

Extraordinary Independent Consulting Committee for Investigation - CIAEA
(Comitê Independente de Assessoramento Extraordinário de Apuração - CIAEA)

Executive Summary of the Independent Investigation Report

Failure of Dam 1 of the Córrego do Feijão Mine – Brumadinho, MG

To the Board of Directors of Vale S.A.

February 20, 2020

Rio de Janeiro, RJ

The official version of this report is the Portuguese language version. In case of any contradiction or difference of interpretation between the translated version and the Portuguese language version of this report, the Portuguese language version will be controlling.

Confidencial – conhecimento restrito ao Conselho de Administração da Vale

“The disappeared, placed under silence, as if at large.
The mud and the iron have swallowed them, without document or file.”¹
(Carlos Nejar)

¹ NEJAR Carlos. The Invisibles: Brazilian Tragedies. Rio de Janeiro: Ed. Bertrand Brasil, 2019, p. 317.

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1. INTRODUCTION

This executive summary (“Executive Summary”) has been prepared at the request of Vale S.A.’s Board of Directors (“Vale” or “Company”) and is intended to provide a summarized version of the Independent Investigation Report prepared by the Extraordinary Independent Consulting Committee for Investigation (“CIAEA”) and its Annexes. Such documents were delivered by CIAEA to Vale’s Board of Directors.

1.1. Formation and composition of the CIAEA and the Investigation Team

The CIAEA was created by Vale’s Board of Directors at an extraordinary meeting held on January 27, 2019, based on Art. 15, §1º of the Company’s Bylaws, to act in the determination of causes and responsibilities in the context of the failure of Dam 1 of the Córrego do Feijão Mine (“B1”), in Brumadinho, MG, occurring on January 25, 2019.

In order to ensure its independence and autonomy, the CIAEA was composed of three external members, selected with the support of international consulting firm Korn Ferry, and had its final composition established on March 20, 2019²:

- Ellen Gracie Northfleet (independent external member - coordinator) - Retired Minister of the Federal Supreme Court, previously served as the Chair of the Special Committee for the investigation of Petrobras and Chair of the Special Committee for investigation of Eletrobras.
- José Francisco Compagno (external independent member) - Was the lead partner of EY’s forensics area in Brazil between 2002 and 2018 and a lead partner - Transaction Support from 2001 to 2005. Member of EY’s Executive Committee in Brazil, from 2016 to 2017. Auditing partner at Arthur Andersen from 1998 to 2001. Auditing Director at Coopers & Lybrand Independent Auditors from 1987 to 1998. Degree in Accounting Sciences from FMU-SP.
- Manuel de Almeida Martins³ (external independent member) – Civil Engineer, graduated from the UFRJ School of Engineering in 1971, specializing in geotechnical engineering and dam engineering. He worked for thirty years in studies, project detailing, monitoring of construction, supervision, quality control, monitoring and safety

² Available at: <http://www.vale.com/brasil/PT/aboutvale/news/Paginas/Vale-sobre-Comite-Independente-de-Assessoramento-Extraordinario-de-Apuracao.aspx>; accessed on: 02/07/2020.

³ Jean-Pierre Paul Rémy was part of the CIAEA between 02/01/2019 and 03/20/2019, and attended 7 meetings (the last of these meetings was held on 3/12/2019), and was replaced by Manuel de Almeida Martins.

evaluations of dams and land/rock works and foundations in major Brazilian companies as a geotechnical engineer and department manager specialized in geotechnical engineering. Over the last twenty years, he has worked as an independent consultant in geotechnical engineering for infrastructure projects , mainly, dams.

To support its activities in conducting the independent investigation, the CIAEA a hired a Brazilian law firm specializing in internal investigations, Maeda, Ayres and Sarubbi Advogados ("MAS"), and the U.S. law firm Smith Pachter McWhorter PLC ("SPM"), the latter to assist with U.S. legal issues.⁴

To support the CIAEA and the law firms, the following specialized offices were hired: Ernst & Young Assessoria Empresarial Ltda. ("EY"), which performed forensic technical support activities in: (i) electronic data collection and processing technology for structured and unstructured electronic data of interest of the investigation; (ii) financial aspects from the perspective of understanding the financial management and compensation structure; (iii) corporate governance from the perspective of understanding the design of the organization; (iv) project management (PMO and document organization); and a Technical Team comprised of ABSG Consulting Inc. and ABSG Group Services do Brasil Ltda. (collectively, "ABSG"), working together with the firm Geocompany Tecnologia Engenharia e Meio Ambiente Ltda. ("GeoCompany"), for specialized technical support on technical subjects related to dams and geotechnical engineering. Together, ABSG and GeoCompany are referred to as "CIAEA Technical Team." Finally, for expert support and advice regarding the evaluation of technical causes and other relevant technical aspects relating to geotechnical engineering, Professors Idriss⁵ and Steven L. Kramer,⁶ highly specialized professionals in geotechnical engineering ("USA Geotechnical Consultants to the CIAEA"), were also engaged. The work of EY, ABSG, GeoCompany and the Professors was performed at the direction of the MAS and SPM firms, under the attorney-client privilege and work product doctrine.

Together, MAS, SPM, EY, ABSG, GeoCompany and the Professors are referred to as the "Investigation Team."

⁴ The CIAEA also received legal counsel from the law firm of Yazbek Advogados.

⁵ Dr. Izzat M. Idriss is a professor emeritus of geotechnical engineering at UC Davis. He holds a Ph.D. in Civil Engineering from the University of California, Berkeley, 1966. Member of the US National Academy of Engineering (NAE).

⁶ Dr. Steven L. Kramer is a professor at the University of Washington, USA. He received his bachelor's degree, masters and doctorate from the University of California, Berkeley in 1977, 1979 and 1985, respectively. Elected Member of the US National Academy of Engineering (NAE).

In performing its duties, the Board of Directors gave the CIAEA access to Vale's information as well as operational and budgetary autonomy to execute the work with a direct reporting line to the Board of Directors.⁷

The CIAEA and the Investigation Team worked exclusively on conducting the independent investigation, without any participation in Vale's defense or that of any individual in the judicial and non-judicial proceedings initiated by Brazilian authorities with respect to the failure of B1.

1.2. Scope of the work

Considering that non-technical aspects (including organizational, cultural and governance aspects) may be as important as technical aspects for dam safety, the independent investigation conducted by the CIAEA sought to assess not only the technical causes for the failure of B1, but also possible non-technical contributing factors, including indirect factors.

In addition to the causes related to the B1 failure, the investigation conducted by the CIAEA sought to identify possible failures or omissions that may have contributed to the dam breach reaching the scale observed (loss of human life and social, environmental and material impacts).

Thus, the independent investigation included activities aimed at obtaining a broad understanding of the causes and context of B1's failure and the extent of the damage observed. As such, the review procedures carried out included aspects related to governance, risk management, corporate culture, compensation policy and incentives, relationships with external dam safety auditing companies, among others.

⁷ Vale's Board of Directors approved internal regulations for the functioning of the CIAEA, which, among other points, expressly ensured its independent action, with autonomy and sufficient budgetary resources for the performance of its activities.

2. METHODOLOGY AND MAIN ACTIVITIES PERFORMED IN THE INVESTIGATION

The independent investigation conducted by the CIAEA focused on the following activities organized by workstream:

2.1 Processes, controls and governance workstream

The procedures performed included the following activities:

- a) Governance, information flows and communications:
 - i. Understanding of the organizational structure, responsibilities and activities of internal governance and management bodies, such as: (a) Boards; (b) Executive Management; (c) Committees; (d) Subcommittees; (e) Internal Audit; and the (f) Ombudsman.
 - ii. Analysis of documents establishing governance and company management guidelines, such as charters, by-laws, manuals, policies and internal procedures.
 - iii. Analysis of organizational changes occurring between 2015⁸ and the date of B1's failure.
 - iv. Analysis of relevant internal governance bodies' documentation to identify any discussions related to dam safety and related topics.
 - v. Analysis of the flow of information and communications about risk at different levels of Vale's internal governance structure (e.g., from operational levels to Upper Management).
 - vi. Analysis of information from the Ombudsman communication channel, policies and procedures for handling complaints and review of allegations forwarded to the CIAEA by the Ombudsman's Office after the failure of B1.
- b) Risk management
 - i. Understanding of Vale's risk management structure, including lines of defense, responsible areas, assignments, organizational structure and other relevant aspects.

⁸ For purposes of time period delimitation for the review, 2015 was used as the starting period, in order to cover changes that occurred and other measures adopted after the rupture of the Fundão Dam, owned by Samarco, which had as its shareholders Vale and BHP Billiton Brasil Ltda. that took place on 11/05/2015.

- ii. Mapping and analysis of policies, procedures and action plans related to risk management, focusing on aspects of dam safety risks.
 - iii. Understanding of the definition of tolerable risk limits related to dam safety.
 - iv. Understanding of risk reporting lines to Vale's executive levels.
 - v. Analysis of aspects related to the implementation of the PAEBM - Emergency Action Plan for Mining Dams, in particular in relation to B1.
- c) Understanding processes related to dam management
- i. Understanding and mapping of roles and responsibilities of the different internal areas of Vale in relation to the dams in general and B1 in particular.
 - ii. Mapping of Vale's internal processes related to dam safety management.
 - iii. Mapping of regulatory requirements applicable to dam management matters.
 - iv. Analysis of aspects related to the decommissioning plan of B1.
 - v. Understanding of any changes to policies, processes, structures or other relevant aspects, after the failure of the Fundão Dam (11/05/2015).
- d) Relationship with certification companies
- i. Analysis of Vale's procurement procedures, especially with regards to third-party service providers in the area of tailings dam safety, including certification companies responsible for attesting to the condition of stability of the structures.
 - ii. Mapping of companies that provided dam safety services for B1, including certifiers that issued stability condition declarations or conducted relevant studies in relation to B1.⁹
 - iii. Mapping of internal departments and Vale employees whose duties involved interactions with said certification companies.
 - iv. Mapping Vale's relationship with such companies, including contract mapping and financial analysis.
 - v. Analysis of concentration, economic dependence and situations of potential

⁹ The mapping of companies also served as the basis for the gathering of relevant materials regarding the history of safety studies and external audits of B1.

conflicts of interest as applicable, in Vale's relationship with certification companies, including mapping Vale's possible relationship with other companies and parties related to the certifiers based on public database searches.

e) Vale's remuneration and incentive policy

- i. Analysis of Vale's remuneration policy and structure, with the objective of assessing possible impacts of financial components and remuneration in the management of safety risks.

f) Interaction with Government Officials

- i. Mapping of Vale's interactions with government officials in the context of B1 in relation to: (a) obtaining environmental licenses; and (b) dam inspections.
- ii. Analysis of documents related to: (a) environmental licensing of B1; (b) finances and penalties applied to Vale by external control bodies in relation to B1.

g) Maintenance Spending

- i. Analysis of financial aspects related to dam safety, including understanding the process of defining a dam safety budget and procedures for requesting and approving maintenance spending.
- ii. Review of specific aspects related to investments in maintenance and safety relating to B1.

2.2 Electronic data collection and review workstream

The procedures performed included the following activities:

- a) Preservation of electronic data of 296 employees and former employees ("Custodians").
- b) Processing of electronic data for 170 Custodians and hosting a review platform managed by EY, representing a total volume of about 28 TB.
 - i. In all approximately 498,000 unique electronic documents were reviewed.
- c) Collection of relevant Vale databases and systems to conduct technical, financial, governance review, among others.

2.3 External monitoring workstream

The procedures performed included the following activities:

- a) Monitoring and analysis of documents and information available from legal procedures and external investigations related to the failure of B1.
- i. In all, 263 (two hundred and sixty-three) documents were analyzed related to legal proceedings (lawsuits, criminal procedures and administrative processes) regarding the failure of B1.
 - ii. Documents and information from 5 (five) Parliamentary Inquiry Commissions:
(a) Federal Senate - Parliamentary Inquiry Commission of Brumadinho and Other Dams ("CPIBRUM"), instated on 03/12/2019 and concluded on 07/02/2019¹⁰ (b) House of Representatives - Parliamentary Inquiry Commission for the failure of the Brumadinho Dam ("CPIBRUMA"), instated on 04/25/2019 and concluded on 11/05/2019¹¹ (c) Legislative Assembly of the State of Minas Gerais - Parliamentary Inquiry Commission on the Brumadinho Dam ("CPI-ALMG"), instated on 03/13/2019 and concluded on 09/12/2019¹² (d) Belo Horizonte City Council - Parliamentary Inquiry Commission - Dams ("CPI-CMBH"), instated on 02/22/2019 and concluded on 08/20/2019¹³ and (e) Brumadinho City Council - Parliamentary Inquiry Commission No. 01/19, instated on 02/25/2019 and concluded on 08/08/2019.¹⁴
 - iii. Reports published by federal and state agencies, such as the National Mining

¹⁰ CPIBRUM website available at:

<https://legis.senado.leg.br/comissoes/comissao?5&codcol=2246&data1=2019-01-01&data2=2019-12-27> accessed on: 02/07/2020. Approved Final Report available at: <http://legis.senado.leg.br/sdleg-getter/documento/download/acbe1dc8-5656-419e-9ff5-9fcae27730e7> accessed on: 02/07/2020.

¹¹ CPIBRUMA website available at: <https://www2.camara.leg.br/atividade-legislativa/comissoes/comissoes-temporarias/parlamentar-de-inquerito/56a-legislatura/cpi-rompimento-da-barragem-de-brumadinho> accessed on: 02/07/2020. Approved Final Report at: <https://www.camara.leg.br/internet/comissoes/cpi/cpibruma/RelatorioFinal.pdf> accessed on: 02/07/2020.

¹² Commission website at:

https://www.almg.gov.br/atividade_parlamentar/comissoes/cpis/interna.html?idCom=1151&leg=19&as_qdr=y15; accessed on: 02/07/2020. Approved Final Report at: <https://mediaserver.almg.gov.br/acervo/441/150/1441150.pdf> accessed on: 02/07/2020.

¹³ Commission website:

<https://www.cmbh.mg.gov.br/atividade-legislativa/comissoes/temporarias/cpi/2c907f7668a3f9120168c947fcaB110f> accessed on 02/07/2020. Approved Final Report at: <https://www.cmbh.mg.gov.br/atividade-legislativa/pesquisar-reunioes/2c907f766c440b00016c6793618e1445> accessed on: 02/07/2020.

¹⁴ Commission Application of Origin website at: <https://www.cbrumadinho.mg.gov.br/atividade-legislativa/proposicoes/materia/1231> accessed on: 02/07/2020. Approved Final Report at: https://www.cbrumadinho.mg.gov.br/docs/proposicoes/relatorio_final_emitido_pela_cpi_vale_RE_Q-0012019.pdf accessed on: 02/07/2020.

Agency – (Agência Nacional de Mineração, ANM),¹⁵ the Regional Office of Labor and Employment of Minas Gerais - SRTE/MG,¹⁶ Controllershship General of the State of Minas Gerais - CGE/MG,¹⁷ Civil Police of the State of Minas Gerais, under Police Inquiry No. 3881083-001 ("IPL/PC No. 3881083-001")¹⁸ and the Federal Police, under Police Inquiries No. 62/2019 (IPL/PF No. 62/2019) and No. 1464/2019 ("IPL/PF No. 1464/2019").¹⁹

- iv. Analysis of approximately 759,000 electronic documents related to information and documentation made available by Vale in response to requests from administrative and judicial authorities.

2.4 Technical review

The CIAEA Technical Team analyzed relevant documents and information in order to identify factors potentially related to the failure of B1, including:

- a) Mapping, collection and analysis of technical documentation available from the original design of the dam (reports, drawings, technical specifications, descriptive logs, calculation logs and other pertinent documents) and its raisings.
- b) Technical visits to the B1 site in Brumadinho.
- c) Analysis and interpretation of geotechnical field investigation data and laboratory tests performed after B1's failure by the expert panel hired by Vale's executive management

¹⁵ ANM: Technical Opinion No. 07/2019 of the National Mining Agency, published on 11/05/2019, at: <http://www.anm.gov.br/parecer-007-2019-brumadinho-final>; accessed on: 02/07/2019.

¹⁶ SRTE/MG: On the Workplace Accident Analysis Report, of the Regional Labor Superintendent Office of Minas Gerais, presented on 09/25/2019.

¹⁷ CGE/MG: Two reports issued by the Controllershship General of the State of Minas Gerais were reviewed by the Investigation Team: (i) Audit Report No. 1370.1239.19 - State Environment System (SISEMA/SEMAD/FEAM/IEF/IGAM), dated 08/07/2019. Available at: http://cge.mg.gov.br/phocadownload/roteiros_auditoria/pdf/RA_1370.1239.19_Conformidade_B1_SIS_EMA.pdf accessed on: 02/07/2020; (ii) Audit Report No. 1370.1390.19 - State Office of the Environment and Sustainable Development (SEMAD), dated 09/24/2019. Available at: http://cge.mg.gov.br/phocadownload/relatorios_auditoria/2019/RA_1370.1390.19_CMI_COPAM_SEM_AD_DCAPG_24_9_19.pdf accessed on: 02/07/2019.

¹⁸ IPL/PC No. 3881083-001. Criminal Institute of the Civil Police of Minas Gerais. Technical Report No. 2019-024-000210-024-009006634-80. Published on 11/27/2019.

¹⁹ By the conclusion of the CIAEA Independent Investigation Report, the Federal Police had published 6 (six) reports: (i) IPL/PF No. 62/2019: (a) Report No. 1070/2019 – SETEC/SR/PF/MG, Engineering related, dated 6/12/2019; (b) Report No. 1102/2019 – SETEC/SR/PF/MG, Environmental related, dated 07/07/2019; (c) Report No. 1362/2019 – SETEC/SR/PF/MG, Electro-electronics related, dated 07/12/2019; (ii) IPL/PF No. 1464/2019: (d) Report No. 1639/2019 – INC/DITEC/PF, Environmental-related - fauna damage, dated 9/11/2019; (e) Report No. 2224/2019 – NUCRIM/SETEC/SR/PF/SP, environment related, dated 6/19/2019; and (f) Report No. 3565/2019 – NUCRIM/SETEC/SR/PF/SP, environment related, dated 10/17/2019.

("Skadden Panel").²⁰

- d) Image analysis of B1 monitoring cameras, including the moment of the failure.
- e) Analysis of geotechnical instrumentation and monitoring data from B1.
- f) Analysis of seismograph data near the dam.
- g) Analysis of drone images of B1 prior to the failure.
- h) Gathering of national and international guides and regulations related to the design, construction, maintenance and management of tailings dams during the period between approximately 1970 and 2019.

Based on the interpretation of the data from field investigations and existing geotechnical testing, a standard stratigraphy of the tailings storage facility was developed and index parameters and shear strength parameters were determined. The final phreatic surface was established from the instrumentation data. Based on the geometry of the dam obtained through the compilation of available data, computational geotechnical stability analyses via the limit equilibrium method (two-dimensional and three dimensional) and stress-deformation via finite elements method (three-dimensional) were performed.

2.5 Other activities

- a) Gathering of relevant documents and information from Vale's internal departments.
 - i. In total, approximately 36,000 documents were analyzed.
- b) Conducting interviews with employees, former employees and third parties.
 - i. In total, about 160 interviews were conducted.
- c) Weekly meetings between the CIAEA and the Investigation Team, or more frequently as needed, were held to provide updates on the information obtained and to integrate the work.

²⁰ Vale's executive management hired a panel of experts to investigate the technical causes of the rupture of B1. This panel, coordinated by Professor Peter Robertson, was hired through the U.S. office of Skadden, Arps, Slate, Meagher & Flom LLP. The CIAEA's work is different from the Skadden Panel's work, both in relation to scope, as the CIAEA's work covers technical and non-technical factors relevant to the rupture of B1 and the extent of the confirmed damage, and in relation to the independence and reporting line of the CIAEA. Field geotechnical investigation data and laboratory tests performed after B1's rupture under the responsibility of the Skadden Panel, made public by Vale, were reviewed by the CIAEA Technical Team and are referenced, where applicable and as understood to be appropriate by the CIAEA Technical Team, based on an independent review of the procedures performed.

3. Main Observations

B1 began being installed in the Ferro-Carvão riverside valley in 1976 and, until 2001, it belonged to Ferteco Mining S.A. ("Ferteco"). After Vale's acquisition of Ferteco in 2001, the dam remained in operation until July 2016, when depositing of tailings was halted. B1 was designed and predominantly raised using the upstream method,²¹ in which the raisings are built on top of the tailings deposited with water in the dam. B1 contained approximately 11.3 million cubic meters of iron ore tailings and was 86 meters high with crest at an elevation of 942m and a length of 720m.

On 01/25/2019 at 12:28 p.m., the B1 failure occurred. The mudslide originating from the rupture²² spread throughout the downstream region of the dam and resulted in a total of 665 (six hundred and sixty-five) recorded victims, of which 395 (three hundred and ninety-five) were found alive, and 270 (two hundred and seventy) confirmed deaths. Of the fatalities, 259 (two hundred and fifty-nine) deaths had been confirmed by the Legal Medical Institute and 11 (eleven) had not yet been located by the date of issuance of this Executive Summary.²³

Based on the steps taken by the Investigation Team and the information available for review and analysis, the following observations are made regarding the main findings of the independent investigation.

3.1 Main observations related to failure mode and triggers

In order to analyze B1's failure mode and triggers that may have caused its failure, the "failure tree" methodology was used whereby factors that may have contributed to a particular event are established or evaluated for plausibility. The technical review concluded that the B1 failure occurred by structural instability with liquefaction, and that the downstream flow slide was caused by the combination of the occurrence liquefaction in the materials deposited at B1 and the lack of structural capacity of the dam to contain liquefied material.

To identify B1's failure mode, the CIAEA Technical Team ruled out the occurrence of other failure modes such as overtopping, piping and instability without liquefaction and confirmed the occurrence of structural instability with liquefaction. Video analysis of the failure shows that the mud originating from the B1 tailings flowed at high speed as a viscous liquid along the downstream valley of the Ferro-Carvão riverbank, which confirms the liquefaction

²¹ The third stage of the second raising was built using the centerline method.

²² About 9.7 million m³ of ore tailings.

²³ Available at: http://www.vale.com/brasil/PT/aboutvale/servicos-para-comunidade/minas-gerais/atualizacoes_brumadinho/Documents/PDFs/29122019835.pdf; accessed on: 02/07/2020.

hypothesis.

Regarding liquefaction, the CIAEA Technical Team confirmed the existence of the three necessary requirements necessary for its occurrence: (i) presence of material that is contractive and susceptible to liquefaction; (ii) saturation of the material in the dam; and (iii) occurrence of a trigger.

With respect to the presence of material that is contractive and susceptible to liquefaction, the CIAEA Technical Team analyzed data from geotechnical investigation campaigns conducted in 2005, 2016 and 2018 and confirmed the contractive nature of most of the dam's tailings. This means that B1's tailings, when subjected to high shear stresses, tended to contract and reduce in volume, with the generation of excess pore pressures, associated with brittle behavior. This type of material, when saturated, is susceptible to liquefaction.

With respect to the saturation conditions, based on available instrumentation data the CIAEA Technical Team identified a high phreatic surface (water level) within the B1 tailings deposit. In general, the saturation conditions of the tailings within B1 were the result of an inadequate internal drainage system. First, the design of the drainage system provided for no drainage in the starter dam and for undersized drainage in the raisings. It is worth highlighting that at least since 1995, there were already records of internal drainage issues that resulted in the dam's high phreatic surface. Evidence was also found of the poor functioning of the existing drainage system in the raisings. Of the 56 (fifty-six) flow meters installed at B1, only 12 (twelve) showed any flow in 2018. In addition, other contributors to the saturation conditions at B1 included the way tailings were deposited, the contribution of streams and springs in the reservoir area and the infiltration of surface and groundwater.

As for the trigger, the CIAEA Technical Team concluded that it is possible to discard all potential triggers considered except for three. There is a high plausibility that liquefaction was triggered by "creep"²⁴ and reduced strength due to loss of suction in unsaturated materials above the phreatic surface.²⁵ Creep would have brought the material to the limit of peak

²⁴ During "creep," tailings accumulate specific slow deformations under a constant load. These slow deformations may cause liquefaction or bring the tailings to a state in which they are susceptible to liquefaction by other triggers. The following factors increase the plausibility of this trigger: (i) high stress in the dam due to loading caused by a high density material, which may have caused slow deformations and taken the tailings to a threshold state for liquefaction triggering; and (ii) small internal deformations are consistent with small external deformations that were observed in the satellite data analyses and which were measured since the middle of 2015. The CIAEA Technical Team concluded that the phenomenon contributed to the start of the process of failure with liquefaction.

²⁵ The regions of the tailings storage facility above the phreatic surface may present a capillarity effect (negative pore pressures), generating suction between the particles of the tailings and increasing their

undrained strength. This coupled with reduced shear strength of unsaturated materials above the phreatic surface due to the loss of suction as a result of the rainy season, would have culminated in the failure with liquefaction.

In addition, the CIAEA Technical Team evaluated the drilling that was taking place at B1 on the day of the failure.²⁶ Under normal conditions, a drilling campaign should not trigger widespread liquefaction of a dam. However, since the drilling was centered transversely between the points where the first deformations of B1's failure were observed, in the tallest section, overlying the valley floor), and the drilling that was about 100mm in diameter and 70m deep, could have caused disturbances in the tailings' layers which had brittle characteristics, it is not possible neither to exclude nor confirm the hypothesis that this drilling could have contributed to B1's failure.

Finally, it was found that B1 lacked the structural capacity to contain liquefied material. Once liquefaction was triggered in the saturated, loose tailings at B1, its strength would be significantly reduced and an intense flow slide of the liquefied tailings was inevitable. The Investigation Team identified that there was inadequate consideration of issues related to the stability of said geotechnical structure throughout most its existence. In this regard, as described below, low factors of safety had already been indicated in technical reports prepared by engineering companies hired by Ferteco in 1995 and Vale in 2003, for example, and again in 2017 and 2018.

3.2 Main observations related to the safety and stability assessment at B1

The timeline of B1's stability analyses reveals that the dam's fragile situation and the

strength. However, this effect may have been partially reduced by infiltration due to the annual rainy season, resulting in reduction of this suction. This reduction may be a trigger if the tailing is close to the limits of its strength.

²⁶ Between 1/21/2019 and the day of the rupture, vertical drilling was ongoing at B1 from the 8th raising, section 4(E). The drilling (SM-13) was being carried out by the company Fugro In Situ, a Vale contractor. During the drilling, samples of material were to be collected for field investigations for use in the "As Is" project and in the context of B1's decommissioning project. Drilling activities started on 01/21/2019. Based on documentation obtained, the drilling reached a depth of 65.45m by 01/24/2019. On the morning of 01/25/2019, the drilling continued. The drill operator that operated the drill survived and reported that drilling activities occurred until 10:30 a.m., about two hours before the rupture. No documentary records of drilling activities on the day of the rupture remained. As a result, it is not possible to say precisely until what time the drilling activity occurred, or the depth reached on the day of the failure. In any event, it is possible that the drilling reached the foundation of the dam (natural terrain). According to the description of the scheduled investigations, the expected depth for this borehole was 75m. It is estimated that the drilling reached about 70m in depth.

need to adopt risk mitigation measures were known.

In 1995, when B1 still belonged to Ferteco, the company Tecnosolo²⁷ presented considerations in the executive design of B1's 4th raising regarding the dams unfavorable safety conditions especially in relation to the high phreatic surface and low factors of safety.

In 2003, Vale hired the Dam DF Consortium²⁸ to perform an external audit of B1 and the company Pimenta de Ávila²⁹ to audit structures at the Fábrica and Córrego do Feijão Mines, including B1. The Dam DF Consortium report indicated factor of safety values for B1 below the minimum considered satisfactory, the existence of problems with the internal drainage system of the dam and a lack of data about its foundation. In addition, according to Dam DF Consortium's report, the factor of safety values calculated for B1 would indicate an "extremely uncomfortable" situation from a risk standpoint given existing downstream facilities. The Pimenta de Ávila report presented conclusions consistent with those in Dam DF Consortium's report and indicated, in addition, the need to perform a stability analysis considering the possibility of static liquefaction.

Between 2010 and 2013, Pimenta de Ávila, the company responsible for B1's external audit, recommended every year that analysis of the potential for liquefaction of the structure be carried out. The last study was conducted in 2006 by the company Geoconsultoria, in the context of preparing the Executive Design of the 9th and 10th raisings of B1, using data from research studies conducted in 2005.³⁰

Despite the recommendations made between 2010 and 2013 by Pimenta de Ávila for a liquefaction study this study was only conducted in 2014, again by Geoconsultoria. This new study was based on the re-interpretation of the 2005 investigation campaign, not new testing. The results pointed out the susceptibility of B1's tailings to liquefaction with the caveat that the probability of triggering was remote. In addition, the study identified factors of safety in the drained condition ranging from 1.6 to 2.1 and 1.5 to 1.8 in the undrained condition.

It is important to highlight that by re-interpreting the 2005 tests, rather than performing new tests, Geoconsultoria reached results that were possibly not representative of the

²⁷ The company Tecnosolo Engenharia S.A. was the designer of the 4th, 5th, 6th, 7th and 8th raisings of B1.

²⁸ The Dam DF Consortium (formed by the companies Dam Projetos de Engenharia Ltda. and DF Consultoria Ltda.) was hired to carry out the Technical Dam Safety Audit of B1 in 2003.

²⁹ Pimenta de Ávila Consultoria Ltda. provided services to Vale between 2002 and 2016, when it had its contracts interrupted. Among these services, those of external safety auditing of B1 between at least 2006 and 2015 stand out.

³⁰ The phrase "investigation campaign" refers to a set of geotechnical and laboratory tests performed on the dam.

conditions of the dam in 2014. For example, in the 9 (nine) years between performing the tests and performing the liquefaction study, B1 was raised twice (9th raising in 2008 and 10th raising in 2013). Its geometry had changed, the dam was taller and had a greater volume of material in the tailings deposit.

Thus, since the liquefaction study performed by Geoconsultoria in 2014 was limited to the re-interpretation of the 2005 data, Pimenta de Ávila, B1's external auditor in 2015, recommended that liquefaction analysis be carried out based on a new investigation campaign and collection of samples and information representative of the tailings located at the foundation of the upstream raisings.

In November 2015, a few months after Pimenta de Ávila issued the 2015 dam external audit report, Samarco's Fundão Dam failed. This prompted the issuance of State Decree (MG) No. 46.993/2016,³¹ which instituted the Extraordinary Dam Safety Technical Audit ("Extraordinary Audit"). This legal requirement, together with Pimenta de Ávila's recommendations for a new liquefaction analysis, prompted the performance of studies on this topic in 2016. As a result, a new investigation campaign and liquefaction study was conducted by Geoconsultoria, which subcontracted international consultant Scott M. Olson ("Olson").³² The results of these studies provided support for the Extraordinary Audit work conducted in the same year.

Olson made relevant considerations regarding B1, which were not considered by Geoconsultoria in carrying out the Extraordinary Audit the following month. For example, Olson understood that part of the results obtained from laboratory tests should be disregarded and should not be used to calculate the undrained strength ratio³³ for lack of reliability.

The liquefaction studies carried out by Geoconsultoria, for which the reports were finalized in July 2016, presented unfavorable results with respect to B1's stability when using

³¹ Decree of the Minas Gerais State Government. Available at <https://www.almg.gov.br/consulte/legislacao/completa/completa.html?tipo=DEC&num=46993&comp=&ano=2016>; accessed on: 02/07/2020.

³² According to information obtained from public sources, Scott Olson is a Ph.D. in Philosophy, Civil and Environmental Engineering from the University of Illinois, where he is also a professor and teaches a series of courses related to geotechnical engineering. Available at: <https://cee.illinois.edu/directory/profile/olsons>; accessed on 02/07/2020. Scott M. Olson was a member of Vale's Independent Panel of Experts for Safety and Risk Management of Geotechnical Structures (Painel Independente de Especialistas para Segurança e Gestão de Riscos de Estruturas Geotécnicas, PIESEM), having participated in the international version of this panel of experts since its first implementation in March 2017. Regarding PIESEM, see note 41 below.

³³ The undrained strength ratio is used, together with other indicators, to obtain the factor of safety value.

Olson's methodology, which was, according to Geoconsultoria's reports, the methodology used for these studies.

Contrary to what the liquefaction studies indicated, however, at the end of the Extraordinary Audit, Geoconsultoria reached supposedly satisfactory factors of safety for the drained and undrained peak conditions ($FS = 1.3$) and the stability of B1 was certified. In reaching these results, Geoconsultoria used a higher undrained strength parameter than those identified by Olson and recommended by engineering best practices.³⁴ This value was obtained using questionable methodology and in contradiction to Olson's considerations given that laboratory test results that Olson considered unreliable were used. If the results of the liquefaction studies conducted using Olson's methodology had been considered by Geoconsultoria, the factor of safety obtained for B1 in August 2016 would have been very close to 1, thus indicating a situation of imminent failure.

Furthermore, Geoconsultoria did not present a stability analysis that considered the residual/post-trigger undrained condition that had been recommended by Olson. Generally, and in a simplified manner for the purposes of this Executive Summary, the notion of a factor of safety in the context of stability and liquefaction³⁵ analysis, can be divided in two: (i) drained factor of safety, which indicates the stability of a structure under normal operating conditions, with efficient internal drainage and pore pressure dissipation, maintaining a sufficiently low phreatic surface and resulting in a higher factor of safety and strength ratio; and (ii) undrained factor of safety, which considers a liquefaction scenario and indicates the structure's reaction to the liquefaction phenomenon and the structure's resulting stability, considering a high phreatic surface and excess of pore pressure. The latter can be divided into two types: (ii.1) peak undrained factor of safety, which indicates the ability of the structure to resist a liquefaction trigger without its tailings liquifying; and (ii.2) residual or post-trigger undrained factor of safety, which indicates the ability of the structure to resist failure when liquefaction has occurred and the resulting strength falls to a residual value that is much lower than peak strength.

The fact that Geoconsultoria did not submit a stability analysis considering the residual undrained factor of safety is relevant insofar as Geoconsultoria did not test the capacity of B1 to resist liquefaction even knowing that the risk of liquefaction existed.

³⁴ International technical association recommendations (e.g., Canadian Dam Association) and government agencies (e.g., US Corps of Engineers).

³⁵ The notion of a factor of safety considering the case of failure with liquefaction as presented, because, as mentioned in Section 3.1., this was B1's failure according to analysis of the CIAEA Technical Team.

Between the second half of 2016 and the beginning of 2017, Geoconsultoria coordinated the execution of complementary geotechnical tests at B1, but these tests did not change the results obtained in 2016.

In February 2017, Vale's Geotechnical Risk Management³⁶ group hired Potamos³⁷ and Tüv Süd,³⁸ to conduct studies related to the analysis of geotechnical risks. Tüv Süd was hired individually³⁹ in July 2017 to conduct a Periodic Dam Safety Review ("RPSB")⁴⁰ of certain iron ore dams, including B1. The scope of geotechnical risk analysis bore some resemblance to part of the work that would be done for the RPSB, such that Potamos and Tüv Süd interacted and collaborated with each other in 2017 and 2018.

In this context, Potamos and Tüv Süd performed new stability analyses that resulted in a lower undrained strength ratio than that obtained in 2016 by Geoconsultoria, since Potamos and Tüv Süd dismissed laboratory tests that were considered unreliable. The companies understood the resulting values as dispersed and higher than those expected for similar materials. As a result, Potamos and Tüv Süd calculated a peak undrained factor of safety of 1.06.

³⁶ Also referred to as "Corporate Geotechnical".

³⁷ Potamos Engenharia e Hidrologia Ltda. was contracted by Vale on 02/24/2017, in consortium with the company Tüv Süd, to conduct studies under the GRG (Gestão de Riscos Geotécnicos [Geotechnical Risk Management]) project, in which it would be responsible for the issues related to hydrology.

³⁸ The company Tüv Süd Brasil Engenharia e Consultoria Ltda. was contracted together with the company Potamos Engenharia e Hidrologia Ltda. to conduct studies under the GRG (Geotechnical Risk Management) project, being responsible for matters related to geotechnical engineering. Additionally, it was hired to provide several services for B1, between 2017 and 2018, of which the following stand out: (i) preparation of 2018 Periodic Dam Safety Review for 25 Vale dams, including B1; (ii) implementation, together with Tecwise, of an automated geotechnical instrumentation system in B1; (iii) preparation of studies for the "As Is" of Vale dams, including B1; (iv) preparation of a study of alternatives and conceptual design for B1 decommissioning; and (v) conducting the September 2018 Regular Safety Inspection of B1.

³⁹ Vale sought to have Potamos and Tüv Süd jointly conduct the RPSB. For commercial, Potamos declined the invitation and Tüv Süd was hired individually to conduct the work.

⁴⁰ The Periodic Dam Safety Review – RPSB consists of detailed analysis to verify the overall state of tailings dam safety. In accordance with DNPM Ordinance No. 70.389/2017, RPSB comprises (i) examination of all dam documentation and re-evaluation of design, classification, PAEBM, etc; (ii) examination of maintenance and operation procedures; (iii) comparative analysis of the performance of the dam against revisions made previously; (iv) the performance of new stability analyses; (v) the analysis of hydraulic safety due to the filling conditions of the reservoir; (vi) analysis of adhesion between design and construction of the dam; (vii) "As Is" documentation review, depending on the case. The timing of RPSBs varies due to the associated potential damage (APD) of each dam. For high DPA dams such as B1, the RPSB should be performed every 3 (three) years, with the first one being completed by June 2018. The RPSB does not confuse itself with external dam safety audits, which, at the federal level, are called Regular Safety Inspections – (Inspeção de Segurança Regular, ISR) and have become required semi-annually with the issue of DNPM Ordinance No. 70,389/2017. ISRs are intended to identify and assess any anomalies that may affect the safety conditions and operation of the dam. Its scope is reduced and less complex relative to the RPSB to the extent that it consists of (i) identification of general information about the dam (legal representative of the owner, external contracted staff for the ISR, tailings' characteristics, instrumentation control levels); (ii) description of the bi-weekly inspections performed during the semester; and (iii) stability analysis of the dam.

The value obtained for the residual undrained factor of safety was 0.39. These results indicated B1's fragile situation and were presented to Vale's Operations Geotechnical and Corporate Geotechnical departments for the first time in the second half of 2017.

Although these values were presented to Vale, as early as the second half of 2017, they were not used for the purposes of the external dam audit and issuance of a Stability Condition Declaration ("DCE") that year. As will be mentioned below, another company was responsible for the B1 external audit in 2017.

Also during the second half of 2017, Potamos and Tüv Süd expressed discomfort in relation to the methodology employed by Geoconsultoria in the 2016 Extraordinary Audit and insisted on the use of a methodology that resulted in a low factor of safety and that indicated B1's marginal stability. This methodology was aligned with the recommendations, from the same time period, of Vale's Independent Panel of Experts for Safety and Risk Management of Geotechnical Structures (PIESEM);⁴¹ and with observations that Scott M. Olson made to Geoconsultoria in 2016.⁴²

In September 2017 the company responsible for B1's external audit that year, Tractebel,⁴³ included in a draft audit report a recommendation to review Geoconsultoria's 2016 study, especially regarding the results obtained. This recommendation, however, was deleted from the final version of Tractebel's report at the request of a Vale employee from the Operations Geotechnical group.

Based on the results obtained by Potamos and Tüv Süd for B1's stability analyses, these companies were asked to present alternatives for increasing the factor of safety with a focus on the deadline for issuing the DCE of the RPSB in June 2018. Of the alternatives presented, Vale opted for the installation of Deep Horizontal Drains (Drenos Horizontais Profundos, "DHPs"), in conjunction with removing B1's tailings, to lower the phreatic surface notwithstanding the recommendations from Potamos and Tüv Süd that such measures would not be efficient in the

⁴¹ The Independent Panel of Experts for Safety and Risk Management of Geotechnical Structures ("PIESEM") was a panel of experts hired by Vale to address matters related to the safety of its structures. This panel had the national (composed only by Brazilian experts) and international (composed of Brazilian and foreign experts) versions.

⁴² As noted above, Olson was hired by Geoconsultoria in 2016 to provide consulting in the context of liquefaction studies of B1 and other dams. In addition, as mentioned in Note 32, Olson was a member of Vale's PIESEM, having participated in the international version of this expert panel since its first edition in March 2017.

⁴³ Tractebel Engineering Ltda. was contracted to conduct three external audit cycles of B1: September 2017, March 2018 and September 2018. However, it was replaced by Tüv Süd to conduct the September 2018 audit, due to divergence of criteria regarding safety factors.

short term.

In parallel to the discussion of alternatives to increase the factor of safety, the evidence indicates that some Vale employees in the Corporate Geotechnical and Operations Geotechnical areas sought to convince Potamos and Tüv Süd to adopt the methodology used by Geoconsultoria in 2016 – that led to favorable results. To this end, they used Geoconsultoria itself, whose founder and primary geotechnical engineer was also a member of the PIESEM. It is important to note that, at the same time (November 2017), the PIESEM had made recommendations contrary to the methodology that Geoconsultoria was hired to defend (the use of laboratory test data). As Olson observed in 2016 with respect to part of the test data at B1, the PIESEM recommended disregarding lab data in stability analyses, considering the lack of reliability in the results.

In the first half of 2018, Tüv Süd completed B1's RPSB obtaining a peak undrained factor of safety of 1.09 in the stability analysis.⁴⁴ The DCE was issued and the stability of B1 was certified based on a criteria (minimum factor of safety of 1.05) supposedly published in a scientific article by authors Leshchinsky and Ambauen. The adoption of this criterion (minimum factor of safety of 1.05) is inconsistent with other RPSBs prepared by Tüv Süd for other Vale dams at the same time. Moreover, the scientific article cited as a reference is in reality not intended to establish minimum factors of safety.⁴⁵

It is important to note that in November 2017 the PIESEM had recommended that Vale adopt a minimum peak undrained factor of safety of 1.3. This recommendation expressly reflected in the 2nd PIESEM International Meeting Report, submitted by the PIESEM Coordinator to Vale Corporate Geotechnical leadership on 12/20/2017. Even though the report was received in December 2017, it was only widely shared with the other Vale employees in the geotechnical (Corporate and Operations) group on 07/10/2018 (more than six months after receipt), after the RPSB deadline for B1 and the other high associated potential damage (DPA) dams had passed.

⁴⁴ The difference in relation to the value of 1.06 obtained in the previous year was due, according to the RPSB report issued by Tüv Süd, to the reinterpretation of field test data.

⁴⁵ The DCE does not contain detailed information regarding the analyses performed by the certification companies. The DCE is a simple document containing general information about the dam (e.g., location, classification, name of the owner, potential associated damage), which certifies (or not) its stability. The DCE is included in the Integrated Mining Dam Safety Management System – (Sistema Integrado de Gestão de Segurança de Barragens de Mineração, SIGBM) for ANM access. The information regarding stability analyses, including the factor of safety values obtained for the structures, comes from the RPSB report, which subsidized the emission of the DCE. The report is not included in the SIGBM. In accordance with DNPM Ordinance No. 70.389/2017, the RPSB report consists of Annex IV of the Dam Safety Plan – (Plano de Segurança da Barragem, PSB), which in turn shall be available in the enterprise, in physical or electronic format, preferably in the office of the dam safety team, or in close proximity to the structure, for consultation by the supervisory bodies and the Civil Defense.

On other opportunities, the reports from the international PIESEM were shared with the Corporate Geotechnical and Operations Geotechnical teams within weeks of receipt.

The first version of B1's RPSB and internal emails between Tüv Süd employees indicate that, at first, Tüv Süd had understood that it would not be possible to issue B1's DCE in light of it having obtained a peak undrained factor of safety below 1.3.

Between the issuance of the first version of the RPSB – with the conclusion that did not permit the issuance of the DCE – and the version that certified the stability of B1 with a factor of safety of 1.09 (May and June of 2018), meetings were held and emails exchanged between Vale and Tüv Süd. It is worth highlighting that in May 2018, shortly before the issuance of the DCE, Tüv Süd sent an email to a Vale employee in the Corporate Geotechnical area requesting that certain commitments be made as a basis for signing of the DCE. These "commitments" consisted of the execution of future measures to improve the dam's safety and did not alter the condition of the structure at that time.

In the same period, other contracts with relevant values between Vale's Corporate Geotechnical Department and Tüv Süd were being negotiated. Messages exchanged between Tüv Süd employees at the time suggest that the perception of Tüv Süd was that it was possible that there may have been pressure on the part of Vale, including specific mention to a consulting contract that was being negotiated between Vale and Tüv Süd in the same period and was actually signed thereafter.

Following the issuance of the DCE in June 2018, the company that would have been responsible for conducting the September 2018 external dam audit, Tractebel, was replaced by Tüv Süd for an alleged "divergence in criteria." Tüv Süd conducted the work and again certified the stability of B1 in September 2018 based on a minimum factor of safety threshold of 1.05 and the calculated factor of safety of 1.09 from the RPSB.

In January 2019, a few days before the B1 failure, Tüv Süd submitted a stability analysis for B1 indicating a supposed increase in the factor of safety to 1.13. There is no clear justification for the increase, but Vale employees attribute the change to the decrease in B1's phreatic level. According to the CIAEA Technical Team's analysis, there is no evidence to support this change in the value of the dam's factor of safety.

3.3 Main observations related to the halting of tailings disposal at B1 in July 2016

Disposal of tailings at B1 was suddenly ended in July 2016. The order to terminate these activities came on 07/07/2016 from Peter Poppinga (then-Executive Director of Iron Ore) who

indicated in an email that he had become aware that day of a doubt about B1.⁴⁶ The day following Peter Poppinga's determination, José Flavio Gouveia (then-Director of South Iron Ore Operations, Midwest and Manganese) responded to the e-mail stating that he did not know the reasons for Poppinga's decision but that he would adopt the determination. He also stated that neither he nor his team were aware of what would have been reported about B1.

Following the dam failure Peter Poppinga provided explanations about the abovementioned doubt regarding B1. In testimony Peter Poppinga asserted that the decision to cease activities at B1 resulted from a concern that arose in a report prepared by Vale's internal audit group that identified the existence of information gaps regarding the "As Built", and the need to conduct drilling to better understand the dam and to prepare the "As Is."⁴⁷ In addition, Peter Poppinga asserted that in 2016 Vale had made a strategic decision to halt activities at all of the upstream-style dams, as a result of the Fundão Dam failure and the progressive increase in dry processing of iron ore that did not require disposal of tailings in dams.

In the e-mail that determined that all tailings disposal activity B1 cease, Peter Poppinga mentioned that he became aware that same day (07/07/2016) of a doubt about the dam. However, the evidence indicates that the internal audit report on dams had already been shared with Peter Poppinga since at least May 31, 2016. In addition, on 6/20/2016 Peter Poppinga sent an email to Murilo Ferreira (then-Vale CEO) with this report attached, informing him that nothing serious had been identified in the internal audit report on dams and saying that they had even been praised by the Director of Internal Audit.

It should be highlighted that the lack of information about B1's foundation was known for many years (since at least 2003), as reflected in external audit reports provided to Vale by

⁴⁶ On 07/07/2016 at 6:31 p.m., Peter Poppinga sent an email to José Flávio Gouveia and Silmar Silva (then-Director, Planning and Development for the Iron Ore Division), with a copy to Alexandre Campanha (then-Technical Director of Iron Ore), Lucio Cavalli (then-Executive Manager, Strategic Planning and Business Development for the Iron Ore Division) and Paulo Bandeira (then-Executive Manager, Geology and Long Term Planning), saying: "As we discussed and having learned today of the doubt that arose related to B1 of the Feijão mine, we will immediately shut down production activities at this dam until we complete all of the complementary tests and calculations that are underway. I also request that you evaluate reinforcement measures that can be carried out preventively. Peter".

⁴⁷ Design to meet the provisions of Art. 9, §6, of DNPM Ordinance No. 70.389/2017. From the date of effectiveness of the ordinance, in June 2017, companies that had ore dams built before 2010 and did not have the "As Built" executive design (as it was built, containing records of the entire construction process), would have a deadline of two years to provide the "As Is" executive design (as it is currently, containing a study of the current situation of the dam), to compose the Dam Safety Plan. The "As Is" of B1 was supposed to be ready by June 2019 and required field investigations and drilling. Notwithstanding the legal requirement of 2017, consultants hired by Vale's geotechnical area pointed to the need years ago for knowledge of the foundation and the first raisings of B1.

specialized companies since the acquisition of Ferteco.

Finally, evidence suggests that the decision to shut down tailings disposal activities at B1 in July 2016 had been the result of a conversation with Paulo Abrão, a partner at Geoconsultoria, the company that conducted that year's liquefaction studies and the B1's Extraordinary Audit.⁴⁸ Regarding Geoconsultoria's involvement in the context that led to the decision to cease tailings disposal activities at B1, the evidence shows that the company went on a technical visit at the dam and attended meetings with Vale personnel in the Corporate Geotechnical area in the weeks preceding Peter Poppinga's email.

Reference to the decision to cease tailings disposal activities being the result of a conversation with Paulo Abrão and the fact that Peter Poppinga requested an assessment of reinforcement measures that could be implemented in a preventative manner suggests that the decision to cease tailings disposal at B1 may have been based on concerns with B1's safety.

Moreover, at the time of the decision to cease disposal of tailings at B1, the project implementing a Flex line that would have the flexibility for dry and humid processing of ore from the Córrego do Feijão Mine was ongoing. This project was only completed in August 2017, approximately one year after the decision to cease tailings disposal activity at B1. Evidence suggests that the change in the method of ore processing at the Córrego do Feijão Mine did not occur in a scheduled manner. Disruptions resulting from the sudden interruption of the humid processing line were identified days after the decision to cease disposal of tailings at B1. Communications between Vale personnel were also identified advocating to accelerate the implementation of the Flex line. As such, it is not plausible to associate the decision to cease tailings disposal at B1 with a change in the iron ore processing form of the Córrego do Feijão Mine.

3.4 Main observations related to the risk mitigation measures adopted by Vale

With the decision to cease tailings disposal activities at B1 in July 2016, and the completion of liquefaction studies, Geoconsultoria also evaluated the feasibility of a project for

⁴⁸ In a message sent by Alexandre Campanha (then-Iron Ore Technical Director) to Silmar Silva (then-Director of Planning and Development of Ferrous) following Peter Poppinga's message halting disposal of tailings at B1, Alexandre Campanha asked: "Silmar, is this as a result of our conversation with PAbraao?" In reply, Silmar Silva responded: "Yes, I will explain tomorrow".

remining the tailings deposited at B1, which had been prepared by the company VogBR⁴⁹ in 2011. The report produced by Geoconsultoria in this regard indicated the need to lower the phreatic surface of the dam before remining could begin given the risk of rupture by liquefaction in this process. Thus, in 2017, Vale hired the company MdGEO⁵⁰ to evaluate B1's drainage alternatives.

Also in 2017, as mentioned earlier, Vale, Potamos and Tüv Süd, in the context of the geotechnical risk analyses and the RPSB, discussed alternatives to increase B1's factor of safety, which resulted in Vale's decision to install DHPs and remine the tailings. The execution of the DHPs was initiated in February 2018 based on a design developed internally by Vale. It was interrupted on 06/11/2018 due to a hydraulic fracturing in part of the embankment during drilling of the 15th DHP ("DHP 15"), which caused a flow of turbid muddy water (water and fine materials) to seep at the external slope of the dam.

After the DHP 15 event, no specific measures were identified to lower the B1's phreatic surface before the arrival of the next rainy season (between October 2018 and March 2019). As mentioned previously, B1's high phreatic surface was noted by consultants since at least 1995. A measure alternative to the DHPs that had been chosen by Vale, specifically the drilling of vertical wells, had not begun to be implemented at the time of B1's failure. In addition, evidence indicates issues with B1's drainage system structures such as the presence of obstructed or eroded surface channels for water flow and problems in B1's reservoir water pumping system between, at least, December 2018 and January 2019.

There were problems with Vale's responses to the DHP 15 event, including issues that impact the Emergency Action Plan for Mining Dams (Plano de Ação de Emergência para Barragens de Mineração, "PAEBM"). The event was not classified according to legal requirements, a fact that led to the non-activation of PAEBM level 1 (which was necessary, considering the classification of anomalies provided for under applicable legislation). In addition, the DHP 15 event was not properly reported to the National Mining Agency in SIGBM.⁵¹ The internal assessment by Vale's geotechnical area regarding the response to the DHP 15 event at B1 was that there was difficulty and delay in mobilizing materials and equipment as well as failures of communication and action between the identification of an anomaly and the

⁴⁹ The company VogBR Recursos Hídricos e Geotecnia Ltda. was hired by Vale in 2011 to develop conceptual engineering designs, including the B1 tailings mining design.

⁵⁰ The company MdGEO Hidrogeologia e Meio Ambiente was hired in 2017 by Vale to evaluate the possibility of draining the water from the B1 reservoir.

⁵¹ Integrated Mining Dam Safety Management System – dam management system, developed by the National Mining Agency (ANM), in which dam operators enter information to be made available to ANM. Available at <http://www.anm.gov.br/assuntos/barragens/sigbm>, accessed on 12/27/2019.

activation of PAEBM level 1. Vale's geotechnical team indicated, in an internal report produced after the DHP 15 event, that the perception of the team was that the Company was not prepared to activate the PAEBM.

Evidence from studies and other materials reviewed indicate that the impacts of a breach at B1 were known to Vale. The PAEBM and its supporting studies indicated that, in case of breach, B1's tailings would reach the administrative structures in approximately one minute and other studies indicated a high number of deaths, especially in the case of a failure without prior warning. Nevertheless, the adoption of concrete measures to mitigate impacts were not identified nor was the removal of the downstream administrative facilities at B1 discussed.

The main safety risk mitigation measure adopted by Vale after the DHP 15 event was to move forward with the B1 decommissioning⁵² project, despite the technical opinion of external consultants that such a measure would not be effective to increase B1's safety in the short term. No provisional reinforcement and/or safety measures for B1 and/or its surrounding areas were discussed. In addition, evidence indicates that there was information that the preparatory stages of the decommissioning could impact the stability of the structure. Nevertheless, the removal of downstream administrative facilities from B1 was not considered.

3.5 Main observations related to the review of the level of information regarding B1 risk reaching Upper Management

In order to verify, among other relevant aspects, what information regarding safety and dam management would have reached the different levels of Vale's governance bodies, and how this information would have been reported and discussed, the Investigation Team reviewed minutes and supporting materials ("board book") of the meetings of the Board of Directors and their main Advisory Committees that existed during the period under review, which are (i) Governance, Compliance and Risk Committee ("CGCR");⁵³ (ii) Governance and Sustainability

⁵² Decommissioning consists of "closing operations with the removal of the associated infrastructures, except those intended to guarantee structure safety", according to Art. 16, VIII, of the ANM Resolution No. 4/2019. Available at <http://www.anm.gov.br/assuntos/barragens/resolucao-no-4-de-15-de-fevereiro-de-2019>>. Accessed on 02/07/2020.

⁵³ The CGCR material review consisted of the November 2017 period (when it was created) up to - 1/25/2019 (break date and final milestone of review). Currently, the CGCR was reformulated and became to be known as the Compliance and Risk Committee. The Governance part was integrated on the People Committee, which became to be known as People and Governance Committee.

Committee;⁵⁴ (iii) Controllership Committee;⁵⁵ (iv) Sustainability Committee;⁵⁶ (v) Finance Committee;⁵⁷ as well as the minutes and board books of the Fiscal Council, made available by Vale.

The same materials were analyzed relating to the Executive Directors team and its risk-related Committees, which are, (i) Executive Risk Committee and (ii) Operational Risk Subcommittee. The analysis encompassed the period from January 2015 to January 25, 2019 (B1 rupture date).

Following the Fundão Dam failure in November 2015, the topic of dam safety became a frequent subject at meetings of the Board of Directors and its Advisory Committees, as identified in the meeting materials that were made available to the Investigation Team by collecting Vale Corporate Governance network documents and via access to the Vale Governance Portal (Board Vantage System). There were specific references to B1 within the context in which other various topics were discussed in a broader fashion.

At the Board of Directors meetings, there was a reference to B1 at the meeting on 01/28/2016. At that time, a presentation providing an update about Vale's⁵⁸ dams, which, among other information, provided results and tracking of external audits that were performed for issuing DCEs. From a list of dams presented, the following recommendation was included for B1: "carry out liquefaction analysis based on new research studies, collection of samples and information representative of the existing tailings in the foundation of the upstream raisings and the foundation of the starter dam". The presentation indicated that the completion of the analysis was expected for the third quarter of 2016, which did in fact occur,⁵⁹ with report to the Board of Directors on the completion of external dam audits, with a focus on liquefaction.

⁵⁴ The analysis of the Governance and Sustainability Committee material encompassed the period from January 2015 (beginning point of the review) until October 2017, when that committee ceased to exist. The review of the Controllership Committee material encompassed the period from January 2015 (beginning point of the review) until October 2017, when that committee ceased to exist.

⁵⁵ The review of the Controllership Committee material comprised the January 2015 period (initial milestone of the review) until October 2017, when that committee ceased to exist.

⁵⁶ The review of the Sustainability Committee material encompassed the period from November 2017 (when the committee was created) until 01/25/2019 (date of the rupture, and end point of the review). The Sustainability Committee still exists to date.

⁵⁷ The review of the Financial Committee material encompassed the period from January 2015 (beginning point of the review) until 01/25/2019 (date of the rupture, and end point of the review). The Finance Committee still exists as of the issue date of this Executive Summary.

⁵⁸ Presentation by Silmar Silva (then-Director, Ferrous Planning & Development) and Lucio Cavalli (then-Executive Manager, Ferrous Business Development & Strategic Planning).

⁵⁹ In 2016, a liquefaction study was carried out by Geoconsultoria, with the objective of meeting the recommendation made by B1's 2015 external audit as well as the requirement of state legislation.

On 01/28/2016, it was reported to the Board of Directors that the iron ore dams were safe and met all national and international safety standards and practices. The presentation also included a table with information regarding dams, indicating "downstream population", "distance (km)" and "Factor of safety" in the columns. In that table, B1 was 0.44 km⁶⁰ from the downstream population in Brumadinho and the Vale industrial area and had a factor of safety of 1.90 (without any indication of: (i) the method or condition used for the calculation, (ii) what type of factor of safety the value refers to and (iii) the recommended minimum values), and this was the only communication made to the Board of Directors regarding the exact values of factors of safety of Vale's iron ore dams. At other times, there were reports to the Board of Directors about the minimum factor of safety recommended by auditors and international practice (1.5 for drained condition and 1.3 for undrained condition), but without reporting what the exact values were of the factors of safety of the Iron Ore Division dams.⁶¹

No evidence was identified of discussion at the Board of Directors of the ceasing of tailings disposal activities at B1 or its low factors of safety. Overall, it was noted that presentations on iron ore dams made to the Board of Directors and their Advisory Committees signaled the safety of the dams, giving emphasis to the obtaining of the DCEs.

At the Board of Directors Advisory Committees, more specifically the Governance, Compliance and Risk Committee ("CGCR"), the Governance and Sustainability Committee and the Controllershship Committee, some references were made to B1, but as detailed below, there was no evidence of discussions on the ceasing of tailings disposal activities at B1 or its low factors of safety and the associated risks.

Among the specific references to B1, it is noteworthy that at a meeting of the Governance and Sustainability Committee on 12/06/2016⁶², a presentation of the Final Result of the Iron and Fertilizer Dam Management Internal Audit was identified which included two points on B1: (i) "Self-Assessment (Medium Priority)- Dam I: Lack of information on the foundation and material of the first raisings" and (ii) "Self-Assessment (High Priority) - Dam I: Inconclusive liquefaction studies". The Investigation Team found that in the Internal Audit system the B1 items were considered fulfilled based on the following information submitted by

⁶⁰ Probably this distance of 0.44 km refers to the distance from the dam in relation to the downstream population.

⁶¹ Such as, for example, a presentation by Lucio Cavalli (then-Executive Manager, Ferrous Business Development & Strategic Planning) at the 01/26/2017 meeting.

⁶² Presentation coordinated by Lucio Cavalli (then-Executive Manager, Ferrous Business Development & Strategic Planning), with the support of Ricardo Baras (Director of Internal Audit) and Adriane Oliveira (Expert Auditor).

the audited area:

- For the first item: report "Dam B1 - Geotechnical Liquefaction Investigation Studies", dated 07/19/2016, prepared by Geoconsultoria.
- For the second item: (a) report "Dam B1 – Liquefaction Studies Stability Analyses", dated 7/15/2016, prepared by Geoconsultoria; (b) report "Static Liquefaction Study – Dam B1 – Córrego do Feijão", dated 7/26/2016, issued by Geoconsultoria; and (c) memo "Observations from tailings dam site visits and recommendations for liquefaction analysis of tailings dams and dikes", dated 7/8/2016, prepared by Scott M. Olson.

In the same meeting held on 12/06/2016, several initiatives were mentioned that were to be executed in the Iron Ore area, such as (i) geotechnical risk office structuring; (ii) dam risk rating standardization; (iii) external dam auditing; (iv) review of geotechnical engineering studies that would support dam projects and new extraordinary audits in Minas Gerais (conventional analyses and for liquefaction failure mode assessment); and (v) PAEBM review. On the subject of follow-up to the action plans developed to address the Internal Audit, the presentation mentioned that 64% of the action plans developed in relation to the Iron Ore division dams had already been partially or fully addressed. Later meetings noted that audits did not identify any risk that could compromise the safety of the structures⁶³.

With respect to the Controllership Committee, at a meeting on 10/04/2016, a presentation was given on the audit of the Iron Ore, Basic Metals and Fertilizer Dams. The main conclusions of the Audit Report presented at this meeting were the same as mentioned above, related to the Governance and Sustainability Committee meeting on 12/06/2016.

At the Controllership Committee meeting on 07/20/2017, it was presented to that the "Vale governance structure responsible for monitoring active and inactive dams has the same dam management model as that for the Iron Ore, Base Metals and Fertilizers businesses, allowing for standardization of management processes and control and sharing of best practices. The operation of the Integrated Risk Management System, which aims to ensure that established controls are efficient and effective, was also clarified. Additionally, the three business areas presented the Action Plan Status defined in conjunction with Internal Audit. After clarification, the Committee requested that the results of the report on the Iron Ore division of the Panel of

⁶³ Presentation conducted by Alexandre Campanha (then-Iron Ore Technical Director) and Lucio Cavalli (then-Executive Manager, Strategic Planning and Iron Ore Development).

Experts be made available"⁶⁴.

In that same presentation it was mentioned that "97% of the action plans from the Audit were already totally or partially addressed" and that "all the Iron Ore dams at Vale are managed under strict criteria based on international good practices and go beyond legal requirements. All these dams are found to be in total normality".

The Corporate Governance Secretary, in response to a request by the Controllership Committee, sent on 07/28/2017 a presentation regarding the 1st International Expert Panel Meeting (PIESEM-I) of March 2017,⁶⁵ via internal message from the Governance Portal (Board Vantage). That was the only case in which material prepared by PIESEM experts was shared with an Advisory Committee prior to the B1 breach.

In June 2018, both the CGCR⁶⁶ and the Board of Directors⁶⁷ received information on the Internal Audit of the Iron Ore area, which dealt with the subject of the PAEBM and sirens. This Internal Audit presentation, found in the supporting material for the CGCR and Board of Directors meeting, reported on the delay in the delivery and installation of the warning systems that could impact meeting the deadline established in the DNPM Ordinance No. 70.389/2017, scheduled for June 2019.⁶⁸ In addition, the following points were included in the report: (i) "lack of Response Plans of the various areas that have responsibilities described in the PAEBM and Crisis Management Plans in need of preparation and/or updating" (ii) "external simulations with the potentially impacted population not yet performed" and (iii) "absence of corporate strategy to mitigate the risk involving the lack of technical training, human resources and civil defense infrastructure to address emergencies involving dams in the 18 municipalities involved".

This same material included the main action plans for mitigating the points raised by

⁶⁴ Presentation by Lucio Cavalli (then-Director of Planning and Development of Ferrous), with the participation of Andrea Almeida (then-Director of Basic Metals Finance), Loris Molino (then-General Manager, Health, Safety and Environmental, Vale Toronto), Jorge Aldi (Investment Manager, Basic Metals Logistics) and Camilo Silva (Executive Manager, Uberaba Fertilizer Projects).

⁶⁵ Contrary to what occurred at the 2nd and 3rd PIESEM-I Meetings, in the 1st Meeting the experts did not prepare a written formal report. The only existing material is the presentation used by the experts on the last day of the Meeting.

⁶⁶ Presentation given by Ricardo Baras, according to the minutes of the CGCR meeting on 06/19/2018, p. 2 and 3.

⁶⁷ The minutes for the Board of Directors meeting on 06/28/2018 do not refer to this Internal Audit PAEBM presentation. However, a copy of the presentation made at the CGCR meeting of 6/19/2018 was identified in the support material for that meeting.

⁶⁸ Ordinance DNPM No. 70.389/2017 ordered the installation, in the communities found in the Self-Rescue Zone, of the warning system including sirens and other appropriate warning mechanisms, establishing a deadline of up to 24 (twenty-four) months after the effective date of the Ordinance (06/17/2017). Therefore, the deadline for compliance with this order would be in June 2019.

Internal Audit: (i) "implement alternative measures to alert the population, develop another supplier or review siren delivery strategy" (ii) "complete installation of sirens in the self-rescue zone of 75 dams" and (iii) "develop action plans for all areas involved in the PAEBM, develop PC Midwest Operations Center and review the PCs of the North and Southeast Corridors".

Development of the "PAEBM" topic was not found in the minutes and support materials reviewed from other Board of Directors meetings. The subject was monitored by the CGCR⁶⁹, which was updated on the activities that were underway to comply with the action plans (installation of sirens and external simulations performed and scheduled) and the information that the installation of sirens, which was already in progress, would be completed by December 2018.

Although the Internal Audit focused on PAEBM pointed out some issues and points of improvement, reports from August 2018 to the CGCR informed that action plans to meet the points raised by Internal Audit were being executed.

According to information obtained in the investigation: with respect to the sirens at Brumadinho, which included not only B1, but also other dams in the Córrego do Feijão Mine complex, all the planned sirens (14) (fourteen) sirens were installed by October 2018 but had not been tested. The sound test was scheduled to take place in 2019, after performing all the simulations in the communities of the region. The external simulation in Brumadinho was performed on 06/16/2018. The internal simulation, with employees and third parties at the Córrego do Feijão Mine, was carried out on 10/23/2018.

Documentation on discussions related to the topic of "dams" was also analyzed at the level of the Executive Director team, Executive Risk Committee, Operational Risks Subcommittee and Fiscal Council. The main observations are detailed below. No evidence of discussions at the Executive Directors team about ceasing tailings disposal activities at B1 or its condition of fragility was identified in the meeting minutes and board books that were analyzed by the Executive Directors team.

However, evidence suggest that B1 was mentioned in a meeting at the Operation Risk Subcommittee. In this regard, it was noted that at the 09/14/2018 meeting of this subcommittee, the dam risk map was introduced with reference to Geotechnical Risk Management (Gestão de Riscos Geotécnicos, GRG). In this presentation, the results of the risk analysis were reported, shown on a Probability x Consequence chart, with a defined rupture risk

⁶⁹ CGCR meeting on 08/21/2018.

ALARP/Attention Zone,⁷⁰ whose limits had been “discussed and defined together with the Panel of Experts.” The Geotechnical Risk Panel was presented, showing 10 dams within the ALARP/Attention Zone.⁷¹ B1 appeared on the list of the 10 (ten) dams in the ALARP chart Attention Zone.⁷²

Subsequently, in the materials for the Executive Risk Committee (on 09/26/2018)⁷³ and the Executive Directors team (on 10/15/2018 and 10/22/2018)⁷⁴, there was information regarding the ALARP chart and the existence of dams in this zone, but the names of the dams in the Attention Zone were not included in the materials. Instead, the following information appeared in the materials next to the ALARP chart: “100% of Vale iron ore dams were audited in Aug 2018 and had a stability declaration issued by the external auditor with certified safety conditions. All dams are safe, stable and operate within normal range.”⁷⁵

The Investigation Team verified that the then-Executive Director of Iron Ore, Peter Poppinga, received an email on 10/12/2018 with the presentations from the Executive Directors meeting on 10/15/2018. Among the presentations received by the Executive Directors team, there is the follow-up presentation of the Executive Risk Committee meeting, where the ALARP Zone is shown illustrating the 10 dams within the risk zone but without details on the structure names.

In addition, emails exchanged among other employees suggest that, potentially, presentations with reference to B1 in the ALARP/Attention Zone would have been made to Peter Poppinga at meetings that occurred in August and September 2018. However, Peter Poppinga stated that during the September 2018 meeting, only a few slides were actually presented. According to Peter Poppinga, the presentation was made only up to a slide prior to that

⁷⁰ The ALARP (As Low As Reasonably Practicable) analysis, in summary, is a tool for carrying out risk assessment used to map the probabilities of occurrence of events taking into account their possible consequences, in order to define risk tolerance and risk assessment mitigation strategies.

⁷¹ Presentation conducted by Felipe Figueiredo Rocha (Corporate Geotechnical Management Specialist Engineer).

⁷² In a presentation by the Geotechnical Risk Management team at the 2nd National PIESEM meeting, held in June 2018, a list of 10 (ten) dams in the Attention Zone (including B1) is included, with the indication that such dams would be with “probability above the acceptable limit”. No evidence was identified that this reference was used at the Operational Risk Subcommittee meetings or other governance bodies of the Company.

⁷³ Presentation conducted by Felipe Figueiredo Rocha (Corporate Geotechnical Management Specialist Engineer).

⁷⁴ Note that in the meeting minutes a reference to the presentation was not identified, so it is not possible to confirm whether the presentation was actually discussed at the meeting held on that date.

⁷⁵ Presentation by Luciano Siani (Chief Financial and Investor Relations Officer and Executive Risk Committee Coordinator) and Eduardo Montarroyos (Executive Governance, Risk and Compliance Manager).

referencing the Geotechnical Risks Panel and the ALARP/Attention Zone. In depositions, Peter Poppinga stated that he became aware of the ALARP/Attention Zone at an Executive Directors meeting held in October 2018, but that (i) the names of the dams did not appear in the presentation and (2) in the same presentation there was express mention that 100% of the dams had DCEs.

No mention of the ALARP Zone was identified in the material (minutes and board books) of the meetings of the Board of Directors and its Advisory Committees reviewed. However, a presentation was identified on Dam Management, given outside the regular schedule of Board of Director meetings and the Advisory Committees. The presentation was made on 2/23/2018 to a newly appointed Board Member who had assumed coordination of the CGCR and included summary information on Vale's dam portfolio. Among the topics there was information related to the Geotechnical Risk Panel with indication of proposed tolerable risk limits.

A presentation on Dam Management also was identified that had been given to two Board Members (outside the regular schedule of Board meetings and the Advisory Committees), on 11/16/2017, which contained summary information on Vale's portfolio of dams. Said presentation had been one of several presentations held that date for the newly named Board Members, as part of their Company orientation. In the presentation on Dam Management, there is information related to the Geotechnical Risk Panel, but without any indication of proposed tolerable risk limits.

In both cases, in the 11/16/2017 and 02/23/2018 presentations, the "final considerations" were to the effect that 100% of the iron ore dams were certified in safe condition, with the respective DCEs issued, and that the dams were safe and operating normally.

3.6 Main observations related to the cultural, organizational and risk management context in which B1 was included.

In addition to the technical aspects that caused the rupture of B1, the independent investigation conducted by CIAEA evaluated the cultural, organizational and risk management context of B1. The CIAEA sought to contextualize critical aspects of governance and safety risk management with practices from other hazardous industries such as oil and gas, nuclear energy and air transport. Those industries have gone through moments of tragedy and recovery that brought important lessons learned, which were considered by the CIAEA in its analysis. Therefore, in addition to the other activities performed in the investigation, interviews were conducted with employees at various levels of the Company (from operation technicians to members of the Board of Directors). Also, materials related to Vale's risk management, the

existing variable remuneration policy and the organizational structure were analyzed.

The independent investigation identified the existence at Vale of a strong hierarchical culture that is resistant to the exposure of problems to higher levels of the organization. It was also found that a characteristic of the business areas,⁷⁶ including the Iron Ore Division, was that they were closed off from the corporate areas.⁷⁷ These characteristics also may have contributed, to an extent, to the compartmentalization of the different areas. In a “siloes” environment,⁷⁸ problems were addressed within each business area which were resistant to activities of the corporate areas given a tendency not to expose problems or risks or vulnerabilities to other areas. Furthermore, there was no incentive for questioning decisions made at higher hierarchical levels.

By way of example, an event that deserves highlighting is the context of the decision to cease disposal of tailings at B1. As mentioned in Section 3.3 above, Peter Poppinga’s decision was communicated by email to José Flavio Gouveia, then-Operations Director. Peter Poppinga did not document the reasons for his decision in writing, nor did he make those reasons known to higher levels or Vale’s governance bodies.

There was also reluctance to allow others outside the Iron Ore Division to have visibility into its practices. For example, although Internal Audit was invited to participate in the 3rd Meeting of PIESEM-I in October 2018, employees of the Iron Ore Division considered the participation of Internal Audit improper, because the discussions at the PIESEM meeting could include criticism of existing geotechnical risk management practices.

Another relevant feature observed in the investigation refers to the fact that, although Vale acts in an inherently hazardous business industry, with risks to nearby communities, safety aspects were predominantly focused on workplace safety (e.g., prevention and reduction of workplace accidents), without the necessary focus on process safety (e.g., minimization of large-scale risk minimization, inherent to operation in a hazardous industry) .

The experience of other hazardous industries that have achieved significant improvements in operational safety risks management teaches that mere regulatory compliance is rarely sufficient to guarantee the safety of highly complex structures. In the context of B1,

⁷⁶ In this context, “business areas” refer to the areas whose activities are included in the purpose activities of Vale (e.g., Ferrous, Basic Metals, Fertilizers, Logistics).

⁷⁷ In this context, “corporate areas” refers to areas whose activities are tied to the internal functioning of the Company (e.g., Internal Audit, Legal, Compliance).

⁷⁸ The notion of “siloes” refers to the idea of business units that operate in relative isolation from each other and of corporate support units.

regulatory compliance and DCEs attainment were prioritized, regardless of the actual safety situation of the dam. In the case of B1, this phenomenon was evident in the performance of Vale's geotechnical area and of the certification companies, with the use of higher strength parameters and/or lower minimum factor of safety criteria than recommended, based on technically questionable justifications, with the objective of obtaining the DCE by Vale's geotechnical area and certification companies. Moreover, information on the real situation of dam safety and geotechnical risks (not only of B1, but in relation to the dam portfolio as a whole) was not fully portrayed in the reports to other areas or to the Board of Directors and their Advisory Committees; and to the Executive Directors team and their Advisory Committees. As evident in presentations given by the Corporate Geotechnical area, the situation of the dams was predominantly reported with a positive focus and emphasis on the fact that the dams had DCEs.

In addition, as mentioned in Section 3.5 above, reports regarding the Geotechnical Risk Panel and the ALARP/Attention Zone have had different levels of detail when presented at the Operational Risk Subcommittee and the Executive Risk Committee. The same presentation was used for both groups, but in the presentation made to the Executive Risk Committee, the names of the dams on the Geotechnical Risk Panel chart were excluded, such that it was not possible to directly identify them.

In addition to these particular characteristics of Vale, an important phenomenon, common in similar contexts of industries operating with risk activities, that should be constantly combated, is the tendency of "normalization of deviance." The technical and operational areas become accustomed to deviations from the desirable conditions of a structure, which in turn become normal. Consequently, implementation of mitigation measures becomes non-urgent. The history of information related to B1 indicates that such a phenomenon may have occurred in different situations. There was information, from the time when the dam belonged to Ferteco to the most recent period, which indicated a high phreatic surface and marginal stability condition with low factors of safety. Nevertheless, the independent investigation found that there was a "normalization" only of the small deviations as well as the visual signs of saturation and the fragility status of B1.

Another example of this is that in 2017, when the results of the B1 stability analysis of Potamos and Tüv Süd had achieved marginally stable factors of safety, Vale's geotechnical area not only did not understand the low factors of safety as urgent, but also went beyond that and sought Geoconsultoria to work on "counter-arguments" to be presented to Potamos and Tüv Süd. The objective of the "counter-arguments" was that both companies reconsider the

methodology employed in the stability analysis, especially regarding the use of laboratory test data. As mentioned in Section 3.2 above, PIESEM and international consultant Scott Olson understood that lab testing should be disregarded given the lack of reliability of the resulting data.

Aspects of a hierarchical culture, resistance to sharing information and interactions with other areas and a focus on regulatory compliance were enhanced by the absence of an independent second line of defense to address geotechnical risks. The Iron Ore Division Geotechnical Risk Management group, which appeared to perform tasks similar to those of an expert second line of defense, was under the same Iron Ore Executive Management and, therefore, subject to the same characteristics described above. Furthermore, reporting to the business area itself limits the ability to act as an independent line of defense, since safety decisions may conflict with production and operation concerns. This structure also caused the Iron Ore Division Geotechnical Risk Management group to be subject to the same cultural characteristics described above. The geotechnical area of the Iron Ore Division was divided between: (i) Operations Geotechnical area, responsible for the maintenance, operation and monitoring of the structures; and (ii) Corporate Geotechnical area, which was comprised of the Iron Ore Division Geotechnical Risk Management group and the Management of Deactivated Mine Structures and Mine Closures.

The tasks of the Iron Ore Division Geotechnical Risk Management group included, among other activities, the development and updating of the methodologies and criteria to be used in geotechnical risk management, validation of geotechnical risks identified by the Operational area and the monitoring of response actions and risk treatment. The Iron Ore Division Geotechnical Risk Management group was also responsible for contracting external auditors of dams for the issuance of DCEs and for organizing and coordinating the activities of the PIESEM.

The independent investigation found (i) issues involving insufficient human resources and work overload for important dam management activities; (ii) a leadership gap in the Operations Geotechnical management between October 2017 and May 2018, an important moment in the history of B1; (iii) a tendency to migrate from the Operations Geotechnical area to the Corporate Geotechnical area as the professionals developed; and (iv) a lack of clarity regarding the functions and responsibilities of the Operations and Corporate Geotechnical areas, as well as in relation to the PAEBM scope.

In addition, outside of the Iron Ore Division, in the context of the Company's global

business risk management, geotechnical risks were handled by an area that lacked the technical conditions to adequately review the information that was reported to it. The Internal Controls, Risks and Compliance Management group served as a second line of defense (acting in a corporate, non-expert capacity) in the context of the Company's global business risk management. The area had no knowledge of geotechnical risks, serving only as a clearing house of information received from other areas.

Issues related to the autonomy and independence of the second line of defense were discussed at the CGCR meeting held on 6/19/2018, with an indication that the subject could be revisited after presentation of the governance model for the functioning of the lines of defense. No further discussions on the subject were identified.

Another aspect that merits note and which was the subject of analysis in the independent internal investigation conducted by the CIAEA, concerns Vale's relationship with certification companies in the context of B1.

The companies responsible for conducting audits and certification of dam safety were contracted and had their work monitored by the Geotechnical Risk Management group, under the Iron Ore Division. The Iron Ore Division Geotechnical Risk Management group also hired the same companies that audited dams to provide other services, with relevant impacts on the independence of those companies. These factors, combined with the cultural and organizational characteristics described above, including the focus and priority on addressing merely regulatory compliance and obtaining DCEs, may have affected to some extent the effectiveness of external audits as a mechanism for safety management.

For example, Geoconsultoria, in addition to being a designer of two of B1's raisings, was hired to carry out audit and safety certification work on the dam, including reviewing aspects that it itself had designed. Paulo Abrão, founder and one of the primary geotechnical engineers of that company, was also a member of the PIESEM. At the end of 2017, the PIESEM gave opinions on important topics relevant to B1 as to which Geoconsultoria itself was involved in 2016. Although PIESEM made a clear recommendation against the methodology adopted by Geoconsultoria for the calculation of the strength ratio, Geoconsultoria was subsequently used to assist in "counter-arguments" on the same topic, to defend the adoption of a strength ratio with methodology contrary to that which had just been recommended by PIESEM and was being adopted by Potamos and Tüv Süd to carry out studies related to B1. The objective of the "counter-arguments" was to increase the calculated factor of safety for B1, in light of the June 2018 deadline for issuing the RPSB DCE.

In the case of Tüv Süd, in addition to being hired to perform RPSB and safety audits, it was also hired in 2018 to provide other services, including the B1 As Is design and the decommissioning design. The As Is project contract is dated 5/15/2018, the day following a meeting during the course of which pressure was apparently exerted by Vale for B1's DCE to be issued. Soon thereafter, Tüv Süd ended up issuing the DCE, even with a low factor of safety, using a minimum factor of safety criterion that was at the least inappropriate from a technical standpoint.

Another relevant aspect of the relationship between Vale and the companies responsible for external dam audits is the fact that there was a great disparity between the values of the dam consulting and audit contracts. The audit contracts, from a financial standpoint, were less significant than those for consulting, so they could lead companies to compromise their judgment in audits with the aim of maintaining a good relationship with Vale and entering into consulting agreements.

Regarding the PIESEM, the independent investigation sought to focus the analysis on the considerations made by the experts regarding aspects related to dam risk management and governance. The PIESEM's work resulted in important recommendations for improving dam safety processes and some operational advances.

However, the effectiveness of the PIESEM to improve dam safety management was limited by some factors. The main factor is the fact that the sharing of PIESEM's recommendations with the Executive Directors or the Company's Board of Directors, bodies that would have had the authority to implement the most important recommendations, was limited.

In addition, the organization and coordination of PIESEM activities, including the hiring of members, were carried out by the Iron Ore Division Geotechnical Risk Management group, under the Iron Ore Division. In addition, some PIESEM members provided services to Vale (hired by the same Geotechnical Risk Management that organized and coordinated the PIESEM) for other activities, including dam certification and audits, a fact that may have affected the independent and objective performance of the Panel.

One of the topics discussed by the PIESEM and which resulted in important recommendations to Vale was the ALARP methodology, which was under development and deployment by Vale's Geotechnical Risk Management group to support the analysis of geotechnical risks. The methodology adopted by Vale contained significant deficiencies and did not take into account recommendations presented to Vale by experts on the subject. Among other methodological problems, the definition of the ALARP zone – essential for defining risk

tolerance involved in the analysis of the rupture probability of Vale's dams – was based only on the rupture probability of structures, without considering the consequences of possible rupture. In addition, the potential consequences were presented only in monetized terms to upper management and the governance bodies of the Company, without clearly and separately indicating the consequences in terms of loss of life, notwithstanding the recommendations of the PIESEM to the contrary.

While the consequences were presented only in monetized terms and not in a separate fashion to upper management and the Company's governance bodies, it was found that in the 2nd and 3rd International PIESEM Meetings, Vale introduced the ALARP methodology graphs with separate indication of the consequences in terms of loss of life. That is, the review was done but there is no evidence that it was communicated to the Executive Directors team or its advisory committees or to the Board of Directors or its advisory committees.

The independent investigation conducted by the CIAEA evaluated the role of other areas with respect to Vale's risk management and found that the organizational culture of "silos" between different areas of the Company meant that other areas, which could also have played an important role in ensuring comprehensive and robust dam safety management, did not do so. Moreover, there was a tendency towards excessive deference to the geotechnical area to deal with dam issues - understood as purely technical - to which areas other than the geotechnical area would have nothing to contribute.

The Investigation Team also reviewed Vale's compensation and incentive structure and its relationship with aspects related to dam safety. The investigation found a major emphasis on financial aspects. In the case of employees in the Operations Geotechnical area, no specific safety goals for geotechnical structures were identified for the purpose of variable remuneration in fiscal year 2018. For the 2016 and 2017 fiscal years, safety goals consisted mainly of performing external audits and obtaining DCEs. In the Geotechnical Risks Management, in turn, specific dam safety goals represent a small participation compared to financial components in the total variable remuneration. In addition, it has been observed that dam safety goals are essentially linked to regulatory compliance (e.g., obtaining the DCE).

Finally, an effort was made to review the investments realized and amounts outlaid by Vale for safety and maintenance of B1. However, in the Vale budget and financial record systems reviewed, there are no mechanisms that allow for identifying or relating the values incurred by each geotechnical structure.

4. CONCLUSIONS

The CIAEA Technical Team concluded that the B1 failure occurred due to structural instability with liquefaction. Technical aspects most relevant to the failure were (i) inadequate internal drainage and high phreatic surface; (ii) reaching the peak undrained strength due to internal creep and loss of suction in the material above the phreatic surface; (iii) a dam structure not designed to contain liquefied material; and (iv) inadequate consideration of the stability issues identified over the course of B1's existence.

The Investigation Team also concluded that at least since 2003, Vale had information indicating the fragile condition of B1, in addition to information prior to the acquisition of Ferteco. This information became especially relevant following the failure of Samarco's Fundão Dam in November 2015.

In 2016, studies based on field tests performed at B1 indicated that the dam was in a fragile condition. Studies performed in 2017 also indicated a condition of only marginal stability, but Vale's geotechnical area resisted accepting the 2017 results.

Evidence obtained by the investigation suggests that the decision to cease disposal of tailings at B1 in July 2016 was a decision of the then-Executive Director of Iron Ore, possibly due to a safety concern related to B1.

The actions taken to remediate weaknesses and improve safety were limited and unsuccessful (DHPs-which were stopped following the DHP 15 event) or, if they had been implemented (decommissioning of the dam with remaining of the tailings), they would not have been effective in the short term to elevate the stability of B1 to satisfactory conditions. In addition, it was known that in the event of dam failure, Vale's capacity to respond was limited and the impacts would be significant (especially on the administrative facilities downstream of B1) and with minimal reaction time.

Despite knowledge of B1's fragilities and the impact of its potential failure, no evidence was identified of studies and/or measures for removal of the administrative facilities downstream of B1.

The review identified no evidence of discussions regarding the decision to cease disposal of tailings at B1 or its low factor of safety at the Board of Directors, its Advisory Committees or Executive Directors team. Presentations about Iron Ore Division dams made to the Board of Directors, its Advisory Committees and the Executive Directors team pointed to the safety of the dams and emphasized that DCEs had been obtained.

Specific references to the Geotechnical Risk Panel were made on two occasions (November 2017 and February 2018, with and without indicating, respectively, proposed tolerable risk limits based on probabilities), in the context of initial presentations to three newly appointed members of the Board of Directors. The presentations included information that all of the Iron Ore Division dams (“100%”) had their safety certified, with their respective DCEs issued and that the dams were safe and operating normally.

Information about B1 in the ALARP/Attention Zone was confined to meetings of the Operational Risk Subcommittee. As presentations rose to the higher levels of the Vale administration, the names of the structures within the ALARP/Attention Zone were removed. It should be noted, however, that there are emails that suggest that the then-Executive Director of Iron Ore may have had access to the presentation where B1 appears on the list of 10 (ten) dams in the ALARP/Attention Zone.

An important reason why issues known to the geotechnical area of the Iron Ore Division were not disclosed to other areas may have been the non-transparent nature of the business divisions’ “silos,” including the Iron Ore Division. Issues were addressed within the business division and were not aired outside the division. In addition, there was a work environment that lacked transparency and that did not encourage personnel to raise concerns and/or question leadership decisions.

This cloistered and closed structure led to relevant information that was understood as unfavorable to generally remain restricted to the areas within the Iron Ore Division.

Such factors could have been minimized if there was a second line of defense for geotechnical issues that was not subordinated to the same Executive Director. However, the Corporate Geotechnical area of the Iron Ore Division also reported to the Iron Ore Division Executive Director.

— Although Vale’s initiative in creating the Independent Panel of Experts for Safety and Risk Management of Geotechnical Structures – PIESEM, for the Iron Ore Division was positive, some of the PIESEM experts, in particular some of the Brazilian members, did not have the necessary independence, given they were hired by the Corporate Geotechnical area for other services, which created a potential for conflicts of interest.

The same would occur with respect to the external dam auditors, which also were not able to act truly independently, as they were hired and their contracts were managed by the same area of the Iron Ore Division, whose focus was primarily on meeting regulatory requirements (e.g., obtaining DCEs). Furthermore, these companies were engaged to provide

other services, creating potential conflicts of interest and potential for impairment of the effectiveness and impartiality of the outcome of audits.

Given the information obtained during the investigation, the CIAEA formulated a set of recommendations to Vale which were presented to the Company's Board of Directors for consideration.

Finally, with regard to the indication of any potential liability, the factual elements that could lead to the attributing responsibility to employees and third parties are dispersed throughout the Independent Investigation Report of the CIAEA. The Report describes the facts found during the independent investigation, but it was not the scope of the CIAEA to determine any possible legal consequences arising from these facts. The CIAEA recommends that Vale implement a procedure to determine appropriate potential measures, disciplinary or otherwise, regarding individuals or entities that had a role in the facts identified by the independent investigation. Reference to individuals and entities may have been made, in some cases, solely for purposes of contextualization of the accurate facts that were identified, in compliance accordance with the scope of work of the CIAEA. These references in the CIAEA Independent Investigation Report or the Executive Summary do not necessarily imply a presumption or assumption of liability.

5. RECOMMENDATIONS

The following recommendations were prepared based on the results drawn from the independent investigation process. These recommendations are based on aspects of the structure of internal controls that are exclusively related to the topics that are the object of the investigation, and therefore do not provide a complete and general analysis of internal controls and governance of the Company as a whole.

In light of the fact that CIAEA's work involved the analysis of past facts, it is possible that some of the recommendations presented herein have already been implemented or are in the process of implementation by the Company.

The implementation of the recommendations presented herein is subject to the Company's assessment and approval, which should consider the qualitative and quantitative aspects of each recommendation.

Lastly, in the event that the following recommendations are approved, it is suggested that the Board of Directors monitor and supervise their implementation.

Recommendations formulated by the CIAEA address the following topics:

1. Assessment of possible risk of rupture of structures similar to B1;
2. Improvements in the Emergency Action Plan for Mining Dams (PAEBM);
3. Adoption of consistent and risk-based stability criteria;
4. Review the procedures for verification and validation of geotechnical monitoring instrument automation processes;
5. Review of the Operation Manuals for Vale's structures;
6. Review of the process for obtaining DCEs;
7. Improvement of the geotechnical risk assessment methodology;
8. Review of the functions of the Independent Expert Panel;
9. Improvements in the contracting policy for third parties providing services related to dam safety;
10. Improvement in identifying dam-related expenses, costs and investment in financial and accounting management systems;
11. Review composition and resourcing of the Geotechnical team;
12. Improved segregation of duties for the lines of defense;
13. Review of the career path for the Geotechnical area;
14. Review of compensation and benefits policy;
15. Assessment of the applicability of the "Engineer of Record" concept for the

Company;

16. Improvement of cultural aspects;
17. Improvement, fostering and expansion of a safety culture;
18. Detailed recordation of Executive Board meetings;
19. Development of rules and regulations for the Operational Risk Subcommittee;
20. Modify the composition of the Board of Directors and the Fiscal Council to include members with mining expertise or operational risk management in high risk industries;
21. Improvement in the structure of Ethics and Compliance;
22. Improvement of the procedure for handling complaints;
23. Improvements related to internal audit;
24. Definition of a procedure for the treatment to be given to the personnel and third parties involved in the rupture of B1;
25. Definition of mechanisms for follow-up of effective implementation of post-rupture measures and recommendations suggested by the CIAEA.

The CIAEA does not have the responsibility to determine or follow-up on the implementation of these recommendations, in whole or in part, nor does the Committee provide any assurance that they are adequate, effective and sufficient to avoid or minimize risks associated with the Company's dams.

6. LIMITATIONS

The work involved in preparing the Independent Investigation Report, its annexes, and the instant Executive Summary (referred to collectively as the "Report") is limited to its nature and scope. Notwithstanding the efforts undertaken, which we believe were appropriate, it is not possible to ensure that the procedures performed have identified all information or facts which, individually or collectively considered with other elements, can be said to be conclusive for the investigation.

We reserve the right (but we have no obligation) to revise and amend the Report in light of any information that has not previously been brought to our attention or as a result of new developments, which may or may not materially affect our opinion, after the date its emission.

Unless indicated otherwise, this Report was based on the procedures carried out and the information provided and obtained up to February 15, 2020 and it may not reflect events or circumstances that occurred after that date.

The data, documentation and information reviewed and used for the preparation of this document were made available by the Company. We believe that the information in this Report is correct and accurate, but there is no guarantee of integrity, accuracy or reliability with respect to the information and documentation obtained during the process.

Due to the limitations inherent to any internal investigation, it is possible that errors or inaccuracies might occur and cannot be detected. The subjects addressed in this Report are those that were in some way understood to be relevant during the course of the activities performed.

Some representatives of third-party companies, former employees and employees of the Company declined, did not respond and/or did not agree to participate in interviews with the Investigation Team under the terms of CIAEA methodology.

Under no circumstances shall we be liable to Vale's Board of Directors or any other individual or entity for any decision or action taken or not taken on the basis of the information contained in this Report.

The mention of individuals and entities may have been made only for purposes of contextualization of the facts concerned, in compliance with the scope of work assumed by the CIAEA. Such mention in this Executive Summary does not necessarily imply a presumption or assumption of liability.