INTERNATIONAL COURT OF JUSTICE

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

(CHILE v. BOLIVIA)

ADDITIONAL PLEADING OF THE REPUBLIC OF CHILE

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ADDITIONAL PLEADING OF THE REPUBLIC OF CHILE

VOLUME 1

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CHAPTER 1
INTRODUCTION

1.1 This Additional Pleading is submitted in accordance with the time-limits fixed by the Court in its Order of 18 June 2019, directing the submission of an Additional Pleading by the Republic of Chile, limited to the counter-claims presented by the Respondent.

A. Origins and current state of the dispute before the Court

1.2 The dispute between Chile and Bolivia over the Status and Use of the waters of the Silala originated in 1999, when Bolivia first denied the international nature of the Silala River.[1] Prior to that, and for almost a century, both Bolivia and Chile had consistently recognized that the Silala River is an international watercourse.[2]

1.3 Bolivia's change of position in 1999 was not based on any new scientific evidence. Then, between 2000 and 2009, Chile made efforts to engage Bolivia in joint technical studies of the Silala River, in the reasonable expectation that this would allow Bolivia to accept the obvious and previously established legal fact that the River is an international watercourse.[3] These attempts ultimately failed, due to Bolivia's insistence on exclusive ownership of the waters

[1] Chile's Memorial (henceforth "CM"), para. 3.8. See 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, Vol. 2, Annex 27**.

[2] See for a full review of the conduct of the Parties in recognition of the international nature of the Silala River, CM, paras. 4.11-4.66.

[3] CM, paras. 3.16-3.25.

of the Silala and its alleged right to compensation for Chile's century-long use of the waters (the so-called "historic debt"). [4]

1.4 In March 2016, Bolivia's President Evo Morales announced that Chile was "stealing" the waters of the Silala and that Bolivia would present a claim before the Court. This was followed by statements of the Bolivian Minister of Foreign Affairs that the presentation of such claim would take at least two years.[5] Under these circumstances, Chile decided to present a claim before the Court in June 2016, to obtain legal certainty over the nature and use of the Silala River as promptly as possible.

1.5 Only after Chile initiated the present proceedings before the Court did Bolivia for the first time commission scientific studies of the Silala, to be undertaken by the Danish Hydraulic Institute (DHI), acting as Bolivia's expert in the case.[6] This merely confirms that Bolivia's 1999 "volte-face" had no scientific underpinnings but was politically motivated.

1. The dispute has been significantly reduced following Bolivia's Counter-Memorial

1.6 The dispute was significantly reduced following Bolivia's Counter-Memorial of 3 September 2018, in which Bolivia acknowledged the international nature of the Silala River, and that both States have rights and obligations under customary international law with respect to the equitable and reasonable utilization of its water, the obligation not to cause significant harm, and other

[4] CM, paras. 3.24-3.25.

[5] CM, para. 1.8.

[6] Bolivia's Counter-Memorial (henceforth "BCM"), para. 13.

procedural obligations under customary international law relating to international watercourses.[7]

1.7 However, the Counter-Memorial introduced a new contention by Bolivia, of alleged sovereign rights over a portion of the Silala waters which it characterized as "artificial flow".[8] This new and wholly untenable contention is presented as a defence to Chile's principal case, and purports to exclude part of the waters of the Silala from the international law regime.[9] It is also presented as Bolivia's Counter-Claim b), and underpins Counter-Claim c), claiming that any delivery from Bolivia to Chile of this alleged "artificial flow" is subject to the conclusion of an agreement between both States.[10] Counter-Claim a), by which Bolivia claims sovereignty over the artificial channels and drainage mechanisms in its territory,[11] is by contrast not contested by Chile and the Court has no jurisdiction in the absence of a dispute.

1.8 According to Bolivia, the "artificial flow" of the Silala is "produced" by the man-made channels in Bolivian territory, and as such is not subject to the principles of customary international law.[12] The portion of "artificial flow" over which Bolivia claims sovereign rights was estimated by Bolivia's expert DHI in its report annexed to the Counter-Memorial, at 30-40% of the surface flow that crosses the international boundary from Bolivia into Chile.[13] Chile notes that this

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[7] BCM, paras. 16 and 18.

[8] BCM, para. 120.

[9] Ibid.

[10] BCM, para. 181 b) (henceforth also "second Counter-Claim") and c) (henceforth also "third Counter-Claim").

[11] BCM, para. 181 a) (henceforth also "first Counter-Claim").

[12] BCM, para. 120.

[13] BCM, para. 13.

percentage range was reduced to 11-33% in the DHI sensitivity analysis annexed to Bolivia's Rejoinder of 15 May 2019.[14]

1.9 The key point is that Bolivia's distinction between "natural" and "artificial" flow has no basis either in international law or in science and, moreover, runs counter to the increasing need for optimal use of fresh water resources.[15] As Chile explained in its Reply on the Counter-Claims of 15 February 2019, any augmented natural flow, the so-called "artificial flow", resulting from works on Bolivian territory, is solely attributable to acts of Bolivia and could not be the source of legal obligations for Chile.[16] Bolivia cannot somehow benefit from its own conduct to create new categories of sovereign rights over a portion of a shared water resource whose use is governed by the principle of equitable and reasonable utilization and the obligation not to cause significant harm. Chile thus explained in its Reply on the Counter-Claims that the lack of any legal foundation for Bolivia's claims to sovereignty over an "artificial" flow is dispositive of the case and sufficient to reject Bolivia's Counter-Claims b) and c) without any enquiry into the scientific evidence.[17]

1.10 In addition, however, Chile demonstrated important flaws in the DHI modelling set-up, resulting in gross exaggeration of the impact of the channels on the cross-boundary surface flow, by a factor of approximately 20.[18] Chile also explained how a reduction in cross-boundary surface flow as a result of the

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[14] Danish Hydraulic Institute (henceforth "DHI"), *Updating of the mathematical hydrological model scenarios of the Silala spring waters with: Sensitivity analysis of the model boundaries*, April 2019 (henceforth "DHI Sensitivity Analysis"). **Bolivia's Rejoinder** (henceforth "BR")**, Vol. 5, Annex 25**.

[15] Chile's Reply (henceforth "CR"), Chapter 2, in particular Section A "The principles reflected in the Convention on the Law of Non-Navigational Uses of International Watercourses apply to international watercourses and the totality of their waters".

[16] CR, paras. 2.69-2.71.

[17] CR, paras. 1.17 and 3.1.

[18] CR, para. 3.34.

channels in Bolivia (if any) would inevitably be compensated by increased cross-boundary groundwater flow, except for an estimated loss to increased evapotranspiration of no more than 2%, agreed on by both Parties' experts.[19]

1.11 Chile's engagement with the facts and the expert reports presented by Bolivia to support its Counter-Claims b) and c) does not show that "there is a need to look further at the facts" or that the facts are "dispositive of the case", as Bolivia now asserts.[20] They are not. What is dispositive is whether international law recognizes the existence of the alleged "artificial flow." Chile has demonstrated that it does not.

1.12 Chile has nonetheless submitted additional expert reports, and requested the data underlying Bolivia's expert reports, because it takes seriously its obligation as a Party to this proceeding to set the factual record straight, for the benefit of the Court and with a view to any future engagements with Bolivia related to shared water resources.

2. Bolivia's position is further weakened in the Rejoinder

1.13 In its Rejoinder on the Counter-Claims of 15 May 2019, Bolivia continues to contend that customary international law on the use of transboundary watercourses applies "only to the rate and volume of Silala water that flows naturally across the Bolivian-Chilean border".[21] However, it no longer refers to the judicial decisions and State practice relied on in the Counter-Memorial that were conclusively contested by Chile in its Reply, nor does it make any effort to respond to Chile's Reply.

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[19] CR, paras. 3.9 and 3.47. See DHI, *Study of the Flows in the Silala Wetlands and Spring System*, 2018 (henceforth "DHI Report (2018)"). BCM, Vol. 2, p. 267.

[20] BR, para. 7. See also BR, p. 1, heading 1.A, wrongly suggesting Chile's "change of position" on this.

[21] BR, para. 70.

1.14 Instead, Bolivia now claims that its sovereignty over the channels in Bolivian territory "affords" it sovereignty over the "artificial flow" allegedly generated by those channels.[22] This is a *non sequitur* as the legal regime of transboundary watercourses does not follow the territorial sovereignty doctrine invoked by Bolivia. Moreover, the few – and mainly domestic – legal authorities cited by Bolivia in this context are either irrelevant to the law of transboundary watercourses, or do not support Bolivia's case.[23]

1.15 Bolivia seeks additional support for its claim to sovereign rights over the so-called "artificial flow" generated by the channels in Bolivia, in the alleged benefits accruing to Chile from these man-made channels.[24] However, Bolivia seeks to ignore the fact that such benefits, if any, were neither sought nor requested by Chile. The alleged benefits are solely the result of Bolivia's authorization of the 1928 construction of the channels (under the terms of the 1908 Bolivian concession to a British private company), and Bolivia's subsequent decision not to dismantle the channels once it unilaterally terminated the 1908 concession in 1997.[25] This is a further reason why Bolivia's position makes no sense as a matter of customary international law. It follows that Bolivia has no case and that Counter-Claims b) and c) must be rejected.

1.16 Although Bolivia continues to make its Counter-Claims b) and c),[26] it suggests that these will become moot once Bolivia has dismantled the channels on its territory, as proposed under Counter-Claim a).[27] In addition, Bolivia suggests

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[22] BR, p. 38, heading 4.B.1.

[23] BR, paras. 72-77. The referred authorities will be discussed in section 2.A of Chile's Additional Pleading (henceforth "CAP").

[24] BR, paras. 70 and 81-85.

[25] Administrative Resolution N° 71/97 by the Prefecture of the Department of Potosí, 14 May 1997. **CM, Vol. 3, Annex 46**.

[26] BR, p. 56 (Submissions).

[27] BR, para. 100.

that this would also make unnecessary any pronouncement by the Court on Chile's principal claims concerning the nature and the use of the waters of the Silala.[28] This is incorrect.

1.17 The dismantling of the channels and/or restoration of the wetlands in its territory depends on actions (or past omissions) by Bolivia. Such actions (or omissions) cannot somehow render moot the principled disagreement between the Parties over the legal characterization of all the Silala waters. Indeed, Chile would not wish to trouble the Court with this Dispute now that Bolivia has recognized the nature of the Silala River system as an international watercourse, were it not for Bolivia's insistence on the legal existence of an alleged "artificial flow" and its claims to exclusive sovereign rights thereto, contrary to established principles of customary international law applicable to international watercourses.

1.18 Bolivia also states that it is entitled to dismantle the works in its territory "in conformity with its own interests and customary international legal norms governing transboundary watercourses".[29] This is correct and Chile agrees that Bolivia has the right to decide whether and how far to maintain the channels, provided it complies with its obligations under international law, namely (i) to notify, inform and consult Chile with respect to any planned measure and (ii) not to cause significant harm to Chile as the downstream riparian State.

1.19 Bolivia's principal concern in relation to Counter-Claim a) seems to be that Chile's principled position that it is "entitled to its current use of the waters of the Silala River"[30] means that "Bolivia's rights to dismantle the artificial infrastructure could be constrained if its actions resulted in a reduction in the

[28] BR, para. 103.

[29] BR, para. 84.

[30] BR, para. 33, quoting from CM, Submission c).

current flow regime such that it prevents Chile from enjoying its existing uses."31 Bolivia misinterprets Chile's position. Chile says only that the Silala waters it presently uses, and those uses themselves, are consistent with international law, i.e., they qualify as being equitable and reasonable *vis-à-vis* Bolivia. Indeed, Bolivia has not asserted otherwise.[32]

1.20 Thus a reduction (if any) of the cross-boundary surface flow resulting from the dismantling of the channels in Bolivia would not be considered a violation of customary international law unless the obligations that Bolivia has accepted were somehow engaged.[33] Nor would non-man made contamination of the Silala water with larva from insects breeding in the wetlands be considered a violation of these principles.[34]

1.21 Chile considers that Bolivia's sovereignty over the channels in Bolivia is uncontroversial and that there exists no dispute with respect to Counter-Claim a). It has asked the Court accordingly to declare that it has no jurisdiction over Counter-Claim a).[35] In the alternative, Chile asks the Court to declare that Counter-Claim a) is moot or must otherwise be rejected, since Bolivia cannot seek

[31] BR, para. 34.

[32] See BR, para. 23, for Bolivia's recognition that the waters have been used by Chile thus far and that Bolivia has the right to use those waters "to the extent that such uses are consistent with the principle of equitable and reasonable utilization."

[33] BR, para. 20. These obligations include: "'equitable and reasonable utilization of the Silala, prevention of significant harm, cooperation, timely notification of planned measures which may have a significant adverse effect, exchange of data and information and, where appropriate, the conduct of environmental impact assessments.'" Ibid., quoting from CR, para. 1.3.

[34] See BR, para. 43, where Bolivia expresses its concern for the possible sanitary effects of dismantling the channels.

[35] As to Bolivia's argument that Counter-Claim a) is not without object because a decision of the Court "can affect existing legal rights or obligations of the parties, thus removing uncertainty from their legal relations" (BR, p. 20, footnote 65, cite to *Northern Cameroons (Cameroon v. United Kingdom), Preliminary Objections, Judgment, 2 December 1963, I.C.J. Reports 1963*, pp. 33-34), Chile maintains that there is no legal uncertainty since both States agree that Bolivia has sovereignty over its territory and that the referred principles of customary international law apply to the actions of Bolivia *vis-à-vis* the channels in its territory.

from the Court a declaration that is a truism, i.e., that Bolivia has sovereignty over its own territory.[36]

1.22 As to the actual impact of the channels in Bolivia on the cross-border surface flow, the flaws in the DHI model set-up have been further confirmed, and several important additional shortcomings have been identified, by Chile's expert analysis of the modelling data belatedly received on 7 February 2019[37], and the additional modelling data related to the DHI sensitivity analysis, requested by Chile on 27 May 2019 and submitted by Bolivia on 17 June 2019.[38] Among the most relevant finds, Chile's experts confirm that different topographies were used for the different scenarios, of up to 7 m difference: "This is an enormous change in ground level, equivalent to a structure the height of a two-story building spanning the width of the river valley and extending at least 200 m along the river."[39] This is far greater than the changes in channel depth and peat growth that

[36] As to Bolivia's contention that a case is not moot when concessions made by one Party do not dispose of the dispute in its entirety (BR, p. 21, footnote 65, reference to *Southern Bluefin Tuna Case between Australia and Japan and between New Zealand and Japan*, Award on Jurisdiction and Admissibility, Decision of 4 August 2000, UNRIAA, Vol. XXIII, p. 38, para. 46), Chile maintains that, in the present case, the positions of *both* Parties as concerns Bolivia's first Counter-Claim are such that they dispose of the dispute (if any dispute ever existed) in its entirety: Chile agrees that Bolivia has sovereignty over the channels in Bolivian territory and Bolivia agrees that it must comply with customary international law governing transboundary watercourses when it seeks to dismantle those channels (see BR, paras. 35 and 84).

[37] The DHI modelling data were first requested by Chile by letter of 5 November 2018 (**CR, Vol. 2, Annex 99.1**), and again by letters of 30 November 2018 (**CR, Vol. 2, Annex 99.3**) and 21 December 2018 (**CR, Vol. 2, Annex 99.5**). The requested data were finally submitted by Bolivia by letter of 7 February 2019. **CR, Vol. 2, Annex 99.7**. This was too late to be taken into account by Chile's experts in the Reply and Chile reserved its right to refer to these at a later time, see CR, para. 3.4.

[38] Note from the Agent of the Republic of Chile to the Agent of the Plurinational State of Bolivia of 27 May 2019. **CAP, Vol. 2, Annex 100.1**. Note from the Agent of the Plurinational State of Bolivia to the Agent of the Republic of Chile of 17 June 2019. **CAP, Vol. 2, Annex 100.2**.

[39] Muñoz et al., *Assessment of the Silala River Basin Hydrological Models Developed by DHI*, 2019 (henceforth "Muñoz et al. (2019)"), p. 33. **CAP, Vol. 2, Annex XV**.

the scenarios were meant to evaluate.[40] In the informed opinion of Chile's experts, this renders the DHI modelling exercise wholly unreliable and misleading. Indeed, Chile's experts are shocked by the basic errors committed by DHI.[41]

B. The structure of the Additional Pleading

1.23 The structure of this Additional Pleading is as follows: **chapter 2** discusses and rejects Bolivia's claim that its sovereignty over the artificial channels in Bolivia affords it sovereignty over the "artificial flow" allegedly generated thereby; in **chapter 3** Chile addresses the fundamental flaws in the DHI model set-up, this time incorporating in its analysis the model data received from Bolivia on 7 February 2019, as well as the additional model information related to the DHI sensitivity analysis submitted as Annex 25 of Bolivia's Rejoinder. This additional information confirms Chile's earlier conclusion that the percentage of so-called "artificially enhanced flow", if existing at all, is grossly overstated and the outcome of a fundamentally flawed hydrological model.

1.24 This Additional Pleading is supported by a joint expert report by Drs. Howard Wheater and Denis Peach, in turn supported by two underlying studies into the Silala River system that are annexed.

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[40] Wheater, H.S and Peach, D.W., *Impacts of Channelization of the Silala River in Bolivia on the Hydrology of the Silala River Basin – An Updated Analysis*, August 2019 (henceforth "**Wheater and Peach (2019b)**"), pp. 8 and 63. **CAP, Vol. 1, Expert Report**.

[41] **Wheater and Peach (2019b)**, p. 40.

CHAPTER 2
BOLIVIA'S CLAIM TO SOVEREIGN RIGHTS OVER THE "ARTIFICIALLY ENHANCED FLOW" OF THE SILALA RIVER HAS NO BASIS IN INTERNATIONAL LAW

2.1 Chile's Reply devoted a chapter to the proposition that "Bolivia's Claims to the 'Artificially Enhanced Flow' of the Silala River have No Support in International Law and Ignore Key Historical Facts."[42] In its Rejoinder, Bolivia fails to refute, or even contest, Chile's arguments supporting this proposition. Nevertheless, Bolivia continues to cling to its invented distinction between "natural" and "artificial" flows. From all that appears, Bolivia does this because it insists on adhering to its claim that it has sovereignty, in the sense of ownership, over something it calls the "artificially enhanced flow" of the Silala, created by the infrastructure installed by the British company, the Antofagasta (Chili) and Bolivia Railway Company (FCAB), in the late 1920s pursuant to authorization Bolivia itself granted.[43]

2.2 In section 2.A below, Chile responds to Bolivia's untenable theory that sovereignty over the channels in Bolivia affords it sovereignty over the waters allegedly generated by those channels, and the legal authorities relied on by Bolivia in support thereof. In section 2.B, Chile recalls key historical facts related to the construction of the channels that Bolivia has chosen thus far to ignore, and notes the implausibility of Bolivia creating legal rights against Chile based on its own unilateral acts.

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[42] CR, Chapter 2, pp. 9-45.

[43] See for the history of the 1928 channels, CM, para. 4.61 and CR, paras. 2.61-2.64. See for Bolivia's authorization of the construction of the channels, CR, paras. 2.69-2.71. Bolivian authorization of the channel construction is further addressed in Chapter 2.B below.

A. Bolivia's current claim, that sovereignty over hydraulic works in its territory creates sovereign rights over the alleged "artificially enhanced flow" of the Silala River, is unfounded

2.3 Before discussing the legal merits, or lack thereof, of Bolivia's current claim, it bears emphasis that the artificial "enhancement" (if it exists) of the Silala surface flow would result not from water brought in by Bolivia (or anyone else) from outside the natural catchment of the Silala basin (so-called "developed" water), but from slightly increasing the proportion of groundwater that appears as surface water in the river channel. As Chile has previously shown,[44] and as agreed by Bolivia's expert DHI,[45] the groundwater would in any event flow within the aquifer to Chile. Thus, the "enhancement" is fictional: the surface flow may be slightly increased, but the total quantities reaching Chile would ultimately be substantially the same.

1. Territorial sovereignty does not create ownership over a shared natural resource

2.4 In its Rejoinder Bolivia persists in its claim that its "sovereignty over the artificial infrastructure in its territory affords [it] sovereignty over the artificial flows generated by that infrastructure."[46] A moment's reflection demonstrates that this cannot be the case.[47]

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[44] Wheater, H.S and Peach, D.W., *Impacts of Channelization of the Silala River in Bolivia on the Hydrology of the Silala River Basin*, January 2019 (henceforth "Wheater and Peach (2019a)"), pp. 7-8. CR, Vol. 1, pp. 103-104.

[45] DHI Report (2018). BCM, Vol. 5, p. 84: "groundwater level gradients and hydrogeological properties clearly indicate groundwater flow from Bolivia to Chile".

[46] BR, p. 38, heading 4.B.1.

[47] Chile addressed this claim by Bolivia in its Reply. CR, paras. 2.26-2.39.

2.5 None of the water in the Silala River system has been brought in by Bolivia from outside sources. All of the water is generated naturally within the Silala groundwater and topographic catchments. The fact that the water runs through infrastructure in Bolivia, installed with Bolivia's authorization, cannot change the fact that it is Silala water. There is nothing "artificial" about it.

2.6 As Bolivia recognizes, Chile has from the beginning accepted Bolivia's ownership over the infrastructure in its territory.[48] This follows from the fundamental principle of territorial sovereignty. The infrastructure is fixed in place and forms part of Bolivia's territory. Some domestic legal systems would call it a "fixture" or set of fixtures – things, like buildings, that form part of the land and pass to the buyer with the sale of land.[49] Like Bolivia's infrastructure, they cannot be said to be shared with a neighbour.

2.7 But it does not follow that an international watercourse that passes through the infrastructure, constructed with Bolivia's authorization and over which Bolivia has sovereignty, partakes of the sovereign character of that infrastructure. Sovereignty does not somehow "rub off" of water works onto the water they carry. This novel theory is not accepted in international law and, moreover, would be a dangerous and disruptive proposition, given that nearly all of the world's major international watercourses have been subjected to some kind of human intervention.[50] More generally, as Chile has demonstrated,[51] a State cannot, by definition, have exclusive sovereignty over something that is shared

[48] BR, para. 71.

[49] See, e.g., Michael Allan Wolf, 8 *Powell on Real Property* section 57.04, (Matthew Bender, 17 vols., updated quarterly; ISBN: 9780820515502).

[50] Examples abound. To take several regions, there are dams and other works on: the Blue Nile (Africa), the Mekong (Asia), the Danube (Eastern Europe), the Colorado (North America), the Paraná (South America) and the Rhine (Western Europe).

[51] CR, paras. 2.26-2.39.

with another State.[52] In this case, what is shared is the waters of the Silala River system. Those waters include those that pass through the system of channels constructed by the FCAB in the late 1920s. This does not transform them into something over which Bolivia has sovereignty in terms of ownership.

2.8 As Chile noted in its Reply,[53] the *River Oder* case[54] offers useful insights into the validity of claims of exclusive sovereignty over waters of an international watercourse that are, for the time being, situated wholly within the territory of a State. It will be recalled that in that case, despite Poland's territorial sovereignty over portions of an international watercourse, the Permanent Court held that use of the watercourse is not governed by the rule of territorial sovereignty but by the principle of "a community of interest of riparian States".[55] The Permanent Court explained that "this community of interest […] becomes the basis of a common legal right, the essential features of which are the perfect equality of all riparian States in the user of the whole course of the river and the exclusion of any preferential privilege of any one riparian State in relation to the others."[56] While the *River Oder* case involved navigation, the Court applied the

[52] Writers have sometimes resorted to the concept of "limited territorial sovereignty" to describe a State's rights in shared freshwater resources. See, e.g., F.J. Berber, *Rivers in International Law*, pp. 25, et seq., Stevens & Sons, London (1959); L. Caflisch, Règles Générales du Droit des Cours d'Eau Internationaux, 219 *Recueil des Cours* (1989-VII) 9, pp. 55, et seq. (1992); and J. Lipper, Equitable Utilization, in A. Garretson, R. Hayton & C. Olmstead, eds., *The Law of International Drainage Basins*, p. 15, at p. 23, et seq., Oceana, Dobbs Ferry, N.Y. (1967). A State's sovereignty over its territory is said to be "limited" by the obligation not to use that territory in a way that harms other States. This principle was recognized in the *Trail Smelter Arbitration (United States v. Canada)*, 16 April 1938 and 11 March 1941, 13 UNRIAA 1905, at 1965 (1941), which was cited by the tribunal in the *Indus Waters Kishenganga Arbitration (Pakistan v. India)*, Permanent Court of Arbitration, Partial Award of 18 February 2013, para. 449.

[53] CR, para. 2.30.

[54] *Case Relating to the Territorial Jurisdiction of the International Commission of the River Oder (Czechoslovakia, Denmark, France, Germany, Great Britain, and Sweden/Poland)*, 1929, P.C.I.J., (Ser. A) No. 23 (Sept. 10), pp. 5-46.

[55] Ibid., p. 27.

[56] Ibid., p. 27.

community of interest principle to non-navigational uses in the *Gabčíkovo-Nagymaros* case.[57]

2.9 The "perfect equality" of riparian States in the community of interest means that each enjoys equality of right vis-à-vis the other in the use of the shared watercourse. This principle is at the core of the provisions contained in the 1997 UN Convention on the Law of the Non-Navigational Uses of International Watercourses (UNWC or "the Convention"),[58] in particular, the principle that the allocation of rights of the riparians to use an international watercourse is governed by the principle of equitable and reasonable use and the obligation not to cause significant harm.

2.10 The principle of equitable and reasonable use requires that all relevant factors be taken into consideration, including geographical and hydrological factors linked to the territorial sovereignty of the riparian States over the portions of the watercourse located in their territories. Article 6 of the UNWC contains a non-exhaustive list of relevant criteria, and provides that no criterion has preference over the others.

2.11 Equality of right and the related principle of equitable and reasonable use thus preclude Bolivia from asserting territorial sovereignty over Silala waters, whether "enhanced" by infrastructure or not. Just as Poland enjoyed no greater

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[57] *Gabčíkovo-Nagymaros Project (Hungary/Slovakia), Judgment, I.C.J. Reports 1997*, p. 7, at p. 56, para. 85. The Court said there: "Modern development of international law has strengthened this principle for non-navigational uses of international watercourses as well, as evidenced by the adoption of the Convention of 21 May 1997 on the Law of the Non-Navigational Uses of International Watercourses by the United Nations General Assembly." See also *Pulp Mills on the River Uruguay (Argentina v. Uruguay*), *Provisional Measures, Order of 13 July 2006, I.C.J. Reports 2006*, p. 113, at p. 122, para. 39 and p. 130, para. 64, and *Rhine Chloride Arbitration concerning the Auditing of Accounts (The Netherlands/France)*, Permanent Court of Arbitration, Award of 12 May 2014, para. 97.

[58] Convention on the Law of the Non-Navigational Uses of International Watercourses (henceforth "UNWC" or "the Convention"), signed at New York on 21 May 1997, U.N. Doc. A/RES/51/229 (1997). **CM, Vol. 2, Annex 5**.

rights in the Oder's tributaries by virtue of their origin and flow for a significant distance there, Bolivia has no "preferential privilege" in Silala waters by virtue of their origin and flow, for a relatively short distance, there.

2.12 The fact that what Bolivia calls the "artificially enhanced flow" of the Silala is composed of waters of the Silala River, not waters that are somehow imported, combined with the law governing international watercourses as declared by the Court, necessarily excludes any assertion of sovereignty, in the sense of a sole right of control, by Bolivia over any portion of the waters of the Silala.

2. The legal authorities invoked by Bolivia in this context are either irrelevant or do not support its case

2.13 In its Rejoinder Bolivia attempts to bolster its case for sovereignty over what it characterizes as the "artificially enhanced" surface flow of the Silala River by citing various legal authorities. As was the case with the authorities relied on in Bolivia's Counter-Memorial, these are of no help to Bolivia because they are either inapposite to the present case or do not support Bolivia's argument.

2.14 In its attempt to persuade the Court that a riparian State may claim ownership over the "artificially enhanced" waters of an international watercourse, Bolivia relies on two domestic decisions of courts of the State of California, United States of America (USA), one by an intermediate court of appeal from 2012[59] and the other by the California Supreme Court from 1908.[60]

2.15 The first case involved storm water that was stored in a reservoir. The court classified this stored water as "salvaged" water, which according to

[59] *City of Santa Maria et al. v. Adam et al.*, Court of Appeal, Sixth District, California, 211 Cal. App. 4th 266, 149 Cal. Rptr .3d 491 (2012).

[60] *Pomona etc. Co. v. San Antonio etc. Co.*, Supreme Court of California, 152 Cal. 618 (1908).

California law is "water that is saved from waste as when winter floodwaters are dammed and held in a reservoir."[61] Under California law salvaged water is owned by the party that created it. The present case does not involve storm water or any other form of water saved from waste by being held in a reservoir. It therefore does not involve "salvaged water" as defined by that California court and law. This case is thus inapposite to the present one and of no help to Bolivia.

2.16 The second case also involved "salvaged" or "rescued" water. It noted the principle of California law that as long as a downstream user receives the quantity of water it is entitled to receive, it may not complain that an upstream user increased the quantity of water available to it through salvaging or developing the water.[62] This case, also, is of no help to Bolivia. Again, no "salvaged" or "developed" water is involved here.

2.17 The more fundamental difficulty with Bolivia's reliance on these domestic cases is that international law does not recognize the concepts of "salvaged" or "developed" water. These are domestic law expressions that not only describe the manner in which the water was collected by a party, but also carry with them legal rules about the allocation of water rights and the accommodation of competing uses between water users. These domestic legal rules do not necessarily follow the rule of equitable and reasonable use that is applicable to riparian States under international law. Thus the principle stated in the 1908 California case, that a downstream party may not complain so long as it receives the pre-determined volumetric allocation to which it is entitled, is irrelevant to the rights of co-riparians to an international watercourse under customary international law.

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[61] BR, para. 74.

[62] BR, para. 75.

2.18 Domestic law cases decided in similar factual situations may possibly shed light on the implications of claims, such as now made by Bolivia, to except part of the flow of a river from an otherwise established legal regime. In that respect, a more apposite domestic law case, in addition to the one discussed in Chile's Reply,[63] is *Southeastern Colorado Water Conservancy District v. Shelton Farms, Inc.,*[64] a 1974 *en banc* decision of the Colorado Supreme Court, USA. In that case, an upstream riparian landowner, Shelton, cleared areas along the river of phreatophytes (water-consuming plants) and filled in a marshy area. "Shelton claimed he had saved approximately 442 acre-feet [545,198 cubic metres] of water per year, previously consumed by phreatophytes or lost to evaporation, which is not available for beneficial use. […] He asked for the right to augment his previous water rights with the salvaged water […]."[65]

2.19 The Colorado Supreme Court denied Shelton any rights in the water. It reasoned that "in this situation unrestrained self-help to a previously untapped water supply would result in a barren wasteland," because of the incentive such a right would create to denude river banks of trees and other plant growth.[66] But such self-help could also take the form of installing lined canals or channels to enhance available water supplies. Like the removal of phreatophytes, this could,

[63] This case is *R.J.A., Inc. v. The Water Users Association of District No. 6, et al.*, Supreme Court of Colorado, Sep. 10, 1984, 690 P.2d 823 (1984), discussed in CR, paras. 2.8-2.9. As explained in the Reply, the case involved facts that are similar to those of the present case.

[64] *Southeastern Colorado Water Conservancy District v. Shelton Farms, Inc.,* 187 Colo. 181, 529 P.2d 1321 (1975). This case was referred to in footnote 34 of CR, at p. 13.

[65] Ibid., p. 184.

[66] Ibid., p. 191. The court memorably stated that if Shelton were to prevail, "the use of a power saw or a bull-dozer would generate a better water right than the earliest ditch on the river." Ibid., p. 191. (The court's reference to the "earliest ditch" refers to the prior appropriation doctrine applied in Colorado, in which "first in time is first in right.")

in the words of the court, "create a super class of water rights never before in existence."[67]

2.20 Bolivia also refers to the European Union (EU) Water Framework Directive of 2000.[68] It is not clear to Chile how this helps Bolivia, or the Court. Bolivia quotes definitions of two terms ("Artificial water body" and "Heavily modified water body"), neither of which appears to apply to the Silala River. The Silala is not "a body of surface water created by human activity" and is thus not an "Artificial water body;" nor is it "a body of surface water which as a result of physical alterations by human activity is substantially changed in character," and is thus not a "Heavily modified water body." Even if the Silala qualified under one of these definitions, the EU Water Framework Directive, if applicable, *quod non*, does not contain rules that would provide guidance in this case. While it is no doubt an important regional instrument in the field of water management, the EU Water Framework directive is inapposite to the present case.

3. *Bolivia's claim to sovereign rights over the "artificially enhanced flow" of the Silala River runs counter to the principles reflected in the Convention on the Law of the Non-Navigational Uses of International Watercourses, in particular, the principle of equitable and reasonable utilization*

2.21 The Convention on the Law of the Non-Navigational Uses of International Watercourses (UNWC) is considered in material parts to reflect rules of customary international law, and Bolivia has accepted in its pleadings the

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[67] Ibid., p. 190. A practical difficulty noted by the Colorado Supreme court was the technical one of determining the amount of water salvaged, or saved, through the actions of upstream users. This would be an issue in the present case, as well, if Bolivia were to leave the infrastructure installed by the FCAB in place.

[68] BR, para. 76.

customary nature of the basic obligations reflected in the Convention.[69] Foremost among these obligations is that of equitable and reasonable utilization, recognized in its Article 5. The Court confirmed the fundamental nature of that principle in its judgment in the *Gabčíkovo-Nagymaros* case,[70] decided four months after the conclusion of the UNWC, in which it cited a State's "basic right to an equitable and reasonable sharing of the resources of an international watercourse."[71] The Court in that case also referred to the Convention as evidence of modern development of international law that has strengthened the principle of community of interest for non-navigational uses of international watercourses.[72]

2.22 Assertions of sovereignty over shared freshwater resources, like the Silala River, in the sense of property rights, are antithetical to the principles expressed in the UNWC, and indeed, everything the Convention – and thus, the corresponding rules of customary international law – stands for. It is impossible to reconcile the concept of a community of interest with assertions of exclusive sovereignty over that in which such a community exists.

2.23 The only time the word "sovereign" is used in a substantive provision of the Convention is in Article 8, on the General Obligation to Cooperate. Article 8(1) of the Convention 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."[73] Thus, "sovereign" equality is a basis of cooperation, not a basis for a State to go its own way.

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[69] This may be inferred from Bolivia's repeated reliance on the Convention, and its preparatory work, beginning with its first written pleading. See BCM, chapter 3, pp. 57 et seq.

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

[71] Ibid., p. 54, para. 78.

[72] Ibid., p. 56, para. 85.

[73] UNWC, art. 8(1). **CM, Vol. 2, Annex 5**.

2.24 The "artificially enhanced flow" over which Bolivia asserts sovereignty, is solely Silala water. It originates, and forms part of, the Silala River system. It was not brought in by Bolivia from outside the basin. It does not even consist of captured storm water, such as that involved in some of the domestic-law cases on which Bolivia relies. It is Silala River water, even if it passes through infrastructure that, according to Bolivia, maximizes surface flow. As such, it is governed by the rules of customary international law reflected in the UNWC.

2.25 Bolivia in its Rejoinder challenges Chile's reference to Article 25 of the UNWC, entitled "Regulation."[74] Chile explained in its Reply that regulation of watercourses in the sense of Article 25[75] is a very common practice, and that many forms of such regulation may have the effect of optimizing surface flows – whether through lining or straightening channels, fortifying river banks, or other such works. And yet these works have not heretofore to Chile's knowledge given rise to claims of sovereignty over optimized flows.

2.26 Bolivia asserts that "Chile does not engage in any effort to show how [Article 25] applies to non-state parties to the Convention."[76] Apart from the fact that the relevant provisions of the UNWC are recognized as a reflection of the basic rules of international law governing the non-navigational uses of international watercourses, something Bolivia has accepted in its pleadings,[77] Chile's point in referring to Article 25 was not so much to deploy it as a reflection of a legal rule as to indicate a general and widespread practice of installing

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[74] BR, para. 72. Chile refers to Article 25 UNWC in CR, para. 2.7.

[75] Article 25 defines the term "regulation" to mean: "the use of hydraulic works or any other continuing measure to alter, vary or otherwise control the flow of the waters of an international watercourse." UNWC, art. 25(3). **CM, Vol. 2, Annex 5**.

[76] BR, para. 72.

[77] See BCM, para. 133, for Bolivia's recognition that it is bound by those provisions of the UNWC that reflect customary international law.

infrastructure in international watercourses that may have the effect of augmenting the volume of those watercourses.

2.27 Bolivia maintains that Article 25 "was never intended to address the augmentation of the volume of the watercourse flow through artificial works, but only […] the augmentation of the efficiency and quality."[78] Yet the Convention's definition of the term "regulation" leaves ample room for flow augmentation through artificial works. Article 25(3) of the Convention defines "regulation" to mean "the use of hydraulic works or any other continuing measure to alter, vary or otherwise control the flow of the waters of an international watercourse." Variation of the flow could obviously be by way of augmentation.

2.28 Indeed, it is clear from the *travaux preparatoires* that the International Law Commission took into account, among other things, the set of nine articles on the regulation of the flow of international watercourses adopted by the International Law Association (ILA) in 1980 in preparing Article 25.[79] The ILA's articles define "regulation" to mean: "continuing measures intended for controlling, moderating, *increasing* or otherwise modifying the flow of the waters in an international watercourse for any purpose; […] " (emphasis added).[80] Nothing in the ILC's commentary to Article 25 indicates disagreement with this definition.

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[78] BR, para. 72.

[79] The ILA's articles are referred to in the ILC's commentary to the U.N. Convention, 1994 *Yearbook of International Law*, vol. II, part two, p. 127, footnote 393. This footnote contains a cross-reference to the Fifth Report of the Special Rapporteur, where the ILA's articles are set forth in full. Stephen C. McCaffrey, Fifth Report on the Law of the Non-Navigational Uses of International Watercourses, 1989 *Yearbook of International Law*, vol. II, part 1, p. 91, at p. 125 (henceforth "Fifth Report"). It is clear from the Convention's *travaux* that the ILC's work was generally influenced by that of the ILA, particularly the ILA's Helsinki Rules on the Uses of the Waters of International Rivers, ILA, Report of the Fifty-Second Conference, Helsinki, 1966, p. 484, ILA, London, 1966.

[80] Fifth Report, p. 125.

2.29 There is therefore no evidence that either the ILC or the diplomatic conference that negotiated the UNWC on the basis of the ILC's articles[81] intended to (a) exclude increased flows resulting from regulatory works from the concept of "regulation," or (b) accept that the State in which regulatory works are located has sovereignty over any increased flows. This confirms the conclusion that flow augmentation is not excluded from the ambit of Article 25.

2.30 In addition, Bolivia's argument that Article 25 was intended to address "only […] the augmentation of the efficiency and quality" of the volume of the watercourse flow through artificial works, not "the augmentation of the volume of the watercourse flow through artificial works,"[82] collapses on itself since augmentation of efficiency would ordinarily have the effect of increasing volume.

2.31 The use of efficiency as part of an equitable utilization analysis is anticipated by Article 6 of the UNWC, which in subparagraph (f) refers to "[c]onservation […] and economy of use of the water resources of the watercourse" as possibly relevant factors. This would make sense particularly in arid environments such as that of the Silala River, which is located in one of the driest areas on Earth. More efficient use leaves more water to be used by the riparians. But contrary to Bolivia's assertion, a State implementing more efficient methods to use water does not thereby acquire ownership over the surplus waters generated by more efficient methods of use.

2.32 As a consequence of these rules of international law, Bolivia has an obligation to utilize the waters of the Silala River system in an equitable and

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[81] At the conclusion of its work, the conference adopted the following "Statement of Understanding": "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." U.N. Doc. A/51/869, 11 April 1997.

[82] BR, para. 72.

reasonable manner. Equitable and reasonable utilization cannot be determined unilaterally or in the abstract. It must be arrived at through consideration of all relevant factors by the States involved,[83] with a view to achieving a solution that is fair, balanced, and reasonable.

4. Bolivia's right to dismantle the channels is not exempted from its obligation under customary international law not to cause significant harm

2.33 In a rather confused section of its Rejoinder entitled "Bolivia's Right to Dismantle the Artificial Infrastructure and Significant Harm Considerations,"[84] Bolivia commits to conduct any work it may undertake to preserve the wetlands in Bolivia, including the possible removal of the stone-lined channels installed in the 1920s, in a manner consistent with its obligations under international law: "If Bolivia sought to dismantle the artificial infrastructure that was installed within its territory and return the Silala to its natural, pre-artificial state, it would do so in accordance to its rights and obligations under international law and in a manner that does not create significant transboundary environmental harm."[85]

2.34 However, having recognized the obligation not to cause significant transboundary harm, and having pledged to follow it, Bolivia proceeds to state that "it is [the obligation's] application to the particular circumstances of the Silala that should be further clarified."[86] Bolivia then states that "[t]he obligation not to cause significant harm must be determined proportionally by balancing

[83] UNWC, art. 6. **CM, Vol. 2, Annex 5**.

[84] BR, p. 16, heading 3.B.2.

[85] BR, para. 35.

[86] Ibid.

against the rights of the acting State to pursue its own interests and priorities, such as development and environmental protection and restoration."[87]

2.35 What Bolivia intends by this sentence is not entirely clear. Bolivia seems to be saying that the obligation not to cause transboundary harm must be balanced "against the rights of the acting State to pursue its own interests and priorities, such as development and environmental protection and restoration."[88] If taken literally, such an interpretation could defeat the "no-harm" obligation itself, as it would allow a State to observe the no-harm obligation unless and to the extent that its interests and priorities dictate otherwise. This amounts, once again, to seeking refuge in sovereignty, in effect asserting a sovereign right in Bolivia to do essentially whatever it believes is in its best interests, notwithstanding rules of international law that dictate otherwise.

2.36 Bolivia seeks support for its interpretation of the no-harm obligation first from the arbitral award in the *Indus Waters Kishenganga Arbitration* and second from the Court's judgment in the *Pulp Mills on the River Uruguay* case.

2.37 Chile would first note that both of these cases involved treaties and the interpretation thereof, the Indus Waters Treaty of 1960[89] and the Statute of the River Uruguay of 1975.[90] Both treaties establish joint commissions between the States involved and are known for being well-crafted and, especially in the case of the Indus Waters Treaty, highly detailed. General lessons from the cases should therefore be drawn with caution.

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[87] BR, para. 36.

[88] Ibid.

[89] Indus Waters Treaty, Karachi, 19 September 1960, entered into force on 1 April 1960, 419 UNTS, No. 6032, p. 125.

[90] Statute of River Uruguay, 26 February 1975, entered into force on 18 September 1976, 1295 UNTS, No. 1-21425, p. 340.

2.38 With respect to the *Kishenganga* case, Bolivia deploys the case in an effort to support its assertion that the no-harm rule should be balanced against the acting State's interests and priorities in the field of development, in particular.[91] Bolivia states that the *Kishenganga* Court of Arbitration "asserted that, '[t]he requirement to avoid adverse effects on Pakistan's agricultural and hydroelectric uses of the waters of the Kishenganga/Neelum cannot, however, deprive India of its right to operate the [Kishenganga Hydroelectric Plant]".[92] Interestingly, this passage appears in a section of the Tribunal's Partial Award entitled "(b) The preservation of downstream flows."[93]

2.39 Unfortunately, Bolivia offers no explanation as to how the quoted passage helps its case. The requirement and right referred to in the quoted passage derive not from customary international law, but from the Indus Waters Treaty, specifically, Paragraph 15(iii) of Annexure D thereof. In the words of the Court of Arbitration, this provision "gives rise to India's right to construct and operate hydro-electric projects involving inter-tributary transfers but obliges India to operate those projects in such a way as to avoid adversely affecting Pakistan's 'then existing' agricultural and hydro-electric uses."[94] India is upstream on the Kishenganga River and Pakistan downstream. Thus, to the extent that the award is at all applicable to the present case, Bolivia would be in the position of India and Chile in that of Pakistan, and the quoted passage would favour Chile.

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[91] BR, para. 36.

[92] Ibid.

[93] *Indus Waters Kishenganga Arbitration (Pakistan v. India)*, Permanent Court of Arbitration, Partial Award of 18 February 2013, p. 168.

[94] Ibid.

2.40 Bolivia then turns to the *Pulp Mills* case. Bolivia invokes Article 27 of the Statute of the River Uruguay, the treaty involved in the *Pulp Mills* case.[95] Unfortunately, however, Bolivia seems to have misread the article. Bolivia states:

> "Article 27 . . . permits State Parties to use the river's water within their respective jurisdiction for permissible purposes without the obligation of complying with certain procedural requirements found in earlier provisions of the Statute, even 'when the use is liable to affect the regime of the river or the quality of its waters.'"[96]

2.41 What Article 27 actually states is the following:

> "The right of each Party to use the waters of the river, within its jurisdiction, for domestic, sanitary, industrial and agricultural purposes shall be exercised without prejudice to the application of the procedure laid down in articles 7 to 12 when the use is liable to affect the regime of the river or the quality of its waters." [97]

2.42 Thus, contrary to what Bolivia suggests, Article 27 preserves the procedure for notification of the Commission established by the treaty. It does not permit the parties to use Uruguay River waters within their respective jurisdictions without having to comply with the notification procedure.

2.43 In fact, quite the contrary, according to the Court:

> "Regarding Article 27, it is the view of the Court that its formulation reflects not only the need to reconcile the varied interests of riparian States in a transboundary context and in particular in the use of a shared natural resource, but also the need to strike a balance between the use of the waters and the protection

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[95] BR, para. 37.

[96] Ibid.

[97] Statute of River Uruguay, Article 27, 1295 UNTS, No. 1-21425, p. 343.

> of the river consistent with the objective of sustainable development.[98]

2.44 Moreover, despite the treaty-based nature of the right of usage in this case, the Court elaborates as follows on the effect of its interpretation of Article 27 in a sentence following the one quoted by Bolivia:

> "The Court wishes to add that such utilization could not be considered to be equitable and reasonable if the interests of the other riparian State in the shared resource and the environmental protection of the latter were not taken into account."[99]

2.45 This would presumably exclude the kind of "balancing" Bolivia seems to have in mind, in which a State's "rights […] to pursue its own interests and priorities, such as development […]," could prevail over its no-harm obligation.[100]

2.46 The Court then concludes as follows with respect to Article 27:

> "Consequently, it is the opinion of the Court that Article 27 embodies this interconnectedness between equitable and reasonable utilization of a shared resource and the balance between economic development and environmental protection that is the essence of sustainable development."[101]

2.47 Although Bolivia quotes most of the latter passage,[102] the quote actually confirms that Article 27 is anything but the *carte blanche* that Bolivia portrays it to be. Therefore, Article 27 of the Statute of the River Uruguay, if anything, supports Chile's case by requiring that normal procedures of prior notification and consultation be followed when a party, here Bolivia, uses the

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[98] *Pulp Mills on the River Uruguay (Argentina v. Uruguay), Judgment, ICJ Reports 2010*, p. 14, p. 74, para. 177.

[99] Ibid., p. 75, para. 177.

[100] BR, para. 36.

[101] *Pulp Mills on the River Uruguay (Argentina v. Uruguay), Judgment, ICJ Reports 2010*, p. 14, p. 75, para. 177.

[102] BR, para. 37.

waters of the river, "within its jurisdiction, for domestic, sanitary, industrial and agricultural purposes […]."[103]

2.48 A more charitable interpretation of Bolivia's proposed "balancing" exercise might be that the obligation not to cause transboundary harm must be applied not in an absolute manner, but in such a way as to permit the "acting State" to pursue in a reasonable way its legitimate interests. If this is just another way of saying that the no-harm obligation is one of due diligence, which the Court has repeatedly made clear,[104] Chile has no difficulty with it.

2.49 And yet the Court's formulation of the obligation would seem to be considerably more exacting than Bolivia suggests. Quoting from its judgment in *Pulp Mills*, the Court in the joined cases of *Certain Activities* and *Construction of a Road*, stated:

> " 'the 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. 22). A State is thus 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.'(*Judgment, I.C.J. Reports 2010 (I)*, pp. 55‑56, para. 101.)"[105]

2.50 Thus Bolivia has an obligation under customary international law to "use all the means at its disposal" to avoid activities in relation to the Silala River

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[103] Statute of River Uruguay, Article 27, 1295 UNTS, No. 1-21425, p. 343.

[104] See, e.g., *Pulp Mills on the River Uruguay (Argentina v. Uruguay), Judgment, ICJ Reports* 2010, p. 14, at pp. 55-56, para. 101, and p. 79, para. 197.

[105] *Case concerning Certain Activities Carried Out by Nicaragua in the Border Area (Costa Rica v. Nicaragua)* and *Case concerning Construction of a Road in Costa Rica Along the San Juan River (Nicaragua v. Costa Rica), Judgment, ICJ Reports* 2015, p. 665, at p. 706, para. 104.

causing significant harm to Chile. This is not an absolute obligation of result, but one of due diligence. However, it is clear that it would not be permissible for a State to negate the obligation by invoking "its own interests and priorities, such as development and environmental protection and restoration"[106] as a justification for causing transboundary harm.

2.51 Bolivia concludes the section by stating that: "Whether Bolivia decides to remove the drainage mechanisms and artificial channels, to utilize Silala water for domestic or economic activities, or to take other action related to the Silala within its borders lies within Bolivia's sovereign rights."[107]

2.52 The decision to do these things unquestionably lies within Bolivia's sovereign rights. However, as has been seen, Bolivia's decisional sovereignty with respect to matters within its borders does not insulate it from responsibility for breach of the obligation not to cause significant transboundary harm. And, in addition, Bolivia's decisional sovereignty does not exempt it from the Court's declaration that a State's utilization of shared waters within its jurisdiction "could not be considered to be equitable and reasonable if the interests of the other riparian State in the shared resource and the environmental protection of the latter were not taken into account."[108] Thus, if and when Bolivia dismantles the infrastructure in its territory, it must do so in a manner that complies with its obligations under customary international law, including its obligation not to cause significant harm to Chile.

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[106] BR, para. 36.

[107] BR, para. 38.

[108] *Pulp Mills on the River Uruguay (Argentina v. Uruguay), Judgment, ICJ Reports* 2010, p. 14, p. 75, para. 177.

B. Bolivia continues to ignore key historical facts, most importantly its own authorization of the channels in Bolivian territory

2.53 In its Reply, Chile pointed out four key facts that further undermine Bolivia's Counter-Claims and that thus far have been ignored by Bolivia:

(a) Bolivia's century-long practice recognising the Silala as a transboundary watercourse without distinguishing between "natural" and "artificial" flow;

(b) The fact that the waters of the Silala were licensed in Chile to British company FCAB in 1906, prior to the 1908 Bolivian concession and the 1928 excavation of the FCAB channels, showing that the waters of the Silala flowing into Chile were capable of exploitation in Chile without the channels in Bolivian territory;

(c) The fact that the 1928 channels were constructed in Bolivia by FCAB with Bolivian authorization, and are therefore a consequence of Bolivia's own sovereign acts, and

(d) Bolivia's decision not to remove the channels and restore the wetlands in its territory, as it could have done after the termination of the 1908 Bolivian concession in 1997.[109]

2.54 In its Rejoinder, Bolivia says nothing about its century-long silence on the alleged existence of "artificial water". As to the remaining three issues, Bolivia either distorts historical fact or simply continues to ignore their legal relevance.

[109] CR, para. 2.52.

1. *Bolivia wrongly suggests that the 1928 channels already existed at the time of the 1906 Chilean concession*

2.55 With respect to the 1928 channels, Bolivia suggests that these already existed at the time of the 1906 Chilean concession, together with two intakes (dams), one in Bolivian and one in Chilean territory, presumably citing from the 1906 concession as registered on the website of the Chilean Direction-General of Water (DGA).[110]

2.56 Bolivia is wrong and its reference to the entry on the DGA website is misleading. The DGA website does not describe the infrastructure as existing at the time of the 1906 Chilean concession, but as it existed in 1990, when FCAB's water rights under the 1906 Chilean concession (which did not contain a volume restriction) were adjusted to the modern Chilean Water Code and fixed at 237 l/s.[111] Moreover, Chile has demonstrated that the first intake and pipeline were constructed in 1910 and that the earth channels were excavated years after that, in 1928, for sanitary reasons.[112] Bolivia has not proven otherwise and the entry on the DGA website does not support its case.

2. *Bolivia cannot create obligations for Chile, including the obligation to negotiate "delivery" and compensation of an alleged "artificial flow", by its own actions and/or omissions in relation to the channels in its territory*

2.57 Bolivia maintains silence on the fact that it authorized the channels in Bolivian territory under the 1908 Bolivian concession to the British company

[110] BR, para. 48, with reference to the website of Chile's Direction General of Water (DGA), 2019. **BR, Vol. 5, Annex 28**.

[111] See DGA website entry, BR, Vol. 5, p. 162.

[112] CM, paras. 2.22 and 2.25; see also CR, paras. 2.61-2.64. Bolivia's assertion that the channels' sanitary purposes were a mere pretext (BR, para. 43), is gratuitous and has no basis in any historic documentation.

FCAB.[113] This is surprising, because Bolivia attaches important legal consequences to the existence of the channels in Bolivia, claiming sovereign rights on the "artificial" flow allegedly "engineered" or "produced" by the channels in Bolivia (Counter-Claim b)), and corresponding legal obligations for Chile related to the (albeit only future)[114] delivery of this so-called "artificial flow" (Counter-Claim c)).

2.58 Bolivia never convincingly explains why the unilateral installation of infrastructure that regulates the Silala River in its territory should give it rights against Chile on the optimized flow of said watercourse, when Chile played no part in the decision to install that infrastructure or in the implementation of that decision. Following the accepted general principles of *res inter alios acta* and *pacta tertiis nec nocent nec prosunt*, legal doctrine is unanimous that "a State can act unilaterally in exercise of its sovereign rights in order to reaffirm its rights, but not in order to acquire new rights by imposing obligations on third parties without the latter's consent."[115]

2.59 Bolivia's default position seems to be that it is entitled to a share of the benefits that, according to Bolivia, Chile is accruing from the channels in Bolivia. In particular, Bolivia claims that Chile has benefitted from receiving additional surface flow that otherwise would have entered Chile as groundwater

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[113] Nor does Bolivia refer to Note N° GMI-656/99 from the Ministry of Foreign Affairs of Bolivia to the General Consulate of Chile of 3 September 1999, in which it stated that the 1908 Bolivian concession was granted to a private company (FCAB) and not to the Chilean State and that all actions undertaken by that company were in the private sphere and with full acknowledgement of the Bolivian jurisdiction. See for Chile's discussion of this point, CR, para. 2.70. The Note was submitted by Chile as **CM, Vol. 2, Annex 27**.

[114] See BR, para. 100: "Contrary to Chile's assertion, Counter-Claim c) relates to the conclusion of an agreement between the parties on the conditions and modalities of future delivery of artificially-flowing Silala waters from Bolivia to Chile."

[115] Third report on unilateral acts of States, by Mr. Victor Rodríguez Cedeño, Special Rapporteur, Document A/CN.4/505 of 17 February 2000, para. 54.

and would have been more costly to exploit.[116] Chile notes that numerous springs in Chile contribute to the surface flow along the course of the Silala River and that some of the "additional groundwater" may emerge naturally. Moreover, even if it were the case that Chile benefitted from the channels (Chile's experts do not confirm a relevant increase in surface flow as a result thereof), this is still a *de facto* situation that resulted from Bolivia's own unilateral acts. It cannot constitute the basis for rights and obligations between Bolivia and Chile vis-à-vis the waters of the Silala, different from those arising from customary international law regarding international watercourses.

2.60 In this context, Bolivia also claims that it is under no obligation to maintain the infrastructure in Bolivian territory, absent any agreement between Bolivia and Chile on the benefit accruing therefrom.[117] Chile has already confirmed in its Reply that it does not disagree with Bolivia's (unremarkable) statement that a State has no right to require another State to install or maintain infrastructure for its benefit, but that this is irrelevant since Chile never requested Bolivia to install the channels in the first place.[118] Whether or not Chile obtained any benefits from the channels as a matter of fact, is equally irrelevant. It cannot be the source of an obligation for Chile to agree on "formulas for mutual benefit", as Bolivia seems to suggest.[119]

3. Any damage caused to the wetlands in Bolivian territory is attributable to Bolivia, not Chile

2.61 Bolivia dedicates a significant section of its Rejoinder (pp. 22-31) to describe the magnitude and characteristics of the channels in Bolivian territory.

[116] BR, para. 83.

[117] BR, para. 84.

[118] CR, para. 2.49.

[119] BR, para. 85.

The declared purpose of this section is to illustrate the impact that the waterworks, if only due to their extension, must have had on the natural flow of the Silala River.[120]

2.62 To prove its point, Bolivia submits with its Rejoinder two studies of evaluation of environmental impacts in the Silala, by Bolivian non-governmental organization FUNDECO.[121] FUNDECO estimates the current extension of the wetlands at 0.76 hectare,[122] in the same range as the 0.6 hectare estimation of the Ramsar Advisory Mission report, previously submitted by Bolivia.[123] Chile notes that DHI agrees with Chile that the Ramsar low estimate of 0.6 hectare is not credible and that "it seems that the areas in the Ramsar report are not reflecting the full wetland".[124]

2.63 A methodological flaw common to the FUNDECO and the Ramsar reports is the absence of a natural ecological baseline of the wetlands, prior to the excavation of the 1928 channels. This limitation was acknowledged in the Castel study, commissioned (but not submitted) by Bolivia, which refrained from estimating the wetland extension prior to the channelization in the absence of evidence.[125] Chile notes that the Castel study does not support Bolivia's thesis of progressive degradation.[126]

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[120] BR, para. 47.

[121] FUNDECO, *Study of Evaluation of Environmental Impacts in the Silala*, May 2018 (henceforth "FUNDECO Study of Evaluation"). **BR, Vol. 3, Annex 23.3**. FUNDECO, *Study of Evaluation of Environmental Impacts in the Silala, Palynology*, 2018 (henceforth "FUNDECO Study of Evaluation Palynology"). **BR, Vol. 3, Annex 23.4**.

[122] FUNDECO Study of Evaluation, pp. 7 and 55. BR, Vol. 3, pp. 13 and 61.

[123] Ramsar Convention Secretariat, Report Ramsar Advisory Mission No 84, Ramsar Site Los Lípez, Bolivia, 2018. **BCM, Vol. 5, Annex 18**.

[124] DHI, *Analysis and assessment of Chile's reply to Bolivia's counter claims on the Silala Case*, March 2019 (henceforth "DHI Analysis of Chile's Reply", submitted as **BR, Vol.5, Annex 24**), p. 35. BR, Vol. 5, p. 41.

[125] Ana Paola Castel, *Multi-Temporal Analysis through Satellite Images of the High Andean Wetlands (bofedales) of the Silala Springs, Potosí – Bolivia*, September 2017 (henceforth

2.64 The Castel study points out significant inter-annual and seasonal fluctuations in the wetlands extension.[127] This factor is not taken into account in the FUNDECO studies. According to Bolivia's expert DHI, FUNDECO's failure to consider the difference between dry season and wet season vegetation, "might cause the wrong interpretation of the data".[128] DHI also questions the methodology used by FUNDECO to estimate the extension of the vegetation cover of the wetlands.[129]

2.65 FUNDECO attributes the degradation of the wetlands directly to the channelization in Bolivia: "This period of desiccation began around 1908, which is a clear sign of the effects that canalization had on the Silala springs".[130] Chile notes that FUNDECO is apparently unaware that the FCAB channels were excavated in 1928, twenty years after the 1908 Bolivian concession, and therefore could not explain an alleged "period of desiccation [that] began around 1908". [131]

2.66 FUNDECO's single-cause theory for the degradation of the wetlands is not shared by Bolivia's expert DHI. Indeed, DHI notes that FUNDECO fails to take into account other possible factors for desiccation, such as potential climatic changes during the last 100-120 years, which it says may have contributed to the

"Castel"), p. 38. CR, Vol. 2, p. 271. The Castel study was cited and referenced in the DHI Report (2018). Chile requested the Castel study, together with all other documents referred to or relied on in Annexes 17 and 18 of the Counter-Memorial that are not publicly available, in a letter to the Agent of Bolivia of 5 November 2018. A first set of documents was submitted by Bolivia on 22 November 2018, including the Castel study. Chile submitted a full translation of the Castel study as **CR, Vol. 2, Annex 98**.

[126] CR, para. 3.42.

[127] Castel, p. 38. CR, Vol. 2, p. 271.

[128] DHI, *Technical Analysis and Independent Validation Opinion of Supplementary Technical Studies concerning the Silala Springs*, December 2018 (henceforth "DHI Technical Analysis", submitted as **BR, Vol. 2, Annex 23**), p. 22. BR, Vol. 2, p. 96.

[129] DHI Technical Analysis, p. 34: "All analysed cores are taken from the central part of the valleys and cannot be used to estimate the extension of the vegetation cover for the bofedales." BR, Vol. 2, p. 108.

[130] FUNDECO Study of Evaluation Palynology. BR, Vol. 3, p. 142.

[131] Ibid.

observed changes in the wetlands.[132] DHI also suggests that the more advanced desiccation process in the 1950s and 1960s reported by FUNDECO "can be taken as an indicator that natural variation may also be a substantial part of the reason for the observed changes".[133] Chile's experts point out that cattle grazing may also be a relevant factor, based on interviews with the local community reported by FUNDECO.[134] Chile's experts conclude that "causal association with channelization of the wetlands has not been proved and statements to that effect by Bolivia and its experts are simply untrue".[135]

2.67 In any event, it is within Bolivia's sovereign power to take the restoration measures in its territory that it deems necessary to ensure the biodiversity and good health of the Orientales and Cajones wetlands. For reasons never explained, Bolivia has failed to do so thus far, even though it could have after the termination of the 1908 Bolivian concession in 1997.[136]

2.68 Chile cannot of course be fixed with responsibility for Bolivia's inaction in its own territory. Chile encourages Bolivia to take such measures as it deems necessary and appropriate in relation to the wetlands, whilst complying with its obligations to Chile under customary international law, including notification and consultation. In this context, Chile is of course willing to coordinate with Bolivia and support its policies and regulations concerning the

[132] DHI Technical Analysis, p. 25. BR, Vol. 2, p. 99.

[133] DHI Technical Analysis, p. 29. BR, Vol. 2, p. 103.

[134] **Wheater and Peach (2019b)**, p. 62.

[135] Ibid.

[136] As Chile pointed out in its Reply, in 2000 Bolivia preferred to grant a concession to the waters to Bolivian company DUCTEC S.R.L., for commercial exploitation to Chilean end-users. After this scheme failed, Bolivia considered, and partly developed, several projects including a fish farm, a small dam and a mineral water bottling plant, none of which prevailed. See CR, para. 2.75 for further details.

conservation of the wetlands in Bolivia, as established in Article 5 of the Ramsar Convention.[137]

C. Conclusion: Bolivia's claim to sovereign rights over the "artificially enhanced flow" of the Silala River is untenable under international law and Bolivia's second and third Counter-Claims must be dismissed

2.69 Bolivia's Rejoinder insists on the existence of an "artificially enhanced" flow of the Silala River over which it claims sovereign rights. This is the basic premise that underlies its Counter-Claims b) and c).

2.70 Leaving aside much of the jurisprudence and doctrine relied on in its Counter-Memorial, Bolivia now claims that its sovereignty over the infrastructure in its territory affords its sovereignty of the water allegedly "produced" thereby. This is not an accepted theory under customary international law, which establishes the principle of equitable and reasonable use of all transboundary waters and the obligation not to cause significant harm. Bolivia also claims entitlement to a share of the benefits allegedly enjoyed by Chile from the "artificially enhanced flow", even though the channels in Bolivia were authorized by Bolivia without any involvement from Chile. Again, this runs counter to the basic principle of international law that States cannot create rights for themselves by unilaterally imposing obligations on other States. Bolivia's Counter-Claims b) and c) must be rejected.

[137] As requested by Bolivia, see BR, paras. 95-96.

CHAPTER 3

FURTHER ANALYSIS OF THE DHI NEAR FIELD MODELLING RECONFIRMS THAT BOLIVIA'S CONTENTIONS ON THE ALLEGED IMPACT OF THE CHANNELIZATION ARE UNTENABLE AS A MATTER OF FACT

3.1 In their report annexed to Chile's Reply, Chile's experts Wheater and Peach demonstrated that the DHI modelling results, estimating an impact of the channelization on surface flows of 30-40%, grossly overestimated those effects and were based on a fundamentally flawed numerical model.[138] At that time, the DHI modelling data that had been requested by Chile had not yet been received.

3.2 The DHI modelling data made available to Chile in February 2019 confirm the conclusions reached by Chile's experts. Moreover, their in-depth analysis has revealed many unreported differences between the models used for the three scenarios, which render their results incomparable. Based on this new information, Chile's experts have developed their assessment of the DHI modelling. They now confirm that the DHI results "are wholly unreliable and should be disregarded by the Court."[139]

3.3 In section 3.A, Chile demonstrates that Bolivia's response in the Rejoinder to Chile's criticism of the DHI Near Field Model is either insufficient or incorrect. In section 3.B, Chile presents the most salient new insights into the DHI modelling exercise, based on Chile's experts' analysis of the DHI modelling data. While Chile recalls that Bolivia's Counter-Claims b) and c) can and should be dismissed solely on the legal grounds set out in Chapter 2, the basic errors made by Bolivia's expert DHI further undermine the credibility of Bolivia's Counter-Claims b) and c).

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[138] Wheater and Peach (2019a). **CR, Vol. 1**.

[139] **Wheater and Peach (2019b)**, pp. 9 and 64.

A. DHI's response to the fundamental criticism of Chile's experts of the Near Field Model set-up is insufficient or incorrect

1. DHI acknowledges that the model results of the three scenarios (Baseline, No Canal and Undisturbed) are most likely affected by the Near Field boundary conditions

3.4 In their Reply report, Chile's experts Wheater and Peach criticized certain basic assumptions of the DHI Near Field modelling used to evaluate the impact of the channelization in Bolivia on cross-boundary flows, which was based on three different scenarios: the Baseline scenario, the No Canal scenario and the Undisturbed (or Restored Wetlands) scenario.

3.5 Wheater and Peach showed that the DHI decision to model a small area (approximately 1% of the entire Silala water catchment), drawn closely around the man-made channels in Bolivia (the Near Field) with "fixed head" boundary conditions, grossly exaggerates the modelled differences between the scenarios. In particular, and remarkably, it results in very different inflows in the three scenarios, even though the recharge area and precipitation remain the same.[140] The different inflows in the three scenarios are the main driver of the different outflows in the scenarios. Thus, the alleged 30-40% "enhanced flow" is a result of the modelling exercise, not of the channelization.[141]

3.6 DHI now acknowledges the impact of its modelling set-up on the results obtained. Specifically, DHI recognizes that "in the Near Field model

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[140] A "fixed head" boundary condition allows the model to draw on an infinite amount of water, which means that when the hydraulic gradient within the model area changes water will flow into the model in response to the changed hydraulic gradient, irrespective of whether that water is available in the natural system. See Wheater and Peach (2019a), pp. 20-21. CR, Vol. 1, pp. 116-117. It goes without saying that no infinite amount of water is available in the Atacama Desert.

[141] Wheater and Peach (2019a), pp. 5-6 and 44. CR, Vol. 1, pp. 101-102 and 140.

groundwater flows are closely tied to groundwater boundary conditions. DHI acknowledges that the model results, including the impacts of the drainage network, are most likely sensitive to boundary conditions".[142] DHI's conclusion is that their previous results represent an upper bound estimate of what might be feasible effects,[143] which suggests that – even according to DHI – these earlier results are not a realistic assessment.[144]

3.7 DHI also acknowledges that reduced surface flow will be compensated by increased groundwater flow[145] (except for the increased evapotranspiration). Thus, DHI does not dispute that the overall effect of the channels in Bolivia on the total cross-boundary flow (surface and groundwater) is practically non-existent.[146] Insofar as the scientific and technical facts are relevant at all, this is the one fact that the Court needs to focus on. The Silala waters flow as surface water or as groundwater, down the hydraulic gradient, into Chile, regardless of the channelization.

3.8 Returning to the issue of the quantum of specifically surface flows, in response to Chile's criticisms, DHI conducts a sensitivity analysis of the Near Field Model, resulting in a significant reduction of its earlier estimate of the

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[142] DHI Analysis of Chile's Reply, p. 23. BR, Vol. 5, p. 29. They also recognize that "[w]ith higher groundwater heads internally in the Near Field model less water enters the model domain through the fixed head boundaries as the gradient changes". DHI Analysis of Chile's Reply, p. 24. BR, Vol. 5, p. 30.

[143] DHI Sensitivity Analysis, p. 7. BR, Vol. 5, p. 55.

[144] **Wheater and Peach (2019b)**, p. 20.

[145] DHI Analysis of Chile's Reply, p. 24: With no canals, less waters enters the surface water system and more enters the groundwater inside or outside the Near Field model domain. […] Groundwater entering the Near Field or flowing past the Near Field domain will likely flow into Chile." BR, Vol. 5, p. 30.

[146] BR, para. 68 points to a difference in flow velocity between surface and groundwater flow, apparently suggesting that this would affect the availability of water in Chile. Bolivia's own experts DHI disagree: "Differences in flow velocities between a porous media and a canal is not an appropriate measure of change or modification." DHI, Technical Analysis, p. 13. BR, Vol. 2, p. 87.Chile's experts explain that the flow velocity does not affect the discharge across the border. **Wheater and Peach (2019b)**, p. 1, footnote 1.

impact of the channels on the surface flow, from 30-40% to 11-33%.[147] As noted above, in these new simulations, the "fixed head" boundary assumption provides the upper bound results.[148] The lower bound results are obtained by assuming no change of groundwater inflow into the Near Field Model area in the different scenarios, i.e. by replacing the "fixed head" boundary condition by a "fixed flux" boundary condition.[149] Chile's experts agree that this is an appropriate assumption.[150] The lower bound results are contained in Table 1 below:

Table 7-2 Results of the outer bounds of the sensitivity analyses of the upper head boundary conditions as changes in l/s from the flow components in the baseline simulation with the canals

	Canalised situation (l/s)	Changes from canalised conditions (l/s)	
	Baseline	Lower Bound	Upper Bound
Inflow to model	253.6	-1	-27.9
Surface outflow	149.0	-16	-48.6
Groundwater outflow	106.3	4	10.8
Evapotranspiration	10.0	3	3.4
Storage and num. inacuracy	-11.7	8.4	6.6

Table 1. DHI Sensitivity Analysis, p. 32, Table 7-2. BR, Vol. 5, p. 80.

3.9 Notwithstanding the adjustment of the "fixed head" boundary condition, the DHI lower bound results in further difficulties.

3.10 The principle of conservation of mass dictates that, for a steady-state simulation, as specified by DHI,[151] inflow must equal outflow. However, DHI's lower bound simulation of the impact of channelization shows a decrease of 16 l/s in surface outflow, an increase of 4 l/s in groundwater outflow and an increase in evapotranspiration of 3 l/s in the No Canal scenario, as compared to the Baseline scenario, leaving 9 l/s unaccounted for in the No Canal scenario. This makes no

[147] DHI Sensitivity Analysis, p. 8. BR, Vol. 5, p. 56.

[148] DHI Sensitivity Analysis, p. 7. BR, Vol. 5, p. 55.

[149] DHI Sensitivity Analysis, p. 31. BR, Vol. 5, p. 79.

[150] **Wheater and Peach (2019b)**, p. 9.

[151] DHI Report (2018). BCM, Vol. 5, p. 67.

sense. It is due to the change in storage and numerical inaccuracy of the lower bound results, stated by DHI to be 8.4 l/s, and is more than half of the supposed impact of the channels the model is intended to estimate. Further, DHI's stated error in the Baseline simulation is 11.7 l/s. This means that the combined model errors exceed the estimated effect of the channels, discrediting the modelling results.[152]

3.11 The missing water and large margin of error in the DHI sensitivity analysis are indicative of major issues with the DHI model set up, beyond the "fixed head" boundary issue noted by Chile's experts in their Reply reports.[153] These additional issues have been identified, thanks to the modelling data submitted by Bolivia in February 2019, and will be addressed in section 3.B below.

2. DHI's characterization of Chile's experts analysis as "vastly simplified" is misplaced

3.12 DHI considers that Chile's criticisms of the DHI modelling are "highly simplified and ignore the peculiarities of the flow of Silala waters."[154] In particular, DHI questions Chile's "simplified impact calculations" that, according to DHI, "do not support the claim that DHI's impacts are exaggerated. The analysis is based on the one-dimensional Darcy equation, which is only valid under idealized conditions not satisfied at Silala."[155]

3.13 DHI refers to Chile's text-book calculation of hillslope groundwater flows (Appendix 1 to the Wheater and Peach (2019a) report), but misinterprets its

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[152] **Wheater and Peach (2019b)**, pp. 21-22.

[153] **Wheater and Peach (2019b)**, p. 22.

[154] BR, para. 60.

[155] DHI Analysis of Chile's Reply, p. 7. BR, Vol. 5, p. 13.

purpose. This text-book calculation was used by Chile's experts to demonstrate the effect of a "fixed head" boundary condition close to the modelled channels, on the Near Field modelling results. It was never intended, nor used, to produce Chile's own estimate of the expected effect of the channelization.[156] Chile's experts would be the first to acknowledge that the calculations are simplified, but they "nevertheless show convincingly that an inappropriate choice of a fixed water table elevation at the Near Field boundary exaggerates the effects of water table rise and increased hydraulic resistance, by the order of a factor of 20."[157] They stand by this conclusion and find further support in the modelling data as will be set forth in section 3.B.

3.14 Bolivia and its experts also question Chile's "simplified analysis" of the complex geology of the Silala River area and signal that this "is a clear inconsistency, which brings into question the validity of their assessments of the canalization impact".[158]

3.15 In so far as this comment is directed at Chile's experts' text-book calculation of the exaggeration factor of DHI's modelling results, it is misdirected. As said above, this calculation does not purport to assess the impact of the channelization impact and does not consider, nor intend to consider, the real geology or geography of the Silala River area.

3.16 In so far as the comment is directed at Chile's substantive criticism of the geology and hydrogeology of the Silala River basin on which the DHI model is built, it is unfounded. Far from a "simplified analysis", Chile's experts have thoroughly reviewed the evidence provided by Bolivia's experts and found it severely wanting.

[156] **Wheater and Peach (2019b)**, p. 4.

[157] Wheater and Peach (2019a), Appendix 1, p. 58. CR, Vol. 1, p. 154.

[158] BR, para. 61.

3.17 For example, Bolivia has insisted on the existence of an alleged fault system with high hydraulic conductivities, running from the Orientales wetland to the Cajones wetland, bending around to follow the course of the Silala River from Bolivia into Chile.[159] This so-called "Silala Fault" is provided by Bolivia as an alternative for the origin, location and alignment of the Silala River ravine, which they say was later eroded by glacial and fluvioglacial action rather than the purely fluvial origin of the ravine, which was demonstrated by Chile.[160] As Chile's experts pointed out, no evidence was provided with the Bolivian Counter-Memorial to support the existence of this major fault.[161] In the words of Chile's experts, its existence is "so unlikely that we believe it impossible".[162]

3.18 In the Bolivian Rejoinder, Bolivia submits additional studies by Bolivian expert F. Urquidi,[163] the Bolivian geological survey SERGEOMIN,[164] and the Tomás Frías Autonomous University of Potosí (TFAU),[165] to support the existence of the "Silala Fault" and associated fractures.[166] Chile's experts have not

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[159] Peach, D.W. and Wheater, H.S., *Concerning the Geology, Hydrogeology and Hydrochemistry of the Silala River Basin*, 2019 (henceforth "**Peach and Wheater (2019)**"), p. 29. CR, Vol. 1, 195.

[160] **Wheater and Peach (2019b)**, p. 50.

[161] Peach and Wheater (2019), p. 32. CR, Vol. 1, p. 198.

[162] Peach and Wheater (2019), p. 23. CR, Vol. 1, p. 189.

[163] **BR, Vol. 3, Annex 23.5** (henceforth "Urquidi Report"). Chile notes that the Urquidi Report is particularly unfavourably reviewed by Bolivia's own expert DHI, in the DHI Technical Analysis Report. **BR, Vol. 2, Annex 23**. DHI points out inconsistencies in data used and conclusions drawn, which contradict DHI's own findings (BR, Vol. 2, p. 79). Some of the data relied on in the report is confirmed to be of dubious quality, and several statements are found to be unsupported by data and therefore cannot be reasonably evaluated (BR, Vol. 2, p. 115). DHI even questions the author's objectivity: "[T]he reviewer recommends limiting the findings to technical determinations rather than non-technical conclusions such as whether Silala is an international river course. […] However, the author's narrative seems not solely based on technical objective interpretation of data and analyses presented. This impression stems from the numerous unsupported statements and lack of presentation of or referencing materials on which the author's conclusions are drawn." (BR, Vol. 2, pp. 115-116).

[164] **BR, Vol. 3, Annex 23.5, Appendix a** (SERGEOMIN 2003); **BR, Vol. 4, Annex 23.5, Appendix b** (SERGEOMIN 2017).

[165] **BR, Vol. 3, Annex 23.5, Appendix c** (TFAU 2018).

[166] BR, para. 62.

found any evidence for the existence of a Silala fault in these reports. DHI relies on the SERGEOMIN (2017) geologic mapping that "indicates a relatively small displacement of 5 m. at the border", as evidence of the fault.[167] However, Chile's experts confirm that any displacement by the alleged fault as proposed by Bolivia would be in the opposite direction than indicated by the Bolivian geologists and that the 5 m displacement is more reasonably explained by the fact that the Silala ignimbrite in Bolivia is tilted to the west.[168]

3.19 More generally, Chile's experts find that the new reports submitted by Bolivia "contain important errors and inconsistencies in the understanding and interpretation of stratigraphy, structural geology and in petrography. These errors and inconsistencies have led to errors in development of a hydrogeological conceptual model, upon which DHI relied for the design of their numerical models, particularly, the NFM [Near Field Model]."[169]

3.20 In particular, Chile's experts note significant confusion in the Bolivian reports concerning the ages of the various geological units.[170] Bolivia's geologists also invert the sequence of rock strata (or stratigraphy), mapping older geological units as overlying younger geological units, which is clearly impossible.[171] This means that the Near Field Model is based on an incorrect understanding of the geometry and extent of the deep aquifer in the permeable ignimbrite deposits, including the lack of inclusion of a shallower aquifer found in Chile.[172] This has considerable consequences for the modelled groundwater flow regime that the

[167] DHI Analysis of Chile's Reply. BR, Vol. 5, p. 24.
[168] **Wheater and Peach (2019b)**, p. 50.
[169] **Wheater and Peach (2019b)**, p. 43.
[170] **Wheater and Peach (2019b)**, pp. 44-45.
[171] **Wheater and Peach (2019b)**, pp. 46-49.
[172] **Wheater and Peach (2019b)**, p. 56.

DHI models are purporting to represent.[173] This is compounded by inconsistencies and errors in the naming of rock types, leading to an inability to have confidence in the Bolivian geological interpretations.[174]

3.21 Chile's experts point out that DHI acknowledges the existence of two distinct sources of groundwater discharging to the Silala springs, but has decided not to include this in the model, because "it would not reflect on the split between surface and groundwater discharge from the wetlands due to channelization".[175] Chile's experts disagree. Groundwater flows from different aquifers with different piezometric heads will interact differently with surface water. Not taking this into account will lead to an incorrect understanding of the groundwater flow regime, and most likely incorrect modelling results.[176]

3.22 Chile's experts conclude that the new evidence presented by Bolivia, in response to Chile's criticism of the DHI modelling, confirms their view that the geology and hydrogeology that underpin the DHI's modelling is incorrect and does not represent reality. If only for that reason (there are many others), the models are likely to produce results that are very seriously in error.[177]

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[173] **Wheater and Peach (2019b)**, p. 56.

[174] **Wheater and Peach (2019b)**, pp. 53-54.

[175] DHI Analysis of Chile's Reply, p. 21. BR, Vol. 5, p. 27.

[176] **Wheater and Peach (2019b)**, pp. 54-55.

[177] **Wheater and Peach (2019b)**, p. 11.

B. The DHI modelling data submitted on 7 February 2019 reveal further flaws in the Near Field Model which render the modelling results wholly unreliable

1. DHI uses different models for the Baseline Scenario on the one hand, and the No Canal and Undisturbed Scenarios on the other hand, which make them not directly comparable

3.23 The modelling data received in February 2019 revealed that DHI uses a different configuration of models for the Baseline Scenario on the one hand, and the No Canal and Undisturbed (or Restored Wetlands) Scenarios on the other hand, all within the Near Field Model area.

3.24 In all three scenarios, DHI uses the MIKE-SHE model to represent the hydrology of the Silala River basin, including coupled surface and groundwater flows, evapotranspiration, unsaturated zone and overland flow.[178] In addition, but only in the Baseline Scenario, DHI uses the MIKE-11 model to represent the channel flow. MIKE-SHE and MIKE-11 are coupled in the Baseline Scenario, which allows exchanges of water between the channels and the groundwater system.[179] In the No Canal and Undisturbed scenarios, the channels are not explicitly modelled and so the MIKE-11 model is not included. This has the effect of directing all surface flow in these two scenarios as overland flow, as if a river does not run through its own natural channels.[180] This is of course incorrect. The fact that a different modelling framework is used for the Baseline Scenario is one

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[178] **Wheater and Peach (2019b)**, p. 17.

[179] **Wheater and Peach (2019b)**, pp. 17 and 23.

[180] **Wheater and Peach (2019b)**, p. 23.

reason why the three scenarios are not directly comparable.[181] Other important reasons are explained below.

2. The modelling conditions, including surface topography and inflow, are different in each scenario, invalidating any comparison of the modelling results

3.25 More disturbing than the use of different model configurations in the three model scenarios is the fact that there are basic unreported differences between the three scenarios that have only been detected by Chile's experts after thorough analysis of the modelling data.

3.26 Clearly, for the three scenarios to be comparable, their topography should be identical, except for the differences resulting from the elimination of the channels in the No Canal and Undisturbed Scenarios and an allowance for possible peat growth in the Undisturbed Scenario.[182] Chile's experts were therefore very surprised indeed to find that very different topographies were used for the MIKE-SHE model for the Baseline Scenario as compared with the other two scenarios, and that different topographies had been used in the Baseline Scenario for the MIKE-SHE and the MIKE-11 models.[183] As can be seen in Figure 1, the topography of the No Canal and Undisturbed scenarios show differences of almost 7 m from the Baseline MIKE-11 model and almost 3 m from the Baseline MIKE-SHE model. This is far more than the 0.50 – 1.00 m depth of the channels, or the 60 cm possible peat growth in the Undisturbed Scenario, the effects of which the model scenarios are meant to simulate.[184]

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[181] **Wheater and Peach (2019b)**, p. 23.

[182] **Wheater and Peach (2019b)**, p. 23.

[183] **Wheater and Peach (2019b)**, pp. 23-24.

[184] **Wheater and Peach (2019b)**, p. 24.

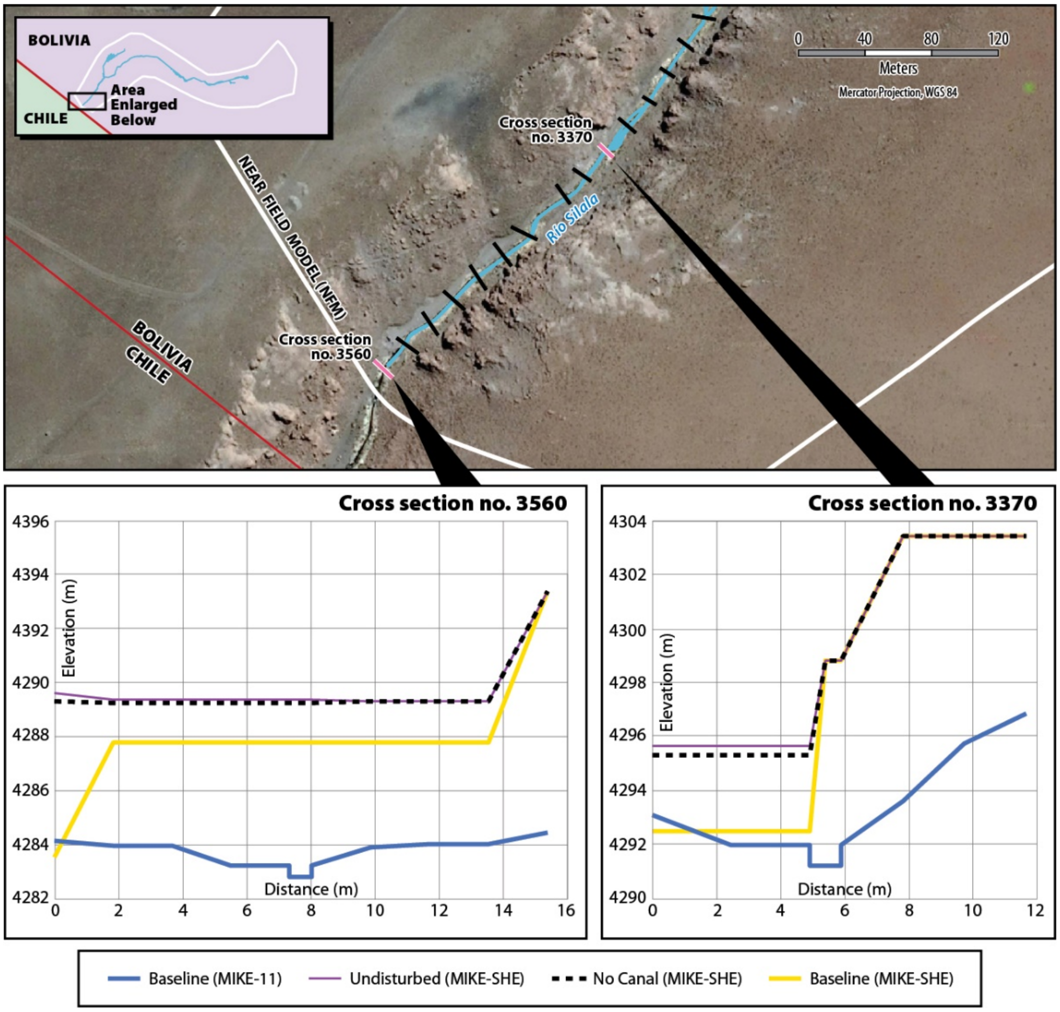

Figure 1. Ground surface elevations used in the four Bolivian models compared at two cross sections of the main channel near the international border (Muñoz et al., 2019, p. 30, Figure 4-3. ***CAP, Vol. 2, Annex XV****).*

3.27 The raising of the ground surface in Bolivia in the No Canal and Undisturbed Scenarios has the effect of reducing the groundwater inflows into the model and increasing the groundwater outflow, so less water will be available to appear as surface flow, in comparison to the Baseline Scenario. This is exactly the effect that Bolivia attributes to the removal of the channels. This renders the whole modelling exercise meaningless.[185]

3.28 Another unreported and disturbing difference between the three model scenarios concerns the inflows in each scenario. Chile's experts had noted unexplained differences in the volume of inflow in the three scenarios, from the DHI report submitted with Bolivia's Counter-Memorial.[186] However, they assumed that the inflow in all three scenarios corresponded to groundwater input across the Near Field Model boundaries.[187]

3.29 It is now apparent from the modelling files that, apart from the groundwater inflow, distinct amounts of additional water are introduced to the Near Field Model, at the location of the springs: 42 l/s in the Baseline Scenario and 31 l/s in the No Canal and Undisturbed Scenarios. In the Baseline Scenario, this water is added directly to the surface flow, whereas in the No Canal and Undisturbed Scenarios it is partitioned between surface and groundwater flow.[188] The difference of 11 l/s and their different treatment as surface and groundwater flow is arbitrary and neither reported nor explained by DHI in its reports.[189] The difference of 11 l/s is of the same order of magnitude as the purported effects of the channels that the models are designed to simulate.

3.30 Further anomalies in the modelling are reported in more detail in the Wheater and Peach (2019b) expert report submitted with the Additional Pleading, based on the detailed analysis of the modelling data undertaken in the Muñoz et al. (2019) report, also submitted hereby.[190] However, the different topographies in

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[185] **Wheater and Peach (2019b)**, p. 27.

[186] **Wheater and Peach (2019b)**, p. 49.

[187] **Wheater and Peach (2019b)**, p. 32.

[188] **Wheater and Peach (2019b)**, p. 33, footnote 6.

[189] **Wheater and Peach (2019b)**, p. 33.

[190] Muñoz et al. (2019). **CAP, Vol. 2, Annex XV**.

the three scenarios, compounded by the unaccounted-for additional 11 l/s added to the Baseline Scenario, are inexplicable errors made by DHI that render their modelling results wholly unreliable. The DHI modelling results should be dismissed by the Court.

3. Bolivia's reliance on the 1922 Fox flow estimate to confirm the results obtained from the DHI modelling is not credible

3.31 Bolivia seeks support for the DHI modelling results in field observations conducted in 1922 by FCAB engineer Robert H. Fox, which it says documented 131 l/s cross-border flow.[191] According to Bolivia, this is 18-38% lower than present observations (160-210 l/s), and therefore corresponds to the 11-33% findings of the DHI sensitivity analysis.[192]

3.32 Bolivia's reliance on the Fox flow estimate is not credible, and it is even misleading.

3.33 First, there is no evidence in the Fox article for Bolivia's affirmation that the measured daily flow of 11,300 cubic metres (or 131 l/s) corresponds to the cross-border flow. The article does not specify the precise location of the measurement. However, a possible inference from the article is that the flow was measured at the "small dam" (or Intake N° 1) that was built in 1909 and operative from 1910 onwards, located in Bolivian territory just below the confluence of the Cajones and Orientales ravines, at approximately 600 m upstream from the international boundary.[193] Both Bolivia's and Chile's experts report major changes to the flow rate at different locations along the river, due to continuous

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[191] BR, para. 65. Reference is to R.H. Fox, "The Waterworks Department of the Antofagasta (Chili) & Bolivia Railway Company", *South African Journal of Science*, 1922, p. 123. **CM, Vol. 3, Annex 75**.

[192] BR, para. 65.

[193] See for the location of Intake N° 1, CM, para. 2.22.

interaction between surface and groundwater flows.[194] Hence, no conclusions can be drawn about the cross-border flow from one single measurement, of uncertain location.[195]

3.34 Second, the methodology used for the measurement is unknown, and hence its accuracy and reliability.[196] Chile's and Bolivia's experts concur that, even in the Twenty-First century, the Silala River flow is notoriously difficult to measure accurately, due to the extreme conditions of the *altiplano*.[197] DHI reports that comparison of long term flow records from the permanent gauging stations in Bolivia and Chile "shows significant differences in both the mean flow levels and temporal variation".[198] DHI also notes that none of the series from these two sites seems to be free of gauging inconsistencies, "which may be due to the remote locations and harsh climate".[199] In addition, short term measurements made by Bolivia in 2017 show "inconsistencies both at the individual gauging points and also when cross comparing the data".[200] Fox's single estimate is prone to these same limitations and more, and cannot be accepted at face value.

3.35 In short, a century-old single estimate, at a location that is uncertain, but possibly 600 m removed from the international boundary, using an unknown methodology, cannot credibly be used to validate the results of the DHI modelling, which for many reasons, as explained before, have no scientific value and should be disregarded by the Court.

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[194] **Wheater and Peach (2019b)**, p. 38.

[195] **Wheater and Peach (2019b)**, p. 39.

[196] **Wheater and Peach (2019b)**, p. 39.

[197] **Wheater and Peach (2019b)**, p. 39.

[198] DHI Report (2018). BCM, Vol. 2, p. 395.

[199] Ibid.

[200] Ibid.

C. Conclusion: The DHI Near Field modelling is so severely flawed that its results are meaningless and should be dismissed by the Court.

3.36 The dispute before the Court can and should be decided solely on legal grounds, and Bolivia's Counter-Claims b) and c) must be rejected because they have no basis in international law.

3.37 That being said, Chile has made use of its right to respond to Bolivia's factual allegations, in particular, that the channelization of the Silala River on Bolivian territory has caused its cross-border surface flow to increase by an estimated 11-33% (formerly 30-40%). Bolivia relies entirely on its expert DHI, and the results of the DHI Near Field modelling, for this estimation. An evaluation of the quality of the DHI modelling exercise is therefore of particular interest to Chile and the Court.

3.38 Chile's experts have demonstrated that the DHI Near Field modelling is not scientifically sound, for the following reasons:

(a) completely different topographies were used for the different scenarios, with the differences in topography very much larger than the relatively small differences associated with channelization and assumed peat growth;

(b) there are basic errors in the geology and hydrogeology that mean that the geometry and aquifer properties are wrong;

(c) arbitrary amounts of water have been added to the wetland springs, with different amounts for the different scenarios (and different partitioning between surface and groundwater), thus adding to the simulated effects of channelization, and

(d) errors and inaccuracies, including changes in storage, account for similar rates of flow to the effects ascribed to the channelization and peat growth.[201]

3.39 Chile's experts have stated in plain language that they are shocked by the basic errors made by DHI.[202] The results of the DHI Near Field modelling are unreliable, even meaningless, and should be dismissed by the Court.

[201] **Wheater and Peach (2019b)**, p. 40.

[202] **Wheater and Peach (2019b)**, p. 40.

SUBMISSIONS

With respect to the counter-claims presented by the Plurinational State of Bolivia, Chile requests the Court to adjudge and declare that:

(a) The Court lacks jurisdiction over Bolivia's Counter-Claim a), alternatively, Bolivia's Counter-Claim a) is moot, or is otherwise rejected;

(b) Bolivia's Counter-Claims b) and c) are rejected.

Ximena Fuentes T.
Agent of the Republic of Chile
16 September 2019

Expert Report

Wheater, H.S. and Peach, D.W., *Impacts of Channelization of the Silala River System in Bolivia on the Hydrology of the Silala River Basin – an Updated Analysis*

IMPACTS OF CHANNELIZATION OF THE SILALA RIVER IN BOLIVIA ON THE HYDROLOGY OF THE SILALA RIVER BASIN – AN UPDATED ANALYSIS

Drs. Howard Wheater and Denis Peach

August 2019

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LIST OF ACRONYMS AND ABBREVIATIONS

BCM	–	Counter-Memorial of the Plurinational State of Bolivia
BR	–	Rejoinder of the Plurinational State of Bolivia
CM	–	Memorial of the Republic of Chile
CR	–	Reply of the Republic of Chile
DHI	–	Danish Hydraulic Institute
ha	–	hectares
km^2	–	square kilometres
l/s	–	litres per second
m	–	metres
mm/year	–	millimetres per year
NDVI	–	Normalized Difference Vegetation Index
NFM	–	Near Field Model
UKFS	–	Uyuni-Khenayani Fault System
WBM	–	Water Balance Model

1 INTRODUCTION

1.1 Experts' Terms of Reference

In 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, there has been considerable agreement by both parties and their technical experts, through the exchange of written pleadings. It is agreed (CR, Vol. 1, pp. 99-101; BCM, Vol. 2, pp. 266-267) that the Silala River is an international watercourse, and that both surface water and groundwater from the Silala River topographic catchment and a larger groundwater catchment naturally flow from Bolivia to Chile. It is also agreed that the channelization of the wetlands and natural Silala River channel in Bolivia is expected to have increased the surface water discharge and decreased the groundwater flow from Bolivia to Chile[1]. Further, it is agreed by both parties that if the channels were removed and the wetlands restored to their pre-channel state, there would be a reduction in surface flow, a small increase in wetland evaporation, and an increase in cross-border groundwater flow.

An important area of continuing scientific disagreement between the two parties concerns the magnitude of the impacts of the channelization on trans-border surface and groundwater flows. Bolivia has based its estimates primarily on modelling by the Danish Hydraulic Institute (DHI) of the Near Field, a small area

[1] We note some confusion in Bolivia's understanding of these changes. BR, para. 68, correctly states that surface water flows much faster than groundwater, but seems to imply, mistakenly, that this has relevance to the points of legal or scientific disagreement (BR, Vol. 1, p. 37). What is important to the dispute is the distribution of water resources between surface water and groundwater, which depends on the discharge of water, as a volumetric flow rate (l/s), and not the flow velocity (m/s). Bolivia notes (in the same paragraph) that 'The surface flows of the Silala from Bolivia to Chile have been enhanced in terms of volume and flow.' (BR, Vol. 1, p. 37). The use of the terms 'volume' and 'flow' shows some conceptual confusion. It is the *volume flow rate* that is important, and not the *flow velocity*. The fact that surface water flows more rapidly than groundwater does not affect the discharge (volumetric flow rate) across the border. The high velocity in the river channel applies to a small river cross section, whereas the orders of magnitude slower velocity of groundwater applies to a large geological cross-section of aquifer.

including the Bolivian headwater springs and wetlands and the river corridor to the international border. This modelling produced large estimates of the impact, whereas in the opinion of Chile's experts, these effects will be small.

In this context, the Republic of Chile has requested our independent expert opinion, as follows:

> "Questions for Dr. Howard Wheater, as a hydrological engineer:
>
> (i) Do the digital data provided by Bolivia in support of the Counter-Memorial after Chile's Reply was finalized materially change your assessment of the modelling by Bolivia's Experts of the effects of channelization and of the effects of possible long-term peat growth?
>
> (ii) Do the further modelling and other studies by Bolivia's Experts, presented in Bolivia's Rejoinder, reflect a correct assessment of the magnitude of these effects?
>
> Questions for Dr. Denis Peach, as a hydrogeologist:
>
> (i) Does the information provided by Bolivia's Experts, presented in Bolivia's Rejoinder, materially change your assessment of the geology and hydrogeology that underpins Bolivia's modelling of the effects of channelization and of the effects of possible long-term peat growth?
>
> (ii) What are the implications of this new information, if any, for the validity of Bolivia's modelling of the effects of channelization and possible long-term peat growth?"

This report is restricted to addressing these questions. At this stage of the proceedings, we feel it is a distraction to the Court to rebut all of Bolivia's misinterpretations of our previous reports, or to address other errors in the science reports presented by Bolivia in its Rejoinder. However, we refer the Court to the review of several of these works by Bolivia's international experts, DHI (BR, Vol. 2, Annex 23), who point to the very variable quality of the science that has been presented.

1.2 Report background and structure

Through the exchange of written pleadings by Chile (Memorial (CM) and Reply (CR)) and Bolivia (Counter-Memorial (BCM) and Rejoinder (BR)), substantial agreement has emerged between the parties and their technical experts concerning the hydrology of the Silala River system. Key points of agreement were summarized by us in CR, Vol. 1, p. 101, as follows:

> "We and Bolivia's experts agree that:
>
> 1. The Silala River flows naturally from Bolivia to Chile. The river rises in two sets of springs in Bolivia, which maintain the Cajones and Orientales wetlands.
> 2. The river is primarily fed by groundwater and interacts with groundwater along its course to the border and beyond.
> 3. In addition, there are substantial groundwater flows from Bolivia to Chile, likely of an equivalent magnitude to the surface water flows.
> 4. Construction of drainage channels and river channelization in the 1920s will have had some effect on the flow. An increase in flow due to these works is expected.
> 5. The impact of drainage on evaporation from the wetlands is small."

Further, it is agreed by both parties that if the channels were to be removed, there would be a reduction in surface flow, a small increase in wetland evaporation[2], and an increase in cross-border groundwater flow.

An important area of scientific disagreement between the two parties and their international experts concerns the magnitude of the impacts of the channelization on trans-border surface and groundwater flows. Bolivia has based its estimates primarily on modelling by the DHI of the Near Field, a small area of 2.56 square kilometres (km^2) including the Bolivian springs and wetlands and the river corridor to the international border. Three scenarios were modelled, representing the status quo, the removal of the channelization, and the removal of channelization plus the possible long-term growth of peat soils in the wetlands.

[2] Both parties agreed that wetland evaporation is a small component of the water balance.

This modelling produced large estimates of the impact, whereas in the opinion of Chile's experts, these effects will be small (CR, Vol. 1, p. 141).

In Bolivia's Counter-Memorial (BCM, Vol. 1, pp. 52-53), it was stated that if the channels and drainage works were removed, the Silala River surface flows would decrease by 30-40%, evaporation from the restored wetlands would increase by 20-30%, and groundwater flow across the border would increase by 7-11%. Chile noted that the assumed boundary conditions used for the models would exaggerate the effects, and illustrated the error using a simplified text-book example calculation. DHI and Bolivia misinterpreted this example calculation (BR, Vol. 1, p. 33), which was used only to demonstrate the problem with their inappropriate use of these boundary conditions, and not to produce an estimate of the expected effect of channelization, but nevertheless DHI accepted that our criticism of the boundary conditions was justified and its calculations had overestimated the expected effect (BR, Vol. 5, p. 55). Consequently, DHI presented revised modelling results in BR, in which the previous results were regarded as an upper limit: 'if the channels and drainage mechanisms were removed, cross-border surface flows in the Silala would decrease by 11% to 33% of current conditions […] evapotranspiration from wetlands without canals will increase by 28% to 34% of the reference values, i.e. between 2.8 and 3.4 l/s, while groundwater flows across the […] border will increase between 4% and 10% as compared to current conditions' (BR, Vol. 1, p. 35).

This report addresses continuing and serious concerns for the validity of DHI's modelling, summarized in Section 2. The data files used to model the effects of channelization for Bolivia's Counter-Memorial were provided by DHI after the preparation of Chile's Reply, and in section 3 of the report we analyze these to show that the modelled results of the different scenarios are not comparable, and the results that have been presented are seriously misleading to the Court. There are many issues of concern, but one particularly important factor is that different topographies have been used in modelling the different scenarios. The results of the different scenarios are not comparable, and the differences in topography between the scenarios are much greater than the dimensions of the channels and hypothetical peat growth, the impacts of which, the modelling is designed to quantify. These problems recur with the revised modelling results from Bolivia's Rejoinder.

Further, all of DHI's modelling has been based on Bolivia's interpretation of the geology of the Silala River basin, and in section 4 of the report we show that Bolivia's understanding of the geology of the Silala River catchment is incorrect, which invalidates the conceptual hydrogeological models that underlie all of DHI's modelling.

In section 5, we address Bolivia's recent evidence for the impacts of the historical channelization on the wetlands in Bolivia. While these works, undertaken with the consent of Bolivia, are the responsibility of Bolivia, it is relevant to the future management of the Silala River, the restoration of the wetlands, and future downstream flows, that the reasons for historical changes are clearly understood. While we do not dispute that there are impacts on wetland ecosystem health to be expected from channelization, we agree with DHI, who provided an independent review of some of the supporting documents, that there are several reasons why the wetlands have changed over time, notably including climatic changes. We conclude that Bolivia's documentation includes exaggerated and wholly unsubstantiated claims about the extent of wetland changes and the role of the channelization. In section 6 we present our conclusions and answer the questions posed to us by Chile.

2 SUMMARY

While there is general agreement between the Parties concerning the hydrology of the Silala River basin and the nature of potential changes due to historical channelization in Bolivia, there is important disagreement concerning the likely magnitude of these effects. Bolivia asserts that there have been large effects of the channelization on streamflow, while acknowledging that any changes in surface water flow across the border would be accompanied by associated changes in groundwater flows across the border. Chile has stated that these estimates are unrealistic. Given the relatively small reductions in water table depths associated with the drainage of the wetlands and channelization of the main river, any effects are likely to be small.

Bolivia's estimates of change are based on simulations by the Expert consultants, DHI, which were presented in the Counter-Memorial. Based on the limited information provided by Bolivia at that time, Chile noted two issues of concern for the credibility of the modelling. The first concerned the incorrect specification of boundary conditions for DHI's Near Field Model (NFM), on which the estimates of effects were based. The second concerned Bolivia's incorrect interpretation of the geology, on which all of DHI's modelling was based. In Bolivia's Rejoinder, DHI accepted the criticism of the boundary conditions and renamed the previous results as an upper bound estimate of the effects. In parallel, Chile had requested further information to substantiate Bolivia's modelling results, and this was finally provided in February 2019.

In this report we review the additional data and address Bolivia's revised results in the Rejoinder. In short, in addition to the concerns noted in Chile's Reply, analysis of DHI's digital data showed a large number of issues of concern, and many unreported differences between the modelled scenarios, leading to our conclusion that the results are wholly unreliable, as explained below.

We also review the new documentation, provided in the Bolivian Rejoinder, concerning the basis of their geological interpretations and understanding of the geology of the Silala River basin. These, on detailed examination, were found to contain significant errors, misinterpretations, to be often confused and with many internal inconsistencies, which leads us to conclude that the Bolivian modelling is based on an incorrect understanding of the geology and hydrogeology.

In addition, because it is important for wetland restoration and the prediction of impacts on downstream flows to understand correctly the impacts of channelization on the wetlands, we comment on reports by other Bolivian experts, which provide useful data on historical changes, but make unjustified assertions concerning the causal effects of the wetlands.

We therefore address the questions posed to us by Chile, below. The first two questions were addressed to Wheater, and the second two to Peach. The answers to (i) and (ii) have therefore been drafted by Wheater, and the answers to (iii) and (iv) by Peach. However, they reflect our joint opinion.

(i) Do the digital data provided by Bolivia in support of the Counter-Memorial after Chile's Reply was finalized materially change your assessment of the modelling by Bolivia's Experts of the effects of channelization and of the effects of possible long-term peat growth?

The digital data provided by Bolivia in February 2019 has allowed detailed analysis of DHI's modelling, used to support Bolivia's claims concerning the impacts of historical channelization of the Silala River in Bolivia, as reported in Bolivia's Counter-Memorial. Analysis of model configurations, parameters, input data and simulation results showed that there were many aspects of the modelling that gave serious concern for the reliability of the results, in particular for the modelling of a 2.56 km^2 area designated by DHI as the Near Field that includes the source water springs and wetlands in Bolivia, and the river channel to the international border.

The Near Field Model was used by DHI to simulate three scenarios, the Baseline Scenario (current conditions), a No Canal Scenario (with the channels removed), and an Undisturbed Scenario (with channels removed and an allowance for the long term growth of peat in the wetlands), to evaluate the effects of the historical channelization of the Silala River and its wetlands in Bolivia, and of possible future peat growth in the wetlands. Bolivia relies on these results to claim large impacts of historical channelization on Silala River cross-border flows.

We had noted previously, in Chile's Reply, that there were errors in the geological interpretation on which the modelling was based (and hence the model configuration and parameterization), and that there was a major problem in the choice of boundary condition for the NFM, which caused exaggeration of the reported effects. However, inspection of the digital data by Chilean hydrologists (Muñoz et al., 2019) revealed many *unreported differences* between the models used for the inter-comparison of scenarios, and in the model boundary conditions and initial conditions. These unreported differences were compounded by unexplained methodology, and incorrect assumptions. Perhaps of greatest impact was the fact that we found that different topographies had been used for the different scenarios, including different topographies used in the Baseline Scenario for the modelling of catchment processes (the MIKE-SHE model) and the modelling of channel flow (the MIKE-11 model). These differences in topography, of up to 7 m, were far greater than the small changes in channel depth and peat growth that the models were being used to evaluate, and in themselves would generate large differences between the scenarios. While the *reported* model errors and inaccuracies for the NFM were of a similar magnitude to the effects being simulated, which in itself casts doubt on the validity of the conclusions from the modelling, we conclude that the large effects proposed by Bolivia are mainly an artefact of these *unreported* differences between the modelled scenarios.

In short, our assessment of the reliability of the modelling by Bolivia's Experts has materially changed. In our professional opinion, the published results of the effects of channelization and of the effects of possible long-term peat growth are wholly unreliable and should be disregarded by the Court.

(ii) Do the further modelling and other studies by Bolivia's Experts, presented in Bolivia's Rejoinder, reflect a correct assessment of the magnitude of these effects?

We were pleased to note from Bolivia's Rejoinder that DHI accepted our criticism of the choice of boundary conditions for the NFM, and now considers these results to set an upper bound for the effects of channelization and possible long-term peat growth. DHI also provides a lower bound estimate of the simulated effects, based on a constant flux at the boundary. We agree that this is an appropriate condition to give a lower bound estimate. However, the simulation results presented are subject to all of the errors and inconsistencies noted above, and have errors that are of a similar magnitude to the effects being simulated. In addition, they differ from the BCM results for the same simulation, which is a further indication of an unreliable modelling process. Again, in our professional opinion, these further modelling results are misleading and should be disregarded.

We note that DHI refer to a historical estimate of flow, made in 1922 prior to the channelization, to support their simulations and conclusions. However, in our opinion, a single estimate, made at a location that is uncertain, and in a difficult environment where contemporary measurements have had large errors, cannot be considered reliable.

Related studies by other of Bolivia's experts considered the relationship between the historical channelization and observed changes in the wetlands. Understanding the causes of wetland change is important given the desire of both Parties to see wetland restoration, and to understand the effects on downstream river flows. While these studies shed important light on some of the changes that have taken place in the wetlands, they erroneously attribute the single cause of observed changes to the channelization. Given that the dates of reported changes bear no relationship to the dates of channelization, it must be concluded that other factors are playing a significant role. We agree with Bolivia's experts, DHI, that climate changes are likely to be one of the more important controls.

(iii) Does the information provided by Bolivia's Experts, presented in Bolivia's Rejoinder, materially change your assessment of the geology and hydrogeology that underpins Bolivia's modelling of the effects of channelization and of the effects of possible long-term peat growth?

Our assessment of the Bolivian interpretation of the geology and hydrogeology of the Silala River basin has resulted in our clear view that the geological interpretation that underpins Bolivia's modelling is substantively flawed. Bolivia have introduced new geological evidence in the BR that is often confused and inconsistent. Further, they have ignored Chilean evidence and simply asserted that Bolivian interpretations are correct.

(iv) What are the implications of this new information, if any, for the validity of Bolivia's modelling of the effects of channelization and possible long-term peat growth?

The geology and hydrogeology of the area around the Bolivian wetland springs and downstream beneath the Silala River, defined by DHI as the Silala Near Field, is complex, and given the limited data, is open to differing interpretations. However, concerning the geology and hydrogeology, DHI has adopted a set of models that do not represent the best understanding of reality, and are based on many erroneous conclusions, assumptions and internally inconsistent interpretations, in addition to the issues noted above in answer to question (i). The models are therefore likely to produce results that are grossly in error. We have no doubt that Bolivia's estimates of the effects of channelization are highly exaggerated. This conclusion is in part due to the adoption of boundary conditions for the NFM that are incorrect, both in their condition and location, as well as the use of inconsistent and highly variable topography. But it is also due to the misrepresentation of aquifer geometry, the use of aquifer property distributions that do not take into account the correct geometry and stratigraphy, and the fact that the existence of an important shallow aquifer system has been ignored.

The NFM not only does not reflect reality, but is not consistent with the stated Bolivian conceptual understanding of the groundwater flow regime.

3 MODELLING THE IMPACTS OF CHANNELIZATION ON THE HYDROLOGY OF THE SILALA RIVER SYSTEM

3.1 Introduction

In Bolivia's Counter-Memorial, a suite of models was used by DHI to represent the hydrology of the Silala River and its groundwater catchment area, estimated by DHI to be 234.2 km^2 (Figure 1). Based on DHI's MIKE-SHE modelling platform, three models were developed. A model for the Far Field, known as the Water Balance Model (WBM), was used to simulate the water balance of the topographic catchment area as well as groundwater flows and residence times from the extended groundwater catchment. A Near Field Model was developed to represent the Silala River valley from the international border to the groundwater springs, which are the sources of the Silala River surface flows, and the associated Cajones and Orientales wetlands, an area variously described as 2.7 km^2 (BCM, Vol. 2, p. 301) and as 2.56 km^2 (BCM, Vol. 5, p. 13). A third model, the Near Border Model, was developed to represent the interactions between surface water and groundwater in more detail, for an area of the Near Field Model between the confluence of the Orientales and Cajones tributaries and the international border (BCM, Vol. 5, pp. 72-76). The three model areas are shown in Figure 2. Given their relevance to the outstanding issues of disagreement between the parties, we focus on the Far Field and Near Field Models in this report. Results of these models are summarized in Bolivia's Counter-Memorial Volume 2 (BCM, Vol. 2, Annex 17), and the models are presented in more detail in Volumes 3 and 5 (BCM, Vol. 3, Annex 17, Annex E; BCM, Vol. 5, Annex 17, Annexes G and H).

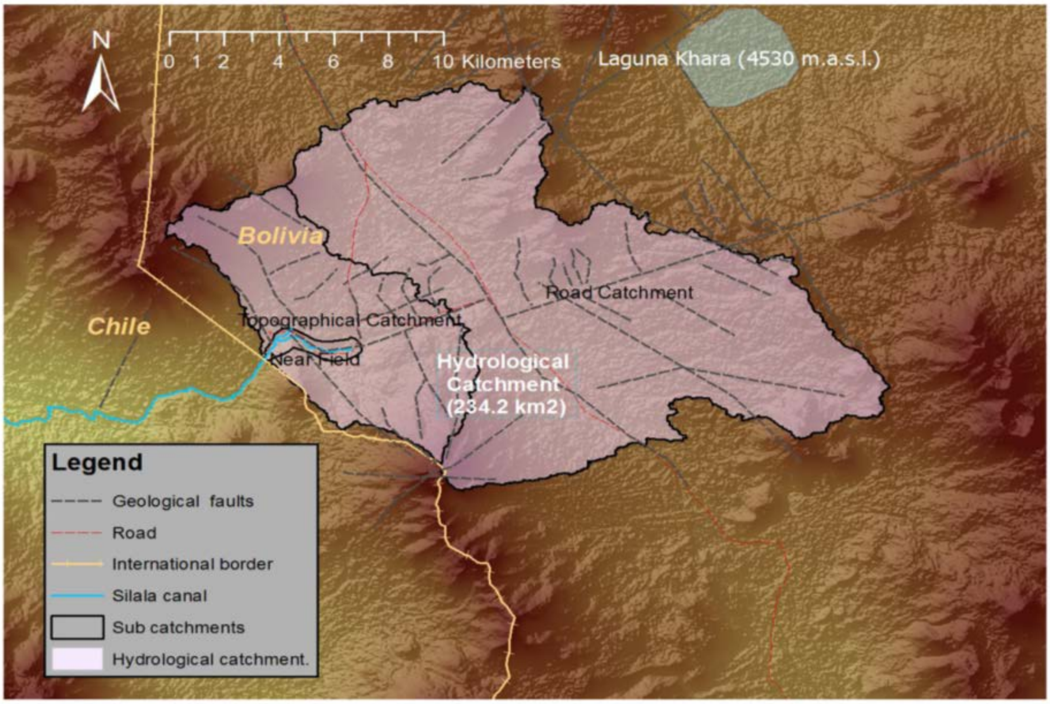

Figure 1. Hydrological catchment and Silala Near Field area defined by DHI (BCM, Vol. 2, p. 328).

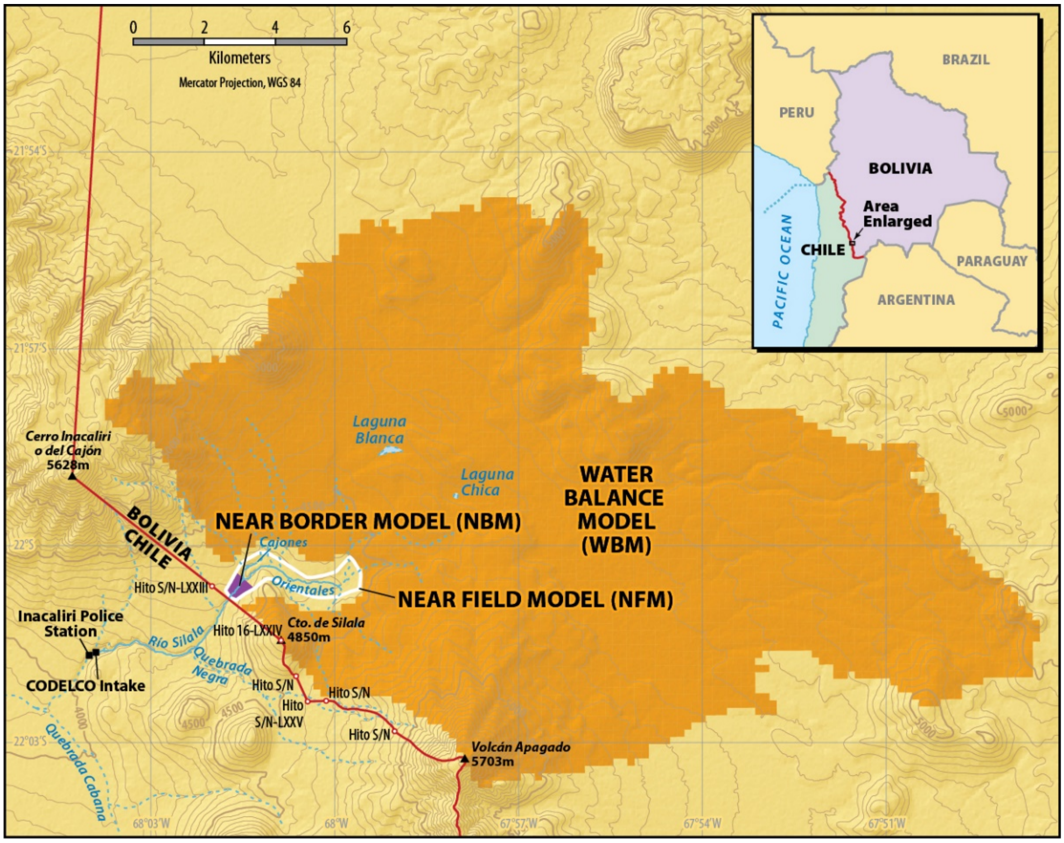

Figure 2. Domains covered by the three different DHI models (Muñoz et al., 2019).

With the limited information available from the BCM, we presented a report on the DHI modelling (Wheater and Peach, 2019) that outlined major concerns for the validity of the Near Field modelling. Concerning the estimates by DHI that the natural surface flows without drainage and channelization would be 30-40% less than the current situation, as stated in BCM (BCM, Vol. 2, p. 266), we noted that 'In our opinion the very large estimates made by DHI are implausible, and indeed defy common sense' (CR, Vol. 1, p. 98).

Given our concerns about the limited information presented in Bolivia's Counter-Memorial to define DHI's models and results, Chile requested access to the digital files that define the model configuration, parameterization, input and output data, in a letter to the Agent of Bolivia dated 5 November 2018. A letter dated

3 December was received from Mr. Jensen of DHI declining to provide the data. Dr. Wheater wrote to the Agent of Chile on 19 December, 2018, noting that the information provided in the Bolivian Counter-Memorial was inadequate to define the models that were used, or the modelling process that was followed, and furthermore the detailed results had not been provided.

A further request was sent to the Agent of Bolivia on 21 December 2018, and the digital data were finally received on 7 February 2019, which was after the finalization of the editing of Chile's Reply, that was presented to the Court on 15 February 2019. The data provided essential information to study the configuration, parameterization and performance of DHI's models, and a detailed analysis was made by Chilean hydrologists (Muñoz et al., 2019), under our supervision. The digital data proved to be extremely illuminating, and show conclusively that the DHI results are invalid, and should be discounted by the Court. The full Muñoz et al. (2019) report is attached to Chile's Additional Pleading. Below we highlight key findings and conclusions.

3.2 Water balance modelling

The WBM (BCM, Vol. 3, Annex 17, Annex E) was run to provide insights into the possible groundwater contributing area, the recharge that determines the magnitude of cross-border surface water and groundwater flows, and groundwater travel times. Estimates were made of the water balance over the topographic and groundwater catchments (excluding the Near Field area). The resulting estimate of recharge was 24 mm/year, though sensitivity analysis indicated a range of 19-49 mm/year[3]. The mean groundwater travel time was estimated to be 1,500 years, with a range from 50-6,000 years.

[3] We note that in DHI's Provisional Report 3 (Muñoz et al., 2019, Appendix D, p.11), Water balance of the basin and groundwater aquifer and update of measured flow recharge using the

The water balance from the WBM was estimated using a simulation period of 17,500 days, or just less than 48 years. Results from one of the files provided in February 2019, version Silala_model_gw_200m_v12_final.she, are presented in Table 1. The flows in mm/year and l/s were calculated using the simulation period and the area of the model's active cells. The table shows that 198 l/s of groundwater leaves the model through the NFM boundary.

	Cumulative water depth (mm)	Average depth rate (mm/year)	Average flow rate (l/s)
Precipitation	-6023	-126	-911
Evapotranspiration	4854	101	734
Recharge (prec.–evap.)	-1170	-24	-177
Total storage change	-170	-4	-26
Net groundwater boundary outflow	1309	27	198
Error	-30	-1	-5

Table 1. Water balance from the "Water Balance Model" - Silala_model_gw_200m_v12_final.she version (Muñoz et al., 2019).

It can be noted that even after 48 years, the SHE model has not quite converged to steady state (there is a net storage change of 170 mm (4 mm/year) over the simulation period), a point we return to later.

DHI note the need for long-term simulation to estimate the water balance (BCM, Vol. 3, p. 471). However, it is relevant to point out that while a period of 48 years smooths the day-to-day and short-term inter-annual variability, this period does not represent the climate variability over the 6,000 year period that was estimated by DHI as the maximum groundwater travel time.

Muñoz et al. (2019) also point out that there is an inconsistency between DHI's hydrogeological conceptual model and the boundary conditions for the numerical

same model is estimated to be 56 mm/year. No explanation has been provided by DHI for why the estimate was reduced in their final report.

WBM (Figure 3). A no-flow boundary is assumed at the model's south-western boundary, including a section along the Chile-Bolivia border. This will affect the modelled groundwater flows to the Near Field, and influence the partition of recharge between surface water and groundwater.

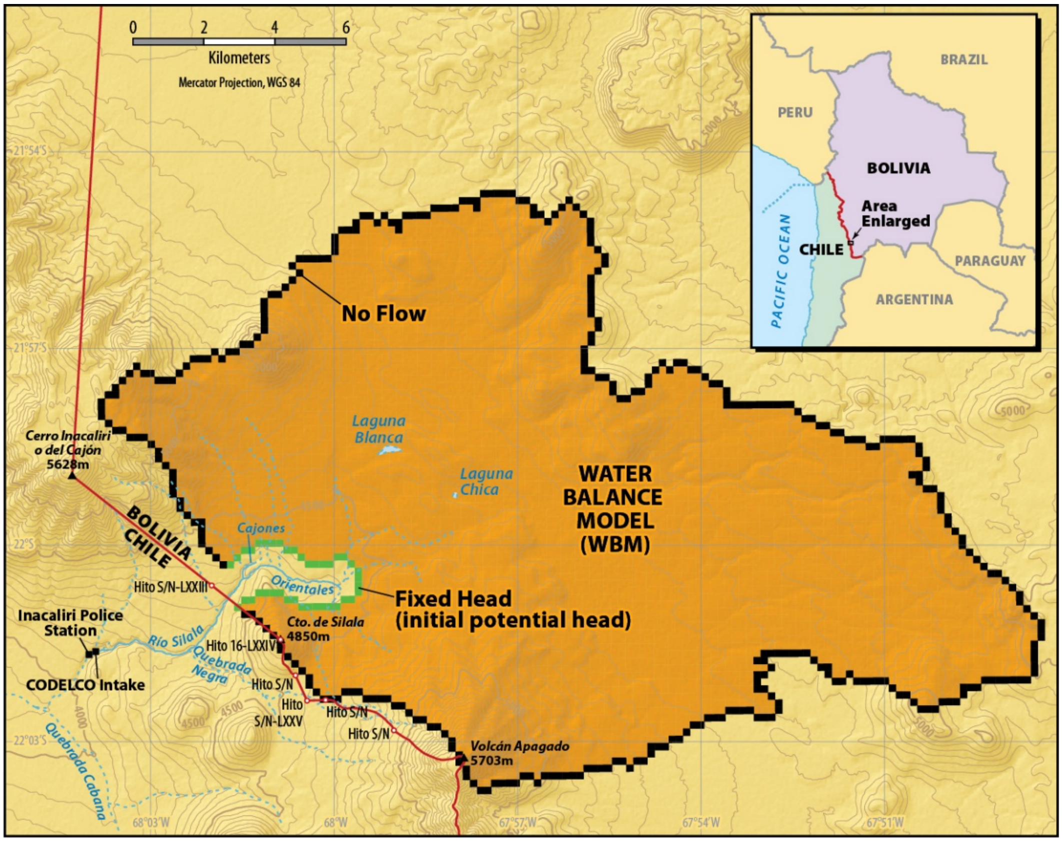

Figure 3. Boundary conditions of the Water Balance Model (Muñoz et al., 2019).

These issues of failure of the model to reach steady state and of inconsistency in boundary conditions are of limited importance for the water balance estimation, but are a recurrent theme for DHI's modelling, and have much greater significance for the Near Field modelling, as discussed below.

3.3 Near Field modelling

3.3.1. The Pleadings to date

DHI's Near Field modelling lies at the heart of the disagreement between the Parties. The Near Field Model has been run for three scenarios (BCM, Vol. 5, pp. 66-72):

i) "Baseline": represents the current situation with channelization.

ii) "No Canal": represents the situation without channels.

iii) "Undisturbed": represents a 'restored' situation without channels and with assumed long-term development of wetland peat soils, of up to 60 cm depth[4].

We note that in simulating the Baseline Scenario, DHI's MIKE-SHE model is used as the base model to represent the catchment response, including the unsaturated zone, groundwater, overland flow and evapotranspiration. To represent flow in the channels, the MIKE-11 surface-water flow model is used. MIKE-11 links to the MIKE-SHE model and allows exchanges of water between the channels and the underlying groundwater system. The "No Canal" and "Undisturbed" scenarios are also based on the MIKE-SHE model, but in these cases there is no explicit representation of river channels; the MIKE-11 model is not included.

In Bolivia's Counter-Memorial, based on the Near Field modelling, DHI stated that 'Without canals […] a reduction in surface flow of 30-40% is estimated compared to current conditions', 'The groundwater flow […] at the border *increases* by 7-11 %' and 'The evapotranspiration increases by 20-30 % by removing the canals and restoring wetlands. This however, correspond to a

[4] We note that Bolivia's Counter Memorial refers to a "Wetland restoration scenario" (e.g. BCM, Vol. 5, p. 66) whereas Bolivia's Rejoinder refers to "Wetland restoration (Undisturbed Scenario) (BR, Vol. 5, p. 73), and later as simply "Undisturbed" (BR, Vol. 5, p. 79) for the same scenario.

reduction of only 2-3 l/s in the combined cross border groundwater and surface water flow.'[5] (BCM, Vol. 2, pp. 266-267).

A key aspect of the NFM is that it represents a small area (2.56 km^2), located at the bottom of the groundwater and topographic catchments (Figure 4). Given the large uncertainties in the recharge to, and properties of, the groundwater catchment, DHI elected not to run a fully integrated model for the Near Field and Far Field (BR, Vol. 5, p. 67). The inflow of groundwater to the NFM was therefore determined by the choice of the boundary conditions for the model. As shown on Figure 4, a fixed 'head', i.e. a fixed groundwater water table elevation, was specified at the boundaries where groundwater was allowed to enter the Near Field. Many of the lateral boundaries to the model were defined as no-flow boundaries, while the lower, south-western boundary had a specified head gradient as the boundary condition. Specified values of head and head gradient were based on recent observations.

[5] DHI's italics

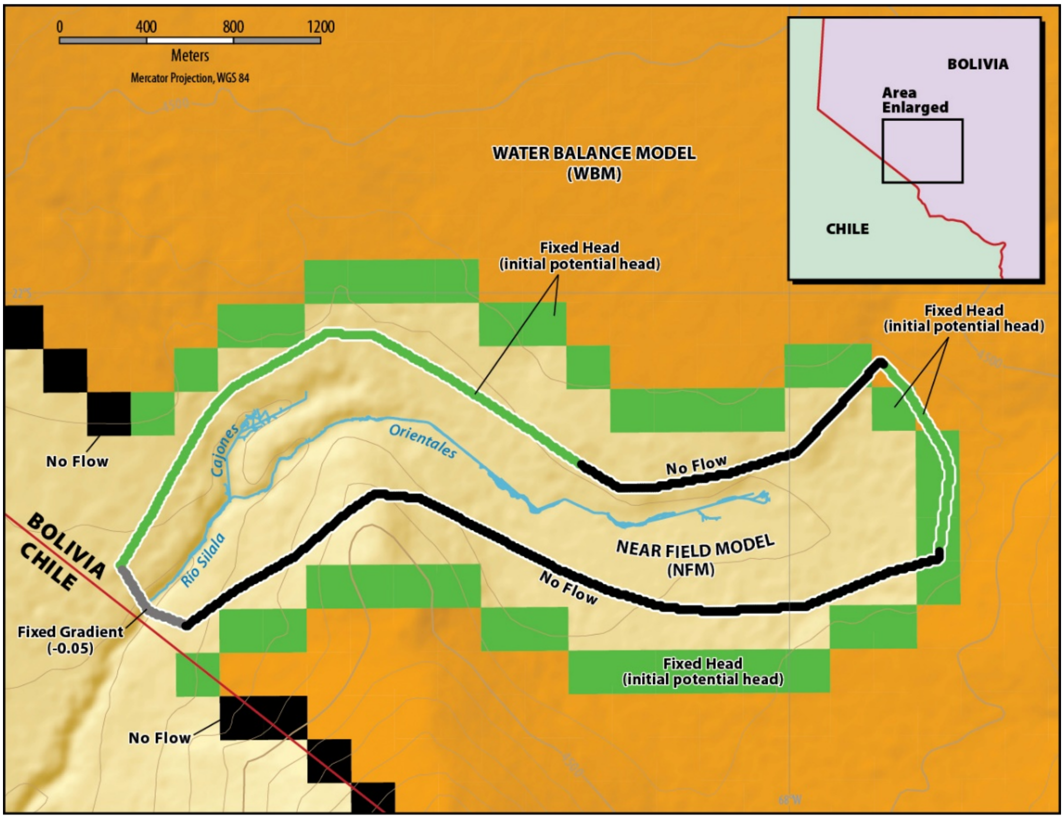

Figure 4. The area of Bolivia's Near Field Model. The green color represents Fixed Head boundary conditions, the black color represents No-Flow boundary condition and the grey color represents Fixed Gradient boundary condition (Muñoz et al., 2019).

In Chile's Reply (Wheater and Peach, 2019), we noted that the fixed head boundary condition was inappropriate, because water table conditions at the model upslope boundary are held constant in the model, while the interior of the model changes to represent changing channelization and peat growth. In reality the water table this close to the channel would respond to the changes. The constant water table boundary condition forces unrealistic changes in the inflow to the model, which are reflected in unrealistic changes to the outflow. We used simple calculations for an idealized two-dimensional hillslope cross-section to show that this boundary condition grossly exaggerates the simulated effect of the channelization and possible peat growth, perhaps by a factor of 20. We also noted that there were significant errors in the geology, on which the modelling was based. Concerning DHI's proposed changes, we concluded: 'We agree that these effects may occur, but find DHI's large estimates to be implausible. These estimates are wholly based on hydrological modelling […], which we find to be fundamentally flawed.' (CR, Vol. 1, p. 100)

In Bolivia's Rejoinder (BR, Vol. 5, p. 55), DHI accepted the validity of our criticism of the boundary conditions: 'It has been found, however, that the model boundaries are affected by the changes introduced by the removal of the canals and that the chosen boundary conditions will therefore also have a bearing on the produced results for a situation in which the canals have been removed.' They now take the position that the sensitivity to the boundary conditions should be investigated 'When considering the baseline model and the "no canal"/ "Undisturbed" scenario results, the sensitivity and uncertainty should therefore be taken into account' (BR, Vol. 5, p. 55). DHI's report (BR, Vol. 5, Annex 25) therefore investigates the sensitivity of the NFM to the assumed upstream and downstream boundary conditions. The previously adopted fixed head upslope boundary conditions are now seen as providing an upper bound 'Assuming that no changes will occur on the boundary will lead to the largest impacts on the surface water flows and, hence, such analysis will represent the upper bound' (BR, Vol. 5, p. 55). This can be interpreted as acknowledgment that the upper bound results are unrealistic, and that the impacts will be less than these values. The lower bound assumption for the upslope boundary condition is that there will be no change in the groundwater inflow to the NFM, which we agree is a conservative assumption. In addition, it is acknowledged that the assumed fixed gradient lower boundary condition will also affect the results.

As a result of the sensitivity analysis, Bolivia's estimates of the impact of removing the channels and possible long-term peat growth have been reduced, but still represent significant effects. The range of results obtained from the scenarios without canals from the upper and lower bounds for the upslope boundary condition is as follows (BR, Vol. 5, p. 56):

- '[…] the simulated range of decrease in transborder surface flow […] is 11% - 33%.
- The groundwater flow will increase between 4% and 10% [...]
- The evapotranspiration from the wetlands […] will increase between 28% and 24% of the baseline values or between 3 and 3.4 l/s.'

The different components of the water balance of the model are specified in Table 2 below.

Table 7-2 Results of the outer bounds of the sensitivity analyses of the upper head boundary conditions as changes in l/s from the flow components in the baseline simulation with the canals

	Canalised situation (l/s)	Changes from canalised conditions (l/s)	
	Baseline	Lower Bound	Upper Bound
Inflow to model	253.6	-1	-27.9
Surface outflow	149.0	-16	-48.6
Groundwater outflow	106.3	4	10.8
Evapotranspiration	10.0	3	3.4
Storage and num. inacuracy	-11.7	8.4	6.6

Table 2. Different components of the water balance of the model (BR, Vol. 5, p. 80).

It will be recalled that the lower bound of DHI's estimated impact range was based on no change in the water inflow to the NFM, and from the principle of conservation of mass, for a steady state simulation, this means no change in total outflows. However, the results presented by DHI for the lower bound simulation show a decrease in surface outflow of 16 l/s, an increase in groundwater outflow of 4 l/s, and an increase in evapotranspiration of 3 l/s. In other words, 9 l/s has gone missing. This is due to the change in storage and numerical inaccuracy of the lower bound results, stated by DHI to be 8.4 l/s (see Table 2) , and is more than half of the supposed impact of the channels the model is intended to estimate. Further, DHI's stated error in the Baseline simulation is 11.7 l/s. This means that the combined model errors from the scenarios being compared exceed the estimated effect of the channels, discrediting the modelling results. Clearly, there are major issues with the modelling in addition to those arising from the fixed head upstream boundary conditions that we noted in Chile's Reply. We turn next to the files provided by DHI in February 2019, and the analysis of Muñoz et al. (2019) to provide further insights.

3.3.2. Information from DHI's model files

The results of any hydrological model depend on assumptions made by the modellers. These include the detail assumed for the geometry of the system (in this case including not only the topography but also the representation of channels and drains and their interactions with surface and subsurface flows), the material properties used to represent the soils and aquifers and their spatial distribution, and the assumed boundary conditions of the model, which, as discussed in section 3.3.1, determine the inflows to and discharges from the model. In addition, with a complex non-linear model, such as the models used by DHI, there are also issues of numerical performance that are of concern, for example are there instabilities in the model or other numerical errors that affect the results, and for a steady state simulation, has the simulation converged to a steady state? As noted above, the information provided by DHI in Bolivia's Counter-Memorial was insufficient for us to review these aspects in any substantive detail. However, the provision of the associated digital data files by Bolivia in February 2019, and the subsequent purchase by Chile of licenses to run the models, enabled a comprehensive analysis to be undertaken by Muñoz et al. (2019).

3.3.3. Topography of the modelled scenarios

We recall from 3.3.1 above that DHI have modelled the Near Field using three scenarios:

The "Baseline" Scenario represents the current configuration of the river system, including the historical wetland drainage channels and main river channelization. DHI's MIKE-SHE model is used to represent the catchment response and MIKE-11 to represent flow in the channels. MIKE-11 links to the MIKE-SHE model and allows exchanges of water between the channels and the underlying groundwater system.

The "No Canal" Scenario, to represent the situation with channels removed, and the "Undisturbed", or restored wetland, Scenario, to represent the possible long term development of peat soils (of up to 60 cm depth) are based on the MIKE-SHE model alone, the MIKE-11 model is not included.

The lack of a MIKE-11 component for the No Canal and Undisturbed scenarios means that all surface water flow is routed as overland flow, using the MIKE-SHE model, using a relatively coarse spatial discretization compared to the MIKE-11 flow routing. This represents a situation in which there would be no surface water flow channels if the channelization was removed, which is of course incorrect.

Clearly, for the modelled scenarios to be compared, the models must be comparable. We note from the above scenario descriptions that there are differences in model configuration (MIKE-SHE plus MIKE-11 for Baseline versus MIKE-SHE alone for No Canal and Undisturbed). However, one of the most basic requirements is to have comparable representation of the topography of the Near Field, while allowing of course for the removal of channels and peat growth. We were astonished to discover that very different topographies have been used for the different scenarios, and for the Baseline Scenario a different topography has been used for the MIKE-11 model and for the underlying

MIKE-SHE model, with which it links. The differences are illustrated for selected cross sections in figures 5 and 6. We recall that the aim of the modelling is firstly to simulate the effects of channels, which in the wetlands are generally less than 0.5 m deep, and in the main channels are all less than 1 m deep (BCM, Vol. 5, pp. 31-39), and secondly to simulate the effect of possible peat growth, of up to 60 cm. It can be seen from Figure 5 that the topography of the Undisturbed Scenario (MIKE-SHE) shows differences of almost 7 metres from the Baseline (MIKE-11) channel bottom in cross section number 3560 and of almost 3 metres from the Baseline (MIKE-SHE) topography in cross section 3370.

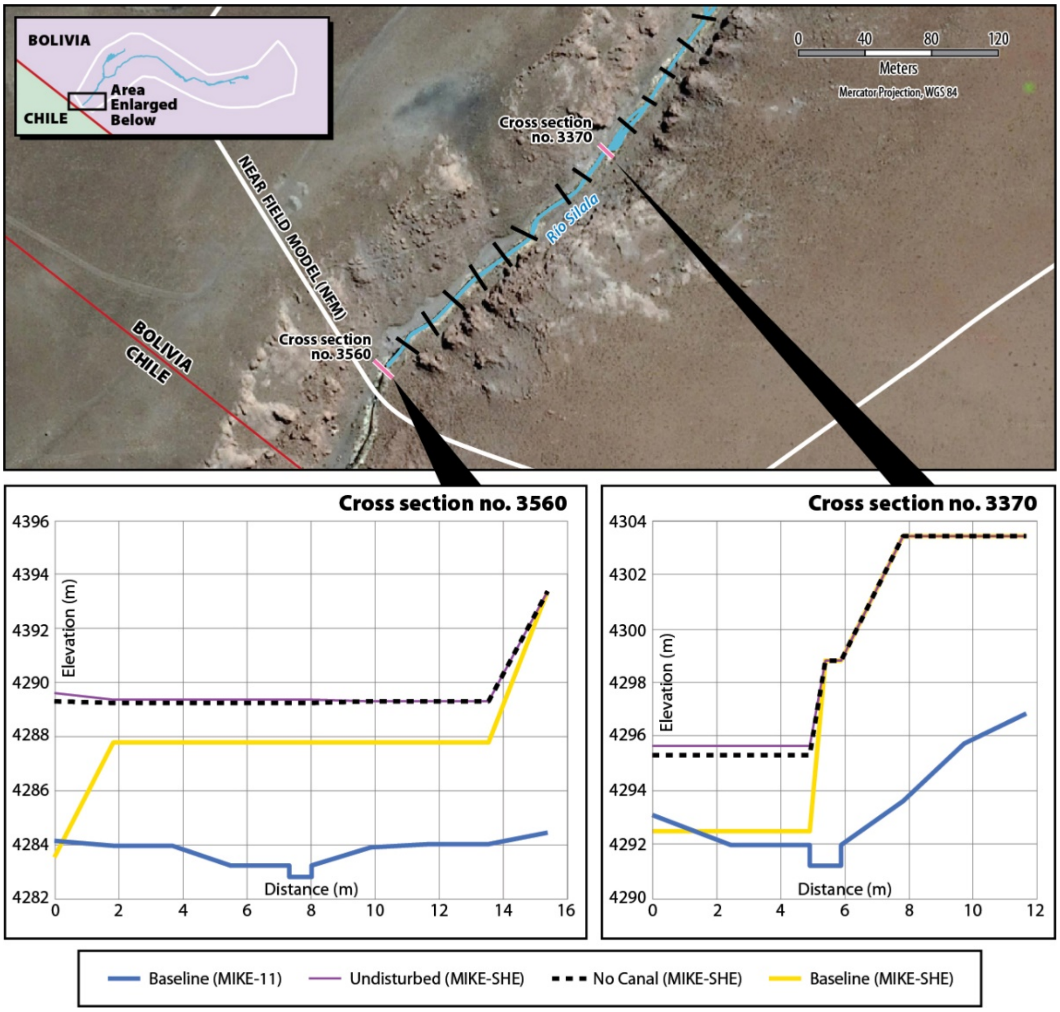

Figure 5. Ground surface elevations used in the four Bolivian models compared at two cross sections of the main channel near the international border (Muñoz et al., 2019).

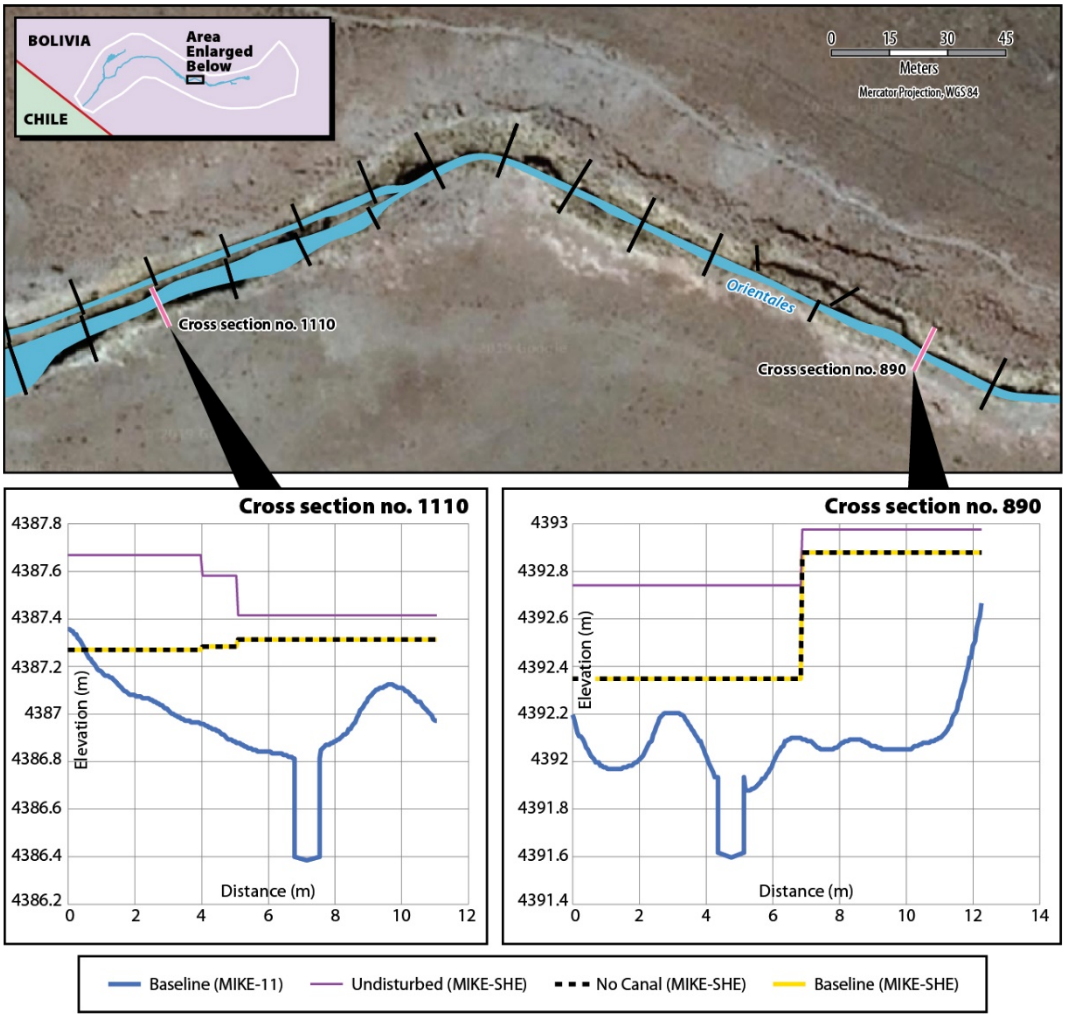

Figure 6. Ground surface elevations used in the four Bolivian models compared at two cross sections of the main channel in the Orientales wetland. Specifically, in these cross sections the Baseline and the No Canal topographies from the MIKE-SHE model coincide and the black dotted line obscures the yellow line (Muñoz et al., 2019).

Clearly, the three scenarios are not comparable, and the large imposed differences in topography are much greater than the effects that the models are supposed to distinguish. The No Canal and Undisturbed scenarios are not simply representing the removal of the channels, but also a large increase in the level of the land surface on the Bolivian side of the border. The dramatic raising of the ground surface will have the effect of increasing the groundwater heads at the inflow and outflow boundaries, which will in turn reduce the groundwater inflows to the model, and increase the groundwater outflows, leaving less water available to appear as surface water flow in their model. In other words, the imposed topographic changes will give rise to most, if not all, of the simulated effects that are supposed to be due to the channelization. The results of the scenario comparisons are clearly meaningless, and should not, in our opinion, be taken seriously by the Court.

3.3.4. Hydrogeology and boundary conditions

The DHI models depend on DHI's conceptualization of the hydrogeology of the Silala River basin, which in turn depends on interpretation of the geology. In section 4 below, we show that Bolivia's interpretation of the geology is wrong in several important respects. For example, errors in Bolivia's dating of rocks have led to incorrect specification of the vertical sequence of the rocks. The ignimbrite deposits, which are the major deep aquifers in the basin, are shown by Bolivia as underlying the Miocene Volcanics, whereas in fact, the Miocene rocks are older than the ignimbrites, and cannot therefore underlie the ignimbrites (section 4.2.1; Muñoz et al., 2019; SERNAGEOMIN, 2019b). One direct consequence of this is that DHI's interpretation of the geometry of the aquifer is incorrect. Figure 7 shows a screen shot from one of DHI's model files, which shows simulated groundwater flow in part of the Near Field where in reality the low permeability Miocene deposits will restrict the flow. While the direct effect of these errors in interpretation of the geology is mis-specification of the geometry of the system, other effects include consequential errors in the specification of aquifer properties. Clearly, when the effects to be simulated are small and quite subtle, these basic errors mean that the simulations will be unreliable.

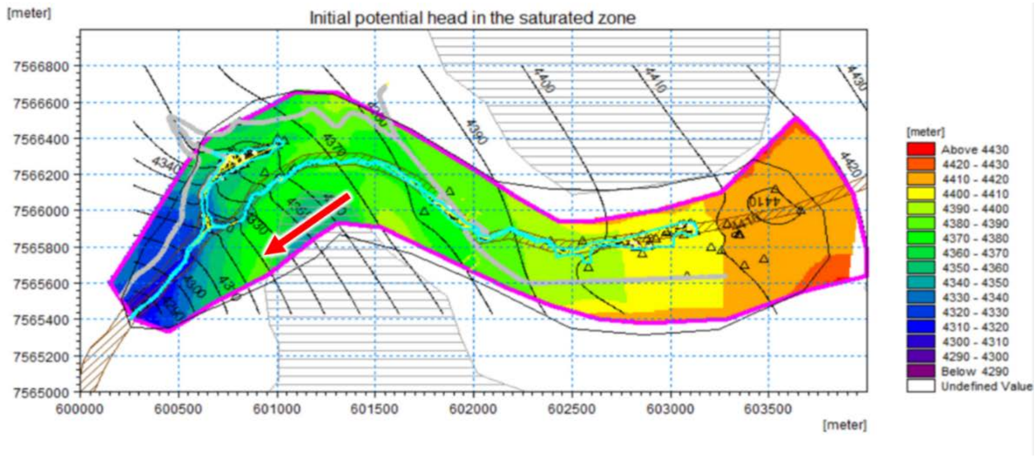

Figure 7. Groundwater level maps used in definition of groundwater component boundary conditions (BCM, Vol. 5, p.19). Black lines represent the piezometric contours, the polygons filled with grey lines represent the HGU4 unit. The added red arrow represents the implied groundwater flow through the HGU4 unit (Muñoz et al., 2019).

We turn next to the model boundary conditions. Here we note differences between DHI's own interpretation of Bolivia's groundwater data, and the boundary conditions used for the NFM. As pointed out in section 4, below, Bolivia's groundwater data are open to different interpretations, depending on the interpretation of the hydrogeology. However, there should at least be consistency between DHI's interpretation of the data and their model boundary conditions. In Figure 8 A) we show DHI's groundwater contours from Figure 40 (BCM, Vol. 4, p. 97). We note that groundwater flow direction is determined by the gradient of groundwater level, and that the direction of flow should be perpendicular to the contours. We have therefore added arrows to DHI's figure to show the implied flow directions. In figures 8 B) and 8 C) we reproduce DHI's figures 6 and 7 (BCM, Vol. 2, p. 371), which provide a very different interpretation of the groundwater flow to the springs. However, the boundary conditions used in the model are quite different from either of these interpretations, as shown in Figure 8 A) (Muñoz et al., 2019). For example, much of the southern boundary of the model is a no-flow boundary in the model, which is not what is shown by either of

DHI's contrasting interpretations of the data. And as noted above, the boundary conditions for the NFM are also different from those used by DHI for the Water Balance Model, which was used to simulate flows from the Far Field groundwater catchment to the Near Field. We conclude that DHI's model boundary conditions, which as noted above are crucial to the modelling, are simply not consistent with the available groundwater data.

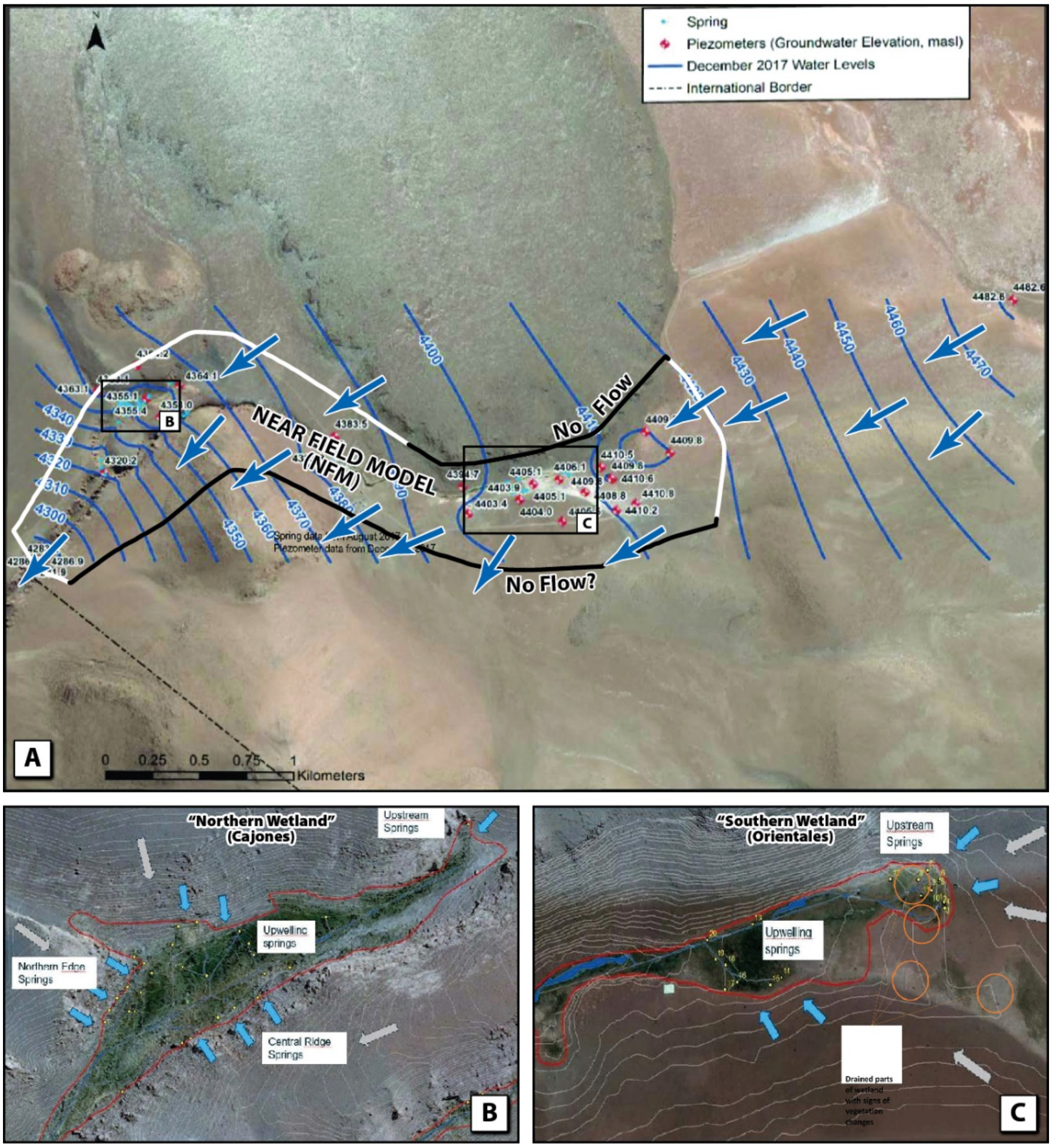

Figure 8. A) Groundwater level contours in the Silala NFM, interpolated from piezometer wells, spring elevations, and wetlands excavations for soil sampling (Adapted from BCM, Vol. 4, p. 97). The NFM domain is delimited by the polygon with a black and white border that shows in black the DHI no-flow boundaries and in white the boundaries through which water can pass. The blue arrows represent the direction of groundwater flow interpreted from the contour lines. B) Northern and C) Southern wetlands overall flow directions. (Adapted from BCM, Vol. 2, p. 371). Note: The text in the lower label of panel C is: "Drained part of wetland with signs of vegetation changes" (Muñoz et al., 2019).

3.3.5. Numerical performance and other modelling issues

In section 3.3.2 above we noted that there are a range of concerns when using complex, highly non-linear models, related to numerical performance. We recall (section 3.3.1) that the MIKE-SHE model was used for all scenarios, and that for the Baseline Scenario, the MIKE-11 model was used to represent the channelized surface flow. We highlight here some of the more important issues of concern. A more complete analysis is presented in Muñoz et al. (2019).

Concerning MIKE-SHE, DHI state (BCM, Vol. 5, p. 67) that 'The integrated surface water - groundwater model has been set up and run as a steady-state model.' This means that there should be no change in the internal storages in the model, and the model outputs should equal the model inputs. However, all of the results presented by DHI (e.g. BCM, Vol. 5, p. 67, Table 1; BR, Vol. 5, p. 80, Tables 7-1 and 7-2) indicate storage change. This means that the simulated water balances are incorrect. In 3.3.1 we pointed out that the results of the sensitivity analysis presented in Bolivia's Rejoinder show that the combination of storage and numerical inaccuracy accounts for 11.7 l/s in the Baseline Scenario, and 8.4 l/s in the lower bound No Canal simulation, when the lower bound simulation shows changes in surface flows due to channelization to be 16 l/s. The errors in the modelling are therefore of the same order as the effects to be modelled. Clearly the results must be considered unreliable.

A further implication of the failure of the models to reach steady state is that the initial conditions, which are used to set the initial states and hence storage values of models, will influence the final results. Muñoz et al. (2019), found that DHI had used different initial conditions for the different scenarios. Since these scenarios represent different physical configurations it would be reasonable for them to have different initial conditions, but two problems arise. Firstly, there is a methodological inconsistency in DHI's simulations: the same initial conditions are used in the Baseline and No Canal scenarios but not in the Undisturbed

Scenario. Secondly, the differences between the initial groundwater pressures (represented as an equivalent height of water and known as potential heads) in the Baseline and No Canal scenarios and the Undisturbed Scenario, shown in Figure 9 vary between -18 m and +16.5 m. These differences only came to light from inspection of DHI's digital files, and have not been explained or justified by DHI. Muñoz et al. (2019) conclude that the very large imposed differences in the initial conditions mean that the simulations of the three scenarios are 'neither equivalent nor comparable'.

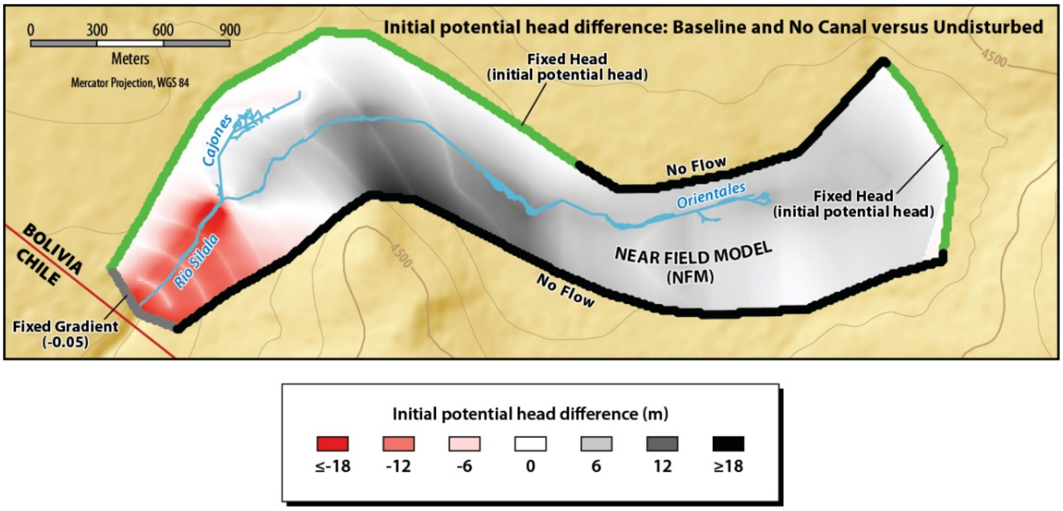

Figure 9. Initial potential head difference between the Baseline and No Canal scenarios and the Undisturbed Scenario. Positive values correspond to locations where the initial potential head is higher in the Undisturbed Scenario (Muñoz et al., 2019).

Inspection of the data files by Muñoz et al. (2019) also showed unexplained anomalies in the various model scenario configurations. It is agreed by both Parties that the springs in Bolivia are fed by groundwater flow, partly from the topographic catchment and partly from a more extensive groundwater catchment. A physically based model of the Near Field, the small area around the springs, should therefore represent the inflow to the springs as a groundwater input across the NFM boundaries, and this was our understanding of the modelling from DHI's reports in BCM and BR. However, from the model files it is apparent that additional water is introduced to the Near Field at the locations of the spring sources, and this has neither been explained nor justified. 42 l/s of water is introduced as an external input of "spring recharge" in the Baseline Scenario. In contrast, 31 l/s is input into the two No Canal scenarios. These amounts appear arbitrary and are not mentioned in any of the reports available to us, let alone explained or justified. But clearly a difference of 11 l/s has been introduced into the scenario comparisons, an amount that is more than half of the simulated change in surface flows due to the channelization, further enhancing the simulated effect[6].

We turn next to the MIKE-11 model, used in the Baseline Scenario to represent surface water flow in the channels. There are a large number of issues and concerns with the model set-up and results, described fully in Muñoz et al. (2019). We mention a few of the more important issues here.

We noted in 3.3.3 above that a different topography was used for the MIKE-11 and MIKE-SHE models in the Baseline Scenario. Additional topographic issues were found in the MIKE-11 model for this scenario. It was found that water at some of the modelled cross sections does not flow through the main channel, as illustrated in Figure 10. Further, a key parameter in hydraulic models of surface water flow is the effective roughness of the channel, commonly represented by a parameter known as Manning's coefficient (n). As explained by Muñoz et al. (2019), DHI have used unrealistically large values for this parameter, way beyond feasible literature values for the types of channel represented here. One result of this large roughness is that flow velocities are slower than would be expected, and hence the flow depths are larger, an effect exacerbated in the lowest reaches by an inappropriate lower boundary condition for the hydraulic model (Muñoz et al.,

[6] It is also the case that this injected water is treated differently in the different scenarios. As explained in Muñoz et al. (2019), in the baseline scenario water is added directly to surface runoff. In the other scenarios it is added to a MIKE-SHE grid cell as recharge and subsequently partitioned between overland and subsurface flow, so that the partitioning between surface water flow and groundwater flow is influenced by this different treatment.

2019). This perhaps explains why, in DHI's model, the channel is flooded in places, and the water flows as over-bank flow (Figure 11). Clearly the representation of channel flow in the MIKE-11 model does not represent the reality of channel flow in the Silala River system, and this also affects the simulation of surface water-groundwater interactions.

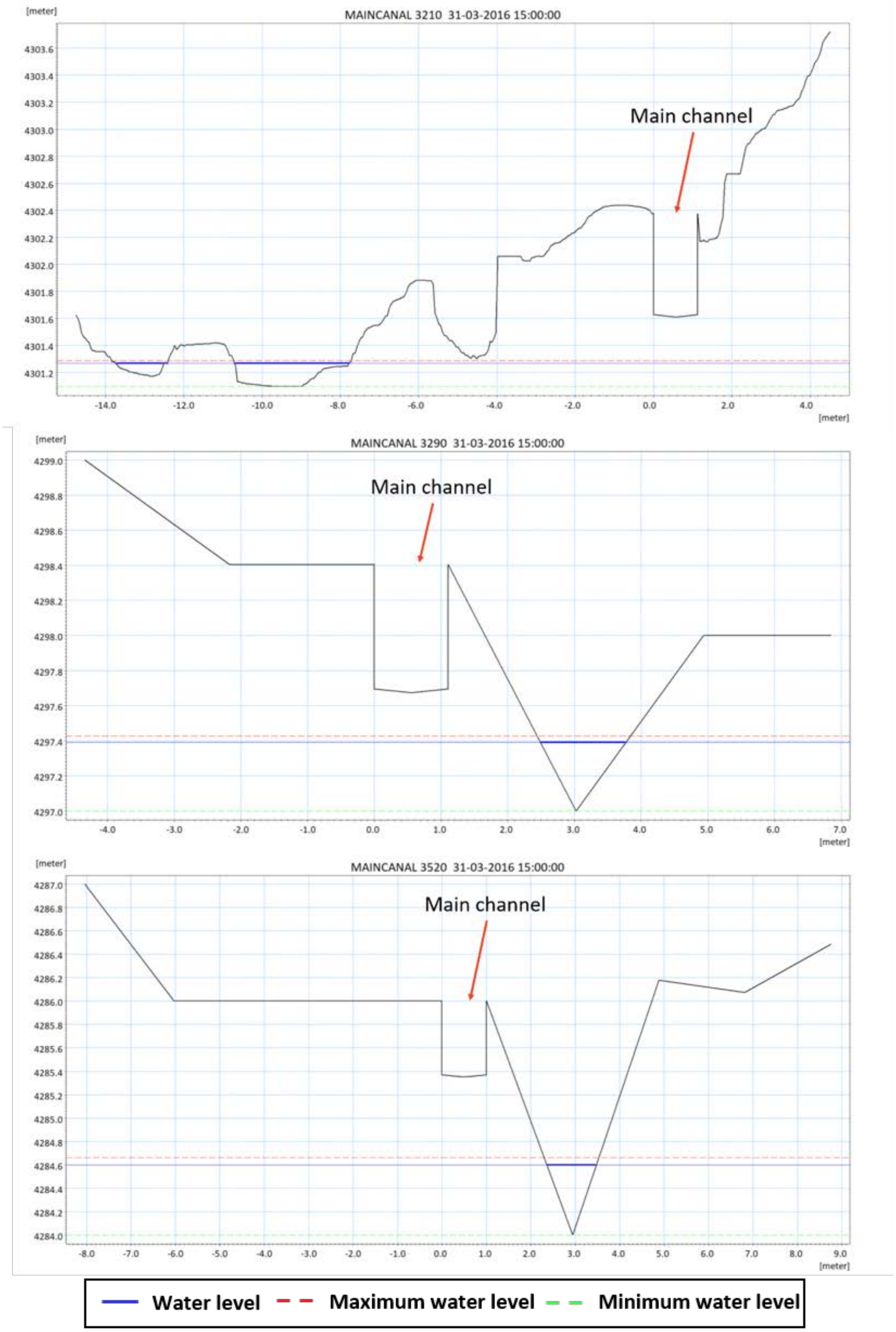

Figure 10. Some of the cross sections where the water does not flow through the main channel (Muñoz et al. 2019).

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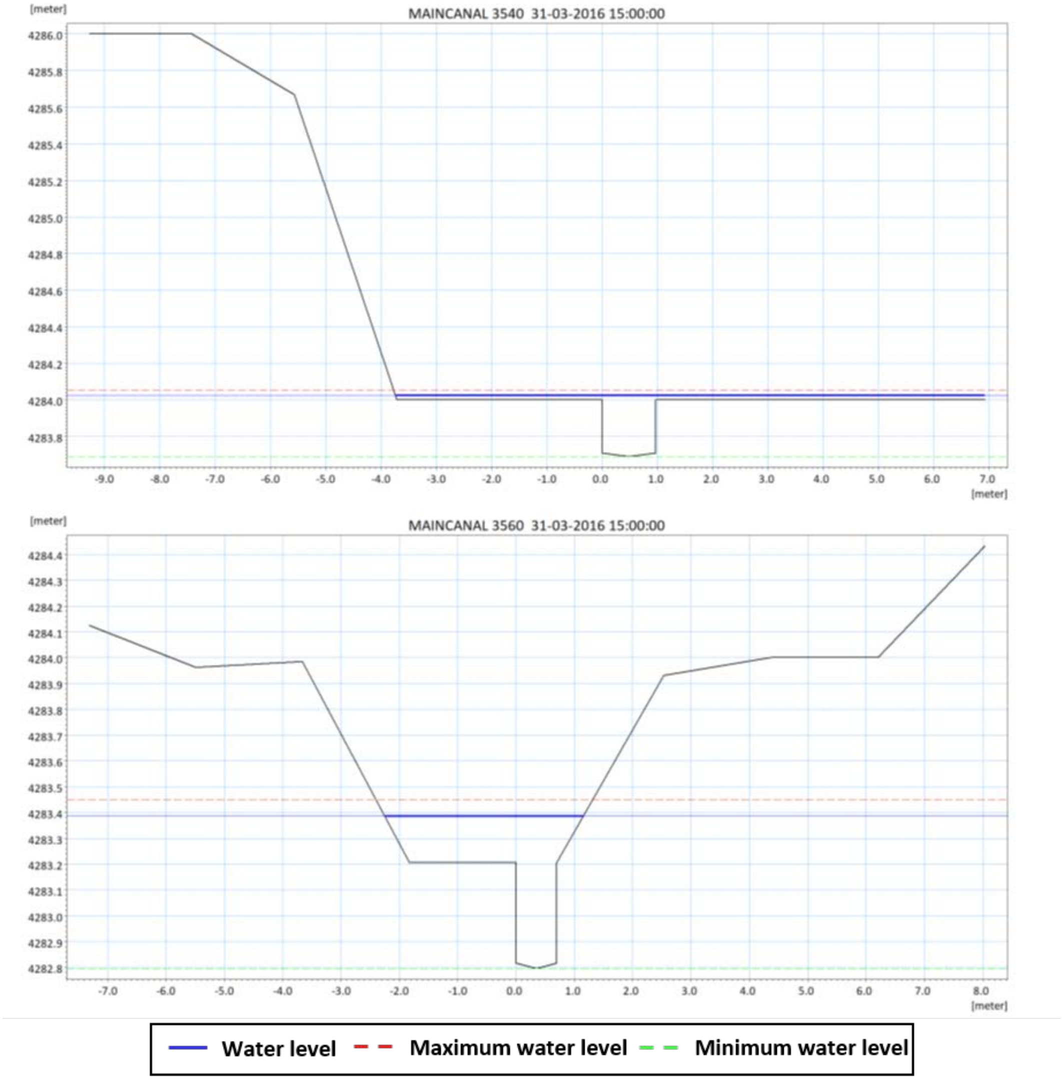


Figure 11. Cross sections where the channel is flooded (Muñoz et al., 2019).

Returning to the issue of numerical stability, Muñoz et al. (2019) found that the MIKE-11 simulation results showed abrupt changes in river flow at various locations, and flow variations along the river that never stabilized, illustrated in Figure 12. More importantly, there were unexplained differences between the MIKE-SHE and the MIKE-11 simulated discharges. Overall there was an unexplained 7 l/s over-estimate of the flows from MIKE-11 compared to MIKE-SHE for the current conditions.

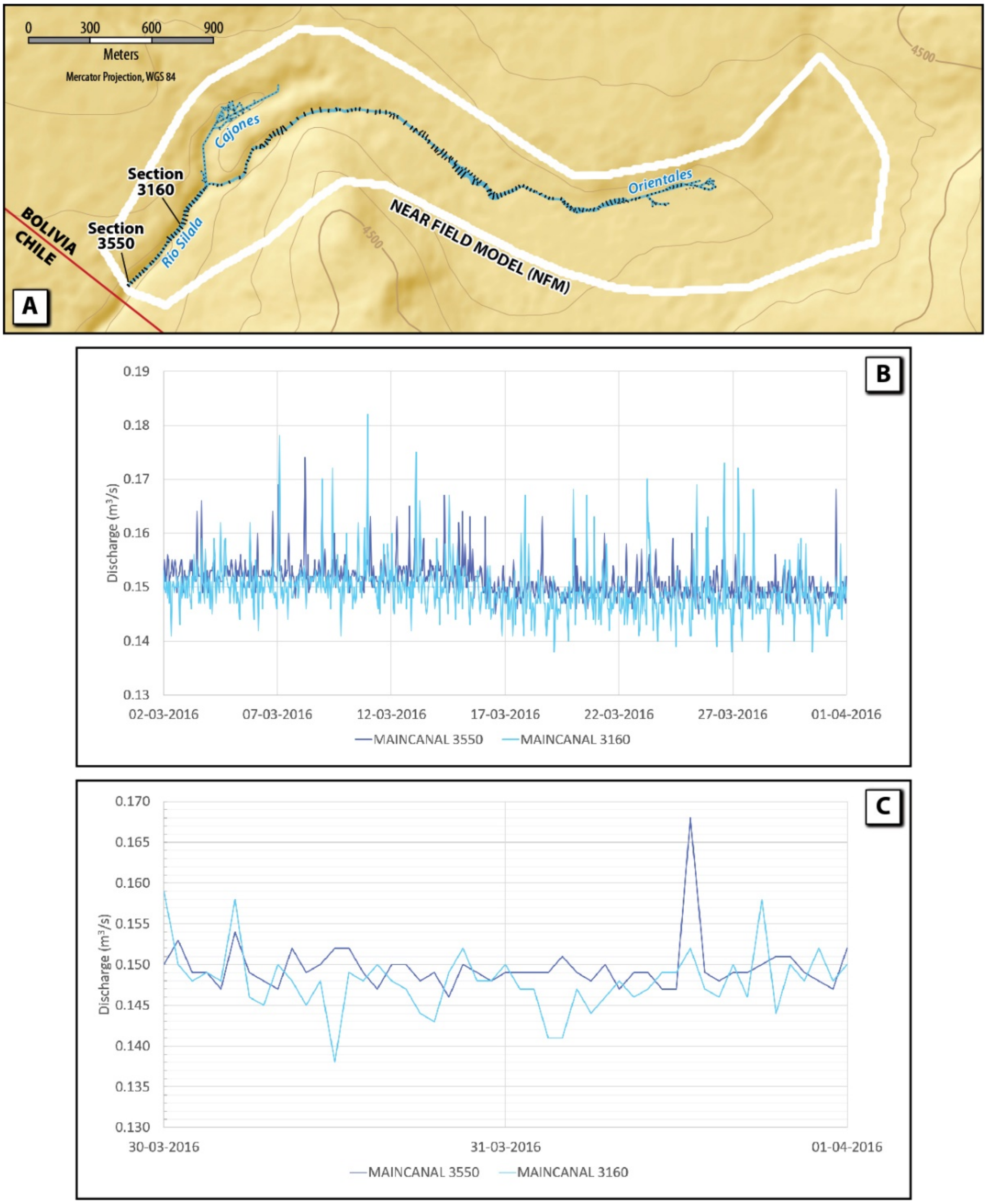


Figure 12. Flow variations in two sections of the reach between the Cajones and Orientales confluence and the international border. (A) Plan view of the NFM domain that depicts the locations of the two sections analyzed. (B) Discharge time series of the flow at sections 3550 and 3160. (C) Zoom into the last two days of the flow at sections 3550 and 3160 (Muñoz et al., 2019).

A final inconsistency concerning DHI's numerical results is that in Bolivia's Counter-Memorial, DHI's estimate for the Undisturbed Scenario (removal of channels and long-term peat growth) is that the river flow is reduced by 40% relative to current conditions (BCM, Vol. 2, p. 303). However, in Bolivia's Rejoinder, where the same simulations were used to represent the upper bound estimate of the impacts, DHI reported that the river flow was reduced by 33% (BR, Vol. 5, p. 56). In attempting to understand this clear contradiction, Muñoz et al. (2019) found that 10 l/s of additional surface water flow had appeared in the results for the Undisturbed Scenario presented in Bolivia's Rejoinder. This was not explained, but it was included in the Excel spreadsheet named "Water balance tables – Sensitivity Report.xls", delivered by DHI along with the files provided to support the Rejoinder modelling (Muñoz et al., 2019, Appendix C). Once again, an unexplained and apparently arbitrary change to the model had been made to change the results.

3.3.6. Flow estimate from Fox (1922)

A measurement of flow in the Silala River was reported by Robert H. Fox, a water supply engineer, in a paper published in 1922. Fox noted a flow of 11,300 cubic metres per day, or approximately 131 l/s. This is of course lower than current flows at the border, and hence DHI (BR, Vol. 5, p. 80) state that this flow measurement supports their argument that prior to the channelization, flows in the river would have been lower.

There are however several factors to bear in mind. Firstly, the location of the measurement is unknown, and as reported by Bolivia and Chile, there are major changes to the flow rate at different locations along the river, as springs add to the surface flow, and water is lost from the channel to groundwater. DHI state (BR, Vol. 5, p. 80): 'Fox measured 131 l/s […] at a location which from his description must be pretty close to the present de-siltation chamber.' However, no measurement location was specified in Fox's paper. A possible interpretation from the paper is that the measurement was made at the "small dam" (or Intake N° 1) that was built in 1909 and operative from 1910 onwards, located in Bolivian territory just below the confluence of the Cajones and Orientales ravines, at approximately 600 m upstream from the international boundary. This does not justify Bolivia's claim that the flow represents the cross-border flow (BR, Vol. 1, pp. 35-36).

Secondly, the method of measurement is unknown, and hence its accuracy and reliability. The recent, 21st century, experience from both Bolivia and Chile, is that the Silala River is a very difficult environment in which to accurately measure flows. Chile (CM, Vol. 5, p. 247) noted 'difficulties in flow measurement due to the extreme conditions of the Silala River', and Bolivia (BCM, Vol. 2, p. 395) reported that comparison of the long term flow records from the permanent gauging stations set up by Bolivia and Chile 'shows significant differences in both the mean flow levels and temporal variation. None of the series from the two sites seems, however, to be free of gauging inconsistencies, which may be due to the remote locations and harsh climate.' In addition, short-term measurements made by Bolivia in 2017 show 'inconsistencies both at the individual gauging points and also when cross-comparing the data.' (BCM, Vol. 2, p. 395).

It is clear that, even today, the Silala River is a very difficult environment in which to measure flows, and given that only a single estimate was reported by Fox, in 1922, using an unknown method at an uncertain location, then little credibility can be attached to his reported value.

3.4 Conclusions

The analysis of the digital files provided by Bolivia in February 2019 has provided extensive and definitive evidence that DHI's modelling, upon which Bolivia's estimates of the effects of historical channelization are based, is fatally flawed. While there are very many issues of concern, perhaps most striking are that: 1) completely different topographies were used for the different scenarios, with the differences in topography very much larger than the relatively small differences associated with channelization and assumed peat growth, 2) there are basic errors in the geology and hydrogeology that mean that the geometry and aquifer properties are wrong, 3) arbitrary amounts of water have been added to the wetland springs, with different amounts for the different scenarios (and different partitioning between surface and groundwater), thus adding to the simulated effects of channelization, and 4) errors and inaccuracies, including changes in storage, account for similar rates of flow to the effects ascribed to the channelization and peat growth.

Since our report on the impacts of channelization in Chile's Reply (Wheater and Peach, 2019), DHI has provided new results in Bolivia's Rejoinder. While we were pleased to note that DHI accepted our criticism of their earlier work for the BCM, and agreed that their choice of boundary condition biased the results, nevertheless the revised results from their sensitivity analysis are subject to all of the errors pointed out above. In addition, the BCM and BR results differ for the same simulation, and it appears that unexplained amounts of water have been added to the flow model to produce this change.

In truth, we were shocked by the basic errors made by DHI, and their failure to report crucially important aspects of the modelling. We conclude that DHIs' modelling results must be regarded as meaningless, and in our professional opinion should be discounted by the Court.

4 ISSUES RELATED TO THE GEOLOGY AND HYDROGEOLOGY OF THE SILALA BASIN

4.1 Introduction

Bolivia's estimates of the impact of the channelization of the Bolivian wetlands, known in Chile as Cajones and Orientales or in Bolivia as Bofedales Norte and Bofedales Sur, and of the Silala River in Bolivia, have been based on the results of DHI's modelling of the surface and groundwater systems of the Silala River, including its extended groundwater catchment. The numerical models used to provide these estimates have been constructed from a hydrological and hydrogeological conceptual model (BCM, Vol. 4, pp. 62-102), which in turn has relied heavily on the Bolivian understanding of the geology of the area.

In essence, Bolivia's interpretation of the geology is incorrect in several important respects, which in turn leads to DHI's conceptual model of groundwater and surface water flow being incorrect. In consequence, the construction of DHI's numerical models, which are based on that understanding, is also wrong. This will inevitably result in errors in the estimates of groundwater and surface water flows, and in particular the results of the NFM, which was used to simulate various scenarios with and without channelization, as explained in Section 3 above.

A detailed study of the documents listed below which pertain to the geology of the Silala River groundwater catchment in Bolivia presented to support the BR has been made by the Chilean geologists (SERNAGEOMIN, 2019b). This is included in Chile's Additional Pleading as Appendix 2 to this report.

1. Annex 23.5: F. Urquidi, "Technical analysis of geological, hydrological, hydrogeological and hydrochemical surveys completed for the Silala water system", June 2018. (BR, Vol. 3, pp. 233-332).
2. Annex 23.5, Appendix a: SERGEOMIN (National Service of Geology and Mining), Study of the Geology, Hydrology, Hydrogeology and Environment

of the Area of the Silala Springs, June 2000-2001, Final Edition 2003. (BR, Vol. 3, pp. 333-401).

3. Annex 23.5, Appendix b: SERGEOMIN, “Structural Geological Mapping of the Area Surrounding the Silala Springs”, September 2017. (BR, Vol. 4, pp. 5-136).
4. Annex 23.5, Appendix c: Tomás Frías Autonomous University, (TFAU), “Hydrogeological Characterization of the Silala Springs”, 2018. (BR, Vol. 4, pp. 137-462).
5. Annex 24: DHI, “Analysis and assessment of Chile’s reply to Bolivia’s counter-claims on the Silala Case”, March 2019. (BR, Vol. 5, pp. 5-46).

In their report, SERNAGEOMIN, 2019b, list numerous errors and inconsistencies in the Bolivian documentation, which have a significant impact on the hydrogeological understanding and have resulted in the flawed construction, including aquifer parameterization and boundary condition location and type, of DHI’s NFM. We highlight some of the more important examples of these errors and inconsistencies in this section, and their consequences, which have led to a severely flawed representation of the groundwater flow regime and hence incorrect results of the modelling they rely upon to estimate the effects of channelization of the Bolivian wetlands and their supporting springs.

In addition to the errors in geological interpretation, DHI’s conceptualization of groundwater flow has been compared to DHI’s model construction by Muñoz et al. (2019), and detailed in section 3 of this report. It has also been noted that the boundary conditions imposed on the NFM are inconsistent with DHI’s own stated conceptual understanding of the groundwater flow regime. This is a further source of model error, as has been discussed in section 3.

4.2 Geology and Hydrogeology of the Silala River wetland springs and surrounding area

In this section we discuss the errors and internal inconsistencies in the Bolivian documentation and methodologies used to develop their geological interpretations, hydrogeological conceptual model and the incorporation of this understanding into the numerical models prepared by DHI. This discussion is developed to show the flawed nature of these models and likely consequences for the accuracy of their estimates of the impacts of channelization.

One of the most basic laws in geology is the "law of superposition" which states that in undeformed sequences of strata, the oldest strata will be at the bottom of the sequence. The study of these sequences of rock strata is known as stratigraphy, which is discussed in section 4.2.1. Another important area for consideration is the deformation that the rock deposits have undergone over geological time. This will be dealt with in section 4.2.2 on structural geology. The branch of science concerned with the origin, structure, and composition of rocks is called petrology and the detailed descriptions of rocks, their mineral content and the textural relationships within the rock is known as petrography. There are several inconsistencies and errors in the description and naming of rock deposits, which have contributed to the confusion concerning the geological understanding of the Bolivian geologists (SERNAGEOMIN, 2019b), some of which are briefly discussed in section 4.2.3.

The Bolivian reports listed above contain important errors and inconsistencies in the understanding and interpretation of stratigraphy, structural geology and in petrography. These errors and inconsistencies have led to errors in development of a hydrogeological conceptual model, upon which DHI relied for the design of their numerical models, particularly the NFM. DHI's interpretation of the hydrogeology is discussed in section 4.2.4 below.

4.2.1 Stratigraphy

The Bolivian understanding of the stratigraphy of the Silala Basin is significantly flawed, due in part to errors they have made in the attribution of radiometric dates to the sequence of ignimbrite deposits (the ignimbrite succession) (SERNAGEOMIN, 2019b). These form the major deep aquifer of the Silala groundwater catchment, and hence are fundamental to the modelling of the groundwater system.

In Bolivia the Ignimbrite succession has been divided into three geological sub-units (Nis-1, Nis-2 and Nis-3, Nis-1 being the lowest sub-unit) of one formation they call Silala Ignimbrites (Bolivian name, hereafter Bol) (BR, Vol. 4, pp. 43-51), whereas in Chile only two ignimbrite units have been found. These have been identified in surface outcrops and borehole cores (SERNAGEOMIN, 2017; SERNAGEOMIN, 2019a; Arcadis, 2017). However, it is accepted by Chile that beneath the Bolivian wetland areas there may be, at depth, further ignimbrite units, but these have not been found in Chile.

Bolivian geologists assign an age range for the ignimbrite succession in Bolivia of 7.8-6.6 Ma (BR, Vol. 3, p. 248; BR, Vol. 4, pp. 39, 43 and 46). A radiometric age date of 7.8 Ma has been given by Bolivian geologists to the Silala Ignimbrite (Bol). This age was assigned to a sample from Bofedales Norte (Cajones) and was said, by Bolivia, to come from a sample collected 16.5 km to the south east (SERNAGEOMIN, 2019b; Baker and Francis, 1978). However, according to the original paper of Baker and Frances, 1978, this age should be attributed to andesitic lavas located 8 km east of the Silala Grande (Bolivian name, Volcán Apagado in Chile). This age has been extrapolated erroneously to the ignimbrites of the Silala area. Quite clearly there is considerable confusion demonstrated here and a significant error has been made by the Bolivian geologists.

In Chile two units of ignimbrite have been identified; the Silala Ignimbrite (Chilean name, hereinafter Chi) and the Cabana Ignimbrite (Chilean name, hereinafter Chi), with ages of 1.61 Ma and 4.12 Ma respectively (CR, Vol. 3, pp. 202-203). These units have been identified in outcrop in Chile and in a cored borehole in Chile very close to the international border. Further, the Silala Ignimbrite (Chi) is seen to cross the border at outcrop and can be traced, using satellite imagery, into Bolivia. It can be observed on satellite imagery underlying Pleistocene andesitic lavas (1.48 Ma) (CR, Vol. 3, p. 203) and unconformably overlying the Silala Ignimbrite Nis-3 (Bol) in Figure 13, which is the uppermost ignimbrite unit that is described by the Bolivian geologists. They attribute this ignimbrite unit as having an age of 6.6 Ma (BR, Vol. 4, p. 115). Clearly this is not the youngest ignimbrite since the Silala Ignimbrite (Chi) unconformably overlies the Silala Ignimbrite Nis-3 sub-unit (Bol). The presence of two separate ignimbrite deposits in Chile, one of which can be traced into Bolivia in the area of the Bofedales Sur (Orientales) has been ignored by Bolivia. Furthermore, the Silala Ignimbrite Nis-2 sub-unit (Bol), which underlies Nis-3, is described as Dacitic ignimbrite with andesitic clasts (BR, Vol. 4, pp. 48 and 158). This is significant because these clasts "[…] pertain to the first Inacaliri volcanic event" (BR, Vol. 4, p. 158) and this is the reason for the andesitic composition. However, the Inacaliri volcanic lavas have been dated at 5.84 Ma (Almendras et al., 2002), which clearly means that the Nis-2 sub-unit must be younger than the Inacaliri andesitic lavas (5.84 Ma) and therefore the Silala Ignimbrite Nis-3 sub-unit (Bol) must be even younger since this deposit overlies the Nis-2 sub-unit (SERNAGEOMIN, 2019b).

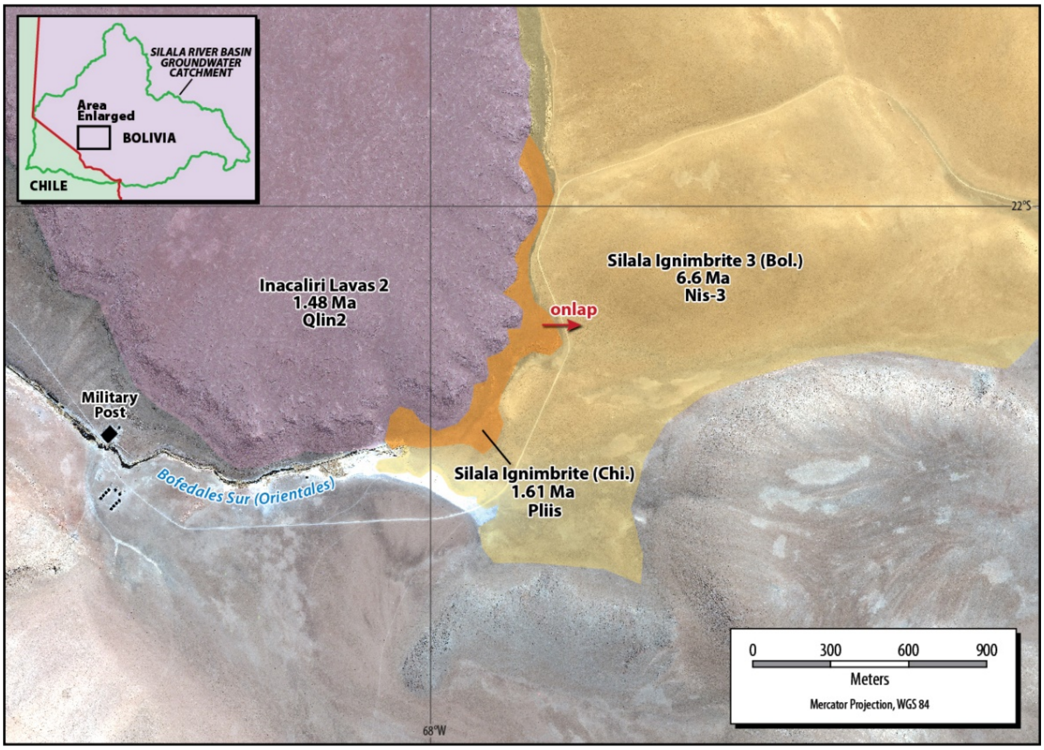
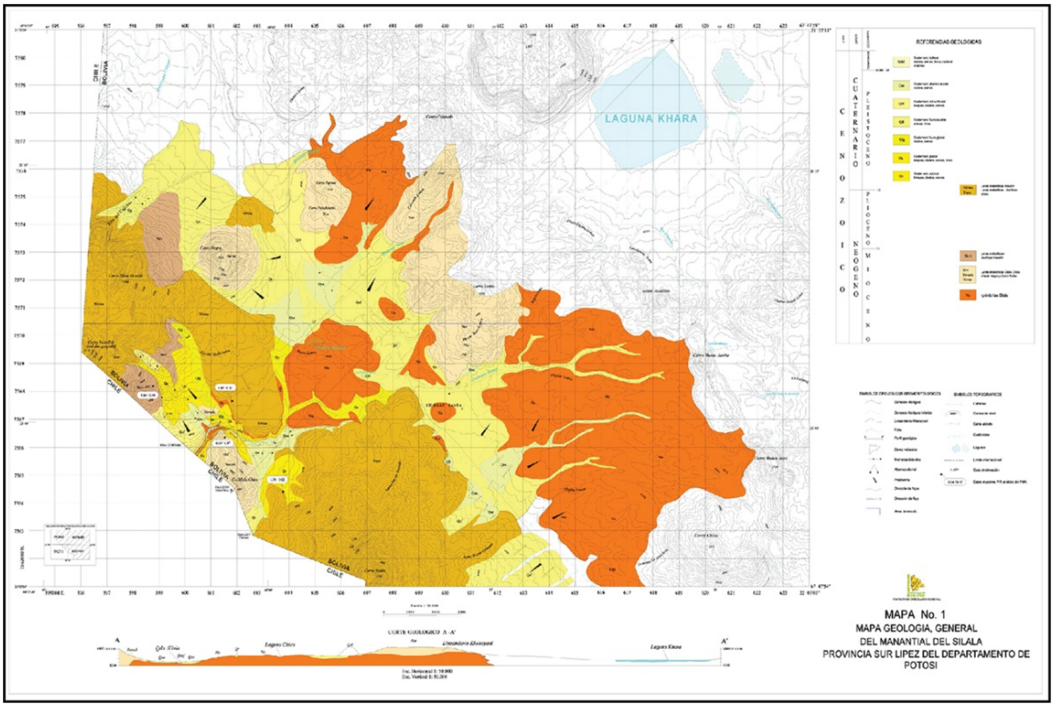


Figure 13. The Silala Ignimbrite (Chi) clearly overlying Silala Ignimbrite Nis-3 (Bol), located at the East of Bofedales Sur (Orientales). The younger Inacaliri Lavas 2 overlie the Silala Ignimbrite (Chi) (SERNAGEOMIN, 2019b).

Miocene Volcanics have been identified by Bolivia with an age of 6.04 Ma (BR, Vol. 4, p. 115) as outcropping in the Silala Chico (Bolivian name, Cerrito de Silala in Chile) volcanic dome but intruding the ignimbrite succession (Figure 14). However, this age is older than both the Silala Ignimbrite (Chi) and the Cabana Ignimbrite (Chi), which clearly must overlie these Miocene Volcanics and cannot be intruded by them. Also, in the Bolivia's "Generalized Geological Section of the Silala Springs" (BR, Vol. 4, p.125), see Figure 15, a further error is found, as the Silala Chico (Cerrito de Silala) dome unit, with the age 6.04 ± 0.07 Ma, is shown overlying the Silala Grande (Volcán Apagado) volcano deposits, which have younger age of 1.74 ± 0.02 Ma. This is clearly impossible. These are just two examples of the disturbing errors in geological mapping and stratigraphic interpretation made by Bolivian geologists.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Lineamiento Khenayani
Laguna Khara
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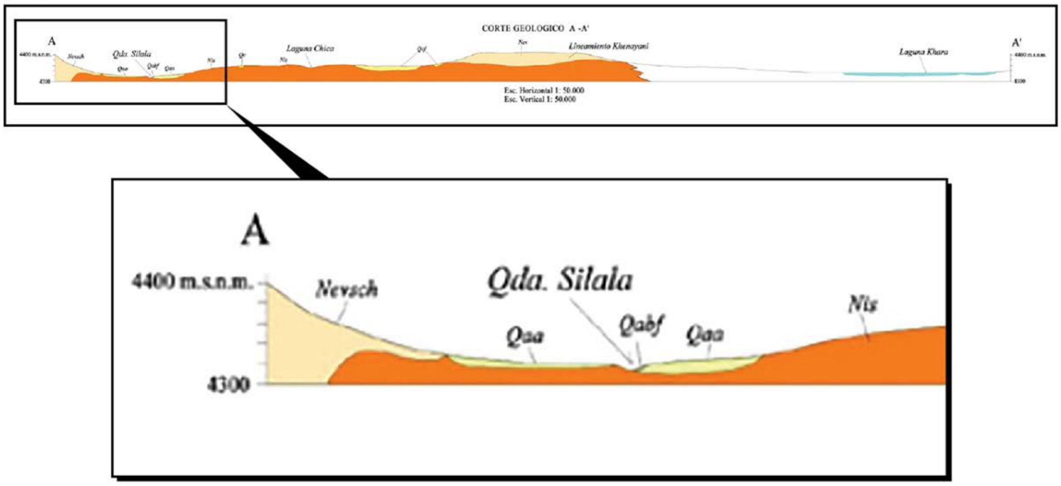
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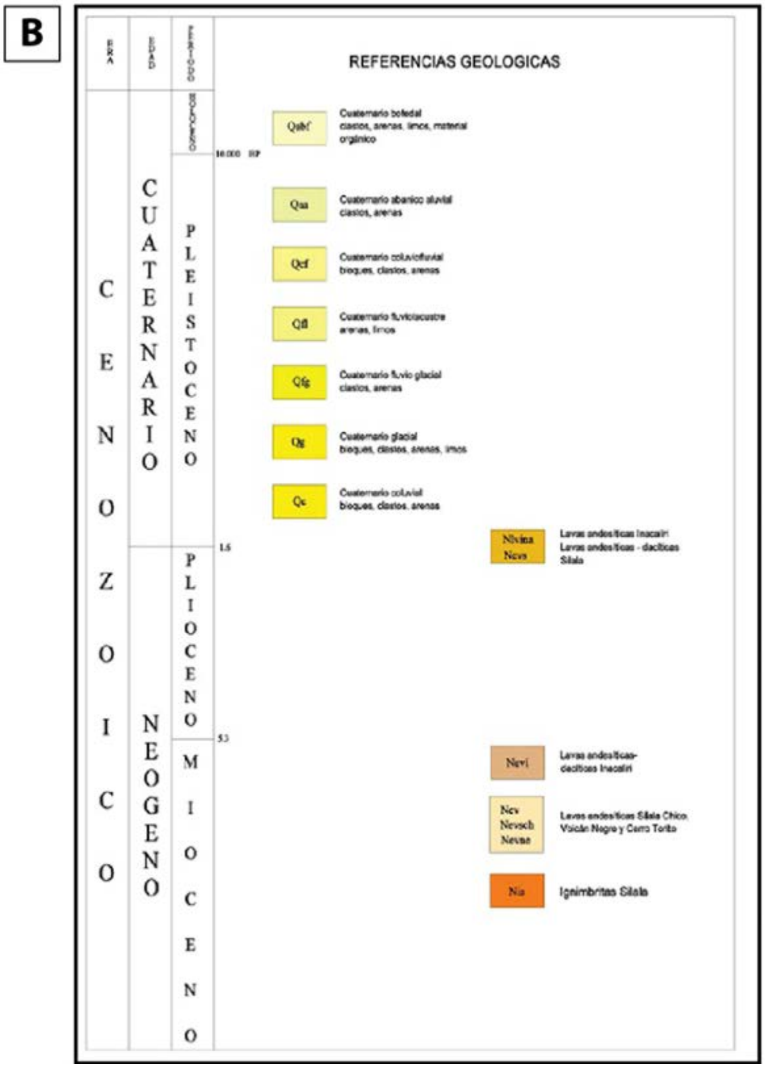

Figure 14. Geological Map of the Silala Study area (BR, Complete Copies of Certain Annexes, Vol. 2, Annex 23.5 Appendix a, p. 69). (A) Expanded view of the cross section and (B) legend from Bolivia's geological map reproduced at Figure 2-1.

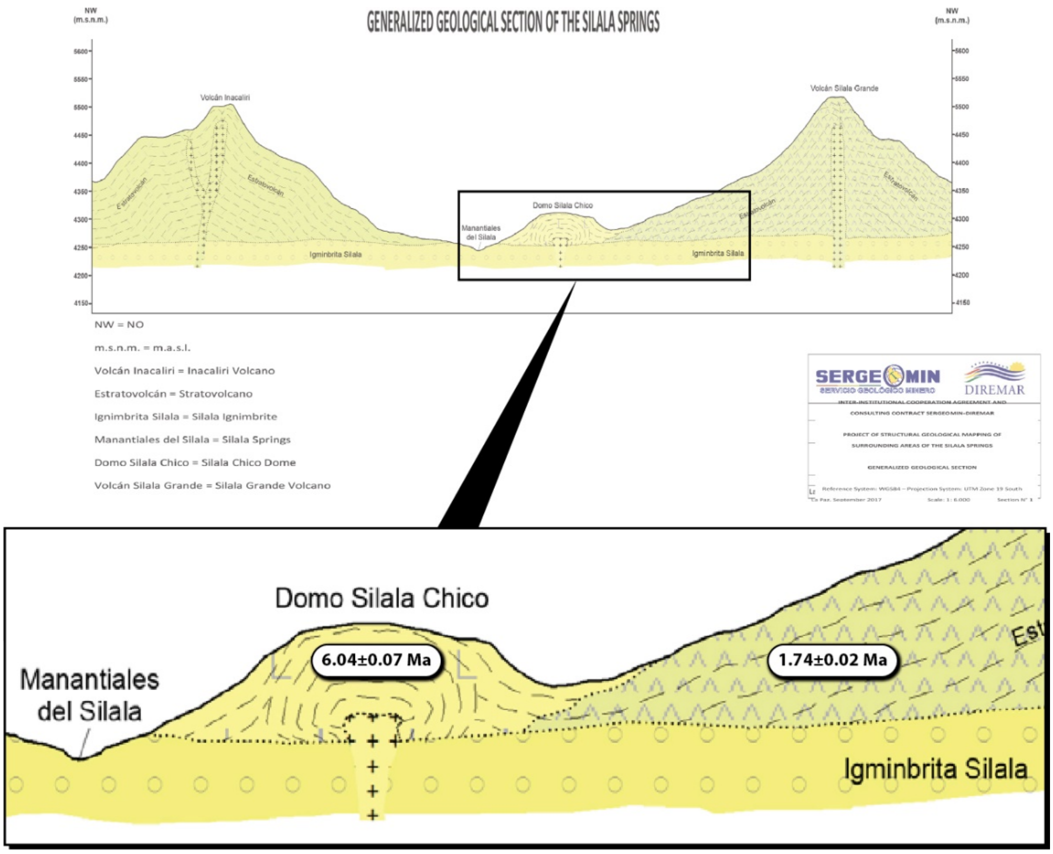

Figure 15. Generalized Geological Section of the Silala Springs (BR, Vol. 4, p. 125) shows that the ages cited by Bolivia (added for clarity in the figure) do not support the stratigraphic relationship determined by Bolivian geologists (BR, Vol. 4, p. 115). In the cross-section, older rocks (Miocene Volcanics) are seen to overlie younger lavas. This is clearly incorrect. The section also shows the ignimbrites underlying the lavas of the Silala Chico (Cerrito de Silala) dome, which is also incorrect, since they are younger than the lavas of the dome. The Chilean age for the Silala Ignimbrite (Chi) is 1.61 Ma and for the Cabana Ignimbrite (Chi) is 4.12 Ma (SERNAGEOMIN, 2019b)

Further, the three scenarios that were simulated by DHI with the NFM gave results indicating different inflows for each scenario (BCM, Vol. 5, p. 67, Table 1)

1. Baseline – 253 l/s
2. No Canal – 221 l/s
3. Undisturbed – 216 l/s

If the groundwater recharge area remains the same for each scenario, then if the inflow to the NFM changes as above, the difference between the inflows is lost to somewhere else. This is highly unlikely to be flowing to Chile as groundwater through the Miocene Volcanics, and is much more likely to be flowing to Chile in the Silala and Cabana Ignimbrites (Chi) through the narrow restricted region mentioned above.

4.2.2 Structural Geology

The DHI conceptual model invokes a fault system, the Silala Fault (BCM, Vol. 4, pp. 75-76), see Figure 16, which has been included in the NFM as a narrow region of high hydraulic conductivity, and hence as an important pathway for groundwater flow in their model. This fault is described as a NNE-SSW trending structure, which follows the Silala River ravine and crosses the international border into Chile (BR, Vol. 3, pp. 254 and 283). Analysis of the evidence presented by Bolivia for this fault has been studied by SERNAGEOMIN, 2019b, and found wanting. Bolivia contend that this structure controlled the location and form of the Silala River ravine. DHI write (BR, Vol. 5, p. 24) “Sergeomin (2017) geological mapping indicates a relatively small displacement of 5 m at the border”. However a structural analysis (SERNAGEOMIN, 2019b) of this proposed fault indicates that any displacement would be in the opposite direction to that indicated by Bolivian geologists. The slightly higher position of the south eastern ignimbrite layers can be explained more reasonably by the fact that the Silala Ignimbrites (Bol) unit is tilted to the west as indicated by the Bolivian geologists (BR, Vol. 4, p. 149). Chile has previously submitted evidence that demonstrates the fluvial origin of the Silala River ravine (Latorre and Frugone, 2017; SERNAGEOMIN, 2017), but Bolivia appears to persist with an alternative origin, indicating that the Silala Fault, which Chile has shown does not exist, is responsible for the location and direction of the Silala River ravine.

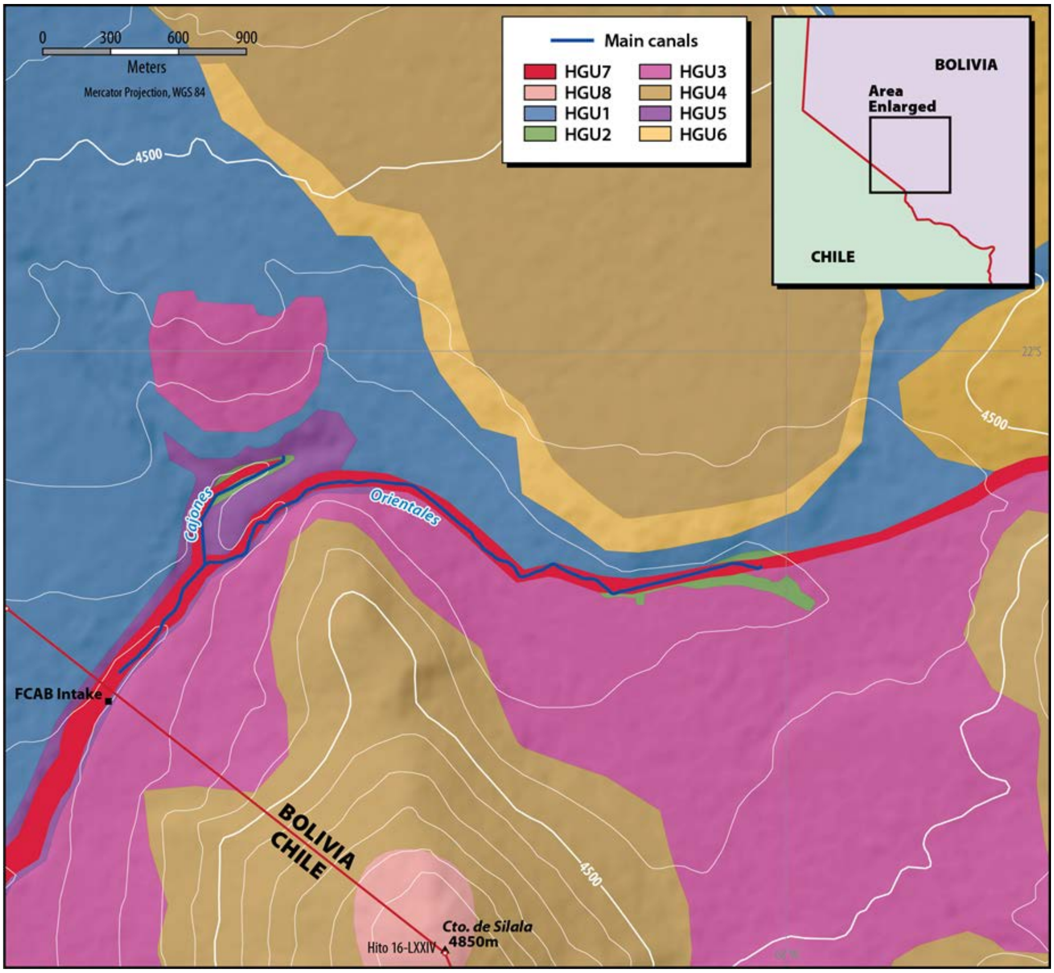

Figure 16. Amended map from DHI, 2018a (BCM, Vol. 4, p. 76, Figure 29) showing in red the postulated Silala Fault system (CR, Vol. 3, p. 211).

Bolivian geologists indicate that this fault plane, which does not exist, coincides with the current alignment of the Silala River ravine, and that the vertical and almost vertical walls of the ravine are "strong evidence of the formation of the ravines by tectonism and movement of glacial ice and fluvioglacial waters" (BR, Vol. 3, p. 323). SERNAGEOMIN's recent studies of the Bolivian documents (SERNAGEOMIN, 2019b) indicate that even if it existed, which it does not, the angle of the fault at 48 degrees could not produce the near vertical walls of the ravine.

Further analysis of Bolivian structural data has revealed the use of inappropriate data, such as cooling joints, to assess structural trends. Since these are not caused by structural deformation (tectonic processes) they cannot be used to assess the structural stress regime. Examination of the principle stress relationships leads to the conclusion that many of the fractures are a result of compression, which would mean the fractures would be unlikely to conduct water because they would be closed (SERNAGEOMIN, 2019b).

Further, Bolivian geologists assert that the ignimbrites of the Bolivian Silala River springs area have been affected by the “Silala Fault”, which they attribute to an extension of the Uyuni-Khenayani Fault System (UKFS), in Bolivia (Sempere et al., 1990; Martínez et al., 1994; Elger et al., 2005). This is a major fault system found in Bolivia that was active until 10 Ma. Not only does the southerly extension of this fault system lie 31 km ENE of the Silala River, but it was only active well before the deposition of any of the ignimbrite deposits found near the Silala River wetland springs in Bolivia or in Chile, so this tectonic episode cannot be responsible for fracturing or faulting or any other deformation in those ignimbrites. The location of the UKFS can be seen on Figure 17.

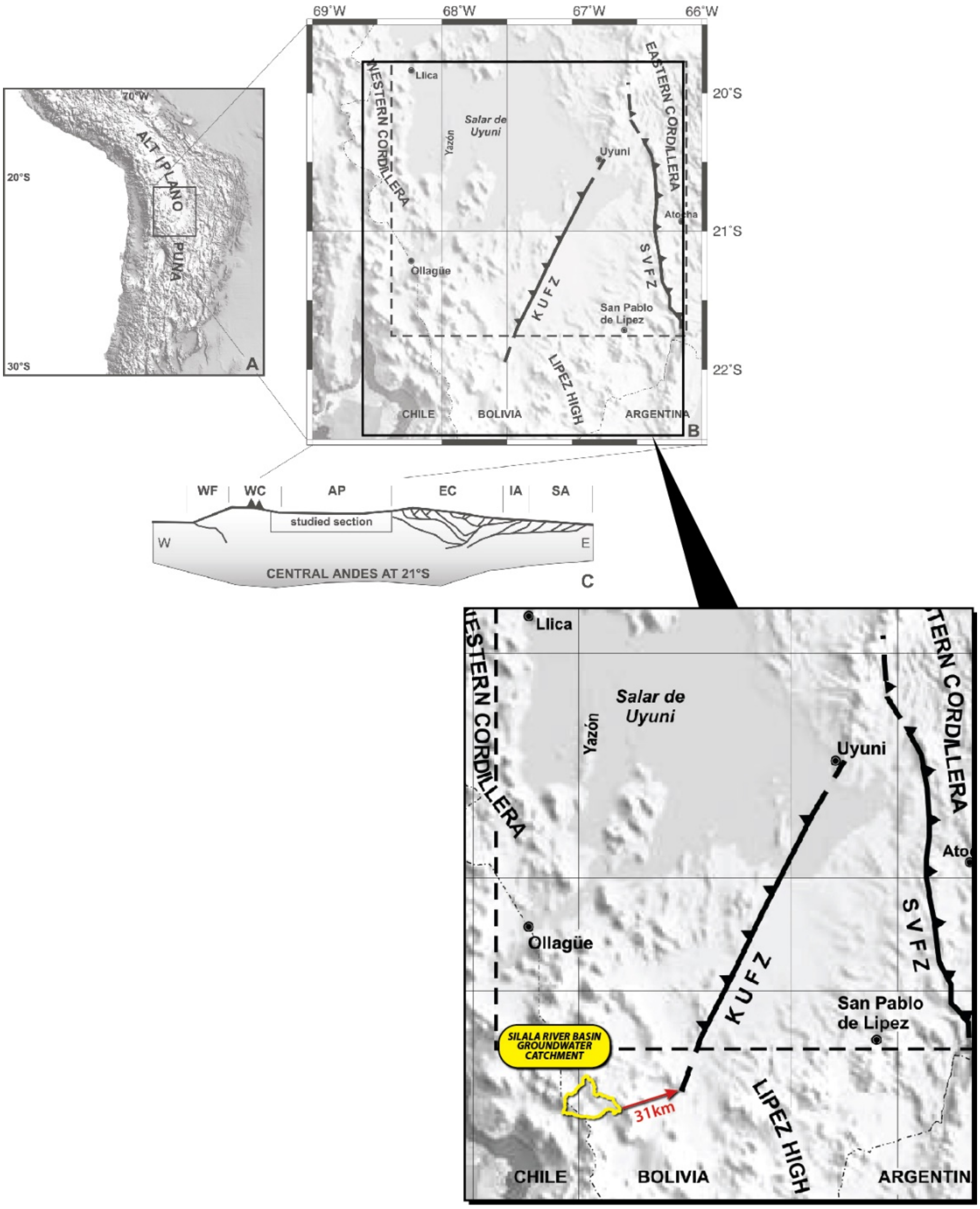

Figure 17. UKFS, located 31 km to ENE of the Silala River basin groundwater catchment. The abbreviation KUFZ in the figure refers to the UKFS, which has been used in this report (SERNAGEOMIN, 2019b).

4.2.3 Petrography

Numerous inconsistencies and errors have been found in the petrographic description of the various rock types found in the Silala River basin, in particular concerning the mis-identification of the mineral assemblages in the three Bolvian named Ignimbrite sub-units.

For example, a rock sample from the Silala Ignimbrite (Chi) collected in the Silala River ravine, within 10 m of the border (sample number RSP-52t) is the same deposit as the Silala Ignimbrite Nis-1 (Bol). This sample collected in Chile, at the border, is andesitic ignimbrite (SERNAGEOMIN, 2019b). However, in all descriptions in the Bolivian documents, they refer to Nis-1 as a dacitic ignimbrite.

Another example concerns the comparison of mineral assemblages compiled from SERGEOMIN (Bolivia), 2017 and TFAU, 2018, in the petrography of the Silala Ignimbrite Nis-1, Nis-2 and Nis-3 (Bol), which were found to be different (SERNAGEOMIN, 2019b).

These inconsistences and errors lead to a highly concerning lack of confidence in the resulting geological interpretations of the Bolivian geologists.

4.2.4 Hydrogeology

The Parties agree that a deep aquifer exists beneath the Silala River groundwater catchment, although the interpretation of the aquifer geometry is distinctly different. In Chile the main aquifer is the Cabana Ignimbrite (Chi), with the younger Silala Ignimbrite (Chi) overlying a Debris Flow deposit that is also highly permeable (Wheater and Peach, 2017; Peach and Wheater, 2019; Arcadis, 2017; Muñoz et al., 2019). The often highly welded Silala Ignimbrite forms in part a confining or semi-confining layer.

Evidence has previously been presented (Peach and Wheater, 2019; Arcadis, 2017; SERNAGEOMIN, 2019a; Herrera and Aravena, 2017; Herrera and Aravena, 2019) to support the existence of a shallower perched aquifer system in Bolivia and Chile, which has been found in Alluvial deposits in Chile. This has been acknowledged as a possibility by DHI (BR, Vol. 5, p. 27) and they "clearly concluded that it is likely that there are two primary and distinct sources of groundwater discharging to the Silala springs". However, they have not included this understanding in their NFM and state "it has not been the intention to represent the various sources of groundwater explicitly in the model as it would not reflect on the split between surface water and groundwater discharge from the Silala Wetlands" (BR, Vol. 5, p. 27). This is misleading, since groundwater flow from distinct aquifers would be driven by differing piezometric level distributions. Since the surface water flows are driven by groundwater/surface water interactions, which would be head-dependent, they would be likely "to reflect on the split between surface and groundwater discharge" (BR, Vol. 5, p. 27). No account has been taken of the two-aquifer system by DHI in their conceptual model or the construction of their piezometric map (BCM, Vol. 2, p. 293). This will inevitably lead to an incorrect understanding of the groundwater flow regime, which would in turn lead to incorrect parameterization of aquifer properties and assignment of boundary conditions.

Concerning the groundwater flow regime in the NFM area, examination of the Bolivian conceptual understanding of groundwater flow directions (BCM, Vol. 2, p. 371, figures 6 and 7) reveals that they are in conflict with those interpreted from DHI's potentiometric map, as shown in section 3 above. They are also in conflict with the location and type of boundary conditions adopted in the NFM, since flow directions are indicated (Figure 8) across the southern boundary of the NFM, but this is a no-flow model boundary. This leads to the conclusion that the NFM does not represent the DHI conceptual understanding of the groundwater flow regime in the region of the Bolivian wetland springs. If the DHI conceptual model of groundwater flow directions is incorrect, the estimates of the impact of channelization made with the NFM are likely to be in error (section 3; Muñoz et al., 2019).

Review of the Bolivian technical documentation provided in support of the BR has identified errors of geological mapping, interpretation of the geological sequence of deposits, their contact relationships and their petrography. These errors and inconsistencies mean that the NFM is based to an important degree on erroneous information concerning the geometry of the deep ignimbrite aquifer and its parameterization, including the lack of inclusion of a shallower aquifer. The lateral extent of the ignimbrites, in particular the Silala Ignimbrite (Chi) and Cabana Ignimbrite (Chi), is constricted by Miocene low permeability volcanics in its subcrop from the region of the confluence of the Bofedales Norte (Cajones) and Bofedales Sur (Orientales) ravines down gradient in Bolivia and into Chile, thus influencing the aquifer geometry and the parameterisation of the NFM. It has been shown by SERNAGEOMIN (2919b) that the Silala Fault does not exist, thus a main premise of the DHI conceptual hydrogeological model and hence the NFM is based on a false interpretation of the geology and its material properties. And not only is Bolivia's geology and DHI's conceptualization incorrect, but in addition, Muñoz et al. (2019) have shown, using only Bolivian documentation, that the groundwater flow regime incorporated into NFM is in conflict with DHI's own conceptual hydrogeological model.

In summary, it is agreed by both parties that a deep ignimbrite, often very permeable, aquifer exists in the Silala River groundwater catchment. In Chile this aquifer is semi-confined or confined, as evidenced by water level monitoring and drilling (Arcadis, 2017). However, it is not agreed that the ignimbrite succession lies beneath the Miocene Volcanics, as proven in the discussion above and in detail in SERNAGEOMIN (2019b), thus the areal extent of the ignimbrite aquifer is constrained by the Miocene Volcanics, making the aquifer geometry quite different from that proposed by Bolivia. It is also not agreed that the so-called Silala Fault exists at all and it cannot be invoked to support a narrow zone of high permeability along the Silala River ravine. And it is not agreed that the shallow aquifer system can be ignored in understanding the groundwater flow to the Bolivian springs.

4.3 Conclusions

A large number of errors and inconsistencies have been found in Bolivia's geological mapping and structural analysis. Consequently, DHI's interpretation of the hydrogeology and its implementation in the NFM contains many errors, the most important of which are listed below:

1. An error in the assignment of a radiometric date to establish the age range of the Silala Ignimbrites (Bol) leading to an incorrect interpretation of the stratigraphy, which has important impacts on aquifer geometry and the distribution of permeability in the NFM, the ignimbrite aquifer having a much more restricted areal extent than proposed by Bolivia

2. The stratigraphic position and contact relationships between different deposits has been ignored leading to an incorrect formulation of aquifer geometry and distribution of aquifer properties,

3. Bolivia has ignored the existence of the Silala Ignimbrite (Chi) and Cabana Ignimbrite (Chi) in their establishment of the Ignimbrite stratigraphy. The Silala Ignimbrite (Chi) is highly welded, and outcrops unconformably over much older Ignimbrites in the Bofedales Sur (Orientales). The Cabana Ignimbrite (Chi) is highly permeable. Both have a limited lateral extent and are constrained between two hills of Miocene low permeability volcanics, thus limiting the flow of groundwater through this region. This would impact on the NFM parameterization and aquifer geometry incorporated into the NFM

4. The Silala Fault, invoked as a high-permeability groundwater pathway by DHI, does not exist and could not be related to tectonic events that took place millions of years before the ignimbrites or the Miocene Volcanics were deposited and cannot be used to specify and narrow high-permeability zone running down the Bofedales Norte (Cajones), Bofedales Sur (Orientales) and Silala River ravine.

5. The Bolivian structural analysis is flawed leading to erroneous interpretations in the structural geology, and presence and location of open fractures able to conduct groundwater, so there is a likelihood of incorrect assignment of aquifer properties in both conceptual and numerical modelling
6. The Bolivian descriptions, and naming, of rock types was found to be confused, inconsistent and often in error, leading to the conclusion that the geological mapping in Bolivia is flawed, which means that the hydrogeological understanding is likely to be flawed
7. DHI has ignored Chilean evidence of a shallow aquifer system and its own acknowledgement of two sources of groundwater to the Bolivian wetland springs, leading to incorrect interpretation of the groundwater water table distribution (potentiometry)
8. The Bolivian conceptual model and potentiometric contours used for the NFM are in conflict and represent different interpretations of the groundwater flow regime
9. The NFM boundary conditions, with respect to both type and location, are in conflict with the Bolivian hydrogeological conceptual model and the potentiometric contours used for the NFM, which would lead to a different flow regime than that simulated in the NFM.

All of these listed issues affect the representation of groundwater/surface water interaction in the NFM and in turn affect the estimation of the impact of the channelization on surface and groundwater flows.

This list is disturbing and leads to the conclusion that the modelling which has been used to support and justify the Bolivian estimates of the impact of channelization on the surface and groundwater flows from the Bolivian wetlands at headwaters of the Silala River is incorrect. The models developed by DHI as

Bolivia's expert advisors are based on an incorrect understanding of the geology and hydrogeology of the Silala River surface and groundwater catchments.

5 ERRONEOUS STATEMENTS AND FLAWED ATTRIBUTION CONCERNING WETLAND DEGRADATION

Chile acknowledges that drainage of the wetlands in Bolivia may have had an impact on their spatial extent and associated ecosystem health (e.g. CR, Vol. 1, p. 128). However, while the impacts of wetland drainage in Bolivia, undertaken with the consent of Bolivia, are the responsibility of Bolivia, it is relevant to the future management of the Silala River, the restoration of the wetlands, and future downstream flows, that historical changes are clearly understood. Hence, we wish to point out to the Court that the Bolivian Rejoinder exaggerates the historical decline in the area of the wetlands and imputes a causal relationship between changes in wetland extent and the effects of channelization that is unsupported by scientific data.

Firstly, we consider the wetland area. In Bolivia's Rejoinder estimates of historical and current wetland area are reiterated from the Counter-Memorial (BCM, Vol. 5, p. 163), which were based on the Ramsar report: 'prior to the channelization, the Silala River region within Bolivia was covered by high altitude wetlands known as *bofedales* that spanned an estimated 141,200 m^2 (or 14.1 Ha). Today, those wetlands have shrunk to a mere 6,000m^2 (or 0.6 Ha).' (BR, Vol. 1, p. 18). We note some confusion on the part of Bolivia with respect to the area affected - their footnote 58 in the Rejoinder (BR, Vol.1, p. 18) that supports this comment also cites the FUNDECO report which states that the area affected is 11.48 Ha (BR, Vol. 3, p. 61). More importantly, the estimate of 0.6 Ha for the current wetland area is clearly erroneous and disagrees with Bolivia's own experts' assessment. The area of active wetland is subject to large seasonal and inter-annual variability, as clearly stated by Bolivia's experts, Torrez Soria et al. (BCM, Vol. 3, p. 73) 'bofedals have a seasonal behavior, which can be evidenced by presenting dramatic changes according to the season and the annual variations'. They cite Bolivia's expert Castel (2017), who reports an analysis of Landsat data from 1975 to 2000. This shows high variability of active wetland area, varying between 2 and 8 Ha, with a slightly increasing trend. Chile's original analysis (CM, Vol. 4, p. 37), also based on Landsat data, similarly showed strong seasonal variability, with a possible increasing trend, although with somewhat larger estimates of wetland area. Higher resolution (10 m) satellite data, presented in Chile's Reply (CR, Vol. 1, pp. 127-139) enabled more accurate assessment of the active wetland area to be made, albeit over a limited period (July-November 2018). This confirmed the strong seasonal variability in vegetation activity (the property sensed using the satellite NDVI data) and showed the maximum extent of active wetland area for the two Bolivian wetlands of 9.9 Ha, with the lowest active area recorded (3 Ha) at the beginning of that period. We also reiterate that these data, presented in the Reply, show that active wetland vegetation currently occupies the entirety of the valley bottoms.

We reiterate that Bolivia's repeated estimate of the current wetland area (0.6 Ha) is not credible, and note that DHI agrees with us. 'It seems that the areas in the Ramsar report are not reflecting the full wetland' (BR, Vol. 5, p. 41). We therefore note that Bolivia's statement (BR, Vol. 1, p. 47) that 'the reduction of the bofedal area as a consequence was of approximately of 94%' is grossly inaccurate with respect to the areas involved. We note in passing that Bolivia (BR, Vol. 1, p. 46) attacks Chile's analysis of the high resolution data summarized in CR, Vol. 1, p. 136, 'The growth from 2.86 Ha to 7.50 Ha in a period of two months is an overestimation that reveals flawed calculation that cannot be reasonable accepted.' Bolivia apparently ignores the evidence of its own experts, Torrez Soria et al. (BCM, Vol. 3, p. 73) and Castel (2017), and confounds the normal expansion and contraction of areas of active wetland vegetation that takes place as the seasons progress, with the growth of wholly new areas of vegetation.

Secondly, we address the issue of causality, and consider the statement (BR, Vol. 1, p. 50) that 'The scientific evidence shows that the hydraulic works generated the fragmentation of the bofedals'. The FUNDECO studies, on which this statement is based, are themselves extremely confused. One strand of evidence summarized by FUNDECO (BR, Vol. 3, p. 142) is based on geochemical survey. They state that the geochemical survey shows gradual desiccation. 'This period of desiccation began around 1908, which is a clear sign of the effects that canalization had on the Silala springs.' But the date of installation of drainage works in the wetlands is 1928. So these changes were initiated 20 years before the channelization. A similar statement is made by FUNDECO, based this time on pollen analysis, 'From 1908 onwards, a gradual desiccation process took place and is evidenced by the change in palynomorph composition […]' (BR, Vol. 3, p. 142), so again they note a change that predates the drainage construction. They also note that 'this desiccation process reached its climax around 1950 […]' (BR, Vol. 3, p. 142), which to our knowledge does not coincide with any channel changes, and again points to other causes of change than channelization. A further strand of evidence comes from analysis of soil profiles (BR, Vol. 3, p. 155):

> "The first change of soil stratum happened near the point with dating that corresponds to an age of 680 – 862 years ago, and therefore in a period prior to the canalization process […] This type of stratum continued until the next change, which occurred between 1960 – 1980 years (Figure 6). This period corresponds to the critical period, due to a lack of water, that occurred approximately 50 years after the canalization works were installed—which remain in operation until the present time."

So multiple strands of evidence point to major changes in the wetlands at points in time that bear no relationship to the channelization works. As pointed out by DHI, in their review of this and other Bolivian science reports (BR, Vol. 2, p. 99), 'the study does not look further into other climatic aspects such as potential climatic changes during the last 100-120 years to assess whether such changes could have been the cause for some of the observed changes to the bofedales.'

We agree with DHI (BR, Vol. 2, p. 78) who state, with respect to the changes in flow paths associated with the channelization of the wetlands, that 'this change *may*[7] be one of the main reasons for the alterations in the habitats, which have taken place during the last century.' But in our opinion, and as also suggested by DHI, climate changes are likely to have been a major factor, to which we add that the impact of human activities may also be relevant (FUNDECO report (BR, Vol. 3, p. 38), from interviews with members of local communities that the bodefales were used for cattle grazing). At any rate, what is clear is that causal association with channelization of the wetlands has not been proved and statements to that effect by Bolivia and its experts are simply untrue.

6 CONCLUSIONS

(i) Do the digital data provided by Bolivia in support of the Counter-Memorial after Chile's Reply was finalized materially change your assessment of the modelling by Bolivia's Experts of the effects of channelization and of the effects of possible long-term peat growth?

The digital data provided by Bolivia in February 2019 has allowed detailed analysis of DHI's modelling, used to support Bolivia's claims concerning the impacts of historical channelization of the Silala River in Bolivia, as reported in Bolivia's Counter-Memorial. Analysis of model configurations, parameters, input data and simulation results showed that there were many aspects of the modelling that gave serious concern for the reliability of the results, in particular for the

[7] Our italics

modelling of a 2.56 km^2 area designated by DHI as the Near Field that includes the source water springs and wetlands in Bolivia, and the river channel to the international border.

The Near Field Model was used by DHI to simulate three scenarios, the Baseline Scenario (current conditions), a No Canal Scenario (with the channels removed), and a Undisturbed Scenario (with channels removed and an allowance for the long term growth of peat in the wetlands), to evaluate the effects of the historical channelization of the Silala River and its wetlands in Bolivia, and of possible future peat growth in the wetlands. Bolivia relies on these results to claim large impacts of historical channelization on Silala River cross-border flows.

We had noted previously, in Chile's Reply, that there were errors in the geological interpretation on which the modelling was based (and hence the model configuration and parameterization), and that there was a major problem in the choice of boundary condition for the NFM, which caused exaggeration of the reported effects. However, inspection of the digital data by Chilean hydrologists (Muñoz et al., 2019) revealed many *unreported differences* between the models used for the inter-comparison of scenarios, and in the model boundary conditions and initial conditions. These unreported differences were compounded by unexplained methodology, and incorrect assumptions. Perhaps of greatest impact was the fact that we found that different topographies had been used for the different scenarios, including different topographies used in the Baseline Scenario for the modelling of catchment processes (the MIKE-SHE model) and the modelling of channel flow (the MIKE-11 model). These differences in topography, of up to 7 m, were far greater than the small changes in channel depth and peat growth that the models were being used to evaluate, and in themselves would generate large differences between the scenarios. While the *reported* model errors and inaccuracies for the NFM were of a similar magnitude to the effects being simulated, which in itself casts doubt on the validity of the conclusions from the modelling, we conclude that the large effects proposed by Bolivia are mainly an artefact of these *unreported* differences between the modelled scenarios.

In short, our assessment of the reliability of the modelling by Bolivia's Experts has materially changed. In our professional opinion, the published results of the effects of channelization and of the effects of possible long-term peat growth are wholly unreliable and should be disregarded by the Court.

(ii) Do the further modelling and other studies by Bolivia's Experts, presented in Bolivia's Rejoinder, reflect a correct assessment of the magnitude of these effects?

We were pleased to note from Bolivia's Rejoinder that DHI accepted our criticism of the choice of boundary conditions for the NFM, and now considers these results to set an upper bound for the effects of channelization and possible long-term peat growth. DHI also provides a lower bound estimate of the simulated effects, based on a constant flux at the boundary. We agree that this is an appropriate condition to give a lower bound estimate. However, the simulation results presented are subject to all of the errors and inconsistencies noted above, and have errors that are of a similar magnitude to the effects being simulated. In addition, they differ from the BCM results for the same simulation, which is a further indication of an unreliable modelling process. Again, in our professional opinion, these further modelling results are misleading and should be disregarded.

We note that DHI refer to a historical estimate of flow, made in 1922 prior to the channelization, to support their simulations and conclusions. However, in our opinion, a single estimate, made at a location that is uncertain, and in a difficult environment where contemporary measurements have had large errors, cannot be considered reliable.

Related studies by other of Bolivia's experts considered the relationship between the historical channelization and observed changes in the wetlands. Understanding the causes of wetland change is important given the desire of both Parties to see wetland restoration, and to understand the effects on downstream river flows. While these studies shed important light on some of the changes that have taken place in the wetlands, they erroneously attribute the single cause of observed changes to the channelization. Given that the dates of reported changes bear no relationship to the dates of channelization, it must be concluded that other factors are playing a significant role. We agree with Bolivia's experts, DHI, that climate changes are likely to be one of the more important controls.

(iii) Does the information provided by Bolivia's Experts, presented in Bolivia's Rejoinder, materially change your assessment of the geology and hydrogeology that underpins Bolivia's modelling of the effects of channelization and of the effects of possible long-term peat growth?

Our assessment of the Bolivian interpretation of the geology and hydrogeology of the Silala River basin has resulted in our clear view that the geological interpretation that underpins Bolivia's modelling is substantively flawed. Bolivia has introduced new geological evidence in the BR that is often confused and inconsistent. Further, they have ignored Chilean evidence and simply asserted that Bolivian interpretations are correct.

(iv) What are the implications of this new information, if any, for the validity of Bolivia's modelling of the effects of channelization and possible long-term peat growth?

The geology and hydrogeology of the area around the Bolivian wetland springs and downstream beneath the Silala River, defined by DHI as the Silala Near Field, is complex, and given the limited data, is open to differing interpretations. However, concerning the geology and hydrogeology, DHI has adopted a set of models that do not represent the best understanding of reality, and are based on many erroneous conclusions, assumptions and internally inconsistent interpretations, in addition to the issues noted above in answer to question (i). The models are therefore likely to produce results that are grossly in error. We have no doubt that Bolivia's estimates of the effects of channelization are highly exaggerated. This conclusion is in part due to the adoption of boundary conditions for the NFM that are incorrect, both in their condition and location, as well as the use of inconsistent and highly variable topography. But it is also due to the misrepresentation of aquifer geometry, the use of aquifer property distributions that do not take into account the correct geometry and stratigraphy, and the fact that the existence of an important shallow aquifer system has been ignored.

The NFM not only does not reflect reality, but is not consistent with the stated Bolivian conceptual understanding of the groundwater flow regime.

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Statement of Independence and Truth

1. The opinions I have expressed in my Report 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 Expert Report that accompany the Additional Pleading 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 Report, to be accurate and complete in answering the questions posed by the Republic of Chile in the terms of reference which are reproduced in the Report. I consider that all the matters on which I have expressed an opinion are within my field of expertise.

4. In preparing this Report, 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. In respect of facts referred to which 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.

Dr. Howard Wheater
Hydrological Engineer

03 September 2019

Statement of Independence and Truth

1. The opinions I have expressed in my Report 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 Expert Report that accompany the Additional Pleading 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 Report, to be accurate and complete in answering the questions posed by the Republic of Chile in the terms of reference which are reproduced in the Report. I consider that all the matters on which I have expressed an opinion are within my field of expertise.

4. In preparing this Report, I am not aware of any conflict of interest actual or potential which might impact upon my ability to provide an independent expert opinion.

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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.

Dr. Denis Peach
Hydrogeologist

03 September 2019

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CERTIFICATION

I certify that the annexes and reports filed with this Additional Pleading are true copies of the documents referred to.

Ximena Fuentes T.
Agent of the Republic of Chile
16 September 2019