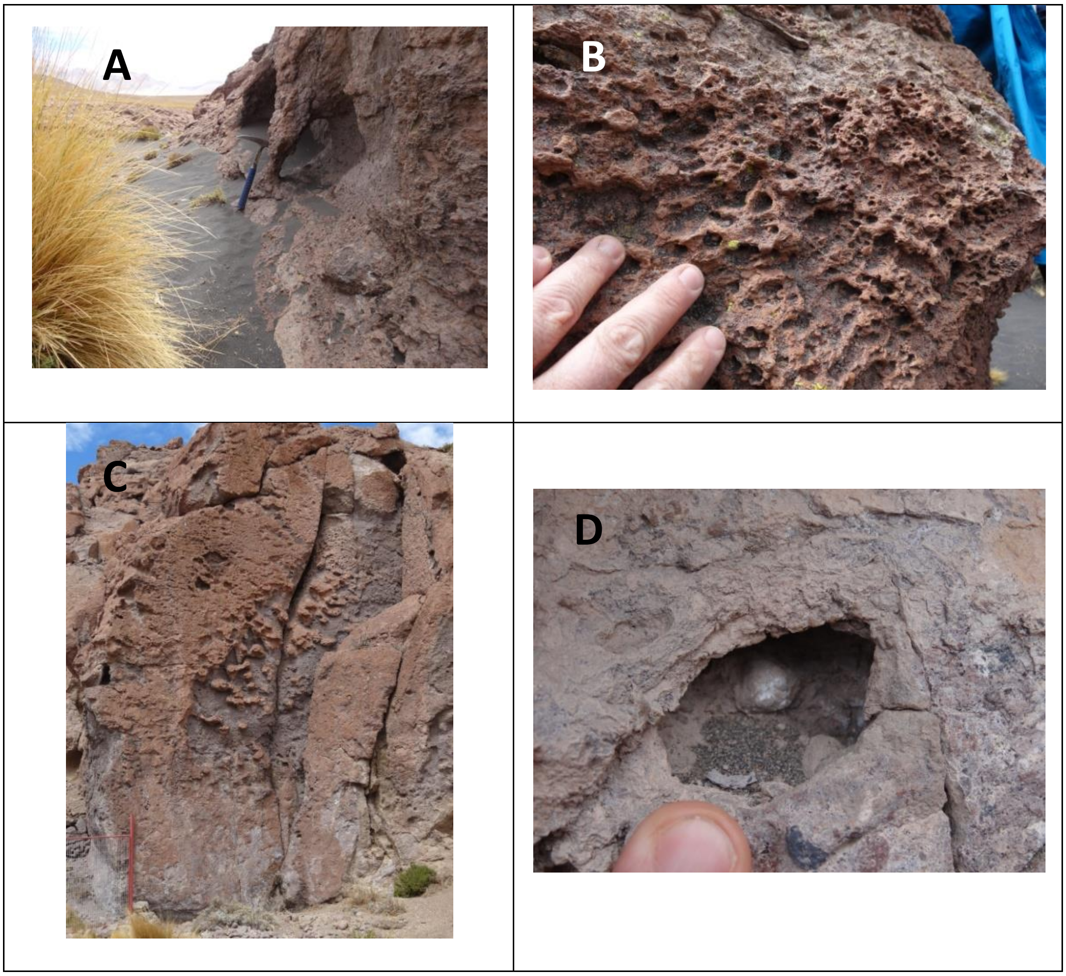


Figure 7-4. Marginal effects of wind erosion on the Ignimbrite walls of the Silala River ravine, (A) Pillars and hollows also showing wind-blown sand accumulated at the base of the wall, (B) Sand grain impact surface, indicating the preferential wind direction, (C) Wear forms in high relief and hollows on surfaces having frontal to oblique exposure to wind, (D) Detail of an oval hollow with sand remaining inside (SERNAGEOMIN, 2017).

The Silala River ravine contains very marked features associated with fluvial activity which indicate strong and long term erosional activity. There is considerable evidence of fluvial sedimentation in the ravine from previous river channels. The geomorphology of the ravine is typical of that developed by a fast-flowing, steep, mountain stream. It displays typical features like *cavettos* and potholes that can be expected of such a stream or river. The evidence of wind erosion is limited to the ravine walls and has had a minor impact on the development of the ravine morphology. Thin deposits of dark grey (basaltic) fine wind-blown sand are found in places on the floor of the ravine and on the terraces.

8. CONCLUSIONS

A detailed programme of geological mapping and identification of the geomorphological features that can be found in the Silala River, ravine and catchment has been carried out in order to establish the dominant geological processes, to track the evolution of the geology and hence understand the present geography and landscape forms of the catchment.

The detailed mapping of the geology of the Silala River catchment and environs, the investigation of the sediments found in the Silala River ravine, the identification of archaeological sites along the ravine and the observation of the evidence for different types of geological processes of sedimentary deposition and erosion have led to an understanding of the evolution of the landscape and morphology of the Silala River catchment and its ravine over the last approximately 6 million years.

We have demonstrated that:

1) There was fluvial activity along the alignment of the Silala River as early as 1-2 million years ago. This period has been constrained by radiometric dates from volcanic rocks above and below the water lain sediments. These sediments appear to have been deposited in a valley which was later infilled by volcanic deposits.

2) The incision of the Silala River ravine began before about 8400 years BP and probably as early as 11-12000 years BP. The modern Silala River ravine has been developing along its present course for over ca. 8400 years and the river has deposited sediments and supported vegetation, then eroded them at

least four times over this period. This has resulted in four identifiable terraces and four different sequences of sediment accumulation.

3) The periods of deposition and erosion were caused by climatic regime changes that resulted in changes in groundwater level. Falls in groundwater levels would have caused erosion and incision of the ravine, and rises would have promoted wetland vegetation growth and the trapping of sediment as water flowed downstream.

4) Considerable evidence for fluvial erosion and sediment deposition has been found and documented in the Silala ravine. Evidence for wind erosion and minor accumulations of wind-blown sands were found in the ravine, but the impact of the wind erosion on the development of the ravine is thought to be marginal.

5) While glacial action played a role in the development of the landscape at high elevations, no evidence of glacial action or deposits was found below approximately 4400 m.a.s.l. The formation of the ravine (at approximately 4000-4300m elevation) was not caused by glacial erosion.

6) Archaeological evidence shows that the Silala River and ravine was a place frequented by humans from about 1500 years ago and probably earlier. This was very likely to be due to the presence of reliable water and food resources.

We address in summary the two questions posed to us by Chile:

ii) What geological, geomorphological and/or other events formed the Silala ravine as it exists today?

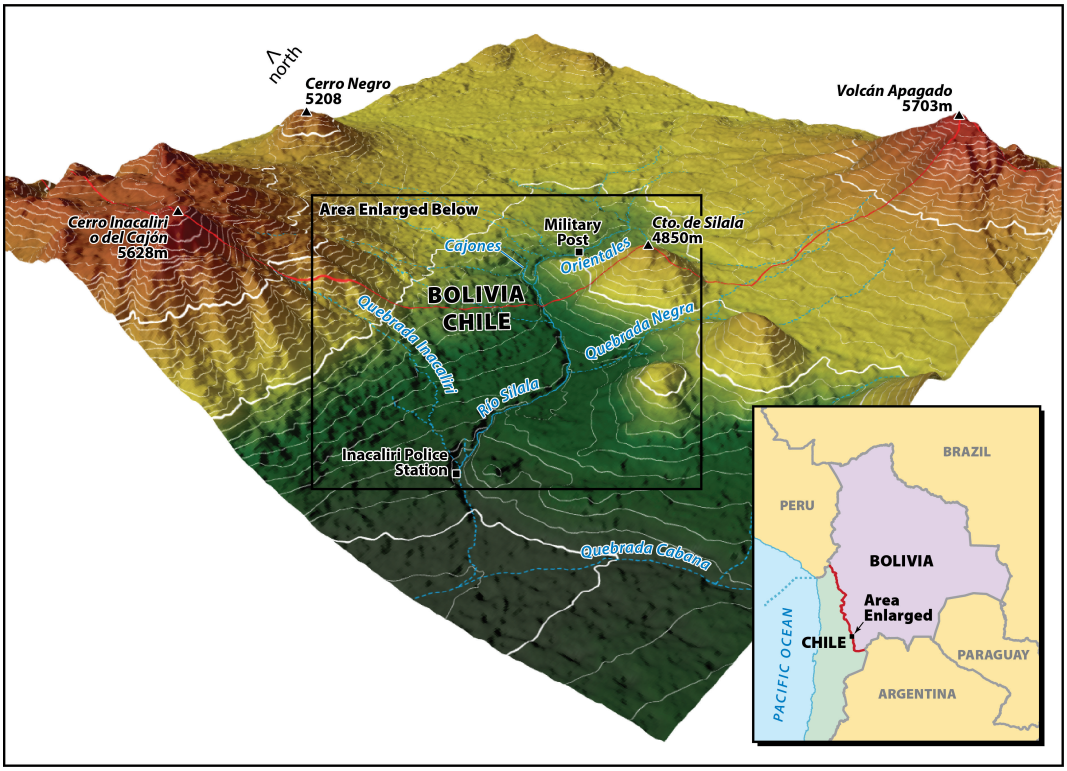
During the period from about 6 million years ago to about 1.5 million years ago the area now occupied by the catchment of the Silala River was subject to episodes of volcanism associated with the collision of the ocean tectonic plate to the west (beneath the Pacific Ocean) and the South American continental tectonic plate. This has resulted in volcanic activity that has shaped the landscape, including the building of the Cerro Inacaliri, Cerrito de Silala and the Volcán Apagado, which are all dominant features of the catchment morphology (Figure 1-2). The basal rocks beneath the Silala ravine are called Ignimbrites and were emplaced by explosive volcanic eruptions extruding flows of rock fragments, molten rock droplets and hot gases, which flowed down the existing topographic gradient at great speed. The first of these (Cabana Ignimbrite) was a very extensive and voluminous event affecting a large area of the Chilean Altiplano. This was followed by a first period of fluvial activity which eroded a valley in the ignimbrite and left fluvial sediments. On top of these early (between ca. 2.6 and 1.5 million years ago) fluvial deposits a further ignimbrite (Silala Ignimbrite) was deposited, probably filling the valley. Subsequently further volcanism led to a massive lava flow erupted from the Inacaliri volcano (1.48 million years ago) which flowed into the headwater area of the Silala River. This lava flow truncated the then-existing drainage network of the Silala River. There appears to have been a hiatus in volcanic activity in the catchment after 1.48 Ma and the next events to impact the catchment morphology were associated with the glaciation of the high peaks, above 4400 m.a.s.l. There is no evidence of glacial erosion or glacial deposits to be found at the level of the current Silala River ravine or in the ravine. The cutting of the ravine, as we know it today, began in the period ca. 12000-8400 years ago. Radio-carbon dating has shown that there are sediments deposited by the current Silala River system in the ravine that are over about 8400 years old. The river began cutting the ravine before that, probably as a result of the melting of the glaciers about 12000 years ago that caused significant runoff and increased flow in the river, and continues in a cycle of erosion and deposition in response to climatic regime changes. ***The cutting of the Silala ravine was caused by fluvial processes. It began in the period 12000-8400 years ago and continues today.***

iii) Does the geological, geomorphological and other evidence point to the historical existence of a fluvial system in the Silala catchment?

Sediments deposited by fluvial systems were laid down over 1.5 million years ago, as evidenced by fluvial deposits found on top of the first (Cabana) ignimbrite and beneath the second (Silala) ignimbrite. About 1.48 million years ago the lava flow from the Inacaliri volcano flowed into the area now occupied by the Orientales wetland in Bolivia (after the deposition of the Silala Ignimbrite) and truncated the existing drainage system. There are four sequences of sediments in the current Silala ravine. The oldest dates for organic material from these fluvial sediments have been found to be approximately 8400 years old and the youngest dates have given ages in the late twentieth century, demonstrating the current fluvial system to have been active for at least about 8400 years and that the cycle of erosion and deposition continues into modern times. Features of fluvial erosion are common in the sides of the ravine. There are four water-cut river terrace surfaces and four sedimentary sequences of deposits several metres thick. These deposits include sands, gravels, silts and organic remains of wetlands. The sides of the ravine contain some wind erosional features and there are some windblown sand deposits to be found, but these are minor features, and would have had no significant impact on the ravine formation. Archaeological surveys have found artefacts and shelters or temporary dwellings along the course of the river, mainly on the upper three terraces. These testify to the human use of the river and its course over the past at least 1500 years. There is no doubt that the geological, geomorphological and other evidence points definitively to the historical existence of a fluvial system in the Silala catchment. The modern ravine, created by fluvial action, has existed for more than 8 millennia.

These geological processes and events have formed the landscape of the Silala catchment and ravine as we know it today. The hydrologic regime today is discussed in our companion report (Wheater and Peach, 2017). We note here that it is not only a reflection of the climate and meteorology but of the nature and topography of the land surface and the rocks found in the subsurface. ***The current topography (Figure 8-1) and river profile (Figure 8-2) are a direct result of the interaction of the atmospheric processes, solid earth processes and biological processes and their variability over the last 6 million years. The natural gradients of the landscape topography and the river channel are such that the river must flow naturally from Bolivia to Chile.***

Figure 8-1 shows detailed contours of the whole catchment topography. These show that natural runoff will drain to the river network and across the international border. Figure 8-2 shows the gradient of the river channel, from the sources of perennial flow in the Orientales and Cajones wetlands in Bolivia, across the international border, to the catchment outlet. It can similarly be seen that this is the natural drainage path of the river system.



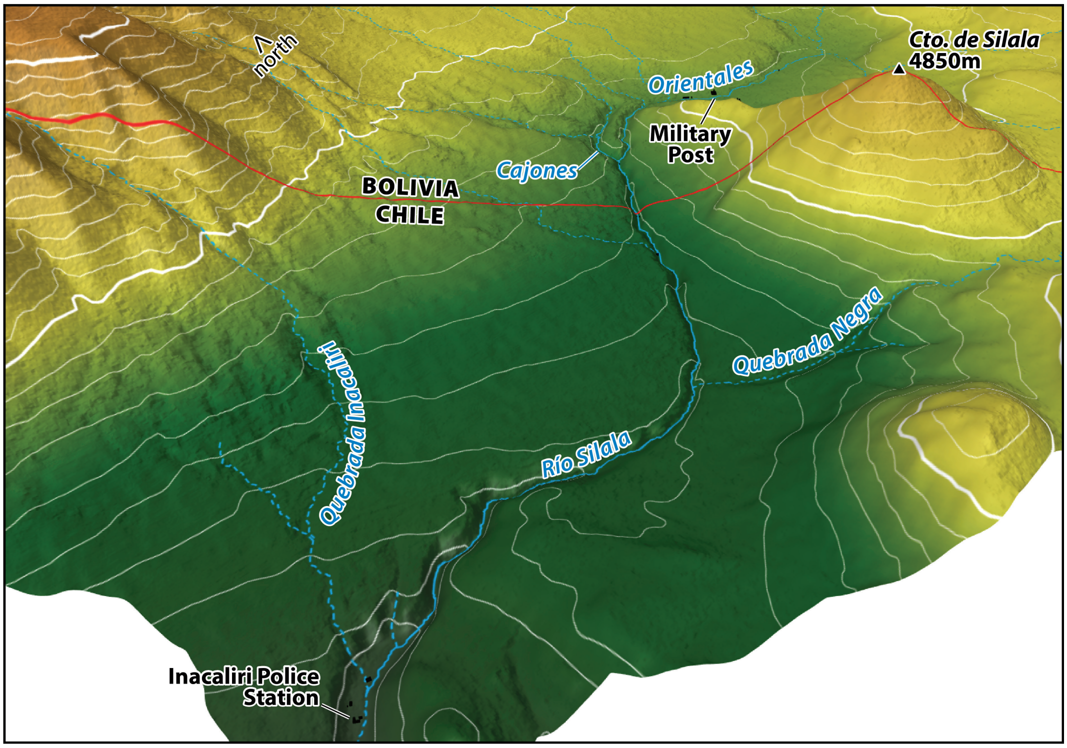


Figure 8-1. 3D topography with contour lines on the terrain in the Silala River basin (Alcayaga, 2017).

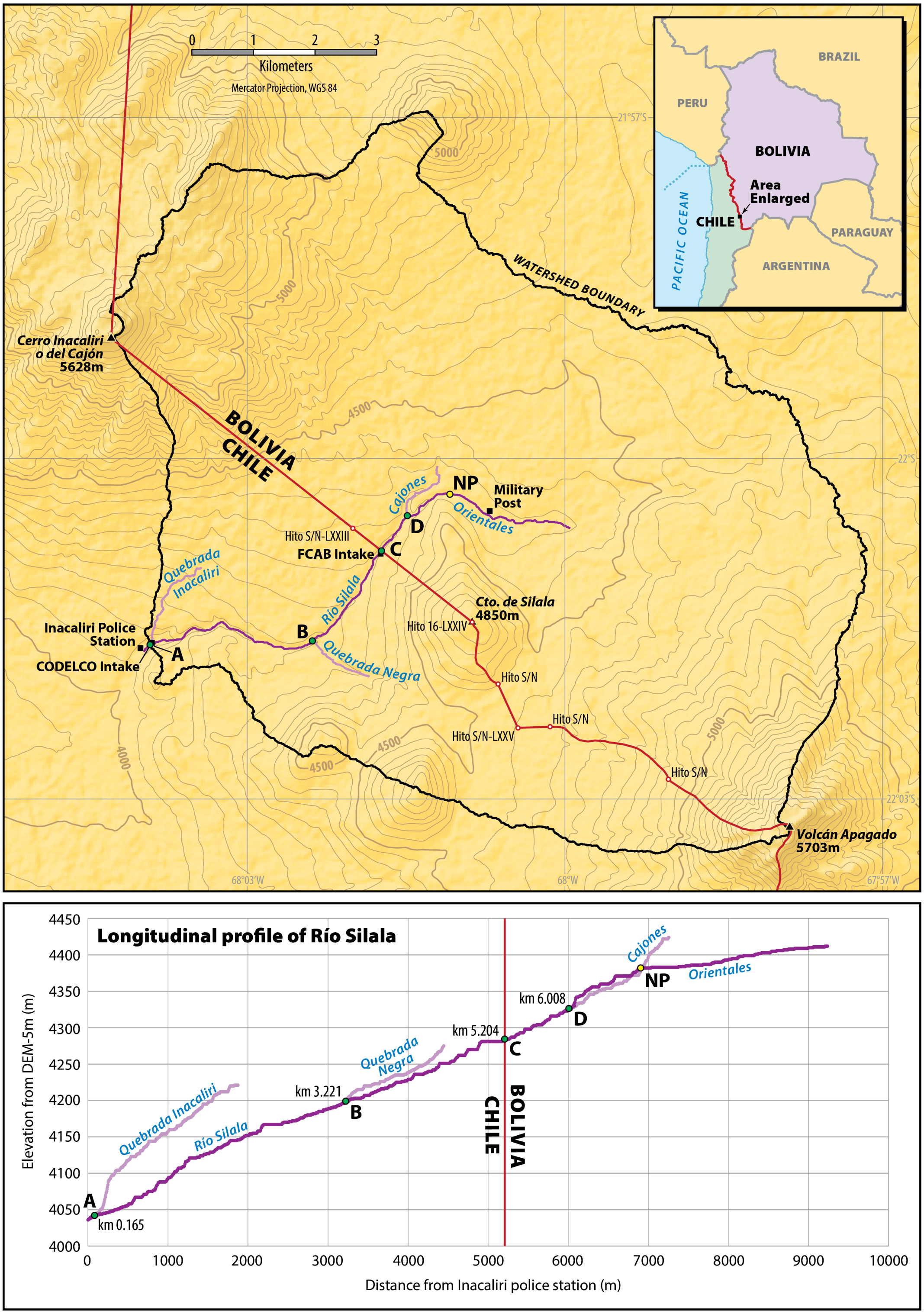


Figure 8-2. Longitudinal profile of the Silala River and main tributaries, extracted from the DEM-5m (Alcayaga, 2017).

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Biographical Details of Dr. Howard Wheater

Dr. Howard Wheater is Canada Excellence Research Chair in Water Security at the University of Saskatchewan (UofS), Canada, Director of the Global Insititute for Water Security, which he founded in 2011, and Director of Canada's \$143million Global Water Futures research programme. He holds the titles of Distinguished Researcher at the UofS and Distinguished Research Fellow and Emeritus Professor of Hydrology at Imperial College London. He is a Fellow of the Royal Academy of Engineering, London, Fellow of the American Geophysical Union and a Life Member of the International Water Academy, Oslo. He is a Chartered Engineer and Fellow of the UK's Institution of Civil Engineers. His prizes and awards include the 2006 Prince Sultan bin Abdulaziz International Prize for Water, the 2004 Baker Medal of the Institution of Civil Engineers, UK and the 1996 President's Prize of the British Hydrological Society.

Dr. Wheater holds a 1st Class Honours degree in Engineering Sciences from the University of Cambridge, and a PhD in Hydrology from the Univeristy of Bristol. He moved to Canada in 2010 as one of 19 leading international scientists awarded a Canada Excellence Research Chair. For the preceding 32 years he held appointments in the Department of Civil and Environmental Engineering, Imperial College London, where he was Professor of Hydrology, Head of Environmental and Water Resource Engineering and Director of the Imperial College Environmental Forum.

Dr. Wheater has authored 189 peer-reviewed journal papers, with more than 7161 citations and an h-index of 43 (i10-index of 151) (Google Scholar®); he has supervised more than 160 graduate students. In the UK he led national research programs, was a member of the Foresight Future Flooding teams (2004, 2008) and a 2008 Cabinet Office flood enquiry, and chair of a government review panel on siting criteria for nuclear waste disposal. In Canada he chaired the Council of

Canadian Academies expert panel on Water and Agriculture in Canada. Dr. Wheater has advised governments and international agencies in the Middle East, Far East, Africa and South America, as well as Europe and the USA. He represented Hungary and Argentina as Counsel and Advocate at the International Court of Justice, The Hague and was recently a member of a Court of Arbitration in The Hague in a dispute between Pakistan and India concerning the Indus Waters Treaty. He is Chair of UNESCO's G-WADI Steering Committee and past Vice-Chair of the World Climate Research Program's (WCRP) Global Energy and Water Experiment (GEWEX).

He is known as a world expert in hydrology and sustainable water resource management. His research focuses on the development of new hydrological science, combining modelling and experimentation, to address water-related societal challenges, including climate and land use change, and flood, water resource, water quality and waste management. He has contributed for more than 40 years to the theory and application of hydrological models. Important contributions include the provision of new modelling tools and development of methods that have resolved key areas of model limitation. These include the modelling of ungauged basins and prediction of the effects of land use and land management change. His UK research into the effects of rural land management change on flood risk, and the potential for flood risk remediation, supported government foresight studies and a Cabinet Office flood enquiry. His arid zone research led to the award of the Prince Sultan International Prize for Water. His work on stochastic rainfall modelling provided new methods to address flood risk management under climate change, and for the downscaling of climate models for climate change impacts assessment. Point process modelling was developed to support a new paradigm for continuous simulation to support flood design, now applied in the UK and Europe. His work on Generalized Linear Models has been widely applied for spatial rainfall modelling and statistical downscaling, with applications in the UK, Canada, Middle East and Africa.

Dr. Wheater led development of phosphorus modelling of eastern England for the EU Water Framework programme and initiated and led a national research programme into groundwater dominated catchments in which his research focused on nitrate transport in Chalk catchments. His research led to new insights into fractured porous media, identified a decadal nitrate 'time–bomb' and developed new models for nitrate management. His research into radionuclide transport supported a national UK research program for safety assessment of the deep disposal of nuclear waste, which he advised. He currently advises Nevada on the Yucca Mountain waste repository.

As Canada Excellence Research Chair at the University of Saskatchewna, Dr. Wheater proposed a new paradigm for transdisciplinary research to address water security under environmental change and established the Global Institute for Water Security. He developed the Saskatchewan River Basin and Mackenzie River Basin as large-scale observatories, endorsed by the World Climate Research Programme as a Regional Hydroclimate Project. Observatories in the key biomes, including collaboration with the Canadian Space Agency and NASA, support improved process understanding and modelling across multiple scales. His research has developed new methods of vulnerability analysis for complex water resource systems, and systems dynamic simulation tools for scenario-based economic analysis of water futures, supported by new downscaling tools for climate model outputs. Water quality research has focused on hydro-ecological response to nutrient loading, the analysis of anthropogenic loads and beneficial management practices. New algorithms have been developed to support large scale hydrological modelling and fine resolution atmospheric modelling is providing new insights into fine scale precipitation, extreme events and the impacts of future warming.

Dr. Wheater has been responsible for research grants totaling nearly $118M over the last four years, including Global Water Futures (GWF), Canada First Research Excellence Fund, 2016-2023, $77.8M; Canada Excellence Research Chair in Water Security, University of Saskatchewan, 2010-17, $30M; Changing Cold Regions Network, Climate Change and Atmospheric Research, NSERC, 2013-18, $5M. GWF is believed to be the largest grant ever made to a University, world-wide, for water-related research.

Biographical Details of Dr. Denis Peach

Dr. Denis Peach practises as an independent consultant in hydrogeology after retiring from the position of Chief Scientist of The British Geological Survey (BGS) in 2013. He is currently a Visiting Professor in the Department of Civil and Environmental Engineering at Imperial College, London. He is an Honorary Professor in the School of Geography, Earth and Environmental Sciences at the University of Birmingham, and he is an Honorary Research Fellow at the BGS. In 2009 he gave the Ineson Distinguished Lecture at the Geological Society of London.

Dr. Peach has a second class honours degree in Geology, a Master's degree in Hydrogeology (1972) and a PhD in Hydrogeology from the University of Birmingham. He has had a varied and broad career spanning water industry, geophysical consultancy, overseas aid, engineering consultancy and research with the British Geological Survey. His first experience was in the UK water industry where he learnt to be a hydrogeologist. At this time he developed a large university collaboration between the University of Birmingham and the Anglian Water Authority, UK, to carry out a research project investigating saline intrusion and older saline waters in Lincolnshire. During this project he had a leading involvement in the development of geophysical logging for hydrogeological studies in UK and took part in some of the earliest Carbon-14 dating of UK groundwaters. He was heavily involved in early digital mathematical modelling of groundwater systems. In his position of Regional Hydrogeologist, he supervised the drilling of well over 100 boreholes for exploration, monitoring and water supply purposes. This was followed by a short period with a geological and geophysical consultancy (Robertson Research Ltd) where he became a company director and was responsible for research and development of geophysical logging equipment and he carried out groundwater investigations in Saudi Arabia.

This was followed by ten years overseas working in Fiji (British Aid) and the Bahamas (United Nations). Here he developed expertise in resistivity and Electromagnetic techniques for groundwater exploration and led the investigation sustainable development of small island groundwater resources in both volcanic island arc and carbonate environments.

On returning to the UK in 1991 he worked for engineering consultants on a variety of projects including water supply, groundwater flooding and arid zone studies. He gained experience in Oman, United Arab Emirates, Columbia, Philippines and Ireland. In Ireland he was responsible for a £1M study into karst groundwater flooding in the Low Burren of Ireland. In the Sultanate of Oman, he project managed studies into recharge dams and did early numerical integrated modelling of surface and groundwater. In the Philippines and Columbia studies for city and power station water supplies were carried out by him.

In 1997 Dr. Peach was appointed programme Manager for Hydrogeology at BGS where he led the research, including government funded, European funded and commercially funded hydrogeological science and academic research. This work included major collaborations with UK and European Universities, The Centre for Ecology and Hydrology, UK water industry and engineering consultants. He led a team of over 60 hydrogeologists, chemists and technicians and developed the research and development strategy for groundwater science. He was Head of Station for the Wallingford Office of BGS. His department was reviewed in 2003 and the research was graded at the highest level.

In 2006 he was appointed Chief Scientist of BGS and a member of the senior leadership team and later to be a member of the three man executive. He developed the 2009-2014 BGS Science strategy and was responsible for the science of about 400 scientists and about £20M of UK science budget expenditure. During his time at BGS his expertise and activity developed in the following areas:

- Conceptual modelling, particularly of the Chalk aquifer, active participation in regional groundwater modelling of the Rivers Darent, Cray and Ravensbourne catchments in the North Downs, Thames, Pang and Lambourn in the Marlborough and Berkshire Downs, and whole Thames Basin, Conceptual models of hydrology of the Eden Catchment.
- Hydrogeology and conceptual modelling of the Cotswold Jurassic Limestones.
- Heterogeneity and scaling problems in the Chalk aquifer.
- Diffuse pollution and trends in groundwater Nitrate concentrations.
- BGS PI for the Changing Water Cycle project: HydEF – Hydrological Extremes and Feedbacks in the Changing Water Cycle.
- Lowland permeable catchment integrated and multidisciplinary science. Project Manager of LOCAR Task Force, NERC project manager (design) for LOCAR project management consortium (£3M infrastructure), project director for groundwater infrastructure implementation (>£1M). Co-investigator on two research grants on LOCAR programme.
- Co-PI on Natural Environmental Research Council (NERC) FREE project - Modelling groundwater flood risk in the Chalk aquifer from future extreme rainfall events.
- Development of teams to develop advanced modelling techniques (object oriented approaches, stochastics and uncertainty) and the development of Integrated Environmental Modelling (IEM), and was a member of the team developing an IEM strategy for the NERC.

Over this period Dr. Peach has been a member of many nation strategy and science boards and committees including; NERC Water Security Knowledge Exchange Programme Steering Committee, to 2013, the Advisory panel for the

Centre for Ecology and Hydrology 2009 to March 2013, Water Resources Panel of Chartered Institution of Water and Environmental Management, 2006-2013, Vice President of the Geological Society of London, 2003-2005, Member of the Council of the Geological Society of London 2002-2005, Chairman of the Hydrogeological Group of the Geological Society of London 2000-2003, Member of the Fellowship and Validation Committee of the Geological Society of London, 1999-2003, Geological representative on the National Capability Advisory Group, 2007-2012, Chairman of the Steering Committee of the UK Groundwater Forum (BGS runs secretariat) 2004-2012, Editor of ICE Water Management Journal, 2008-2011, Member of the Accreditation Committee of the Geological Society of London, 2007 to date.

Dr. Peach has published 47 articles and book chapters and written over 100 reports. He has 443 citations and his H index is 11. He has chaired the NERC STORMS (~£5M) research programme and was a member of the science committee and management committee of the NERC Changing Water Cycle (~£10M) research programme.

He currently lectures on the Imperial College Hydrology MSc course, supervises several Master's student dissertations, and a PhD student. In the past he has supervised several PhD students and externally examined several PhD theses.

His recent consultancy included developing a Groundwater research strategy for the University of Saskatchewan and the province of Saskatchewan and advice to UK engineering consultants.

Statement of Independence and Truth

1. The opinions I have expressed in my Reports represent my true and independent professional opinion. Where I have relied on the observational and monitoring studies under my supervision by the Chilean scientific experts, or data supplied to me by the Republic of Chile, I have noted that in my Report.

2. I understand that my overriding duty is to the Court, both in preparing the two Expert Reports that accompany the Memorial of the Republic of Chile and in giving oral evidence, if required to give such evidence. I have complied, and will continue to comply, with that duty.

3. I have done my best, in preparing the Reports, to be accurate and complete in answering the questions posed by the Republic of Chile under the terms of reference that are reproduced in the Reports. I consider that all the matters on which I have expressed an opinion are within my field of expertise.

4. In preparing these Reports, I am not aware of any conflict of interest, actual or potential, which might impact upon my ability to provide an independent expert opinion.

5. I confirm that I have not entered into any arrangement where the amount or payment of my fees is in any way dependent on the outcome of this proceeding.

6. With respect to facts referred to that are not within my personal knowledge, I have indicated the source of such information.

7. I have not, without forming an independent view, included anything which has been suggested to me by others, including the technical team and those instructing me.

Howard Wheater
Hydrological Engineer

22 June 2017

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Dr. Denis Peach
Hydrogeologist

22 June 2017

LIST OF ANNEXES TO THE MEMORIAL
OF THE REPUBLIC OF CHILE

VOLUMES 2, 3 AND 6

LIST OF ANNEXES TO THE EXPERT REPORTS

VOLUMES 4, 5 AND 6

CERTIFICATION

I certify that the annexes and reports filed with this Memorial are true copies of the documents referred to and that the translations provided are accurate.

Ximena Fuentes T.
Agent of the Republic of Chile
3 July 2017