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Risks of suppressing natural flows within a source-to-sea system

The case of Lake Juparanã, Espírito Santo State, Brazil

In November 2015, the failure of the Fundão tailings dam at the Samarco´s iron ore mining site in the State of Minas Gerais, Brazil, resulted in 19 deaths and severe environmental, economic and social damage. The tailings spill ran approximately 650 km through the Rio Doce to the Atlantic Ocean. It is referred to as one of the worst environmental disasters in Brazil's history.

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What is the issue?

Towards the lower stretch of the Rio Doce near the city of Linhares, in the state of Espírito Santo, there are marginal lakes which are fed by secondary tributaries. Over the course of the last 10,000 years, these water bodies have been disconnected from the main river due to tectonic- and climate change-driven forces (Suguio and Kohler, 1992; Hatushika et al., 2007). Lake Juparanã, the largest of such lakes, was originally connected to its natural source, the Rio Doce, through its natural connector, the Rio Pequeno, from which it has become partially isolated due to the construction of a temporary dam. This dam was installed following a judicial decision to prevent a potential contamination of the lake by the Rio Doce waters after the collapse of the Fundão Dam and the subsequent overflow of tailings.[1] The barrier resulted in the interruption of the natural connection between the lake and the river, thus interfering negatively with the original physico-chemical and biological processes, as well as the water exchange between the river and its surrounding ecosystems. Should the barrier be maintained, the natural lake water overflow during the rainy season would continue to be obstructed, thus increasing the risk of flooding in the surrounding areas and having an impact on the lives of communities. In addition, as an emergency response, the construction of the barrier did not adhere to generally-accepted engineering standards.

In March 2018, the state Court of Justice ruled that Samarco had to construct a permanent dam with floodgates to control seasonal water flow in the region as a means to avoid flooding upstream villages and maintain water supply. Given that the company has appealed and the prosecution case is still ongoing, the permanent dam has not been constructed.[2]

In April 2018,[3] the situation forced the opening of a channel for the first time and again later in September 2018. The work carried out then by the Renova Foundation was a precautionary measure to guarantee that the level of Lake Juparanã remained between 6.5

[1] When it collapsed in November 2015, the Fundão tailings dam released 39 million m^3 of fine and coarse-grained mineral particles, which are deposited after processing iron ore, into the river system and water courses of the Rio Doce Basin.
[2] For more information about the case, please visit: http://www.tjes.jus.br/judiciario-condena-a-samarco-em-acao-movida-pelo-municipio-de-linhares/3
[3] For more information, please visit: https://www.gazetaonline.com.br/noticias/norte/2018/03/cheia-da-lagoa-juparana-atinge-o-centro-de-linhares-1014124032.html
[4] For more information, please visit: https://www.fundacaorenova.org/en/noticia_tag/lagoa-juparana-en/
[5]

Figure 1a.
View of the lower Rio Doce stretch and its marginal lakes. Lake Juparanã is shown in detail.

Why is it important?

The Fundão Dam failure resulted in significant direct and indirect, and short- and long-term impacts on both the communities and the environment. As mentioned earlier, a channel was opened in April 2018 to prevent flooding of the lake's surroundings and the Rio Pequeno watershed (see Figure 2). Consequently, the river's flow was considerably enhanced from 9.13 $m^3.s^{-1}$ on 17 March 2018 to a maximum of 21.78 $m^3.s^{-1}$ on 20 October 2018.

The need to open the dam to allow water to flow towards Rio Doce proves the importance of maintaining a natural connection between the river and its marginal lakes, and highlights the urgency of considering alternatives to the provisional dam. At the same time, it is important to consider the rationale behind past emergency actions and how to ensure a sound technical basis for future decisions. The story of Rio Doce is being watched globally and considered a potential model of watershed restoration after a large-scale disaster. Therefore, the case of Lake Juparanã, in addition to generating lessons related to specific actions, can also have national and international impact.

The role of natural water connections

Source-to-sea system is a comprehensive technical approach used to refer to a watershed in its highest level of ecological influence and dependence, including the

adjacent drainage area, aquifers and surrounding coastal ecosystems (Granit et al., 2017). Natural connections between marginal lakes and their main rivers ensure the renewal of marginal waters, particularly within the riverine lakes. They serve as an important natural mechanism of enrichment of nutrients for both the lakes and the river following periods of rising and falling waters in the hydrological cycle (Junk et al., 1989; Pinto et al., 2003).

Water pulses drive significant changes within the abiotic components of natural ecosystems with considerable shifts to their biota, forming a continuum of events from source-to-sea along a river basin (Granit et al., 2017). Suppressing natural flows, by building barriers, hinders the exchanges of water, sediments and organisms in a natural source-to-sea system. This usually brings detrimental change affecting the conservation and recovery of the pre-existing natural conditions, including water quality, biodiversity and its sustaining systems. Moreover, "the need to maintain certain environmental flows ([in particular] the quantity, timing and quality of water flows) to sustain aquatic ecosystem function has become well recognized internationally" (Granit et al., 2017, p. 28).[6]

The role of water barriers

Obstacles have been shown to have an impact on aquatic habitats and alter organisms' community structures by impounding water, acting as a physical barrier to migratory species and impeding renewal of water quality. In addition, scientific and technical studies show that dam and floodgate operations can reduce water levels and river discharge, and increase pollutant concentrations, such as chemical oxygen demand (COD) and ammonium-nitrogen (NH4-N) (Feng et al., 2016). As a source of water for human consumption, this is particularly important for Lake Juparanã, due to the increase of sewage discharged into the lake from the surrounding villages and non-point sources from agriculture.

A fragmented approach to addressing watershed issues invariably fails to be sustainable in the long term (Bierbaum et al., 2014). For example, hydraulic infrastructure has resulted in over half of the world's major rivers being severely affected by the alteration and fragmentation of their flow regimes (Nilsson et al., 2005). In the case of Lake Juparanã, the absence of exchange between the lake and Rio Doce can be further compromised due to potentially long periods of drought described by existing climate change scenarios (IPCC, 2014; PBMC, 2013), which suggest a decrease in the amount of rain for the south-eastern part of Brazil. Moreover, as it was observed after the construction of the temporary dam, the lack of exchange between the lake and the river can become more of a problem rather than a solution.

What can be done?

One could argue that marginal lakes are naturally-barred systems and the proposed solution to build an artificial barrier only represents a part of natural processes. Notwithstanding, it is important to recognize that the natural forces that disconnected the tributaries and formed the lakes resulted from geological time-scale processes, and not from human-made instantaneous structures. Even so, the natural processes do not predetermine a permanent disconnection between the lakes and the main river (Suguio and Kohler, 1992). The mitigation actions should therefore consider other options to reduce the impacts of a permanent disconnection between the lake and the river, such as building floodgates that open and close depending on water levels, besides allowing for, at least partially, the maintenance of ecological processes and the existing biota.

Following the collapse of the Fundão Dam, investment in sewage treatment plants has clearly become an urgent need in the Rio Doce Basin where, as in many places of Brazil, infrastructure development has been frequently delayed due to inadequate allocation of resources. The situation has somewhat improved, with Renova Foundation's commitment to dedicate BRL 500 million, or approximately US$130 million,[7] to develop basic sanitation facilities for the urban population in 39 municipalities along the river basin – although it must be pointed out that these investments will only be accessible after the presentation by each municipality of its basic sanitation project.

[6] For further reading, please see the following links: https://doi.org/10.3389/fenvs.2018.00045; https://www.conservationgateway.org/ConservationPractices/Freshwater/EnvironmentalFlows/MethodsandTools/ELOHA/Documents/Brisbane-Declaration-English.pdf; doi.org/10.1111/j.1365-2427.2009.02204.x; doi.org/10.1111/j.1365-2427.2009.02272.x

[7] Exchange rate on 10 August 2018.

Figure 2. Cove connecting the Juparanã lagoon to the Rio Pequeno and the Rio Doce.

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Timing is everything

At present, the water quality of the Rio Doce remains compromised. This is confirmed by a significant amount of data regarding water and sediment contamination, as summarized by Hatje et al. (2017). A partial report of the Qualitative and Quantitative Systematic Monitoring Programme of Water and Sediments (PMQQS) published by Renova Foundation (2018) stresses that continuous monitoring is necessary to assess the recovery of the affected rivers. Although it is mandatory to wait for more consolidated information resulting from water and sediment quality monitoring, it is expected that general conditions will improve with the actions being undertaken. In this scenario, it seems reasonable to conclude that there will be no need for a permanent dam to protect Lake Juparanã from contamination brought on by the Rio Doce water's inflow.

On the other hand, according to the precautionary principle and assuming that in the long term there is a potential risk of contamination of Lake Juparanã during very high-water levels of the Rio Doce, the Rio Doce Panel recommends some options to consider for implementation, if needed. The options should take into account actions at local and watershed levels – all of which could provide a pivotal opportunity to be a future reference for other watershed restoration after a large-scale disaster in Brazil and elsewhere.

Conduct a permanent monitoring programme for Lake Juparanã. This entails studies describing the impacts on water quality, aquatic communities, local fisheries and natural flows, investigating in detail the synergistic effects of contaminants which can result in 'reactive chemical cocktails' capable of causing further effects on the biota composition and the local environments.[8]

Based on the studies mentioned in Recommendation #1, and on the awareness that the risk of lake contamination due to the release of tailings in the Rio Doce is higher than the risk of jeopardizing the source-to-sea system, further research should be conducted to determine the need for and potential location of a dam with floodgates. The ecological conditions of the natural flows, as well as the maintenance of sustainable environmental conditions in Lake Juparanã, Rio Pequeno and its connecting ecosystems with the Rio Doce, should be taken into consideration in any decision-making process.

Should a dam be built, implement a management model for the proposed dam that considers the adjustment of functions of the artificial system, including the definition of clear indicators and triggers for a rapid decision-making process, which will guarantee the well-being of the source-to-sea system.[9] In addition, its supervision should be a part of the terms of reference of the *Pontões e Lagoas do Rio Doce* Basin Committee.[10]

[8] For further information, please see Kaushal et al. (2018).
[9] For further information, please see Granit et al. (2017).
[10]

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Cover photo: View of the dam constructed over the channel connecting the Juparanã lagoon to the Rio Pequeno and the Rio Doce. © NITRO – Courtesy of Renova Foundation

Disclaimer: The economic, environmental and social context of the Rio Doce basin is dynamic and rapidly changing. The Rio Doce Panel has prepared this report with the best publicly available information at the time of its F0060 0 7J rOwphicts Fy available imply the eTdrapiureano, ea3.667 Discpurposs imply on fFy debdam ¹Fof R th7 theoureano,