Independent Committee for Extraordinary Advisory on Dam Safety

Final Report

April 30, 2021

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Introduction

Motivated by the importance of achieving the most adequate safety standards for Vale's dams and shortly after the collapse of the B-1 tailings dam in Brumadinho, Vale's Board of Directors, on February 15, 2019, established the Independent Committee for Extraordinary Advisory on Dam Safety based on Article 15, paragraph one, of the Company's Bylaws.

The fundamental purpose of the Committee was to advise the Board of Directors on issues related to the diagnosis of safety conditions, management and mitigation of risks related to Vale's dams, as well as to recommend measures to be taken to strengthen their safety conditions.

The Committee was also focused on the future by dedicating itself to recommendations for measures to be taken and procedures to be adopted to strengthen the safety conditions of dams.

The independence and autonomy of the Committee was ensured by its constitution, which was composed of three external members to the Company and selected by the international consultant Korn Ferry, who selected the three members in March 2019.

Committee composition

Three engineers with extensive experience in dam design and construction works in Brazil and abroad joined the Committee, in addition to being or having been strongly linked to research and engineering teaching. The Committee consisted of:

- Flavio Miguez de Mello (independent external member, and coordinator of the Committee), civil engineer and postgraduate in geology, with more than fifty years of career experience mainly in consulting engineering.
- Willy Alvarenga Lacerda (independent external member), civil engineer and postgraduate in geotechnics, with more than sixty years of professional activity in the field of geomechanics.
- Pedro Cesar Repetto (independent external member), civil engineer and postgraduate in geotechnics, with more than fifty years of career experience in several countries, with an emphasis on mining.

To support the Committee's activities, five professionals were retained: civil engineer Luciano Jacques de Moraes Jr., holder of extensive experience mainly in geotechnics; geologist Fernando Pires de Camargo, of the pioneering generation of engineering geology in the country; civil engineer Wanderley Guimarães Corrêa, with more than sixty years of relevant career experience mainly dedicated to advanced concrete technology; and civil engineer Luiz Cézar da Veiga Pires, also with more than sixty years of experience with recognized expertise in hydrology and hydraulics. Carlos also Abreu is part of the group, with extensive experience in information technology.

Committee scope of work

The Committee was responsible for studying and analyzing Vale's most important dams and dams that presented an operational deficiency or allegedly compromising evidence for safety. Due to its importance, the scope has also been extended to tailings and mining waste piles. Design, construction, operation and monitoring of structures for tailings storage, for sediment retention, for water storage for process, for electric power generation and for drainage of extensive areas were examined. In total, fifty-seven structures in the Southeast and North corridors and hydroelectric power plants in several states of the federation were examined. Several of these structures, since they are under construction and have highlighted importance, were the subject of repeated technical visits, some of them with more than ten inspections and technical meetings.

Support to the Committee

Early on, the Management Council approved the Committee's bylaws expressly guaranteeing its independence of action. The Management Council also approved the program of the Committee’s activities.

Based on the aforementioned approvals and the excellent professionals of the governance team of the Management Council, the Committee has always had sufficient budgetary autonomy to perform the services and has had unrestricted support from the entire Vale staff, from the Board directors to the engineering and management teams, from the consulting engineering companies contracted by Vale for project development to third-party suppliers of logistics support services and administrative activities that were necessary. In the technical and logistics activities, it should be noted that there was also full support in obtaining technical information from Vale professionals and companies contracted by Vale. These supports were consistent throughout the two years of the Committee's activity without any exception at any time.

General and specific characteristics of tailings dams in Brazil

It is not pertinent to describe in this report the general characteristics of traditional tailings disposal structures and new saturated tailings dewatering technologies, geotechnical monitoring, construction works and governance. However, this chapter mentions the Brazilian characteristics due to natural aspects of the territory and the new legislation in force. These characteristics are summarized below.

i- Due to the long construction time that involves successive expansions of reservoir capacity achieved by dam raises, which is common throughout the planet, in Brazil there has usually been a frequent successionof designers for the same dam. This aspect is frequent even in downstream raised dams that typically have higher and less raises than traditional upstream raised dams. The B-1 dam in Brumadinho is one example.

ii- Considering the long construction time, it is common not to have technical documents "*as built",* a procedure that has been adopted since the sixties of the last century in some other countries, for dams that store water. This practice, which greatly contributes to checking the safety conditions and the need of eventual structural reinforcement works, was initiated in Brazil by the power sector in the 1980s, but only in some of the most important dams in this sector. The almost total absence of "*as built*" documents in the mining sector has made it an essential practice to carry out investigations and tests to procure knowledge of the real conditions of the embankment of dams and dikes in documents known as "*as is"* that do not usually have the same accuracy of the "*as built*" documents.

iii- In recent years, especially after the final phase of the nineties, there has been acquisition of mining activities among traditional mining companies in the country. Vale was one of the companies in this area that acquired the most mines that came in with respective tailings dams. In general, these dams did not have detailed design, construction, and monitoring information. These structures have undergone or are undergoing project characterization "*as is*".

iv- In many countries where mining activities are very developed, the climate is much less humid than the climate in the Brazilian territory, namely in the Iron Quadrangle region of Minas Gerais and in the North Corridor where most of Vale's mines are located. In dry climates the disposal of tailings is easier than in humid climates where, to achieve the same quality and factor of safety, greater investments are necessary.

v- In general, in Brazil, mining activities are carried out in areas with considerable thickness of residual and colluvial soils that produce large amounts of waste material. These materials demand the implementation of piles and structures to prevent sediment transportation. Among these structures are reservoirs for sediment accumulation especially needed in the Iron Quadrangle region of Minas Gerais.

vi- In many countries, mining activities are carried out in areas of relatively plain ground, which does not happen often in the Iron Quadrangle region of Minas Gerais where Vale's mining activities are concentrated. In areas of very rugged ground and in areas with high rainfall and thick layers of residual and colluvial soils, it is difficult to perform, maintain and ensure safety of diversion channels surrounding the reservoir areas. Thus, it is common in this country to have small streams and intermittent flow thalwegs flowing into the reservoir area. Although the flows that usually flow to the reservoirs are small, flows corresponding to extreme precipitation calculated by

conservative methods can determine flood discharge peaks that demand the installation of discharge systems of considerable dimensions.

vii- In general, the discharge of tailings in other countries is made from the dam crest. In Brazil, mainly in dams raised downstream or executed in a single stage, in most or even almost all cases, tailings are deposited at the end of the reservoir located away from the crest of the dam. As a result, the deposited tailings do not contribute by forming, in the initial stages of disposal, a thick blanket that would increase the seepage path through the foundation, nor do the formation of beaches upstream of the dam crest occurs that would keep the accumulated water away from the upstream dam slope.

Operational methodologies adopted

Between the beginning of activities in March 2019 to March 2020, when the procedures had to be changed due to the Covid 19 pandemic, several trips were made for beneficial and detailed technical inspection visits to dams and piles, with numerous meetings and professional contacts in offices, construction sites or mines located in Minas Gerais and Pará.

From April 2020 on, until the end of the Committee's work in April 2021, there was a profound change in the methodology of action, as all contacts and meetings transferred to video-conference. It is worth noting the excellent collaboration and availability of Vale's team in attending all meetings convened by the Committee. However, although the virtual meetings relied on the most advanced and secure technologies for transmitting signals, images and information, there was a loss due to the lack of contact with the construction works. In the initial phase, these frequent contacts at the sites of the structures enabled the identification of important aspects that generated recommendations in the construction works and projects.

Therefore, the activities of the Committee had two distinct periods of one year each. The first period with intense technical visits, some construction sites having been visited more than ten times, and the second period with virtual meetings with the field forces and design teams. Altogether, numerous dams, dikes and piles were analyzed, discussed, and visited, and recommendations were issued for 57 geotechnical and hydraulic Vale structures located in the states of Minas Gerais, Pará, Maranhão, Tocantins, Rio Grande do Sul and Santa Catarina states.

Relevant facilities and equipment monitoring technological development and construction activities

In the first roadmap of technical inspections of Vale’s dams and facilities in Minas Gerais in April 2019, it was important to highlight the impactful visit to the Dam Control Room,

known as the Geotechnical Monitoring Center, which was exceptionally equipped with state-of-the-art devices and permanently expanding, installed at the MAC, in Nova Lima, MG. From this Center, the readings from several types of instruments with real-time data transmission of Vale's main dams in Minas Gerais are made and recorded. The expansion of the reception of dam monitoring data has greatly increased the safety of Vale's dams. In an early phase of implementation and already producing benefits to the monitoring of dams in the North Corridor, there is a similar Geotechnical Monitoring Center in Carajás.

It is important to highlight the idealization and preliminary facilities for the implementation of a laboratory for technological testing of materials for dams and for mining waste disposal, taking advantage of existing facilities at Borba Gato, Santa Luzia, MG. This laboratory is intended to fill an important gap for conducting research and special technological tests for which there is no availability in the country. The Committee encouraged this important initiative and suggested agreements with other institutions.

The most impactful activities under construction are related to the purchase and installation of modern construction methods in earthwork for large size and capacity unmanned equipment, operated remotely and mainly intended for the earthwork of large volume geotechnical structures. These equipment and construction processes have been successfully used since the turn of 2020/2021 in the de-characterization of the PDEX pile located in the B3/B4 dam area, which will also be de-characterized by this process. The use of this process is due to the need to avoid the presence of people in workplaces where there may be a risk of collapse of tailings dams by liquefaction.

Stability analysis. Deterministic and probabilistic methods

The Committee has been expressing itself on this subject throughout its performance since October 2019. A summary of these was presented in the technical note NT-02/20 of June 15, 2020, referring to factors of safety in stability analyses. Parts of this technical note are presented below.

Suggested methods for stability analyses

Limit Equilibrium Method (LEM)

Among the suggested methods is the traditional Limit Equilibrium Method, which has been used in virtually all earth and tailings dams, with some examples of failure.

Other causes independent of the strength of the embankment can lead to failure, such as failures by internal erosion (piping), insufficiency or poor execution of the internal drainage system, overtopping, liquefaction, design deficiencies, etc. Therefore, it is often not only the factor of safety of a project, which assumes that the construction work will be well conducted and with independent supervision, which is the cause of the failures.

It can be said that the factors of safety of the current standards are satisfactory, provided that the construction work has been conducted with excellence.

However, according to the "*Tailings Dam Safety"* bulletin of ICOLD International Commission on Large Dams, "*The solution by the Limit Equilibrium method does not take into account the compatibility of deformations and border displacements. In addition, materials are supposed to operate as a perfectly plastic body, and in a two-dimensional plane.*

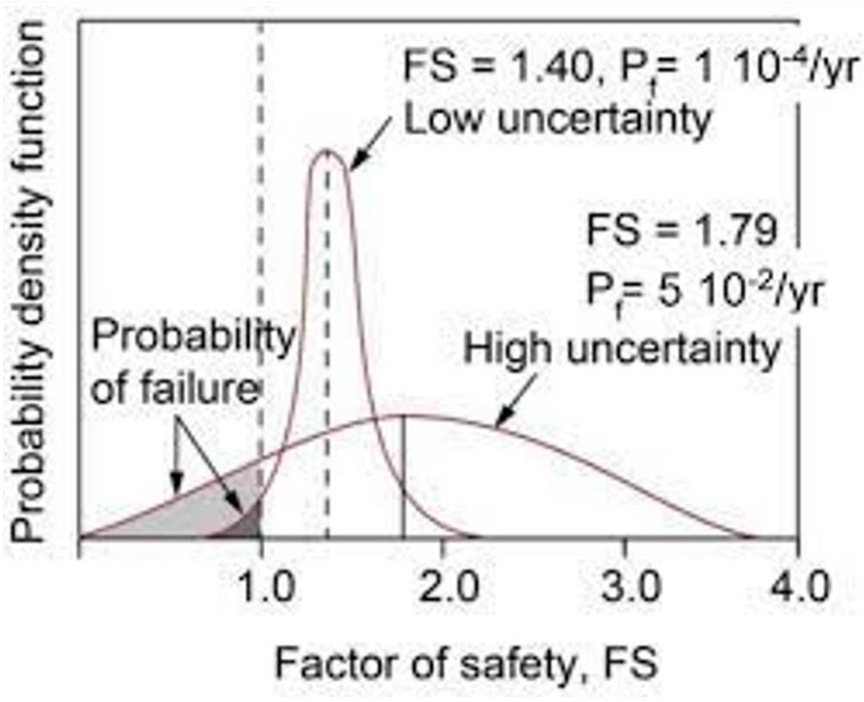
Further, due to its simplicity and its proven history when input parameters are selected with criteria, this method is used in most projects, particularly when the availability of input parameters or the complexity of soil behavior do not justify the use of more sophisticated scopes."

If there is a very large variation in the modulus of deformation of the constituent materials of the analyzed section, it is recommended to use numerical methods, such as Finite Elements Method, or PLAXIS, to make the resistances compatible with the deformations and to obtain a more realistic factor of safety.

Probabilistic Methods

The probabilistic method is particularly useful for considering the uncertainties on the geotechnical parameters that are the input data to any LEM.

As there are a variety of good methods, it is enough to choose one that is simple and easy to implement as a routine. The surprise of this method is that factors of safety values that appear to be satisfactory (above 1.5 for example) may have a higher probability of failure (Pf) than a lower factor of safety, but with less parameter variation, based on many tests performed. The figure below, by Lacasse and Nadim (1998), is self-explanatory.



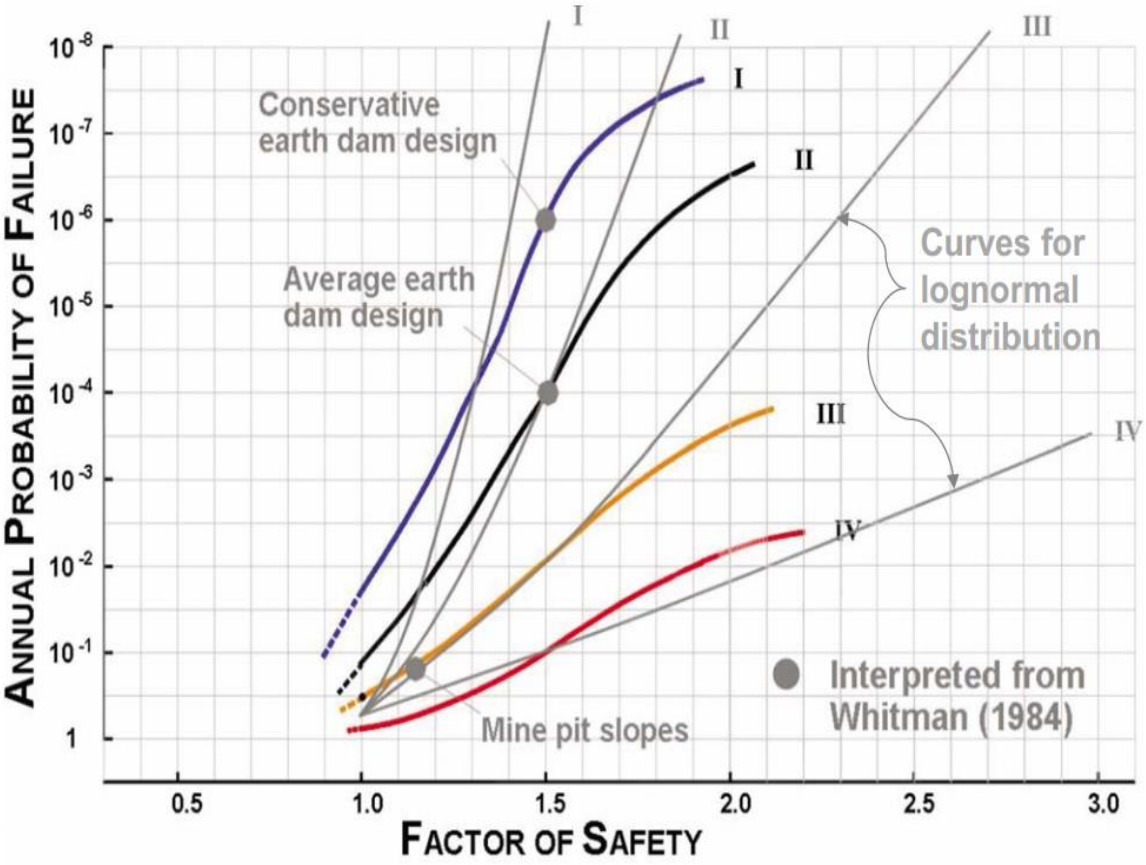
The probability of failure values can be specified. If the uncertainty of the parameters leads to an unacceptable probability, then the design of the dam cross-section must be modified until an acceptable probability is achieved; a higher value of the factor of safety will correspond to this probability.

Therefore, instead of only specifying one factor of safety, an annual probability of failure is also specified, which in general leads to higher factors of safety.

If design modifications (such as flattening slopes, for example, or changing a less resistant material to a stronger one) are economically unacceptable, the uncertainties on geotechnical parameters should be improved, with a greater number of tests.

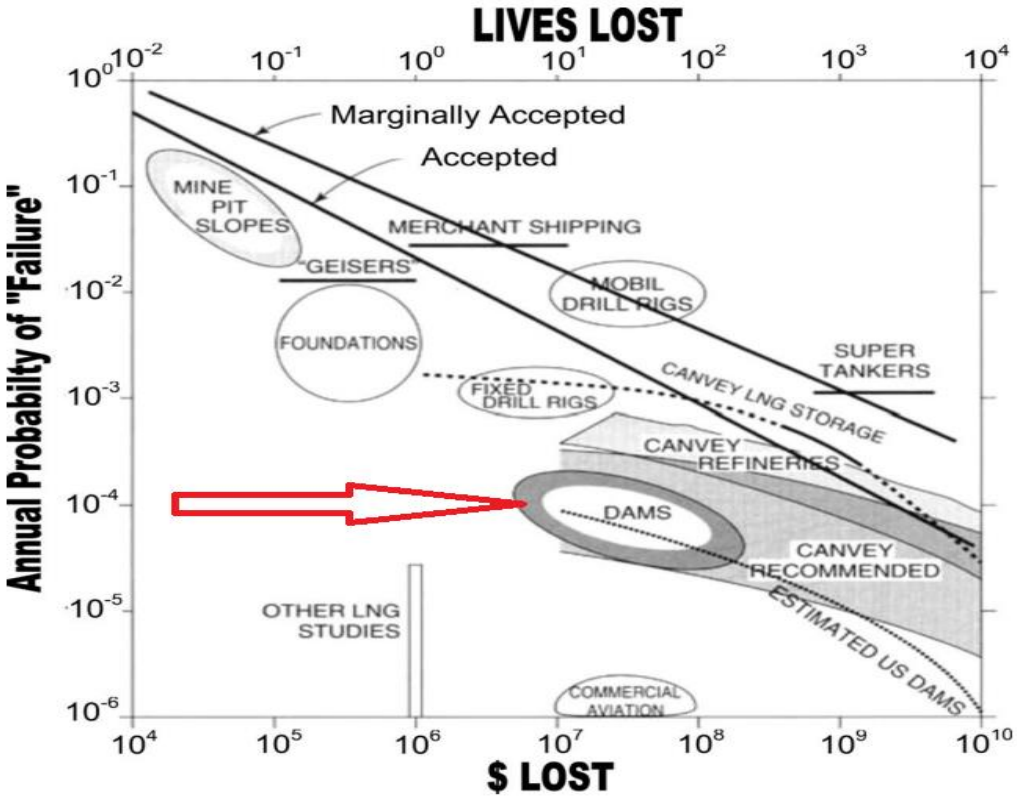
It should be noted that in the design of the pits for Vale's mines, this double criterion for stability is frequently adopted, namely, setting limits for minimum factors of safety and maximum annual probability of failure. The recommended values of both factors of safety and probability of failure are presented by Read & Stacey, as an example.

The figure below from the article by Silva et al. (2008) illustrates this.



In this figure it can be seen that a dam with a factor of safety of 1.5 may have different annual probabilities of failure, depending on the level of uncertainty of the basic data. And the average designs, curve II, have a probability of failure of 10-4, which is a

minimum acceptable probability for dams in general, as can be seen in the figure below, of the same article.



The tolerable risk levels obtained from the technical literature by Lambe et al are highlighted in the figure above. For dams, the annual probability of failure usually accepted is 1 x 10^{-4}. For example, this maximum value is adopted by ANCOLD (Australian National Committee on Large Dams).

Recommendations

The Committee believes that there is a gain in reliability and safety when probabilistic methods are combined with LEM. Thus, it is possible to use the ALARP protocol ("*As Low as Reasonably Possible"*) to decide, due to the probable number of life and property losses, the range of annual probability of failure that will be required in the calculation of the factory of safety.

For existing dams, it is possible to improve the evaluation method discussed above considering that the probability of failure increases with the level of uncertainty. Factors that increase uncertainty are, for example, insufficient geotechnical study; lack of the original construction report (as built); non-technically documented occurrence of deviations during construction; poor or deficient maintenance; existence of cracks, settlements or excessive deformations; anomalous piezometer readings; drainage deficiencies, etc.

Seismic events in tailings dams

The Committee has been commenting on this subject throughout its activities since April 2019. A summary of these comments was presented in the report RL-10/19 of October 24, 2019. The following summarizes the most relevant aspects of this report, in relation to seismic events.

Engineering consulting firms that provide services to Vale for the preparation of containment structures design and/or to analyze the stability of piles and tailings dams, use different seismic criteria for their analyses. For example, for the Capim Branco dam (in the Córrego do Feijão Mine) and the Vargem Grande dam (in the Fábrica Mine), for the peak ground acceleration (PGA), DF+ adopts the value of ah = 0.1 g, where g is the acceleration of gravity. Engecorps, in recent (2019) stability analyses for the Itabiruçu dam, adopted ah = 0.03 g.

It should be noted that the values of the seismic hazard maps are always referred to outcropping sound rock. Considering that it is always necessary to consider that tailings dams are founded on soils that cover rock formations, it is necessary to evaluate the propagation of seismic accelerations to the foundation soils and to the entire dam embankment and its respective reservoir. The procedure for evaluating accelerations propagation is known as convolution.

A particularly important proposal for a seismological hazard chart was presented in the paper published by IAG-USP (Marcelo Assumpção and others). This work was published in Bulletin 96 of 2016 of the Brazilian Geophysical Society – SBGf (pages 25 to 29), titled "Earthquakes in Brazil - Preparing for Rare Events". Its authors, geophysicists specializing in seismology, are: Marcelo Assumpção, Marlon Pirchiner, João Carlos Dourado and Lucas Vieira Barros. The following is a conclusion of the paper:

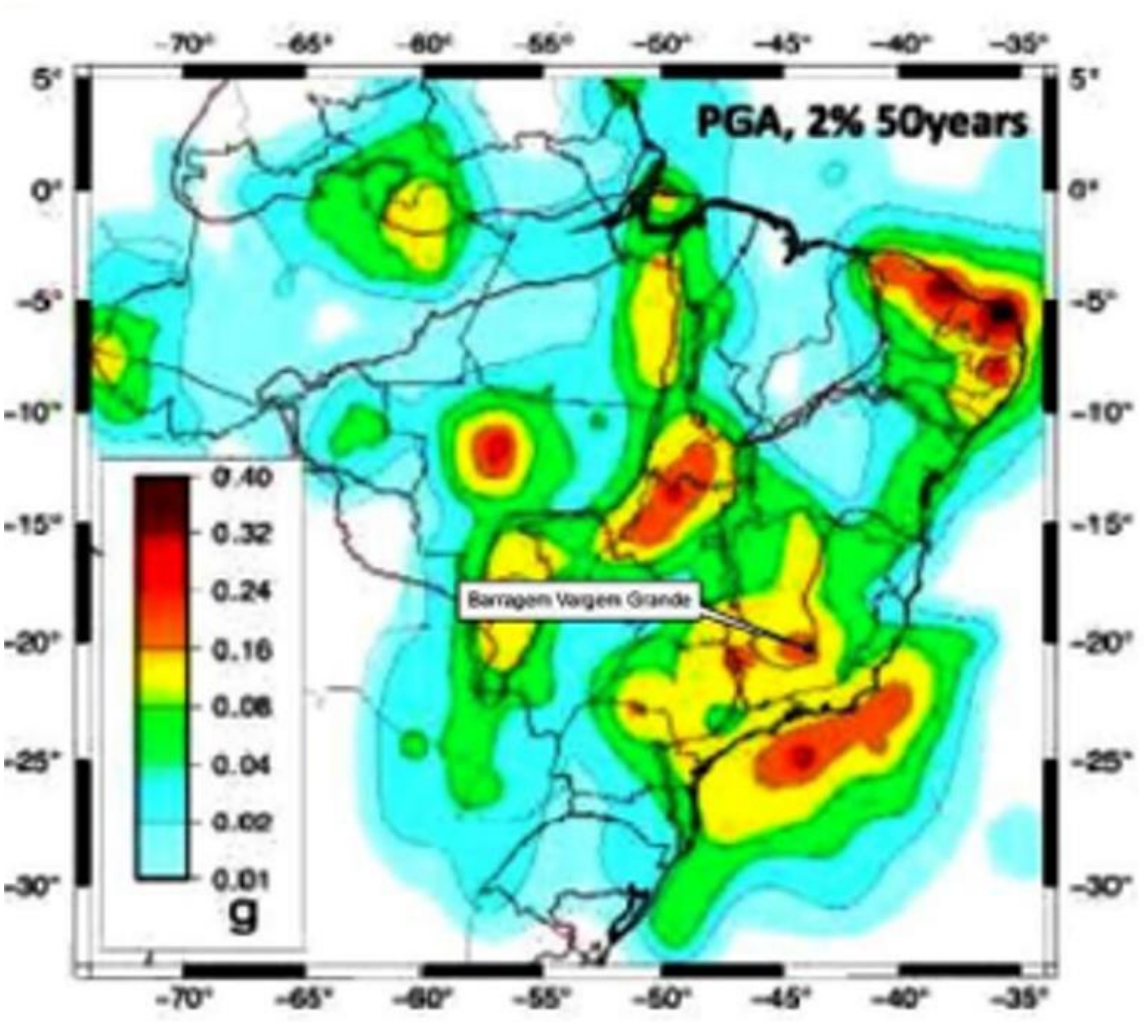
"Seismic activity in Brazil is known to be low. Medium and moderate seismic events (magnitudes up to 5 or 6) can occur in any region, but with probabilities so far considered sufficiently remote, and can be disregarded in most building projects and engineering works. Only critical facilities, such as nuclear power plants and reactors, and hydroelectric dams, have made systematic use of specific seismological analyses. On the other hand, recent seismic hazard studies in Brazil and the preliminary results presented here show that the current seismic standard would need to be revised contemplating accelerations of up to 5% or more in areas previously considered as "zone 0", without appreciable hazard. Extreme events, however unlikely they may seem, often cause surprises."

The most important part of that paper is the presentation of the seismic hazard map of Brazil. The map shows zoning for areas with a probability of exceedance of 10% in 50 years - Fig. 7a of the paper – corresponding to the return period of 475 years. The note of the paper on page 26, 2nd column, 3§, reproduced below, is very important:

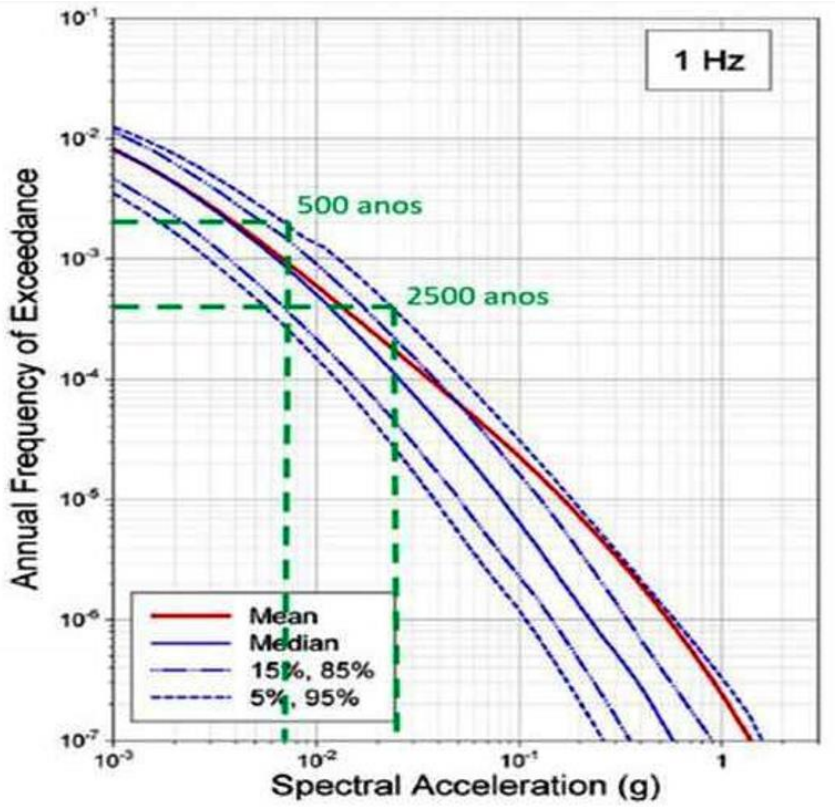
"An important observation is that, apparently, most tailings dams in Brazil are designed for accelerations of 3% to 5% g (acceleration of gravity). The extent of the green areas in Fig. 7 suggests that these values would need to be revised. "

Fig. 7a presents rounded geographical coordinates (20° South and 44° West, point within the Iron Quadrangle region of the Minas Gerais State), the point falls within the green zone of the map, which corresponds to the range of values of a_h = 0.04 to 0.08 g.

Fig. 7b presents zoning for areas with a probability of exceedance of 2% in 50 years, which corresponds to the return period of 2,475 years. The design firm DF+ presented the location of the Vargem Grande dam on the map of Fig. 7b, reproduced below.



Map of Seismic Hazard in Brazil. Peak Acceleration.
2% probability of exceedance in 50 years, which corresponds to a return period of 2,475 years. Indicating the location of the unit.
Adapted from Assumpção *et al*. (2016)



Selection of a horizontal acceleration value of 0.1g, as recommended by USNRC (1997)

Still the available data about vertical ground motions is limited, being assumed as a fraction of the peak horizontal ground acceleration. Generally, 2/3 of the horizontal acceleration is utilized for the vertical acceleration (Werner, 1976).

The point corresponding to the Vargem Grande dam falls within the red zone of the map, which corresponds to the range of values of ah = 0.16 to 0.24 g.

It is recommended that Vale urgently arrange for a qualified study of seismic risks in the Iron Quadrangle region of Minas Gerais State and decide at a high hierarchical level (decision of a technical and managerial nature) which return period should be adopted for each dam project in the Iron Quadrangle region. It is worth noting that currently international best practices for dam design recommends that the selection of the design seismic event return period should be a function of the consequences of a hypothetical dam collapse. The consequences of a collapse are influenced, among other parameters, by the number of people at risk and those who could be affected by environmental and cultural impacts, and the costs of repairing the area affected by the collapse.

As an example, the Canadian Dam Association (CDA) design guide initially recommends classifying the consequences of a hypothetical collapse to select the hydrological and seismic return periods according to the classification of the dam in terms of the damages. The following two tables indicate this procedure.

Dam Class	Population at Risk[1]	Incremental Losses		
		Loss of Life[2]	Environmental and Cultural Values	Infrastructure and Economics
Low	None	0	Minimal short-term loss. No long-term loss.	Low economic losses; area contains limited infrastructure or services.
Significant	Temporary only	Unspecified	No significant loss or deterioration of fish or wildlife habitat. Loss of marginal habitat only. Restoration in kind highly possible.	Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes.
High	Permanent	10 or fewer	Significant loss or deterioration of *important* fish or wildlife habitat. Restoration or compensation in kind highly possible.	High economic losses affecting infrastructure, public transportation, and commercial facilities.
Very High	Permanent	100 or fewer	Significant loss or deterioration of *critical* fish or wildlife habitat. Restoration or compensation in kind possible but impractical.	Very high economic losses affecting infrastructure or services (e.g., highway, industrial facility, storage facilities for dangerous substances).
Extreme	Permanent	More than 100	Major loss of *critical* fish or wildlife habitat. Restoration or compensation impossible.	Extreme losses affecting critical infrastructure or services (e.g. hospital, major industrial complex, major storage facilities for dangerous substances).

NOTES:

1. DEFINITIONS FOR POPULATION AT RISK:
   NONE – NO IDENTIFIABLE POPULATION AT RISK, NO POSSIBILITY OF LOSS OF LIFE OTHER THAN THROUGH UNFORESEEABLE MISADVENTURE.
   TEMPORARY – PEOPLE ARE ONLY TEMPORARILY IN THE DAM-BREACH INUNDATION ZONE (E.G. SEASONAL COTTAGE USE, TRANSPORTATION ROUTES, RECREATION).
   PERMANENT – POPULATION AT RISK IS ORDINARILY LOCATED IN THE DAM-BREACH INUNDATION ZONE (E.G. PERMANENT RESIDENTS).
2. IMPLICATIONS FOR LOSS OF LIFE:
   UNSPECIFIED – THE APPROPRIATE LEVEL OF SAFETY REQUIRED AT A DAM WHERE PEOPLE ARE TEMPORARILY AT RISK DEPENDS ON THE NUMBER OF PEOPLE, EXPOSURE TIME, NATURE OF ACTIVITY AND OTHER CONDITIONS. HIGHER CLASSES COULD BE APPROPRIATE DEPENDING ON REQUIREMENTS.

Dam Class	Annual Exceedance Probability	
	Floods	Earthquakes
Low	1/100	1/100
Significant	Between 1/100 and 1/1,000	Between 1/100 and 1/1,000
High	1/3 between 1/1,000 and PMF	1/2,475
Very high	2/3 between 1/1,000 and PMF	1/2 between 1/2,475 and 1/10,000 or MCE
Extreme	PMF	1/10,000 or MCE

NOTES:

1. ACRONYMS: PMF, PROBABLE MAXIMUM FLOOD; AEP, ANNUAL EXCEEDANCE PROBABILITY; MCE, MAXIMUM CREDIBLE EARTHQUAKE.

CDA (CDA 2014) included AEPs for dams in the passive closure phase as it was recognized that mining dams, especially tailings dams, have a significantly longer life than water dams, and therefore higher AEPs would be more appropriate for the structures in the long term. The suggested AEPs for a dam in the Passive Closure Phase are shown on Table 3.4.

Finally, one more example is given. The failure of the Samarco's Fundão dam generated a report prepared by an independent panel of experts led by Prof. Norbert Morgenstern, renowned and internationally recognized geotechnical specialist. Part of the Panel's report contains text prepared by Prof. Gail Atkinson, geologist specialized in intra-plate seismic events (case of the Iron Quadrangle region of Minas Gerais State). Prof. Atkinson reports that the seismograph installed in the Samarco region detected, on May 2, 2016, a category M3 seismic event (Mw ~2.5) about 70 km to the west. Prof. Atkinson indicates that the maximum horizontal acceleration would have reached values of the order of 12 cm/s², that is, of approximately 0.12 g.

As appropriate, the consulting firm SLR, retained to guide the State Prosecutor's Office of Minas Gerais State, presented a series of recommendations in the audit carried out in 2019. One of the recommendations was: *"A formalized regional seismic analysis needs to be completed by an experienced expert and used in stability analyses."* The Committee agrees with this recommendation.

The regional study mentioned above was initiated in 2019 by Vale's Geotechnical Risk Management. It was expected to be completed in the middle of the second semester of 2020 and was being prepared by a team of geophysicists led by Marcelo Assumpção and João Carlos Dourado. The preliminary results encouraged Vale's staff to request the regional study be expanded to indicate the design seismic event to be adopted for each relevant structure (tailings dam, pile, containment structure) owned by Vale. Due to this, the deadline for the delivery of this report was postponed to the end of the first semester of 2021. The Committee endorses Vale's decision and recommends that this study be finalized and that its conclusions (design seismic event values) be adopted for all stability and stress-deformation analyses of relevant Vale structures.

Some relevant aspects of the Committee's contributions

Hydrology and hydraulics

In 2011, the civil engineer and consultant Mário Cicareli Pinheiro established, and Vale adopted in its projects, the Guidelines for Preparation of Hydrological Studies and Hydraulic Dimensioning in Mining Works. The basic criteria adopted in the guidelines are extremely conservative and allowed to provide high reliability for Vale's hydraulic structures. Considering that all tailings dams drainage areas are quite small and the overflow spillway structures are not controlled by electro-mechanical equipment that demand operators (all are free-flowing spillways), the conservatism of the criteria does not impact heavily on construction costs and ensure hydrological safety to dams with high freeboard.

The verification of the studies and hydrological definitions carried out by the Committee, in its overwhelming majority, concluded that the spillway structures are appropriately sized for the most conservative conditions of extreme inflow discharges to the reservoirs.

The spillways discharge capacity was undersized only for the Maravilhas II, Capitão do Mato and Paracatu dams. However, for these three cases, Vale had already developed studies to expand the spillways discharge capacity. In Maravilhas II, by the deployment of an additional spillway apron. In Paracatu and Capitão do Mato dams, the studies are still being conducted for an alternative design to be adopted.

Regarding spillway systems, only the spillway aprons of the Taquaras and Santana dams showed hydraulic inconsistencies when examined. The Committee recommended complementary works to ensure safety in case of discharge of extreme floods in these dams.

Concrete Technology

Traditionally, Vale has not developed concrete structures as relevant as its geotechnical structures. By the construction of the large concrete gravity containment structures for the Forquilhas, Grupo, Sul Superior and Sul Inferior dams in 2019, in addition to the hydraulic structures with reinforced concrete of the containment of dam B3/B4, Vale and its contractors found themselves dealing with concrete structures of dimensions greater than they previously had, with extremely short construction deadlines due to the urgency established for the implementation of these containment structures.

The Committee collaborated providing continous advice to ensure the quality of the structures that were implemented in a very short time. The main recommendations were related to the smoothing of rock foundations, connection between successive layers of roller compacted concrete (RCC), control of degrees of compaction of the RCC, spacing and location of contraction joints, concreting in diversion and drainage shafts, execution of plugs in diversion adits, foundation and abutment excavations, execution of waterproofing painting, infiltration in RCC dams, placement of joint seals, execution of concrete on hydraulic surfaces subject to high speed flow, displacements and infiltration in concrete, strengthening of spillway slabs executed on soil, treatment of cavities and cracks in concrete structures, execution of zoning by class of concrete without joints, and establishment of critical analysis for projects and construction methods.

Geotechnical

In all projects and construction works examined by the Committee, geotechnics was always the predominant aspect. The fundamental issue was the determination of the geotechnical properties of the different materials of the dam body, tailings, sediments and foundation.

The reduced number of deformability, strength and permeability tests was a reality in most dams in operation or in raising works. For this reason, in the two recent years, Vale's current project designers chose to perform shear strength tests on undisturbed samples collected from the earth dam embankments, either obtained from test pits, for small depths (up to 5 meters), or by samples obtained with the Denison sampler, which is appropriate for greater depths. Even with the increased demand for geotechnical

tests, the number of tests in some cases may not yet be ideal in relation to the dimensions and responsibilities of some large dams that accumulate large amounts of tailings, sediments, or water or all these elements together. The Committee monitored the investigations and supported the recommendations for conducting additional tests on the most relevant geotechnical structures.

In the geotechnical characterization of tailings, the CPTU (*cone penetration test with pore pressure measurement*) tests gave better certainty in assessing the stability of tailings dams that had been raised upstream. These tests have been performed in an acceptable number and provide strength values as a function of the depth of the tailings slurry.

An issue that arose during these investigations to obtain samples or install piezometers and water level indicators in existing dam embankments was the use of circulating water to advance the cutting tool in percussion or rotary drilling. The issue is that a circulating liquid pressure at the bottom end of the drill hole can initiate a localized hydraulic failure and, consequently, cause weak points in the dam embankment. The Committee issued a technical note recommending execution procedures.

Piezometry

In the recent past and in general, the designers and Vale itself have correctly decided to substantially increase the number of piezometers and water level indicators in dams and dikes, thereby improving the confidence in the results of stability analyses.

Some existing piezometers were unusable and had to be replaced. Piezometers for continuous reading and real-time data transmission to the Geotechnical Monitoring Center in Águas Claras were installed since then. Some dams at alert level 3 (notably the Sul Superior, B3/B4 and the Forquilhas group) were not allowed to have land access for operators to perform the pore pressure readings of piezometers and INA's (water level indicators). Readings and maintenance services were performed with helicopter support, with the instrument operators properly secured to the helicopters that remained stationed in the air over the measurement locations. However, in these dams, it was extremely difficult to operate any equipment for new investigations or installation of new instrumentation.

Shear strength testing

For shear strength testing in soils, the triaxial equipment was generally used for measurement of pore pressure. In general, the laboratories performed good quality tests, which served to choose with more certainty the strength parameters to be used for the stability analyses.

Stability analysis

When the Committee had its first contacts with Vale's design firms, virtually all stability analyses adopted the slip circle method surfaces. This method is excellent for homogeneous soils. However, when materials of very different strengths exist in the

dam embankment and/or its foundation, the most likely failure surfaces are not always circular. The Committee recommended to the designers the search of factors of safety using the option of surfaces not necessarily fully circular, such as circle arcs and linear segments, when appropriate. In a short time, analyses were obtained with more correct and less optimistic results, and more realistic factors of safety were determined.

Inclinometry

Inclinometers are excellent indicators of failure surfaces when movement is underway. Dams and natural slopes had few inclinometers installed. The Committee recommended the installation of more inclinometers, which was implemented.

Survey points

Virtually all important dams have survey points to monitor the movement of the downstream slope and the dam crest. The readings may be optical, robotic, or laser. In addition, Vale has the SAR, which indicates the measurement of the displacements of an area through measurements obtained with the use of satellites. The displacements obtained are those of the embankments outer surface. When complemented by inclinometer information, a detailed scenario of the movement as a whole is obtained.

Magnetic settlement indicators ("Tassometer")

Some downstream-raised dams exhibited cracks during raising (Itabiruçu, Maravilhas III, for example). The use of the settlement indicators showed that the settlement was due to the deformability of more compressible materials located in the foundation. These materials undergo significant deformation when subjected to the weight increases of the earthfill layers of the raises and induced traction cracks in the new embankment.

Permeability testing

Few permeability tests had been performed before the Committee's work began. Permeability coefficients were generally adopted according to the clay clayey or non-clay clayey character of the materials used in the dams. In some cases, an exaggerated relationship of 10 between the horizontal and vertical permeability values was used, that is, a horizontal permeability 10 times higher than the vertical permeability, without support in tests.

The Committee recommended greater use of permeability tests on undisturbed samples from the existing earthfill and foundation or on compacted samples from the earthfill in the case of downstream raises currently underway.

Foundation treatment

Techniques used in foundations and earthfill on soft soils that were rarely used, or even unusual in tailings dams in this country, have had recent applications in Vale's structures to solve complex foundation problems.

Jet grouting is widely used in the treatment of permeable granular soils for the formation of cutoff curtains and as reinforcement for the treatment of soft soils for

foundations in problematic soils due to lack of bearing capacity. However, the use of this method is not usual in dams for tailings disposal.

A hollow rod is introduced into the soil. Once the desired depth is reached, the rod is lifted slowly, with a rotary movement, with water injection at very high pressure to soften the natural soil and to mix it with a cement grout injection afterwards. As the jet of cement grout mixes with the soil, soil-cement columns are formed. These columns can have diameters from 40 cm up to 200 cm. A marked drop in the permeability of granular soils or an increase in the compressive strength of fine soils is achieved after the curing time. Desired results can be controlled by dosage of the cement. This method is being applied in the treatment of the compressible foundation of the Maravilhas III dam described below.

The Giken's Gyro Press method was selected and will be applied for the first time in Brazil, to introduce a curtain of metal piles on the ground, practically without transmitting vibration to the soil. This method combines static pressing and rotation of a steel pipe to the desired depth. The bottom of the pipes is filled by the soil that has been penetrated by each pipe and the top of the pipe is filled by carefully placed concrete without impact so as not to induce vibrations. This process will be used very soon for the containment structure of the Minervino dike and the Cordão Nova Vista, described below.

The *deep soil mixing* (DSM) method is generally used to improve the bearing capacity of soft clayey soils under earthfill. It is similar to *jet-grouting*, but the injection pressures of the cement grout are much lower. The resulting columns are semi-rigid, formed by the blending of soil with a particular binder, in this case cement. In the wet method, the binder blended with water is injected into the soil through a rotary tool that promotes homogenization of the soil-cement mixture. Under these conditions it is possible to achieve strengths of up to 3,000 kPa and stabilization of soft soils to depths of up to 20 meters. The nominal diameter of the columns can be controlled and ranges from 40 cm to 100 cm. This process was very recently employed in the reinforcement of the base of EMESA's pile as described below.

Main technical recommendations of the Committee

This item summarizes the main recommendations made by the Committee in its reports and technical notes. Observations of tailings dams, dams that accumulate water for various purposes, including for electric power generation, containment structures, compacted earthfill dams for disposal of tailings and sediments, dikes, waste piles and tailings piles are included. In total, this item brings together 350 recommendations on 50 different dams and dikes, on 4 containment structures and on 4 piles.

The structures, whose recommendations are summarized below, are listed in alphabetical order to make it easier to consult.

8B (Dam)

Report RL-04/19, issued on June 26, 2019.

- The thicknesses designed for the transitions to be performed must be increased from 25 cm to 40 cm or 50 cm horizontally.

B-1 (Dam)

Technical Note NT-11/20, issued on November 19, 2020.

- Recommendation for monitoring the progress of the two cracks in the crest.
- Recommended safety actions and accident prevention.
- Recommendation to study and implement an additional barrier further away from B-1 in an area without a thick layer of dispersed tailings.

Area IX (Dam)

Technical Note NT-10/20, issued November 11, 2020.

- The cross-section of the dam is very heterogeneous.
- There was no control of the material that forms the dam.
- Stability analyses have presented satisfactory results, however with estimated parameters.
- Revision of stability calculations is recommended.
- Further analysis and characterization of the materials is recommended.

B-7 Viga (Dam)

Report RL-10/19, issued on October 24, 2019.

- There is a need to maintain the reservoir at the current water level and carry out works that will increase the factor of safety for reservoir at its maximum water level scenario.
- Complement the stability analyses with composite surfaces (plane-circular), considering the part that intersects the drainage blanket with zero cohesion.
- Careful implementation of filter located at the interface of current and future earthfill with efficient drainage capacity is imperative.

Report RL-13/19, issued on December 27, 2019.

- It is important and essential that the water level in this reservoir is not to be raised. To do so, constant pumping to downstream of the dam shall be maintained.
- Measures that can be implemented to improve the stability of the dam: spigotting from the crest, to create a beach, lowering the water table in the dam

embankment; curtain of relief wells connected to the drainage blanket, executed from the first upper berm; reinforcement with downstream berm and filter at the interface of the earthfill berm with the current downstream dam slope.

Report RL-15/20, issued on January 31, 2020.

- Emphasized the need to maintain the pumping of the reservoir to prevent water level raises.
- It is emphasized that it be carefully examined, and that attempts be made to avoid excavations downstream of the dam, and to examine the possibility of constructing an additional berm enveloping the low-strength soil of the site downstream of the dam.

Report RL-18/20, issued on March 18, 2020.

- Redo the hydraulic study of the design flood conveyance based on volumes corresponding to elevations greater than 923.00 m and based on values or on the equation of the spillway flow rate curve.
- Define the operating criteria for tailings disposal and its final positioning in relation to the reservoir so that, based on these criteria, the calculation of the future volume is truly useful for abatement of the flood wave flowing into the reservoir and, consequently, the definition of the minimum freeboard for the final scenario of dam operation is obtained.
- It is necessary to evaluate in detail the influence of the excavation proposed in conceptual design – up to 12 m deep in the region just downstream of the dam toe - on the stability of the downstream slope of the existing dam during the first phase of construction of the proposed earth buttress. Stability analyses of the current embankment considering this excavation of the alluvium may certainly require even lower water levels in the reservoir than is currently maintained.
- The need for the large extent of the removal (about 100 m) proposed in the conceptual project was questioned – excavation that would later be filled by rockfill - because the new berm will be supported practically outside of this large excavation.
- At the lateral ends (dam abutments) of the berm proposed for reinforcement, perform studies to allow important reductions in width (and quantities) of the berm.
- Review DAM Engenharia's calculation package (CP) that was presented, to include, for example, the permeability coefficients of the granular materials of the filters, transitions and drains. Also, present the justification for the 1/10 ratio of permeability coefficients of compacted earthfill. Also, include the drainage and transition layers in Fig. 2.3. For Fig. 4.5 of the CP, where the groundwater line does not correspond to the flow and equipotential lines shown in the seepage analyses for the full operating condition of the reservoir. The saturation surface of Figure 4.5 assumes the stack chimney filter with efficient performance (which does not occur in the prototype) and located slightly upstream of its actual position. Even with a much higher flow network, with the downstream

shell with a much higher saturated zone, the factor of safety obtained in the analysis apparently does not change, and remains at 2.1, very close to 2.2 as shown in Figure 4.5.

- In the two interfaces of the buttress berm with the two abutments that have large hydraulic gradients, and even at the bottom of the valley, finger drains can be adopted instead of continuous blankets.
- Review the drainage details of the toe berm, as the need to perform a compacted earthfill inside the excavation, enveloped by filters, has been questioned. The rockfill can serve as a base at the foot of the dam. Include a water outlet detail of the internal drainage that allows measuring the effluent flows from the dam embankment.
- The height of the berm (thickness of the earthfill) is small in the vicinity of the toe. Excavation and replacement of the alluvium by rockfill can be avoided by introducing reinforcement in the region of the berm slope toe.
- The lack of information on the characteristics of the clayey earthfill of the dam and its filters makes it important to recommend that the berm, even if slightly thick, is to be extended to the maximum normal water level of the reservoir and that there must be a drainage transition layer between the materials of the current earthfill and the berm.
- The execution of a relief well line located downstream of the inoperative chimney filter must be studied. These relief wells should cross the drainage blanket and reach the foundation ground.
- The sloped layer of clayey soil that in the DAM reports appears in the cross sections near the downstream toe of the current dam, if any, should be removed and replaced by drainage transition, and if not already existing, should not be performed.

Report RL-39/20, issued on October 29, 2020.

- Hydrological studies confirm that possible risks of dam overtopping are negligible due to the incidence of extraordinary floods and extreme discharges.
- It is recommended that the tailings discharge operation and the influence on the variation of the reservoir volume for attenuation of the hydrographs of extreme floods incident to the reservoir be detailed.

Technical Note NT-10/20, issued on November 11, 2020.

- A new stability analysis was requested on surfaces crossing the saprolite.
- Stability recalculation recommended.

<u>B-VI Córrego do Feijão (Dam)</u>

Report RL-10/19, issued on October 24, 2019.

- The repair of the spillway concrete channel should ensure the adhesion between the new concrete and the existing one.

Barnabé (Dam)

Report RL-19/20, issued on April 13, 2020.

- If there is no design, an "as is" must be developed.
- The factors of safety are within the current standard.
- There are erosions and exposed reinforcement in the concrete spillway structures.

Barnabé I (Dam)

Report RL-19/20, issued on April 13, 2020.

- The factors of safety are within the current standards.
- Treat water emergences in downstream areas.

Borrachudo I (Dam)

Report RL-04/19, issued on June 26, 2019

- It is necessary to check the extreme incoming discharges for the designs of the Borrachudo I and Borrachudo II flood spillways and check the risk analysis. Apparently these two aspects of these two dams are not compatible with each other.

Borrachudo II (Dam)

Report RL-04/19, issued on June 26, 2019.

- It is recommended to check the hydrology and risk classification because they appear not to be compatible with the Borrachudo I dam.

Report RL-36/20, issued on September 10, 2020.

- Anomalies in the Borrachudo II flow network are likely due to the clayey layer on the drainage blanket.
- It is recommended to resume the investigations and the testing on undisturbed samples already collected.
- It is recommended to install piezometers upstream and downstream of the vertical filter.

Campo Grande (Dam)

Report RL-04/19, issued on June 26, 2019.

- The execution of new tests to determine parameters for more accurate stability analysis may lead, in the short-term, to favorable conditions for the beginning of reinforcement works and subsequent decommissioning.

Report RL-31/20, issued on September 3, 2020.

- In addition to the low piezometric levels, the CIAE-SB recommends and agrees that the proposed reinforcement should be adopted for de-characterization.

Capão da Serra (Dam)

Report RL-02/19, issued on April 3, 2019

- Recommended verification of the spillway system that was changed from the morning glory installed in 1996 to a free crest spillway on the downstream dam slope in 2004, then to a free crest spillway located on the right abutment in 2005.

Candonga (Risoleta Neves) (Hydroelectric Dam)

Technical Note NT-04/20, issued on June 29, 2020.

- Criteria for the design of concrete dams have proven to be very conservative.
- The Candonga dam was subjected for a long time to stresses far superior to the most conservative ones admitted in the design and maintain the stability intact.
- Additional investigations should be developed to calculate the long-term operation of the dam.

Capim Branco (Dam)

Report RL-10/19, issued on October 24, 2019.

- Defects in the spillway channel must be repaired in the short term.
- Vale must numerically define the partially clogged internal drain criterion, to be adopted by all designers in the stability analyses.

Report RL-42/20, issued on December 4, 2020.

- The spillway is compatible with conservative hydrological design criteria.
- The design should be adopted.

Capitão do Mato (Dam)

Technical Note NT-14/20, issued on December 10, 2020.

- Urgent recommendation to execute deep horizontal drains (DHDs).
- Inclinometer installation recommended.
- Seepage analysis on the unstable slope downstream of the left abutment is recommended.

Technical Note NT-17/21, issued on January 10, 2021.

- The urgency of installing the DHDs on the unstable slope to the hydraulic right of the spillway channel was reiterated.
- The suggestion of installing an inclinometer on the slope downstream of the right abutment was reaffirmed.

Report RL-43/21, issued on January 11, 2021.

- The Committee agrees with the recommendation to keep the water level of the Miguelão reservoir lowered to create standby volume for the 2021 rainy season.
- It is recommended that a small decimetric raising of the crest of the Miguelão dam be studied, which would possibly resolve the conveyance of the flood in the three dams of the area, namely Miguelão, Capitão do Mato and Codornas. The raising of about 30 cm to 40 cm can be done with earthfill on the crest of the Miguelão dam or with interlocking concrete parapets.
- It is recommended to improve/deepen knowledge of the Miguelão dam.

Technical Note NT-18/21, issued on January 12, 2021.

- Recommendation that DHDs on the right abutment should not be limited to only 30 m.
- The Committee accepts the suggestion of installing INAs but only after installing DHDs on the right slope downstream of the abutment.

Cianita 2 (Dam)

Report RL-04/19, issued on June 26, 2019.

- Protect the upstream sand filter.

Dicão Leste (Dam)

Report RL-31/20, issued on September 3, 2020.

- Lowering 5 m the crest of the dam was a positive safety measure.
- There is concern about the lack of internal drainage of the dam embankment.

- It is recommended to deepen the knowledge of the soils located downstream of the dam toe.

Doutor (Dam)

Report RL-04/19, issued on June 26, 2019.

- Initiate water level monitoring as soon as possible.
- Perform a new stability analysis.

Report RL-21/20, issued on April 20, 2020.

- Examine alternatives for utilizing reinforced earth walls to decrease the volume of earthfill of the reinforcement structure.
- Consider adopting a filter of a minimum thickness of one meter horizontally at the interfaces between the current slope and the reinforcement soil and between this and the berm abutments.
- It is suggested to adopt finger drains at the contact of the berm earthfill and its foundation.
- Detailed geotechnical investigation of borrow areas and deposits should be carried out to characterize the materials of the reinforcement structure and technical specifications should be written for simplified execution of the berm.
- A study of additional lowering of the water level beyond that stipulated by the design is suggested, if feasible.

Report RL-27/20, issued on July 24, 2020.

- The probability of overtopping the dam is practically zero.
- The spillway channel design should be adopted.

Report RL-31/20, issued on September 3, 2020.

- It is recommended to study the stability of the selected sections with more detail, considering the left abutment confinement.

EMESA (Pile)

Report RL-06/19, issued on August 26, 2019.

- There is uncertainty regarding the stability of the pile due to the geotechnical uncertainty of its components, the construction method and the position of the water table during the wet period.
- Apparently, as of August the only information about the pile was the due diligence report.
- Stopping operations on the pile and transfer the people and the facilities located at the toe of the pile are recommended.

Report RL-10/19, issued on October 24, 2019.

- The Committee raised uncertainties regarding the stability of the pile due to the lack of investigations and the heterogeneity of the materials placed in the pile.
- It was informed that DAM would recommend stabilizing the pile with buttressing, to which the Committee agrees.

Report: RL-11/19 of 11/04/2019.

- Triaxial tests showed strong contractile behavior, consequently the material is subject to liquefaction.
- Soil laboratory tests may have been interpreted to obtain optimistic parameters for pile stability analyses.
- The pile has factors of safety below those recommended by current legislation.
- Factors of safety in seismic event situations will be even lower.
- The presence of people in the pile area should be minimized as much as possible.
- Because it is extremely heterogeneous, the current stability calculations are not accurate.
- The minimum factory of safety to be reached for undrained condition should be 1.3.
- The minimum permissible factor of safety for drained condition must be 1.5.
- The minimum permissible factor of safety for undrained condition under seismic events must be 1.1.
- The acceleration of 0.05g for the design seismic event must be provisionally adopted.
- The reinforcement earthfill to be constructed to increase the safety of the pile must have construction/compaction conditions that ensure dilative behavior.
- It is recommended that weekly readings be taken of the INAS installed in the pile.
- It is recommended that alert levels be established for different water table levels.
- Check the possibility of implementing displacement monitoring with a total station, preferably robotized.
- Check the possibility of estimating displacements by interferometry.
- Conduct studies for protection of the two lines of the COPASA pipeline system.

Technical Note NT-13/20, issued on November 26, 2020.

- Specification for the soil mixing treatment must be included in the design.
- Stability studies by non-circular surfaces are recommended.
- It is recommended that the design include details of the construction steps and construction planning.

Report RL-13/19 rev. 1, issued on December 27, 2019.

- Evaluate the possibility of mixing cement (in situ soil mixing) with the tailings slurry of the existing pockets, in order to avoid the removal of slurry from the

pockets. Another possibility will be the formation of a stabilization berm enveloping the large pocket of tailings at the toe of the pile.
- Install three inclinometers.
- The procedure of excavating the large deposit of tailings and low strength soils about 15m thick, applied at the bottom of the pile near its toe, is not recommended.

Technical Note NT-06/20, issued on September 10, 2020.

- The design shall include the technical specification of soil mixing.
- The design should consider non-circular failure surfaces.
- The design shall indicate construction steps and construction planning.

Technical Note NT-10/20, issued on November 11, 2020.

- It is recommended to review the stability analyses and perform more testing.

Technical Note NT-22/21, issued on April 9, 2021.

- The natural ground profile should be shown in the drawing.
- The stability analysis results should include two decimals.
- The large dispersion of the total stress tests should be explained.
- It should indicate the location where the temporary material stockpiles have been, are and will be placed.

Estreito (Hydroelectric Power Plant)

Report RL-15/20, issued on January 31, 2020.

- The occurrence of head losses downstream of the tailrace channel may be leading to electric power generation losses. It is recommended to verify these possible losses and their economic consequences.
- Perform studies to define the origin of the yellowish material carried by percolation in various relief drains of the inspection and drainage gallery and the consequences for the safety of the structures by eventual clogging of the subsurface drainage system.
- Perform studies that define the cause of the existence of voids in the foundation massif under the inspection and drainage gallery and possible treatments by fillers with cement slurry injections or by chemicals.

Fábrica (RCC containment structure downstream of the Forquilhas and Grupo dams)

Report RL-05/19, issued on August 1, 2019.

- Provide for additional care of detailing the joints of the end blocks in RCC to avoid damaging effects of forming contraction cracks on the contact of these blocks with the adjacent ones.

Report RL-07/19, issued on September 9, 2019.

- It is very important to confirm the reduction of the tailings slurry volumes to be contained, which resulted in a significant reduction of the dam height (of 18 m).
- It is necessary to consider, in the dam stability analyses, the segments of low recovery detected in the foundation investigations, as in SR-45.

Report RL-10/19, issued on October 24, 2019.

- Provide petrographic analysis of gneiss samples from quarries supplying gravel.
- The spacing between transverse contraction joints should not exceed 20 m.
- Perform rotary drilling inclined at 45° in the left river bank.
- Perform vertical rotary drilling in one of the river banks.
- Remove the thick layer of residual soil in the dam foundation, a layer detected by the SM-21 drill hole.

Report 12/19, issued on November 28, 2019.

- The conventional concrete applied to the upstream and downstream walls, after it has been poured, must immediately receive the RCC to obtain an efficient seal between the two types of concrete. The conventional concrete wall that was executed in a location of the structure was practically hardened, without having placed the RCC adjacent to it. This concrete should be removed and replaced at that site, and the adjacent RCC should be immediately placed to have an efficient seal between the two types of concrete.
- In the case of a possible change in the design of the containment structure to construct it in two steps, so that its top level is reached more quickly, these two steps were suggested: remove the RCC steps already hardened, all loose grains disaggregated on the floor and in the vertical rungs of the steps where the contact of the two steps will be made; place the seal mortar on the horizontal level of the steps and the joints to the vertical walls of these steps. The mortar should have a thickness of 15 cm and a height of 15 cm; immediately after placing the surface concrete on the mortar, place the transition RCC that will be vibrated along with the surface concrete. With this vibration, the sealing mortar will rise through the vertical wall, producing a better connection in the joint.

Report RL-15/2020, issued on January 31, 2020.

- Sprinkle water in the form of mist on the surface of the RCC.

Report RL-17/2020, issued on March 17, 2020.

- In the vertical construction joints, before the application of the RCC, a plastic tarpaulin must be placed on the surface of this joint, so that the new RCC does not adhere to it, except near the upstream surface, where conventional concrete must be applied to a depth of 1.5 m.

Report RL-23/20, issued on April 29, 2020.

- Adopt the spillway design.

Technical Note NT-08/20, issued on October 28, 2020.

- There is no mention of acceptance and cement tests in the construction work.
- The fck for secondary concrete in the gate guides was specified unnecessarily too high.
- Sand tests applied in the construction work indicate that there is no evidence of reactivity of gneiss and hematite aggregates with cement alkalis.
- The specific mass of hematite is very high, which favors the stability of the containment structure.
- The gaskets do not meet the requirements specified by NBR NM 07.
- The specific mass of the RCC meets the design requirements.
- The cement consumption in the RCC is in accordance with the stipulation in the concrete mix design.
- The RCC in the hardened condition meets the design strength at the age of 90 days.
- The two crests (in both stages of construction) should not have concrete with fck of 30 MPa.
- In the first stage, the lower crest should not have the spillway ogee as designed.
- Those responsible for the construction maintain excellent material qualities, which has been successfully achieved.

Technical Note NT-15/20, issued on December 18, 2020.

- The utilized materials are of adequate quality.
- Constructive problems faced and solutions adopted should be disclosed.

Report RL-46/21. Issued on February 7, 2021.

- The aggregate-alkali reaction tests with artificial gneiss sand from Pedreira Irmãos Machado should be repeated.
- Chemical additives should be stored in covered facilities.
- Explain the reasons why degrees of compaction greater than 100% are being achieved.
- Explain the reasons why there are significant variations in concrete modules.
- Explain the reasons why the compressive strength at 7 days for the BGTC (well graded stone treated with cement) is below that required by the standards.
- Explain why for numerous RCC concrete mix designs the average slumps are out of range.
- Explain why obtaining numerous standard deviation results are above 6 MPa that indicate low control standard.
- Inform why the T22 thermometer is inoperative.

Report RL-48/21, issued on March 18, 2021.

- The reports must be reviewed before issuance to avoid frequent errors and omissions.
- Complete results of the tests carried out on each concrete mix design should be provided.
- The report should include a detailed analysis of the reasons that are causing lack of uniformity in the results of the moduli of elasticity obtained and reported.
- The locations of newly installed thermometers must be reported.

Report RL-49/21, issued on April 13, 2021.

- Inform the reasons why the sieve #200 fines determined by CMM are superseding those determined by other laboratories.
- Repeat the reactivity test of the artificial sand from Brucutu-Vale, utilizing cement with high alkali content and without additives that mitigate the reaction.
- Justify the low values of theoretical unit weight presented in Table 7.
- Justify why there are compaction percentages above 100%.
- Justify the reason why the real cement content has only been determined for mix design RCC 9-3 and report the tolerance accepted for the difference between the cement content accepted at the plant and the cement content specified for the concrete mix design.
- Justify the significant variation of the values obtained for the deformation modulus for the several RCC mix design.
- Justify the non-conformities observed in the slumps and compressive strength of the conventional concrete and indicate if it would be appropriate to re-evaluate the Prodocós program.
- Provide the reason why thermometers T39 and T40 were not plotted in the drawings and why there is no information of the RCC concrete mix design where those thermometers are located.

<u>Fernandinho (Dike)</u>

Report RL-04/19, issued on June 26, 2019.

- Perform more frequently monitoring of the water levels in the tailings and/or their surroundings to verify that the removal of tailings accumulated in the dike can be initiated in the short term.

<u>Forquilha I (Dam)</u>

Report RL-19/20, issued on April 13, 2020.

- Three operational piezometers have constant readings; probably clogged. The other piezometers are inoperative.

Forquilha II (Dam)

Report RL-04/19, issued on June 26, 2019.

- It was suggested to analyze the execution of the granular material buttress at the downstream toe of the dam by dropping the earthfill material from the banks.

Report RL-19/20, issued on April 13, 2020

- The effects of mitigating actions cannot be assessed by instrumentation.

Forquilha III (Dam)

Report RL-04/19, issued on June 26, 2019.

- It is necessary to deploy a downstream RCC containment structure as soon as possible to contain the slurry resulting from a potential imminent dam failure.
- After the implementation mentioned above, the reinforcement of the downstream dam slope should be performed.

Report RL-19/20, issued on April 13, 2020.

- Piezometers do not respond adequately in a reliable manner.

Forquilha IV (Dam)

Report RL-12/19, issued on November 28, 2019.

- Complementary stability analyses shall include tensile cracks at the crest of the upstream failure surfaces.
- Study the execution of a reinforcement with properly compacted borrow material, from the bottom of the downstream slope to just a little below (about 10 m to 15 m) of the dam crest. From that point on, the materials that are currently at the top of the dam must be repositioned and compacted on the reinforcement borrow materials, thus converting this dam to a downstream raised structure.

Report RL-13/19 rev. 1, issued on December 27, 2019.

- Carry out studies aiming to convert this center line raised dam to a downstream raised dam

Report RL-15/20, issued on January 31, 2020.

- In the stability analyses, promote convincing upstream failure simulations. The CIAE-SB estimates that this type of failure does not cause a breach opening that would cause downstream water or slurry flow, as long as the water and tailings levels in the reservoir remain as they are at present.

Report RL-19/20. Issued April 13, 2020.

- Factors of safety against downstream collapse are acceptable.
- The cracks in the upstream slope parallel to the dam crest are without apparent movement.

Geladinho (Dam)

Report RL-16/20, issued on February 29, 2020.

- The Committee considers it important that the teams in charge of inspections keep the focus on observations of possible increases in the presence of colloids (at the exit of the internal drainage, next to the Parshall 01 channel) and on the increase of piezometric levels in piezometers PZ-04 and PZ-09.

Gelado (Dam)

Report RL-16/20, issued on February 29, 2020.

- A careful review of the earthfill shear strength parameters is recommended, including verification of the sensitivity of the factor of safety to variations in the value of the cohesion in question.
- The number of consulting engineering companies involved (more than a dozen) in dam design and safety assessments is strange and somewhat disconcerting. This large number of companies can generate discontinuities in concepts and lack of overall vision and dam history.
- Repair services on the spillway apron and side walls are necessary, at least in the medium term, both for filling the cavities and for treating cracks.
- Treatment of infiltrations in the lateral walls should also be performed, aiming to cease existing infiltrations and thus preserve the structure of the walls, giving them greater durability.
- It is strongly recommended that the reinforcement of the dam now under design by WALM, increases the factor of safety from 1.5 to something around 2.0 be completed as soon as possible.
- When this design is completed and sent to the Committee, along with the updated instrumentation data (piezometry, rainfall, prism movements, inclinometer readings and affluent and internal drainage discharges), the Committee will provide an opinion.

RL-20/20 report, issued on April 17, 2020.

- Aeration of the spillway apron is unnecessary.
- The maximum instantaneous peak of the design incoming flood is 229 m^3/s. The flow rate calculated in the report for the effluent is 356 m^3/s. However, as the durations of the extreme rainfall were different, different attenuation levels

were generated, with the maximum reservoir water level being higher according to the design, and therefore, is more conservative.
- Calculation of the hypothetical flood that would cause zero freeboard would be 1,100 m^3/s, which is unlikely for the small drainage area of the dam.
- It is recommended to carry out a study of lamination of the affluent flood to the reservoir, for deposited tailings conditions that reduce the useful volume for attenuation of extraordinary effluent flood peaks.

Germano (Dam)

Technical Note NT-10/20, issued on November 11, 2020.

- The Sela, Selinha and Tulipa dikes should be more reinforced.

Technical Note NT-20/21, issued on January 21, 2021.

- As a solution for overflow discharges, it is suggested considering an alternative tunnel to avoid large and high excavations for channels that demand intense maintenance activities.

Gloria (Hydroelectric Power Plant)

Report RL-15/2020, issued on January 31, 2020.

- Submission of the hydrological studies that established the spillway design discharges and its hydraulic design is requested.
- The suspicion of an alkali-aggregate reaction must be tested. In case of a positive result, mitigating measures should be provided.

Gongo Soco (RCC containment structure downstream of the mine)

Report RL-05/19, issued on August 1, 2019.

- The geological conditions of the foundation rocks require caution and knowledge of the field and design teams and careful monitoring.
- Plan for additional care in detailing the joints of the end blocks in RCC to avoid the damaging effects of the formation of retraction cracks on the contact of these blocks with the adjacent ones.

Report RL-07/19, issued on September 9, 2019.

- The differences in strength between the foundation rock of the left and right abutments are not ideal for a RCC structure foundation that may have to contain tailings currently stored in the Sul Superior and Sul Inferior dams. However, it is

acceptable to continue construction under these conditions, taking into account that the structure in RCC is temporary.

- It is very important to always proceed carefully with acceptance of the foundation in the right abutment, in order to detect pockets of soft rock. These pockets have to be removed and replaced by concrete mass placed as dental concrete if in restricted areas and volumes, or in RCC in larger areas and more representative volumes.
- It is essential to properly store the boxes containing the core from the rotary drilling. In addition, the boxes should be of better quality because, as they are, they are not adequately protecting the core samples.
- Consider the occurrence of a potential seismic event in the stress-deformation analysis for the third loading stage of the RCC structure.

Report -08/19, issued on September 16, 2019.

- Provide the Committee reports to the design company.
- It is convenient to apply shotconcrete on the excavated surface of the foundation rock.
- Forward to the designer firm, for evaluation, the suggestion of placing a concrete blanket reinforced with mesh on the areas of softer rock foundation.
- Review the specification of the concrete for the containment structure because there are differences in relation to the Quality Manual prepared by VALE for these construction works.
- Test other solutions to reduce cement consumption, such as the use of more efficient additives.
- The spacing of the vertical contraction joints shall be reduced from 25 to 20 m.
- The location of the transverse contraction joints must be in accordance with the development of the foundation rock profile, and it is always necessary to place a joint where there is in this profile, a significant abrupt irregularity.

Report RL-10/19, issued on October 24, 2019.

- Determine, for the cement used in the roof support sheats, the sulfur content in the form of sulfide, if CP III 40 type cement is being used.
- Adjust the concrete plant to reduce the variation in cement consumption.
- Place the dosage of each concrete mix design on the statistical control board of the resistance of each concrete mix.
- Immediately repair the cracks that could appear in the leveling concrete.
- The need for anchoring the last RCC block into the left abutment is reiterated.
- Improve the uniformity of the leveling layer.
- Review the value of the net tensile strength adopted for the stress-deformation studies.

Report RL-12/19, issued on November 28, 2019.

- Negative rock slopes will be left at the foundation of the left abutment. In this type of condition (negative slope), cavities may form which would allow the seepage of water and slurry from upstream to downstream. To correct/minimize these features, it is recommended to eliminate these negative slopes by careful excavation and/or the execution of localized dental concrete.
- Immediately repair the cracks that appear in the leveling concrete.
- Provide injection of cement or resin syrup into the transverse joint near the left abutment, so that it does not move.
- The finishing of the containment structure against the rock in the left abutment is precarious, which may bring problems in the future, such as water infiltration, cracking.

Report RL-17/20, issued on March 17, 2020.

- Send the final report of the containment RCC structures to the Committee.

Report RL-22/20, issued on April 26, 2020.

- The spillway design discharge is to be adopted.

Technical Note NT- 03/20, issued on June 25, 2020.

- Despite the speed employed in the construction of the RCC structure, the foundation treatment was adequate.
- Direct shear tests showed that if failure were to occur, it would occur below the concrete/rock contact.
- The containment structure was designed as a temporary structure to contain all the tailings accumulated in the Sul Superior and Sul Inferior dams (conservative hypothesis), which characterizes this structure as having a short expected useful life.
- The Committee corroborates the opinion of Vale technical staff and their consultants, that the stability conditions of the containment structure are satisfactory for the purposes that it was designed.

Report RL-28/20, issued on July 29, 2020.

- The results of the technological control of the construction of the containment structure for the Sul Superior and Sul Inferior dams are satisfactory and met the design requirements.
- It is recommended to implement monitoring and follow-up of the structure.

Grupo (Dam)

Report RL-04/19, issued on June 26, 2019.

- The execution of new tests to determine parameters for more accurate stability analysis may lead, in the short term, to favorable conditions for the beginning of reinforcement works and subsequent decommissioning of this structure.
- It was recommended performing new investigations, tests and stability calculations for undrained condition, in order to verify the possibility of, with new and more accurate basis, the factor of safety could be improved.

Report Rl-19/20, issued on April 13, 2020.

- The factors of safety are not provided.

Itabiruçu (Dam)

Report RL-03/19, issued on June 18, 2019.

- The chimney filter of the second dam phase must be constructed such that it has its upper end under the downstream end of the dam crest.
- It was strongly recommended that the outer walls of the spillway gallery located under the compacted earthfill on the left abutment be inclined by 10V:1H minimum.
- It is recommended to include a infiltration collar around this gallery.
- The Engecorps designer should carry out a detailed study on the possibility of seepage through the right abutment due to the water level increase of about 17m in the reservoir when it will be raised to near El. 850m.
- It is necessary to perform a three-dimensional stress-strain analysis along the gallery, with substantiated parameters.

Report RL-07/19, issued on September 9, 2019.

- Discretely scrape the surface of the slope downstream of the old earthfill in steps before placing the layers of the new earthfill.
- The upper end of the chimney filter must be moved downstream and, from the joint of the new earthfill with the first phase, continue tilted.
- The works, which are paralyzed, can be resumed (provided that the designer company has finished its study of the dynamics of the settlements that occurred and that it agrees with the present opinion of the Committee), provided that the readings of the surface survey points are continued and interpreted twice a day and that the rise of the earthfill is initially limited to two layers daily. The daily analysis of the readings of the surface survey points will allow to decide the continuation of the earthfill construction or whether a new interruption is needed. In any case, when the rains start, the work should be interrupted until this rainy season ends.

Report RL-12/19, issued on November 28, 2019.

- In the reinforcement of the spillway gallery, when concreting a plane structure such as a slab on a concrete base already hardened, it must be ensured that there is perfect adhesion between the two concretes, because otherwise there may be warping of the new slab depending on seasonal variations.

Report RL-36/20, issued on September 10, 2020.

- The cracks were probably due to the settlements caused by the berm construction on a compressible foundation.
- Further studies of the settlements based on the results of the piezometry and settlement monitoring are recommended.

Technical Note NT-21/21, issued on February 15, 2021.

- The verification of the factor of safety for the final raising scenario to El 850 m is recommended.
- Study design alternatives proposed by the Committee if the factor of safety for the final raising scenario does not meet the standards.
- Recover or replace damaged inclinometer 101.

<u>Laranjeiras or Norte Laranjeiras or Laranjeiras Montante (Dam)</u>

Report RL-13/19 rev. 1, issued on December 27, 2019.

- Seal the crack on the downstream slope with gravity cement grouting.
- Do not raise the reservoir level and constant attention should be given to the results of the instrumentation readings until the reason for the crack opening can be understood.

Report RL-15/2020, issued on January 31, 2020.

- Provide consolidation tests on samples of the left abutment and of the embankment.
- The results of the tests performed during construction, carried out at the request of the consultant Prof. Paulo Teixeira Cruz are to be sent to the Committee.

Report RL-26/20, issued on June 26, 2020.

- The probability of overtopping of the dam is practically zero.
- The hydrological design is to be adopted.

Technical Note NT-19/21, issued on January 21, 2021.

- It is recommended to perform a 3D stability analysis.
- Avoid injecting bentonite slurry to decrease the permeability in the dam soil fractures.

Machadinho (Hydroelectric Power Plant)

Report RL-15/2020, issued on January 31, 2020.

- The material transported by the river and deposited downstream of the tailrace channel may be negatively influencing the electric power production. It is suggested that consideration be given to verifying these possible losses in electric power generation and their possible economic consequences.
- Perform an updated assessment of the necessary instrumentation and the replacement of inoperative or inadequately responsive instruments.

Mar Azul (Rockfill containment structure downstream of the mine)

Report RL-07/19, issued on September 9, 2019.

- Much care should be exercised during placement of the five transitions of the thalweg drain, due to its small thickness of 0.50 m.

Report RL-14/2020, issued on January 8, 2020.

- Consider anchorage of the inclined spillway apron in the residual soil foundation in the design.

Report RL-15/2020, issued on January 31, 2020.

- Consider an anchorage system for the slabs of the spillway apron in the foundation ground.

Report RL-17/2020, issued on March 17, 2020.

- No anchorage was made to better adhere the slab of the spillway apron to the foundation soil. It is recommended anchoring the spillway apron to the foundation.
- The definitive design documentation, specifications and results of the concrete technological control of the containment structures has not been sent by Vale, which has so far hindered the analysis of these construction works.
- Provide to the Committee the results of studies, designs and technological control of concrete works of containment structures, in an official manner.
- Request from the design supervisory technical teams and construction supervisors a critical analysis of sizing and construction processes and, if in doubt, resort to specialized external consultants.

Report RL-24/20, issued on May 31, 2020.

- It is recommended that the hydrological and hydraulic design of the spillway be adopted.

Report RL-35/20, issued on August 31, 2020.

- The results of the technological control of concrete indicate that the structures are satisfactorily constructed.
- Regarding design and construction aspects, deficiencies that had been recommended to be avoided were reported by the Committee.

Technical Note 07/20, issued on October 14, 2020.

- The design should require a thorough finishing on the surface of the upper layer of the spillway system that should have a strength of 30 MPa instead of 25 MPa.
- There should be anchors between the side wall and the spillway ogive.

Maravilhas II (Dam)

Report RL-34/20, issued on August 31, 2020.

- The current spillway capacity is clearly undersized by current criteria.
- It is recommended to increase the discharge capacity by implementing the second spillway.
- After the implementation of the increase in the discharge capacity of the spillway system, the possibility of overtopping of the structure is practically impossible.

Report RL-50, issued April 15, 2021.

- For any of the hypothesis of floods, including the most extreme possible to occur in the dam drainage area, the spillway system is entirely adequate.

Maravilhas III (Dam)

Report RL-01/19, issued on April 30, 2019.

- The chimney filter of the first stage should have its highest point under the downstream end of the dam crest.
- The chimney filter of the second stage must be constructed from its bottom point in order to have its top under the downstream end of the dam crest, avoiding chimney filters with horizontal or sub-horizontal segments.
- Clogging tests shall be carried out with the filter materials being used for the dam construction. Note: tests performed with satisfactory results.

Report RL-07/19, issued on September 9, 2019.

- Special attention should be given to the treatment to be performed in the contact zone between the surface of the earthfill now under construction and the future earthfill of the second stage. It is imperative to remove a thickness of approximately 0.5 m from the initial stage earthfill surface finish and excavate

the remaining surface in steps prior to placement of the second stage earthfill (raising works).

Report RL-40/20, issued on September 27, 2020.

- Treatment of the foundation with *jet grouting* may not be effective in materials with karst cavities.

Technical Note NT-10/20, issued on November 11, 2020.

- Filter plugging tests did not indicate plugging. It was recommended to continue the tests related to the compactness of the sand.
  Technical Note 16/21, issued on January 6, 2021.
- It is recommended to investigate the possible aggressiveness of natural elements to the *jet grouting* columns.

Maré I (Dam)

Report RL-19/20, issued on April 13, 2020.

- Factors of safety are at the limit of the current criteria.
- Check the stability of the slope located upstream of the reservoir.

Maré II (Dam)

Report RL-19/20, issued on April 13, 2020.

- The factors of safety do not meet the current standards.

Mello (Small Hydroelectric Power Plant)

Report RL-07/19, issued on September 09, 2019.

- If the drilling for installation of the anchors for the spillway concrete structure has been done by the rotary method, it is recommended that the drilling core be properly stored for analysis of the concrete/rock interface.
- It is recommended to carry out investigations and an *as is* design for a better knowledge of the soil embankments.

Report RL-09/19, issued on September 28, 2019.

- Out of all the fluviometric stations that served as the basis for the hydrological studies, only the Santa Rita do Jacutinga station is appropriate.
- The *Index Flood* method is not the most recommended for conducting extreme discharges. The calculation of the spillway design affluent hydrograph is recommended.

- Conveyance of the affluent flood and its attenuation in the reservoir were not made. A simplified method was adopted considering the incidence of maximum concentrated precipitation in the reservoir area.
- It is recommended performing the flood routing in the reservoir.
- Evaluation of the height-duration curve at the Santa Rita do Jacutinga station is recommended for durations of less than one day.
- Redoing of the stability calculations for the two earth embankments should be properly processed with the new parameters to be defined by laboratory soil tests.
- The concrete has heterogeneous characteristics, locally of poor quality, unconsolidated and without binder.
- The concrete/rock contact is locally open due to poor drilling core recovery. The drilling revealed precarious contact due to the lack of placing of conventional concrete layer in the concrete/rock contact.
- The RCC of the spillway structure presents many voids and high permeability.
- Seal-gaskets in the concrete structures have only been installed on the upstream face, which is detrimental.
- Chemical and bacteriological analyses are recommended to determine whether the reddish spots originate from iron-oxidizing bacteria.
- Based on the precarious results of the investigations carried out, it is recommended conducting a review of the parameters and a more accurate stability analysis.
- It is recommended obtaining undisturbed samples to carry out tests to check the shear strength of the material of the two earth embankments.
- It is recommended that instrumentation readings be taken frequently.
- It is recommended that a new investigation campaign be carried out to define whether and to what extent there are chimney filters.
- It is recommended to send to the Committee the results of the fluency tests of the anchors installed in the spillway structure.

Technical Note NT-11/20, issued on November 19, 2020.

- It is recommended to study the RCC at low levels due to the characterization of low unit weights in that area of the concrete structure.
- It is recommended to check whether concrete has alterability due to the stresses applied to the vertical anchors.
- Stability analysis is recommended considering the low unit weight values found in the concrete structure.

<u>Menezes I (Dam)</u>

Report RL-41/20, issued on September 27, 2020.

- The spillway is compatible with the conservative hydrological design criteria that was used.
- The spillway design should be adopted.

Menezes II (Dam)

Report RL-41/20, issued on September 27, 2020.

- The spillway is compatible with the conservative hydrological design criteria that was used.
- The spillway design should be adopted.

Mirim or Salobo (Dam)

Report RL-16/20, issued on February 29, 2020.

- Regarding the dam raising study, it is suggested that design alternatives be studied that include the combination of technical solutions for the crest and the downstream toe of the dam. At the crest, the raising can be studied associated with not very high walls, made of reinforced earth or pre-cast blocks in structural concrete. In the downstream toe region, solutions involving reinforced rockfill, crib-wall (as in Estreito dam, of Furnas) and RCC wall can be studied if there are appropriate foundation conditions.
- Review the criterion referring to the 1,000-year flood and its freeboard for the current condition, if the next raising above El. 225 m will take time to be implemented.
- Vale is recommended to implement as soon as possible measures 07, 08 and 09 of the Regular Safety Inspection Report (RISR) (page 104 of the WALM report).

Report RL-25/20, issued on June 5, 2020.

- The possibility of overtopping the dam is very remote. The hydrological design must be approved.
- As the disposal of the tailings is made in the reservoir in an area away from the dam, the eventual loss of useful volume for attenuation of the affluent peak flood must be verified in the future.

Monjolo (Drained pile)

Report RL-32, issued on August 25, 2020.

- The pile is very well drained, the phreatic surface is very low.
- The factors of safety are well above those considered acceptable.

- The planned studies and actions should confirm or even improve the favorable results already obtained.

Nova Maurício (Hydroelectric Power Plant)

Report RL-15/20, issued on January 31, 2020.

- Hydrological and hydraulic studies are recommended for updated determination of the design flood attenuation and the spillway system capacity.
- Pathology study of concrete structures is recommended.

Report RL-47/21, issued on March 17, 2021.

- The hydrological and flood routing studies in the reservoir should be adopted because there is no possibility of dam overtopping if the spillway gates are correctly operated.

Nova Santarém (Dam)

Report RL-44/21, issued on January 16, 2021.

- The spillway capacity is compatible with the conservative criteria of the hydrological design adopted.

Paracatu (Dam)

Technical Note NT-09/20, issued on November 4, 2020.

- The Committee recommends considering an alternative to the spillway with easier execution, using the current concrete structure that must be expanded as formwork for the definitive structure.
- The design alternative proposed by the designer must be checked as to the dimensioning of the connection between the original concrete and the new concrete.

Technical Note NT-10/20, issued on November 11, 2020.

- The Committee insists on recommending an alternative solution that is easier to implement. Themag was tasked with presenting a comparison between the design alternatives.

Report RL-45/21, issued on February 7, 2021.

- It is recommended raising of the dam crest to El.892.60 m.
- If the hydraulic section of the spillway is reduced in area as recommended by the Committee, a new hydraulic study is recommended.

Pera Jusante (Dam)

Report RL-16/20, issued on February 29, 2020.

- If the decommissioning of the dam is to be done in the remote future, localized treatment will be necessary in the concrete structures of the spillway and the approach wall, such as: filling of surface cavities, the most critical being the one in the spillway ogee upstream wall; treatment of water infiltration through the walls; removal of fungi on the surface of the structures in the places where it occurs the most.
- The Committee will give an opinion when it has received the de-characterization design being developed by WALM Engenharia and the new instrumentation data that will be obtained in the near future with readings and interpretation of piezometers, prisms, inclinometers and flow rate measurements with a Parshall measuring flume.

Santana (Dam)

Report RL-29/20, issued on July 30, 2020.

- The probability of overtopping of the dam due to the affluence of extreme floods is extremely low.
- The spillway system must be checked hydraulically because apparently during extreme discharge scenarios there may be overflow in the spillway apron generating erosion in the dam and on the right slope.

Report RL- 33/20, issued on August 26, 2020.

- The designed reinforcement will improve the structural safety condition of the dam.
- It is recommended that the transition filter between the original and the new earthfill be extended to the normal maximum water level of the reservoir.
- The original plugging of the diversion gallery located at the far upstream end of the shaft is incorrect.
- Total plugging of the diversion gallery is exaggerated.
- It is recommended to have, along the entire longitudinal direction, a filter and drainage connection composed of granular and permeable material, between the vertical filter of the initial stage and the interface filter between the original earthfill and the reinforcement earthfill.

Serrinha Ferrous (Dam)

Report RL-10/19, issued on October 24, 2019.

- It is recommended that the outlet of the surface drainage be detailed.

Sossego (Dam)

Report RL-16/20, issued on February 29, 2020.

- The internal drainage of the South dikes is a concern, because there are plans to raise them up to El. 271 m, therefore, an additional height of 19 m. For this raising, the Committee recommends that the raising be done downstream and that chimney filters properly connected to drainage blankets be included.
- It is recommended that radioactivity tests be carried out with a sample of the current tailings, at least to have this result in the files, for eventual future information.
- It is recommended that an acid drainage simulation test be performed with a current tailings sample.
- The Committee supports some recommendations of the RISR, namely: i) Based on the "*as is*", update the Operations Manual, including dam and dikes stability analyses considering the embankment parameters obtained from laboratory tests on clayey soil, especially in the West dikes (tests to be done with undisturbed samples to be collected as soon as possible); ii) Install additional piezometers, especially in the West dikes.

Sul Superior (Dam)

Report RL-04/19, issued on June 26, 2019.

- The dam reinforcement design should be modified because it initially comprises the execution of a sand berm on the tailings of the Sul Inferior dam that are located at the toe of the Sul Superior dam. This sand berm, in addition to not efficiently draining the tailings layers, especially the less surficial ones, could cause unfavorable pore pressure increments in the underlying tailings and under the starter dam.
- In view of the current conditions of the Sul Superior dam and the downstream location of the city of Barão de Cocais, it is considered very appropriate to implement a gravity concrete dam in RCC with a height of about 37 m located 6.5 km downstream of the Sul Superior and Sul Inferior dams because both lack appropriate factors of safety.

Taquaras (Dam)

Report RL-30/20, issued on August 18, 2020.

- The probability of overtopping of the dam due to the incidence of extreme floods is very remote.
- The spillway system must be designed to prevent erosion in the dam earthfill.

Torto (Dam)

Report RL-37/20, issued on September 14, 2020.

- It is recommended that the foundation relief joint be carefully monitored through piezometry and flow rate measurements of the relief wells.
- It is recommended to install inclinometers in addition to the instruments already provided.
- It is recommended to install magnetic settlement plates under the downstream slope to measure foundation settlement based on this recommendation.
- It is recommended studying the possibility of performing cement grout injections to seal fractures in the left abutment gneiss outcrop.

Report RL-38/20, issued on September 18, 2020.

- The hydrological design of the dam ensures that the occurrence of overtopping of the structure due to the incidence of extreme discharges is very unlikely.
- The hydrological design must be adopted.

Vale das Cobras (Drained pile)

Report RL-32/20, issued on August 25, 2020.

- The pile has excellent drainage conditions with very low phreatic surface.
- Safety factors are comfortably above what is established as acceptable.
- The planned studies and actions should confirm or even improve the favorable results already obtained.

Vargem Grande (Dam)

Report RL-04/19, issued on June 26, 2019.

- The execution of new tests to determine parameters for a more accurate stability analysis may lead, in the short term, to favorable conditions for the beginning of the reinforcement works and subsequent decommissioning.
- The lowering of the water level of the reservoir can be done only in the central region of the tailings deposit with the installation of a wide channel for outflow of incident discharges. Side slopes to this channel should be smooth and covered with surface erosion protection material.

Report RL-10/19, issued on October 24, 2019.

- Vale should promote a qualified seismic hazard study of the Iron Quadrangle region of Minas Gerais, and decide at a high hierarchical level, the return period to be adopted for each dam design.

Xingú (Pile)

Report RL-31/20, issued on September 03, 2020.

- It is recommended that the RISR guidelines be fully adopted.

Committee Recommendation Status Tables

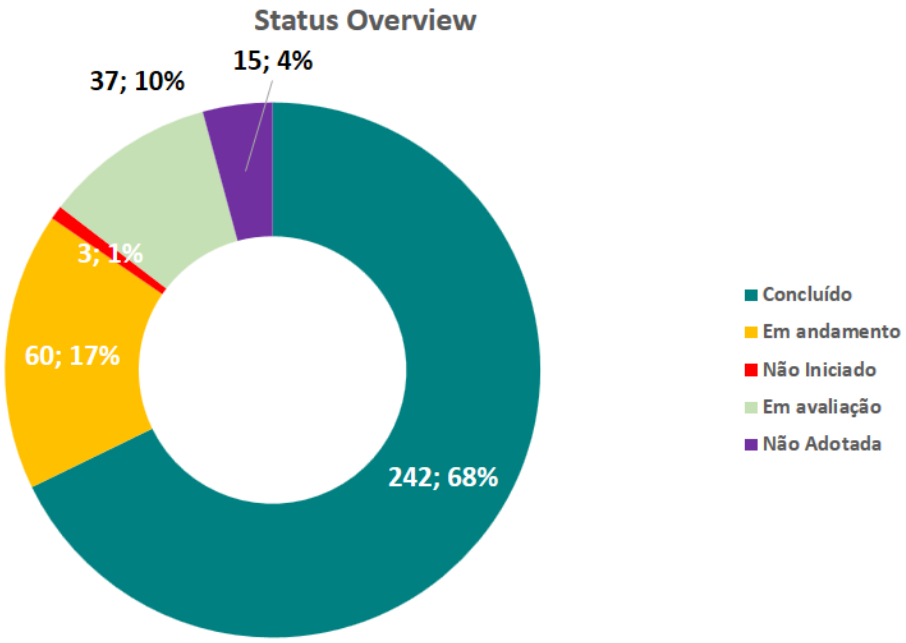
Throughout 2019 and early 2020, the Committee issued a report after each technical visit to the dams, as well as after technical presentations made by Vale teams and design companies. The trips were monthly and included meetings and technical visits to various dams and piles. From March 2020 and until March 2021, the Committee had been providing recommendations through technical reports and technical notes, based on detailed video conferences held with Vale staff and designer teams. In each of these reports and technical notes there are considerations and recommendations issued by the Committee.

For the dams and geotechnical structures of the Ferrosos area, Vale uses a management tool called Recommendation Status Tables to monitor the adoption of the recommendations. This tool is an Excel spreadsheet in which the report/technical note, the mine, the structure analyzed, the Committee recommendation, comment of the Vale team responsible for the analysis and compliance with each recommendation, the deadline for the implementation of each recommendation and the final diagnosis of the actions related to each recommendation are inserted in sequential order for each recommendation. This final diagnosis is well summarized and is color coded for each status. The diagnoses and the respective colors are:

Summarized diagnostic	Color assigned
Completed	green
Under evaluation	light green
Under discussion	blue
Ongoing	yellow
Not started	red
Not adopted	dark blue

The Ferrosos Recommendation Status Table contains a summary page that graphically shows the progress of implementation of the recommendations. This page is known as a *Dashboard*. Below is the reproduction of the *Dashboard* image in the March 17, 2021 edition. The Committee collaborated with this procedure to monitor the adoption of the recommendations issued. The *Dashboard* shows that the vast majority of recommendations have been adopted or are being implemented.

Ferrosos Recommendation Status - *Dashboard* on March 17, 2021



Base Metals

In the area of Base Metals, a document was issued in April 2020 by Vale summarizing the thirteen recommendations made by the Committee and showing that at that time they were all being implemented. Through this Vale document, 100% of the Committee's recommendations were adopted in March 2021.

Energy

In the Energy area, a document was issued on July 7, 2020 by Vale in which the recommendations of the Committee were presented, showing that at that time they were all being implemented in the long-term, including some included in the periodic inspection activities and others in the regular annual inspection activities.

Summary of most relevant structures analyzed by the Committee - Containment structures

Among the numerous structures examined by the Committee, the following are highlighted for their size, importance, problems presented and speed of implementation. These structures were the subject of repetitive and insistent technical visits and several face-to-face meetings and videoconferencing throughout the two years of the Committee's work. These structures were selected to be included in this report because they are also representative of the most important measures related to each type of problem overcome by Vale over the two years of the Committee's activity.

Among the most relevant and recent structures for containment of Vale's tailings are the three large structures that were designed and built in a very short time with the ability to safely retain any potential tailings slurry flow that could result from the collapse of large tailings dams located upstream.

These structures have been completed, or in the final phase of completion, to defend extensive regions that could be affected by the tailings accumulated in the B3/B4 dams of the Mar Azul Mine; Grupo, Forquilhas I, Forquilhas II, Forquilhas III and Forquilhas IV of the Fábrica Mine; and Sul Superior and Sul Inferior of the Gongo Soco Mine.

The design of these containment structures was based on the following assumptions:

i- Dam break studies to accurately determine Self-Rescue Zones (ZAS in Portuguese).

ii- Removal of residents in the ZAS and exercise strict control of these areas.

iii- The structures to contain any slurry, debris and tailings resulting from the potential collapse of the dams must be implemented as soon as possible with the purpose of protecting the assets located in the ZAS.

iv- Considering the speed of construction and the independence of adverse atmospheric conditions, structures in RCC were initially considered.

v- The containment structures should be built in valleys sufficiently distant from the tailings dams to allow complete safety to workers by warning devices, training and signaling, and sufficient time for the safe closure of the floodgates of the river diversion structures and the complete removal of workers from the areas of the structures and the ZAS.

vi- The containment structures should have water intakes equipped with floodgates for rapid and total closure of the upstream water flow to also stop tailings coming through the river valley. Thus, in case of collapse of one or more tailings dams, the structures would contain all the tailings that would be released, avoiding damage to downstream areas that include residential areas.

vii- If the reservoir becomes filled with tailings, the natural river waters would be released downstream after passing over the tailings accumulated upstream of the containment structures, and flow through the free apron uncontrolled surface spillway structures, properly sized for extreme flooding.

viii- Considering the urgency of the implementation of the three structures, they were initially planned to be implemented as concrete gravity structures in RCC. Two of the containment structures were thus implemented, but due to a lack of competent sound rock in the foundation, the containment structure for the B3/B4 dams was implemented in rockfill.

<u>Containment structure for the B3/B4 dams (Mar Azul Mine)</u>

The containment structure of the B3/B4 dam was implemented in the Macacos stream valley and had an innovative design. The structure was designed as a compacted rockfill

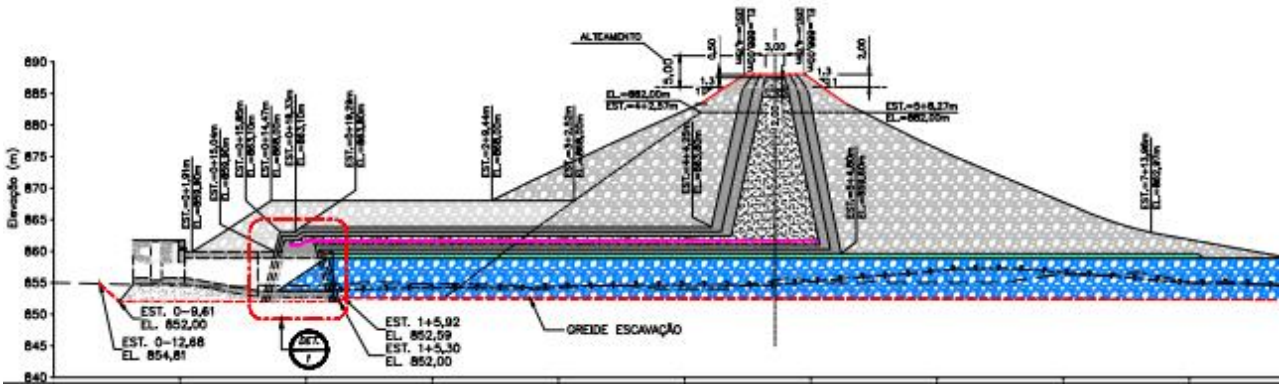
dam with a central core of sand protected by transition layers. The rockfill structure slopes are 1V:2H up to four meters from the crest and then they are 1V:1.3H. In this specific case there is no need for a clayey core because the compacted sand that constitutes the core of the structure can retain the tailings if they come to impinge on the upstream slope and are contained by the rockfill structure. The structure is 33-m high and has the capacity to retain 3.1 x 10^6 m³ of tailings if the B3/B4 dams were to collapse. The volume of the reservoir created by the structure is 4.6 x 10^6 m³ at the elevation of the surface uncontrolled spillway and 6.7 x 10^6 m³ at the elevation of the crest of the structure sand core. Below is an image obtained on December 16, 2020 during the completion phase of the works.

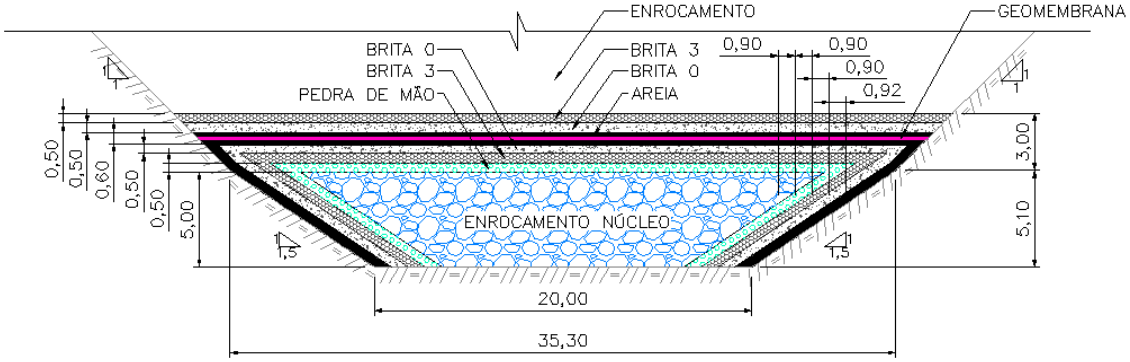
The reinforced concrete water intake structure, composed of four bays equipped with wagon gates, would capture and conduct the affluent discharges of the Macacos stream to a large French drain composed of large diameter sound stone blocks. Due to its dimensions and the size of the rockfill voids in the core of the French drain, this structure was sized to have large discharge capacity.

In the hypothetical collapse of the B3/B4 dams, within the 15 to 20 minutes for the arrival of tailings at the site of the containment structure, the floodgates of the water intake would be lowered and the French drain would lose its usefulness as a discharge structure. The tailings and water reservoir would be formed and the excess water discharged through the surface spillway, a concrete structure with a thick 25-m wide crest discharging in a sub-horizontal channel followed by a step apron to the dissipation basin. The surface spillway with the ogee at El. 883.00 m has a flow capacity of 383 m³/s corresponding to the water level of the reservoir at El. 887.50 m, which corresponds to the top of the compacted sand core. The surface spillway was verified for a reservoir

containing tailings, water level at the crest of the surface spillway and influx of a flood with a return period of 1,000 years, resulting in a peak flow of 293.68 m³/s.

The following figures with dimensions in meters show the typical dam cross-section by the winding river thalweg (downstream slope becomes deformed) and the typical cross section of the large French drain.





When the rockfill structure was in an advanced stage of construction, on January 23 and 24, 2020, intense precipitation occurred in the metropolitan region of Belo Horizonte and Nova Lima, municipality of the B3/B4 dams, characterized as a single event of 202 mm of precipitation in these two days. According to the rainfall records, this was the greatest recorded precipitation.

The pluviometer installed at the site of the containment structure recorded precipitations of 130 mm on day 23 and 72 mm on day 24. It was characterized as a single 202 mm event in two days. This precipitation was estimated to have a return period of 190 years and generated a discharge of 160 m³/s that flowed into the structure.

The discharge was captured by the water intake structure that was fully open, and percolated through the French drain. The rockfill structure performed exceptionally well as a flood control dam, forming an upstream reservoir that reached El. 877.20 m, only

3.80 m below the crest of the surface spillway. It was estimated that the effluent discharge reached the peak of about 110 m³/s with onset of recession of the effluent hydrograph in about 30 hours and total decay in about 60 hours.

The extraordinary performance of the containment structure in attenuating the flood flow that would have affected the downstream areas brought great benefits, avoiding a flood of major proportions. This occurrence raises a possible future use of the structure as an efficient flood control device.

Containment structure for the Sul Superior and Sul Inferior dams (Gongo Soco Mine)

The Gongo Soco containment structure, executed in RCC, was implemented in the municipality of Barão de Cocais, MG, on the São João River, 7.0 km downstream of the Sul Superior and Sul Inferior dams, with a height of 40.0 m. The arrival time of a hypothetical failure of these dams was calculated in 12 minutes and the total volume to be contained in the structure, 7.6 x 10^6 m³, while the structure can store a total volume of tailings, up to the spillway crest of 12.9 x 10^6 m³. At the site of the structure, the foundation is composed, on the right bank, by a predominance of soft ferruginous quartz schists. On the left bank there are banded bodies of reasonably compact ferruginous quartzite, ferruginous phyllite, phyllites and quartzites interspersed with dolomites. Although the foundation characteristics were not ideal for a concrete structure, the design and construction were careful to make them suitable.

The containment structure was dimensioned as a concrete gravity dam for containment of tailings and water, with stepped trapezoidal section, inclination of 1V:0.6H (upstream) and 1V: 0.7H (downstream), comprising a total volume of concrete of 184,212 m³.

The usually small flows of the São João River and the construction having been carried out during the dry season allowed the diversion of the São João River during construction to be done, in the early stages of the construction work, by pumping the affluent discharges to the site of the structure. After implementation of the water intake structure from the four river diversion sluiceways, the affluent flows began to flow

through these sluiceways which, in case of collapse of the upstream tailings dams, will be closed by four wagon gates.

An uncontrolled surface spillway was implemented, with access channel, sill and apron covered with Reno mattress and gabions from its crest to a downstream dissipation basin.

For the RCC structure, an excellent technological control system was set up that ensured a high level of quality even though this structure was concreted in just over two months.

In the construction works, GIG (concentration installation granules) and hematite were utilized for the first time as concrete aggregate which, in addition to their low cost, have proven to be excellent aggregates for concrete because they are not reactive to cement alkalis, have high compressive strength, are non-cyclable (resistant to cycles of marked differences in temperature and humidity), have good adhesion to Portland cement, and have high unit weight.

Core samples older than 90 days, extracted from five blocks of the RCC structure, revealed very reasonable compressive strength (11.3 MPa), well above that required in the design, high unit weight (3,078 kg/m³), and very reasonable permeability coefficient (5.16×10^{-9} cm/s) and modulus of elasticity (13.6 GPa) for this type of concrete structure.

The average effective monthly production of roller-compacted concrete was around 90,000 m³.

Thermometers were installed in the blocks of the RCC structure to measure the evolution of temperatures inside the concrete blocks, especially the temperature drops after reaching the maximum temperatures due to the heat of hydration of the concrete. In this structure, however, temperatures were measured only until the maximum temperatures were reached, and measurements were discontinued from this point on.

The structure construction activities were fully monitored monthly by the Committee and the monthly production reports were analyzed and commented on by the Committee.

Containment structure for the Grupo, Forquilha I, II, II and IV dams (Fábrica mine)

The containment structure for the dams of the Fábrica Mine was implemented in the municipality of Itabirito, MG, in the Dos Porcos river, intended to retain the slurry from a hypothetical failure of the Grupo, Forquilhas I, II, III and IV tailings dams, having been built downstream of these dams, with a height of 94 m at a distance of 7 km from them in a straight line and 10.5 km along the river channel. In the event of failure of those tailings dams, the containment structure may accumulate a volume of tailings of up to 67.7x106 m³. In the case of simultaneous collapse of all these dams, the arrival time of these tailings to the containment structure was calculated as being 27 minutes. The volume of mud resulting from the simultaneous hypothetical failure of all unstable tailings dams located upstream is estimated as being 60x106 m³. The containment structure was designed as an RCC concrete gravity dam.

The valley at the structure site is narrow and asymmetrical, consisting of sound gneiss rocks of excellent geomechanical properties. The right abutment is markedly steep and difficult to work on. The left abutment is not so steep and has thick layers of soil and altered rock up to 20-m thick covering the gneiss, that were properly excavated. In the area of the riverbed and on its left bank, thick layers of soil and decomposed or greatly altered rock occurred and required excavations that were not initially planned.

For the containment of the volume of tailings, the containment structure is being built in two stages. The first stage was intended to contain the tailings from the Grupo, Forquilha II and Forquilha IV dams. Forquilha III dam is not located in the same thalweg as Grupo, Forquilha II and Forquilha IV dams. As the combined tailings from these three dams exceeds the volume of tailings contained in the Forquilha III dam, and as the probability of collapse of all dams upstream of the containment structure occurring at the same time is minimal, in the first stage the containment structure was sized to contain the tailings from the collapse of the Grupo, Forquilha II and Forquilha IV dams. In the second stage, with upstream raising of the containment structure, 100% of the tailings would be contained if all the Grupo, Forquilha II, Forquilha III and Forquilha IV dams collapse due to the same simultaneous phenomenon.

The containment structure was dimensioned with stepped trapezoidal section, with the upstream face with an inclination of 1V:0.61H and the downstream face with an inclination of 1V:0.36H.

The volume of concrete utilized for this structure as of February 7, 2021 was 652,406 m³, which should increase further in view of the continuing construction, and there is also the implementation of a concrete dissipation basin and the reinforcement of Blocks 8 and 9. These additional volumes may raise the total concrete volume to more than 700,000 m³. In the construction of this structure, the maximum monthly peak of concrete placing was 307,989 m3 that occurred in July and August 2020. The maximum daily peak occurred on July 24, 2020, which volume of 6,286 m^3 is a national record for placing concrete in a single day.

For the construction of this structure, it was necessary to divert the Dos Porcos river, which was initially made by an open channel on the left abutment and was subsequently diverted by three diversion galleries equipped with flood gates. As this structure is situated in a narrow valley, the uncontrolled spillway was designed to be constructed on the crest of the concrete structure. OR EMBANKMENT? Em portugues says barragem.

Hematite was also used for this RCC structure as an aggregate, similar to the Gongo Soco containment structure that preceded it chronologically. The image below shows the upstream surface of the containment structure being raised upstream, at an advanced stage of implementation.

An interesting fact verified in the control of the degree of compaction of the RCC was the observation that a unit weight of the concrete determined in the laboratory using the DMA device started to be considered as the reference unit weight for the determination of the degree of compaction, in relation to the unit weight determined in

the field by means of a nuclear densimeter, thus replacing the unit weight determined by other methods, including the unit weight that has been the traditional reference, determined from the consumption of concrete materials, considering the air content null.

Several determinations of the modulus of elasticity of the concrete were made, with an average value of 14.3 GPa at 90 days, with values ranging from 25.5 GPa and 7.9 GPa.

Thermometers were also installed inside blocks of the structure to measure the evolution of temperatures, especially temperature drops after reaching the maximum temperatures due to the evolution of the hydration heat of concrete, which is allowing obtaining data to better clarify the thermal problem in RCC dams. After 250 days of observation of these temperatures, the maximum value observed in the concrete was 39º C, with a maximum temperature drop of 6.6º C, which generated a maximum tensile thermal stress of 0.75 MPa. This thermal tensile stress corresponds to a factor of safety of 1.8.

The evolution of the temperature inside the structure indicates that the probability of the occurrence of thermal cracking is minimal.

For this structure in RCC, an excellent technological control system was assembled that ensured a high level of quality.

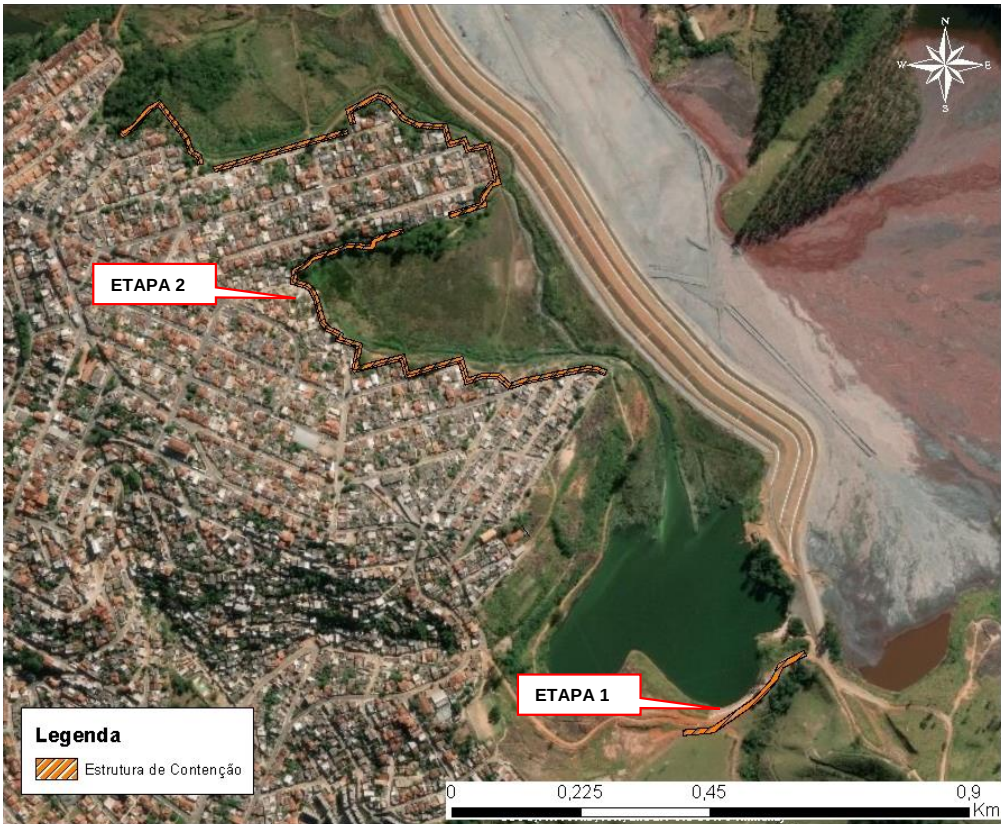
The implementation activities of this structure were also monitored monthly by the Committee, and the monthly production reports were analyzed and commented on by the Committee.

Containment Structure of Minervino Dike and Cordão Bela Vista

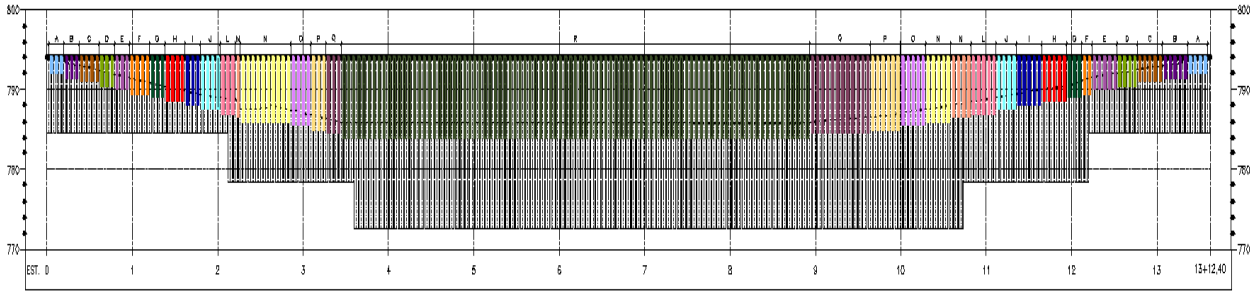
In addition to the three containment structures summarized above that have been completed (Mar Azul and Gongo Soco) or are in the final phase of completion (Fábrica),

there is also the containment structure of the Minervino dike and Cordão Bela Vista that is in the design phase, with construction scheduled to begin soon.

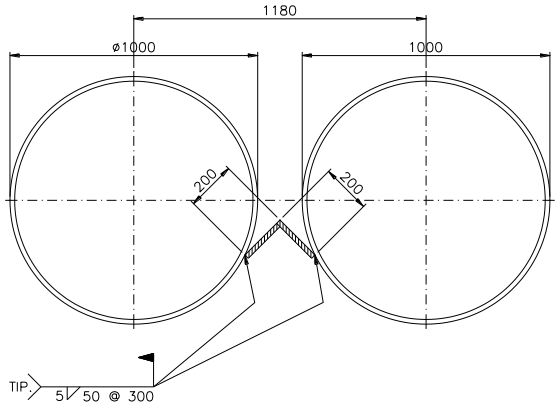
The Minervino Dike and the Cordão Bela Vista are dikes of the Pontal system in Itabira, MG. The dikes are located very close to and just upstream of populous neighborhoods. As they were partly built on tailings, they require a containment structure to protect the downstream population. This structure will be implemented in two stages, through the construction of a curtain of steel pipes introduced into the field by GIKEN's Gyro Press method. This method was selected and will be utilized for the first time in Brazil, by introducing a curtain of metal piles into the ground without practically transmitting vibrations to the surrounding soil. This method combines static pressure and rotation of steel pipes to the desired depth. The lower parts of the pipes are filled by the soil that has been penetrated by each pipe and the upper parts are filled by carefully placed concrete without impact so as not to induce vibrations. The figures below show how this containment structure will be constructed.

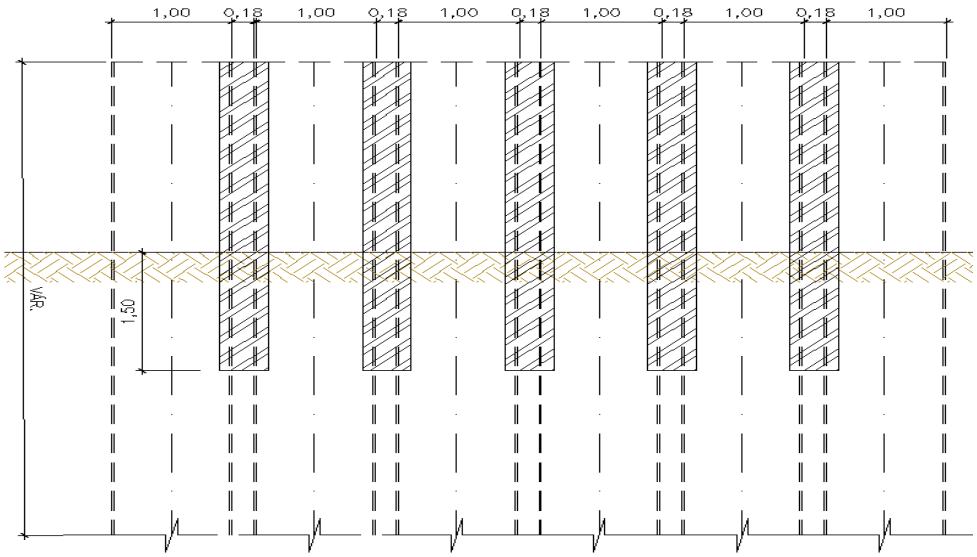


The first step will start shortly. Total protection of the urban area will take about two years. In the first stage, a curtain will be made with one-meter diameter pipes, as shown in the following figure. The top of the curtain will be at El. 794 m. According to the investigations, the maximum anticipated pipe depth will be 22 meters.



Above the ground line, the pipes will be joined by steel connectors welded on the outside of the pipes, as shown in the image and diagrams below.





It is anticipated that at the end of the second stage, the structure will extend for about 1,800 m. The equipment that will install the curtain is shown in the figure below.

Summary of most relevant structures analyzed by the Committee - Dams Among the most outstanding structures analyzed by the Committee are large dams accumulating large volumes of tailings and being raised, having presented problems to be overcome, especially those related to foundation settlements. This group includes large dams such as Itabiruçu and Maravilhas III. Dams with internal drainage deficiencies and structural reinforcement needs are exemplified below by the Santana and B-7 dams. Hydraulic structures, such as flood spillways that required changes, are summarized in the Santana and Capitão do Mato dams, the latter having also demanded stabilization works of the natural slope near the right abutment. Concrete structures that were subjected to extraordinary pressures not foreseen in the design are exemplified by the concrete structures of the Candonga hydroelectric power plant (Risoleta Neves), in the Doce river, whose operation remains interrupted until the time of issuance of this report.

Itabiruçu Dam

The Itabiruçu dam was the subject of the Committee reports RL-03/19 issued on June 18, 2019, RL-07/19 issued on September 9, 2019 and RL-12/19 issued on November 28, 2019. Recently, in February 2021, a technical note was issued by the Committee regarding the results of computational studies and observation of movements through survey points, deep magnetic settlement indicators (tasometers) and inclinometers.

An aerial view of the dam and its tailings reservoir is shown in the figure below. The occurrence of cracks detected in the dam downstream slope was analyzed in the reports mentioned above.

The Itabiruçu dam, after being constructed with compacted earthfill up to El. 836 m, was in the phase of being raised to El. 850 m.

During the raising works to El. 850 m, at the end of May 2019, cracks were observed in the berm ditches on the downstream slope at El. 778 m. In mid-July 2019, new cracks and settlements occurred near the downstream toe. Level 1 of emergency was requested on October 21, 2019.

The cause of the cracks was the significant observed berm settlements on the compressible foundation, which reached 25 centimeters. However, these settlements are getting stabilized due to the consolidation of the compressible foundation soil. Although the chimney filter from the previous phases is not efficient, percolation inside the embankment reflects acceptable levels of the upper saturation line and the settlement is decreasing. On January 23, 2021, the dam was taken out of the emergency level after a thorough analysis of its geotechnical characteristics and is now released within the legal safety standards.

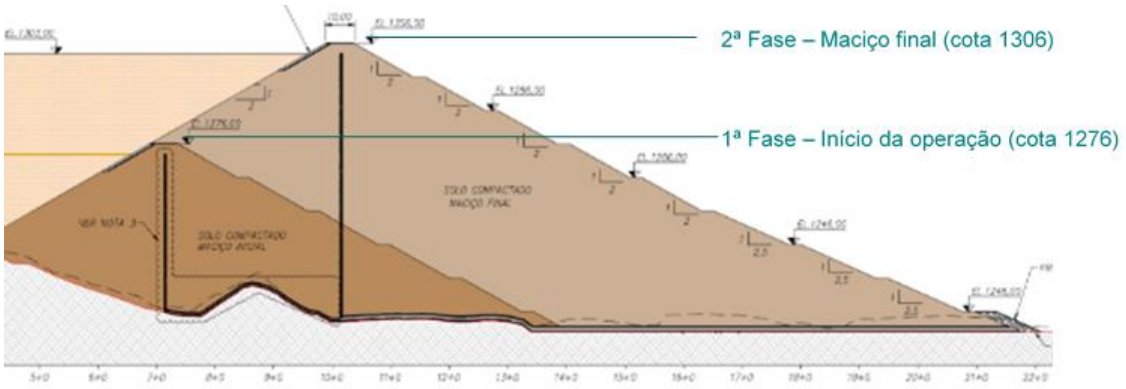
In the February 2021 technical note, the conclusions and recommendations were:

- *"The instrumentation shows a condition of stabilization of the settlements and horizontal displacements;*
- *The only question is regarding the factor of safety when it reaches the 850 m level.*
- *Inclinometers and tassometers (magnetic settlement indicators), in addition to robotic stations, will give invaluable indications to safely monitor the raising of the earthfill, perhaps avoiding alternative measures."*
-

<u>Maravilhas III Dam</u>

The Maravilhas III Dam is in the process of being raised downstream. The dam's foundation is in a complex geological formation. More than fourteen types of rock were identified in the foundation, each one with its specific characteristics.

It was necessary to construct a blanket of low permeability soil to cover a permeable quartzite outcrop. The following figure shows the main dam section, including the raise and with the internal drainage system highlighted.



The Committee has visited this dam since the early months of 2019 and issued several reports on different aspects of the design and construction. The first comment was about the positioning of the vertical filter. The upper portion of the filter was located at the dam axis, very close to the reservoir. The displacement of the filter to downstream in the design documents was recommended.

In the first report issued on April 30, 2019, due to the high entry gradients at the top of the vertical sand filter of the first stage, it was recommended to perform clogging tests. A representative sample of the dam soil was placed in an initially dry, loose state, on the sand representative of the filter, and subjected to percolation under high gradients, greater than 10. There was no clogging of the sand in a one-week test.

Finally, the detection of cracks in the downstream slope, in the part being raised, caused concerns. After an intense field investigation and laboratory testing campaign, it was found that the cause was the presence of a portion of the dam founded on compressible phyllite soil.

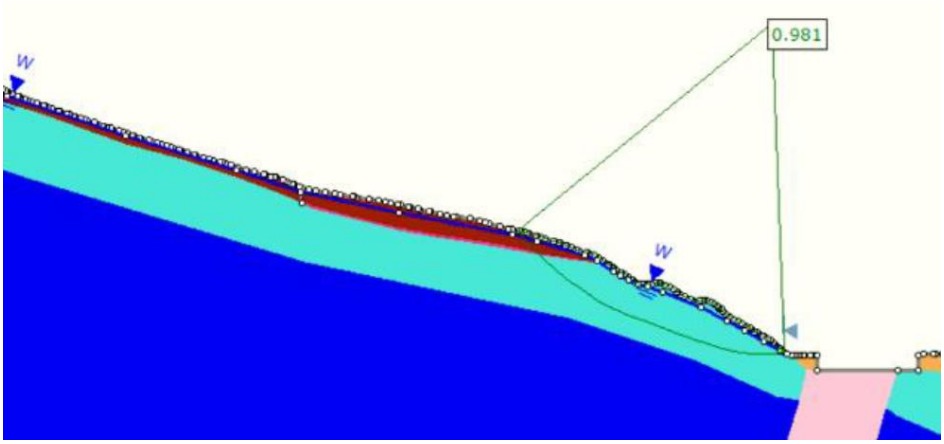
A solution for the foundation treatment is being adopted, consisting of reinforcement of the foundation soil with jet-grouting columns to stabilize the foundation of the downstream toe, consisting of soft and compressible phyllite soils. These soils are also present in part of the previous stage foundation. A field test in a test area was performed, with various combinations of grout injection mixes and drilling characteristics, and it was concluded that the columns were of adequate quality as a foundation treatment.

<u>Capitão do Mato Dam</u>

The Capitão do Mato dam serves to retain sediments from the Vargem Grande Complex. It is 36-m high and was constructed in a single stage, having started operation in 2016. The figure below shows an aerial view of the dam, its reservoir, its spillway and its right abutment.

The dam is located between two Anglo Golden dams, the Miguelão flow control dam and the Codorna hydroelectric power plant. According to the conservative hydrological design criteria adopted by Vale, neither the Miguelão dam nor the Capitão do Mato dam would withstand the design flood. Several combinations of rehabilitation designs for these two dams, which included the construction of new spillways and changes in operating procedures, were considered. The Committee performed a hydrological study that concluded recommending that a simple 40 cm raising of the Miguelão dam crest would be sufficient to attenuate the maximum affluent flood flow peak to these two reservoirs.

Another concern for this dam is the stability of the right slope downstream of the dam abutment. In addition to evident scars of past instabilities, as shown in the image above, there is a colluvial deposit originated from past slides. In accordance with the stability analyses performed, the slope is only marginally stable, as shown in the following figure. In the stability analysis, the area near the flood spillway channel was assumed to have a factor of safety in a limited state. This instability has the possibility of affecting the channel of the flood spillway.



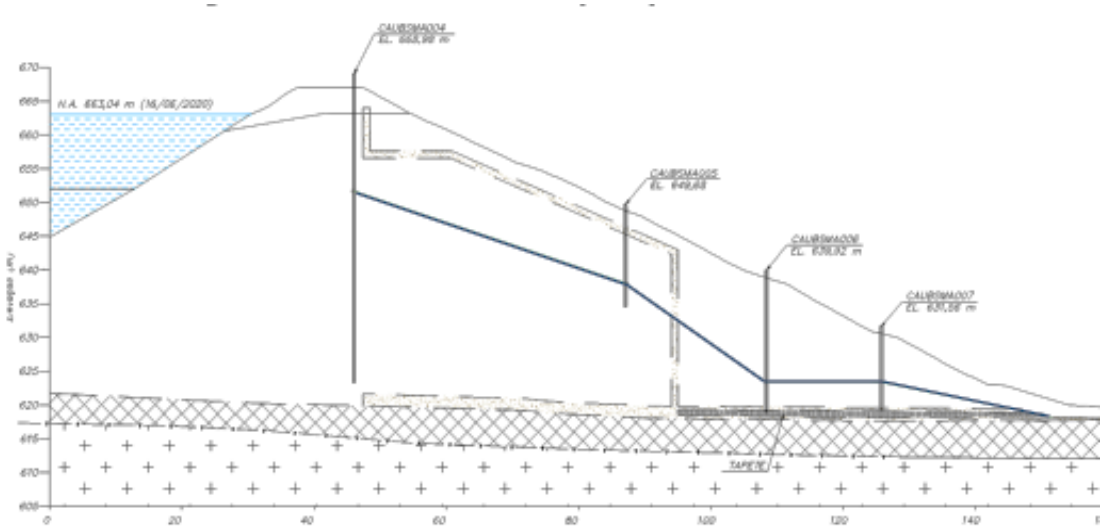
In the evaluation of the problem, the Committee recommended in November 2020, that before the beginning of the 2020/2021 rainy season, deep horizontal drains (DHDs) should be urgently installed up to the bedrock to lower the water table. After several interactions with the project designer and also of Vale with the Prosecution Office of the Minas Gerais State, the first DHD was installed in February 2021. The installation of inclinometers and water level indicators was also suggested.

Santana Dam

The Santana dam deployed in the Jirau stream is part of the Itabira mining complex, Cauê Mine, in the municipality of Itabira, MG. The dam is of rolled zoned soil cross-section type, founded on gneiss saprolite and an altered rock mass, with relatively steep slopes near the crest in the raised portion, from 1V:1.85H upstream and 1V:1.5H downstream.

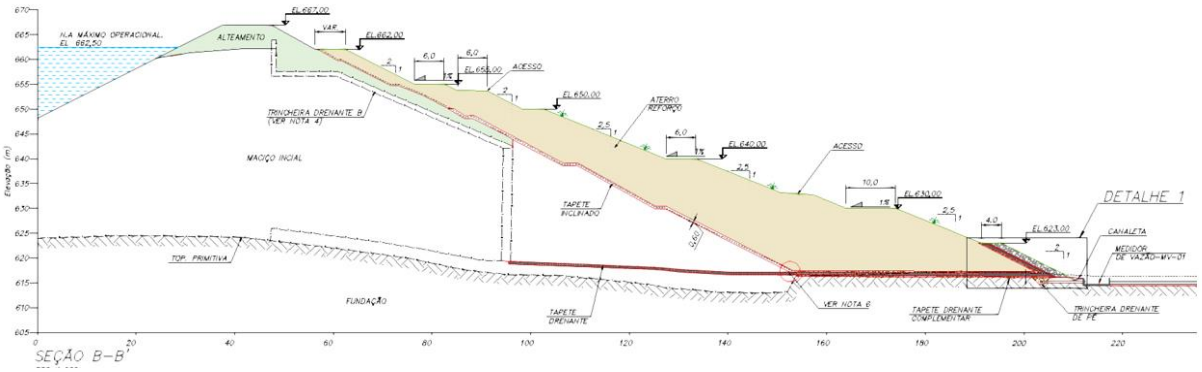
The dam started operating in 1978 with a height of 48.50 m. In 2002, the dam was raised an additional 5.40 m.

Because the vertical chimney filter was in a very downstream position in the typical cross-section, drainage trenches were excavated in the downstream slope, connecting the first phase chimney filter to the chimney filter of the raised embankment of the second phase.



A typical cross-section shows that the water levels inside the compacted earth embankment are high and indicate poor performance of the first stage chimney filter.

The dam will be reinforced with a berm on the downstream slope as shown in the figure below, with a sand filter in the interface with the existing earthfill. This reinforcement berm will bring the factor of safety to levels higher than 2.



In the original design, the river diversion gallery was constructed in concrete on the left bank. For that design, its concrete plug was positioned at the gallery upstream end, in an unfavorable position. It should have been positioned under the dam center line. In the current stage of dam rehabilitation, although unnecessary, the gallery will be conservatively plugged with concrete in its entirety.

The flood spillway system consists of a free-surface spillway constructed in the right abutment. The channel has variable slopes, 2 m side walls in concrete and follows a curve to the hydraulic left in its middle portion before discharging into a dissipation basin. The current spillway crest was constructed on the original crest designed in 1977, and that resulted in a very steep spillway apron that increased the water flow speed. The figure below shows the spillway ogge and the initial part of the channel.

The hydrological evaluation of dam overtopping performed by the Committee resulted in full dam safety in the most unfavorable scenarios possible. However, the spillway system's hydraulic performance must be verified because, for the occurrence of design extreme discharges between 200 m³/s and 300 m³/s, there may be overtopping of the spillway channel downstream of the spillway ogge due to the potential formation of a hydraulic jump and certainly in the curved section with high gradient (34.36%) in which there is no superelevation of the channel or a deflector high wall to avoid overtopping. The recommendations of the Committee will be adopted.

Candonga Dam (Risoleta Neves Hydroelectric Power Plant)

The structures and equipment of the Candonga dam, located on the Doce river, for production of electric power for Vale and Aliança Energia, were affected by the tailings released during the collapse of Samarco's Fundão tailings dam, located in the municipality of Mariana, on November 5, 2015. The structures, mostly built as roller compacted concrete, were subjected to much more severe pressures than those considered in the design, due to the high average unit weight of the tailings that flooded the reservoir of the plant to almost its normal maximum level.

The concrete structures of the dam have a maximum height of about 60 m. The stability analyses of the structures concluded that the structure remains stable if the impoundment level is permanently maintained at the elevation of the surface spillway ogee crest with its gates fully open.

The artificial tailings flood generated by the collapse of the Fundão dam reached the Candonga reservoir at an estimated affluent slurry flow rate of 1,724 m³/s that was discharged through two of the three spillway bays of the surface spillway. The central gate was under maintenance, with the stoplog closing the bay. The image below shows the tailings from Fundão being discharged through the two end bays of the Candonga spillway.

During the flood passage, without being able to count on the central gate, the level of the tailings in the reservoir acting on the upstream surface of the dam reached El. 327.47 m, only 0.03m below the reservoir normal maximum water level. The freeboard between the tailings and the dam crest was 2.53 m only. The higher density of iron mining tailings retained in the reservoir at a high level and during a considerable time, the concrete dam structures were exposed to much higher stresses than the design stresses.

During the outflow of the incoming flood wave, the crests and the two channels of the spillway extreme bays were subject to high flows with unusual characteristics, composed of large liquid discharge with an enormous solids content consisting of iron tailings and various solid materials that were carried from the bed and banks of the Doce river.

The Candonga dam performed safely, even though it was subjected to destabilizing stresses much higher than those considered in the design, which demonstrates the conservatism of the design criteria adopted in this Country.

After the occurrence of the incident in 2015, the spillway has been permanently maintained with the three tainter gates fully open.

In 2017, the plant was withdrawn by the Brazilian Electricity Regulatory Agency from the distribution of gains and losses of electric power from the Energy Reallocation Mechanism - MRE, having been declared inoperative since it remained without generating electricity and could not contribute to the apportionment of the mechanism.

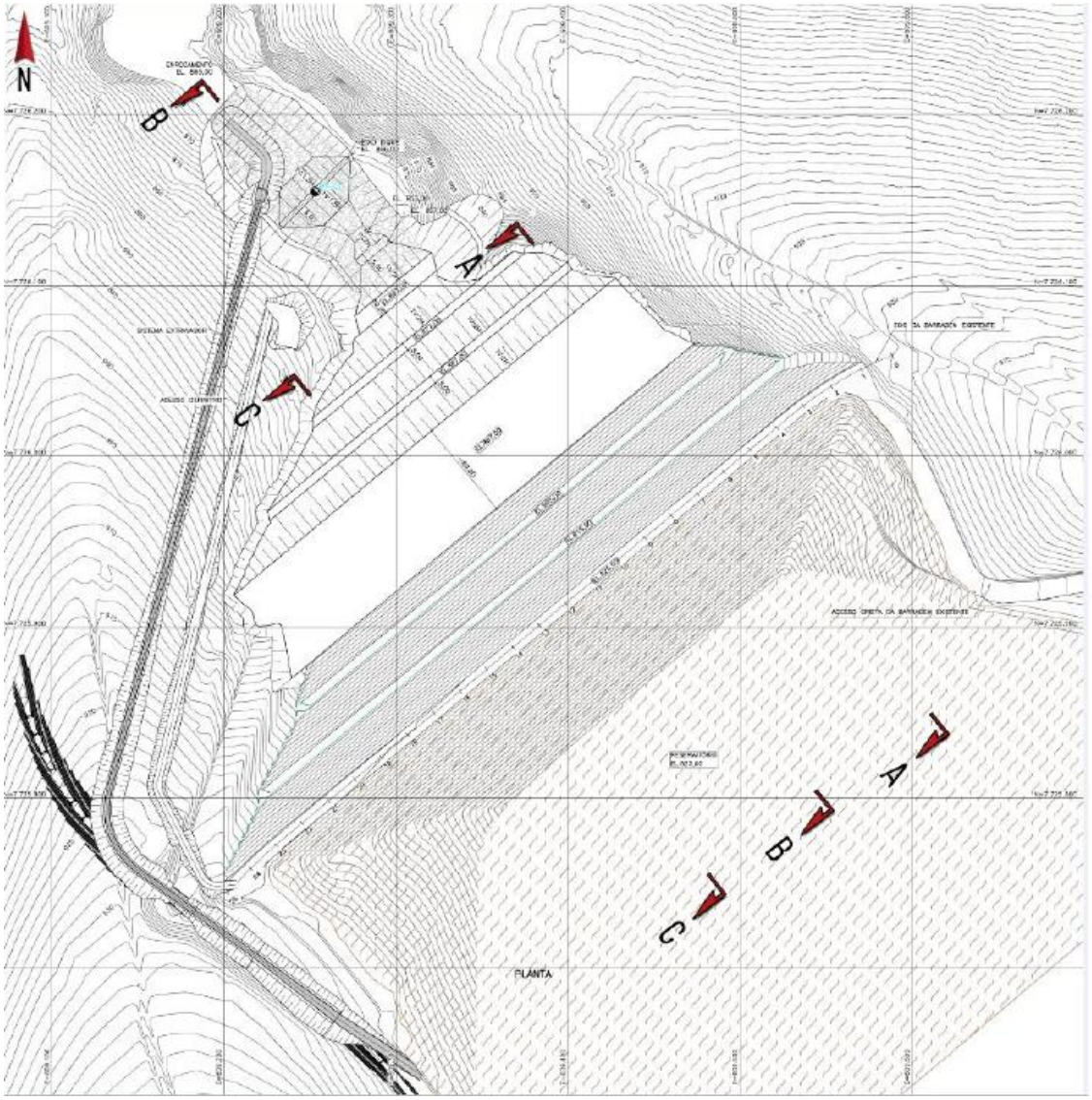
B-7 Dam

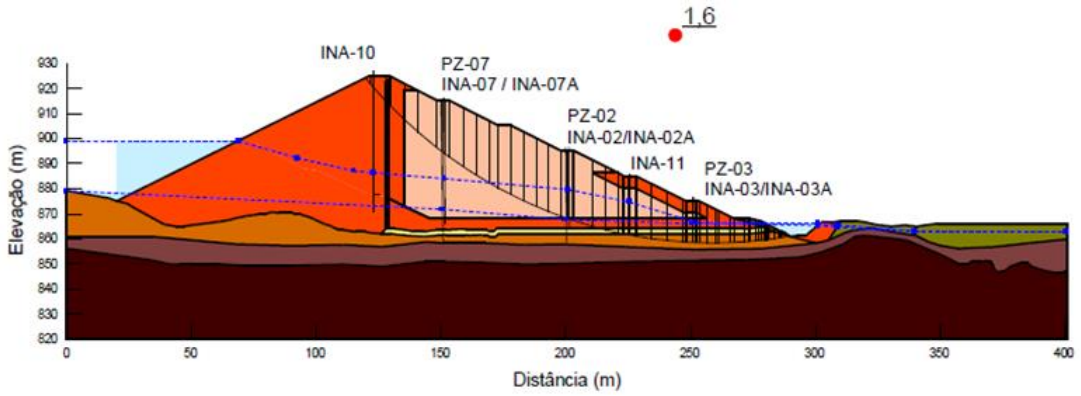
The B-7 dam was acquired by Vale when it bought the Viga Mine from Ferrous. Therefore, its design and construction were not performed by Vale.

The structure is a 64-m high rolled earth dam, constructed in a single stage, to retain the tailings from the Viga Mine, located in the municipality of Joceaba, MG. Originally, the dam was to be raised by downstream to increase its tailings storage capacity. The crest of the dam is at elevation 925 m. The design of a downstream stabilization berm is ongoing, to a maximum elevation of 897 m.

Upon completion of the berm, the plan configuration will be as shown in the following figure.

Attention has been drawn to the position of the water table, indicated by the water level indicators (INAs) installed downstream of the dam axis. The water table in the dam apparently ignores the presence of a (supposed) vertical filter, and remains high, even with the reservoir permanently kept at a low level, indicating that there is clogging of the internal drainage system by low permeability soil.





The lack of information about the characteristics of the dam's clayey earthfill and its filters has led the Committee to recommend that the berm, which is not high in the present design, be extended to the reservoir's normal maximum water level and that it should be a drainage transition layer between the current earthfill and the berm. This

transition will ensure that the internal drainage maintains the saturation line inside the embankment with or without the occurrence of cracks by differential settlement of the current dam compacted embankment. In addition, the installation of a line of relief wells located downstream of the inoperative chimney filter should be studied. These relief wells must pass through the drainage blanket and reach the foundation ground.

The design considers an excavation up to 12 m deep in the region just downstream of the existing dam toe. The existing alluvium in this area is inadequate as a foundation for a berm more than 20-m high. For this reason, the design indicates the need to remove this low strength soil before the reinforcement berm earthfill is constructed.

Gelado Dam

The Gelado dam, located in the North Corridor, in Carajás, serves to contain tailings and sediments, in addition to water storage. The dam was constructed in three stages, consisting of a starter dam of compacted soil and two downstream raises also of compacted soil. Both the starter dam and the two raises had internal drainage consisting of chimney filters and sub-horizontal drainage blankets. However, in all three phases of construction, the drainage blanket was constructed on a thick layer of compacted soil that filled the excavation of the surface soil at the dam site. This backfill had thicknesses from 2 m to 12 m and prevents the contact of the blanket to the foundation soil, wrapping the blanket and preventing it from being a foundation drainage element (same detail as the B-7 dam design). In the design, at all phases and by different project designers, the function of the blanket is only to transport the water captured by the chimney filter to downstream, without relieving the foundation interstitial pressures.

Being about 30-m high, the dam generates a large reservoir with a current volume of 107.6x106 m³, of which 25x106 m³ are filled by water and the remainder volume by submerged tailings and sediments. There are also 31.2x106 m³ of tailings emerging in the reservoir area, on beaches away from the dam.

Although the dam is relatively recent and Vale was, from the beginning, the dam's owner, due to a lack of technical documentation, it became necessary to perform surveys and investigations to determine the "as is" design that was completed in 2019. This need may have been aggravated by the fact that there were many engineering companies involved in several of the dam studies and designs.

In 2018, before the “as is” design definitions, the estimate of the factor of safety was 1.81 for normal operation condition without seismic events. After the completion of the "as is” definitions, with less optimism as to the basic data, the factor of safety for the highest cross-section was 1.5 for normal operating conditions and 1.41 for the scenario of the inflow of the spillway design discharge. For the condition of occurrence of a seismic event, the factor of safety obtained was 1.28. Although the factors of safety obtained were reasonable, considering the insufficient saturation of the samples submitted to triaxial tests, the Committee recommended expanding the testing campaign and performing subsequent stability calculations.

The investigations completed to define the "as is” characteristics determined that there are three different types of typical cross-sections in the dam, without delimiting transitions locations between these segments. Considering the indicated uncertainties, the Committee recommended a reinforcement study to increase the theoretical factor of safety of the dam to 2.

The saddle dike 6, 15.5-m high and constructed with compacted soil, had presented water pop-outs in the downstream slope. The dike was properly reclaimed and reinforced, and a factor of safety of 1.47 was determined after the reinforcement.

The flood spillway is an uncontrolled surface spillway, in concrete, 15-m wide and with a sill discharging into a concrete apron with aeration elements. The Committee recommended concrete repair works, which were reported to have been completed recently.

The Committee calculated the transit of the 1,000-year flood flow in the reservoir, that resulted in a comfortable freeboard of 1.5m. If the dam is not raised in the short term, a review of the 1,000-year flood flow transit study is recommended and the transit of the 10,000-year flood flow is recommended to be adopted.

Summary of most relevant structures analyzed by the Committee - Piles

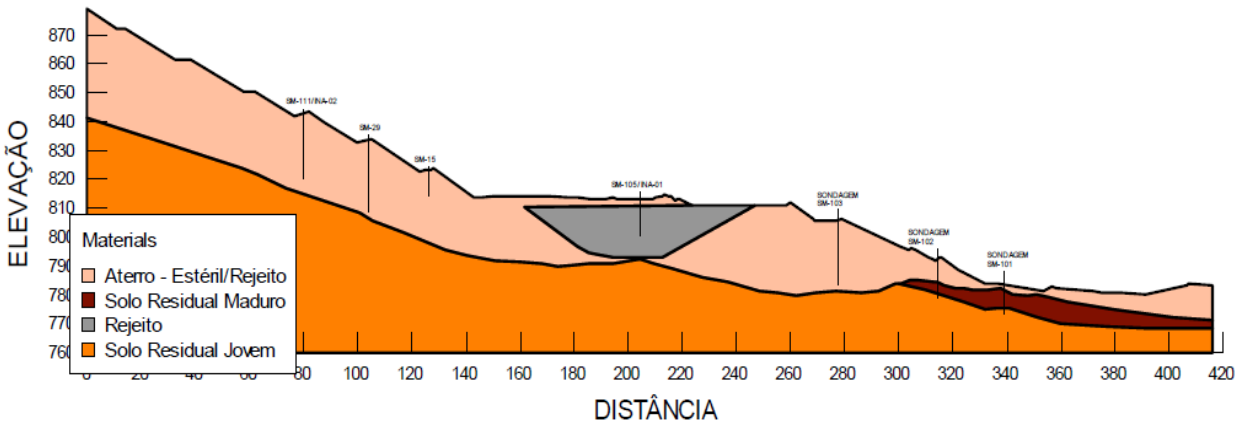
There are many tailings and waste piles at Vale's mining operations. An example of a pile that required investigations, technological testing and analysis to verify its safety conditions is the EMESA pile, where the stabilization work was just completed. On the other hand, well-executed and stable drained piles are exemplified by the Monjolo and Vale das Cobras piles that will have to be de-characterized accordingly to the current legislation in force. These three piles of different safety characteristics are summarized below.

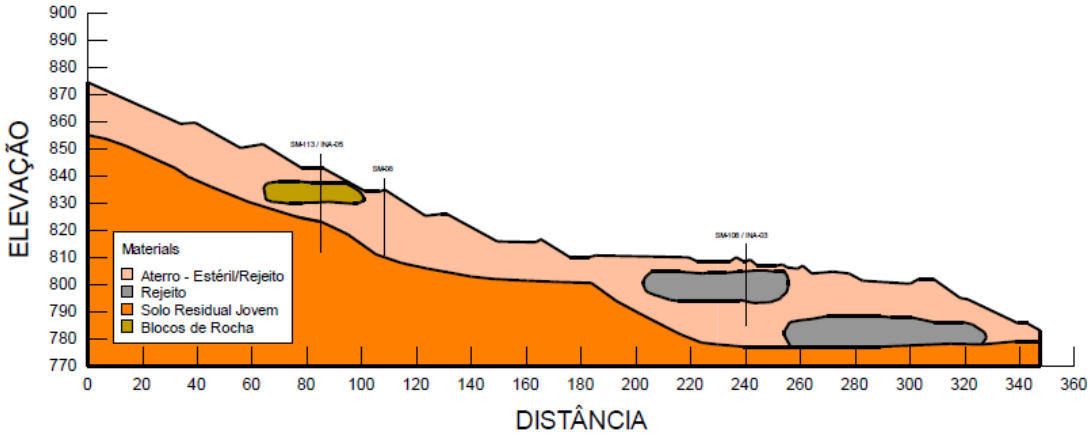
<u>EMESA Pile</u>

This pile shown in the following image, is 125-m high, and was constructed on a slope, with tailings and waste rock from the Esperança Mine, subject of a recent acquisition by Vale from Ferrous.

The Esperança Mine is located in the municipality of Brumadinho and its main structure is a pile of waste and tailings from the Esperança Mine itself and from the Santanense Mine. The pile basically consists of waste wrapping pockets of tailings inside (waste and tailings pile - PDER).

The figures below show the representative pile cross-sections, with low strength and high compressibility tailings pockets identified during drilling that was recently performed.





This pile was implemented against a natural hillside slope and was raised upstream. In this pile, there is a small sediment containment of about 9-m high at a high elevation, an 8-m high outlet dike on the left side and a 5-m high gabion wall at a lower elevation.

As the pile contains heterogeneous materials (tailings and waste), and as the characteristics and positioning of these materials, their compositions and densities were not accurately known, and the positioning of the water table for wet periods was not known, the factor of safety of 1.37 estimated at the time, had a considerable level of uncertainty.

At the toe of the pile there are administrative facilities that were constructed by Ferrous and that housed up to dozens of workers. Also, downstream from the pile, there are two COPASA pipeline systems that transport raw water from the Manso river dam reservoir, one of the main sources that supply the metropolitan area of Belo Horizonte.

The factors of safety of mining piles depend on the type of material stored, the length of time the pile has been in place, and the potential damage of a potential collapse. In accordance with to the information received, in the PDER of the Esperança Mine the tailings must be of very low strength, the pile is permanent, and the potential for damage is high. For this scenario, a factor of safety equal to or greater than 1.5 is internationally recommended. Preliminary analyses indicated a factor of safety of 1.37 as mentioned above, lower than the recommended one. And yet, the exact locations where the compressible tailings are located in the pile were unknown.

The consulting firms report that had been provided to Ferrou, were studied by Vale's civil engineers and indicated the conditions reported in the previous paragraphs. Initially, the Committee recommended, and Vale promptly adopted on August 23, 2019, the removal of the personnel working in the area downstream of the pile. Vale immediately began to study the received technical documentation and recommended the shutdown of operations at EMESA pile, the removal of the administrative and operating personnel from the facilities near the pile until information was obtained that would safely allow the resumption of operations or the reinforcement of the pile.

From then on, an intense drilling campaign was initiated, which showed more accurately the disposal sites of tailings covered by the waste material. Stability analyses were

performed with this knowledge, and low factors of safety were revealed, lower than those previously calculated.

The designer in charge of presenting a design to increase the factor of safety of the pile suggested that part of the pile in its upper position be excavated, and the resulting material placed on the bottom, forming a berm. In addition, it suggested that the zones with compressible tailings material be treated with the DSM (deep soil mixing) process, which consists of mixing cement grout with the tailings, to increase its shear strength.

This treatment was recently completed. In March 2021, the designer reported the evolution of the factors of safety of four cross-sections analyzed. The factor of safety for drained analyses increased from the minimum value in 2019, under the conditions in which Vale took over the pile, from 1.4 to 1.55 after treatment. For undrained analyses, the factor of safety increased from 1.0 under 2019 conditions to 1.30 after treatment in 2021. It is recommended that the pile reconfiguration design be carried out.

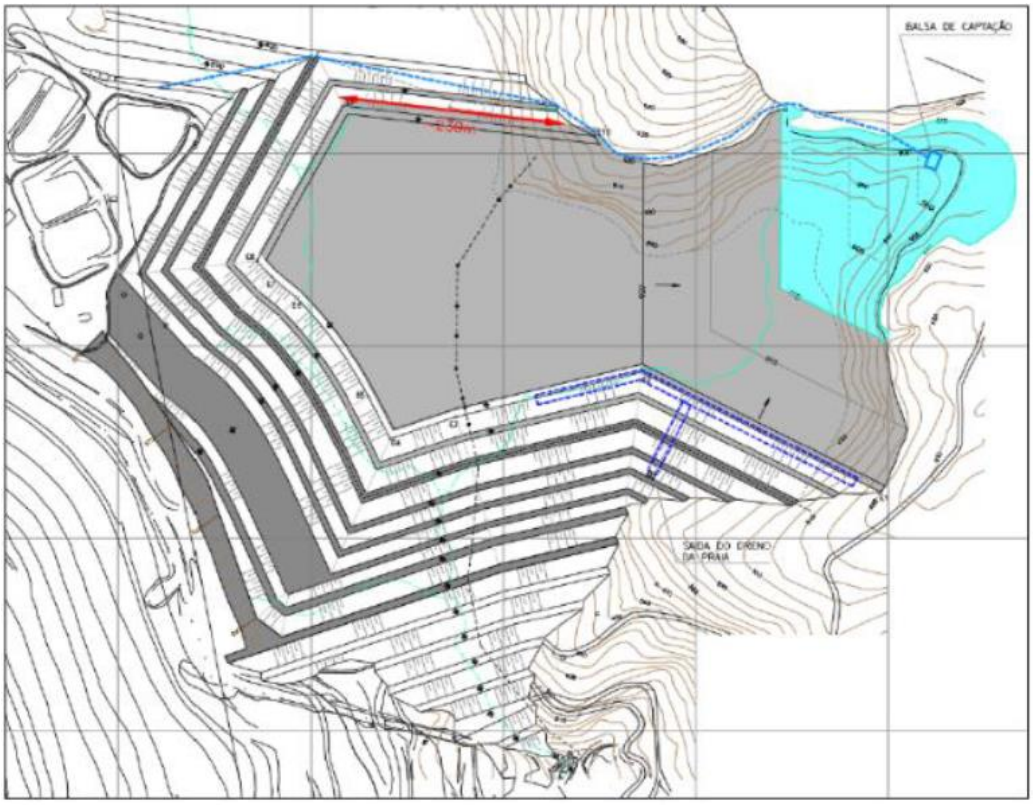
Monjolo Drained Pile

The Monjolo drained pile (ED) is located at the Água Limpa Mine, MG. Its design, monitoring and stability analysis were reviewed by the Committee in July 2020. The stacking has been inactive since 2010, when its capacity was depleted and was replaced by the Vale das Cobras drained pile. Currently it is in the process of studies and design for decommissioning and subsequent reclamation. Design data is scarce and there are no as built design records. Thus, the current investigations are intended to obtain the as is.

The Monjolo drained pile was implemented over a 1-m thick drainage blanket, with a width of 10 meters, to prevent the formation of a water table above this interface. Construction of the pile was initiated with a starter dike, utilizing coarse cyclone material (underflow) with only 10 % passing through the #200 mesh. The predominantly fine fraction from the cycloning (overflow) was deposited in the Diogo dam. Information from the time of construction indicates that the underflow spigoting was performed from the outer periphery to the inside of the pile. Thus, the coarser sand of the underflow sedimented on the outer periphery and was roller-compacted, forming the perimeter slopes. And the finer sand from the underflow flowed with the water to the pile interior. Essentially the peripheral slopes consist of medium sand.

The drained pile has an accumulated volume of 19x106 m³, has a height of 145 m, with 6-m wide berms every 10 m in height, forming an overall slope of 1V:2.7H. An aerial view of the pile is shown below.

The drained pile has three free slopes and in the rest of the area the stack rests on the local elevations. The figure below shows a plan view of the pile, with its shape of an irregular polygon. The external slopes are vegetated and have an efficient surface drainage.



The structure has instrumentation consisting of 7 piezometers, 13 water level indicators (INAs), a flow meter, 22 monitoring prisms, 6 control prisms, and 2 prism monitoring

bases. In addition to this terrestrial monitoring, INSAR satellite monitoring is also performed. The instrumentation installed in the structure is fully adequate and well operated. Th phreatic surface is low, which confirms the efficiency of the internal drainage system. Satellite monitoring has shown no movement of the slopes.

A geotechnical investigation campaign was recently initiated consisting of mixed boreholes, CPTU's, geophysical investigation and collection of disturbed and undisturbed samples for soil laboratory testing. As the results of this research are obtained, the stability calculations for the main cross-section are revised.

There were technical diagnoses performed in 2014 and 2018, and a RISR audit in 2020. The stability analyses indicated satisfactory factors of safety values for all scenarios. The table below shows a summary of static and pseudo static stability analyses results, which meet all requirements established by Brazil's National Mining Agency (ANM).

Monjolo Drained Pile – Calculated Factors of Safety				
Section	**Drained Static Analisys**	**Undrained Static Analysis**	**Drained Pseudo-Static Analysis**	**Undrained Pseudo-Static Analysis**
Critical Section	1.67	1.45	1.42	1.24

The new geological-geotechnical field and laboratory investigations, the decommissioning design, a dam break study, the automation of monitoring instrumentation and the installation of new instruments were ongoing during the Committee’s review.

Despite the above and the adequate characteristics of the drained pile in relation to stability, in 2019, after the collapse of Dam 1 at the Córrego do Feijão Mine, the ANM classified the tailings piles raised upstream, regardless of the internal drainage condition, as subject to the same requirements as the tailings dams raised upstream. For this reason, despite the favorable characteristics of the Monjolo drained pile, due to the legislation in force, Vale is planning the reclamation of this structure.

Vale das Cobras Drained Pile

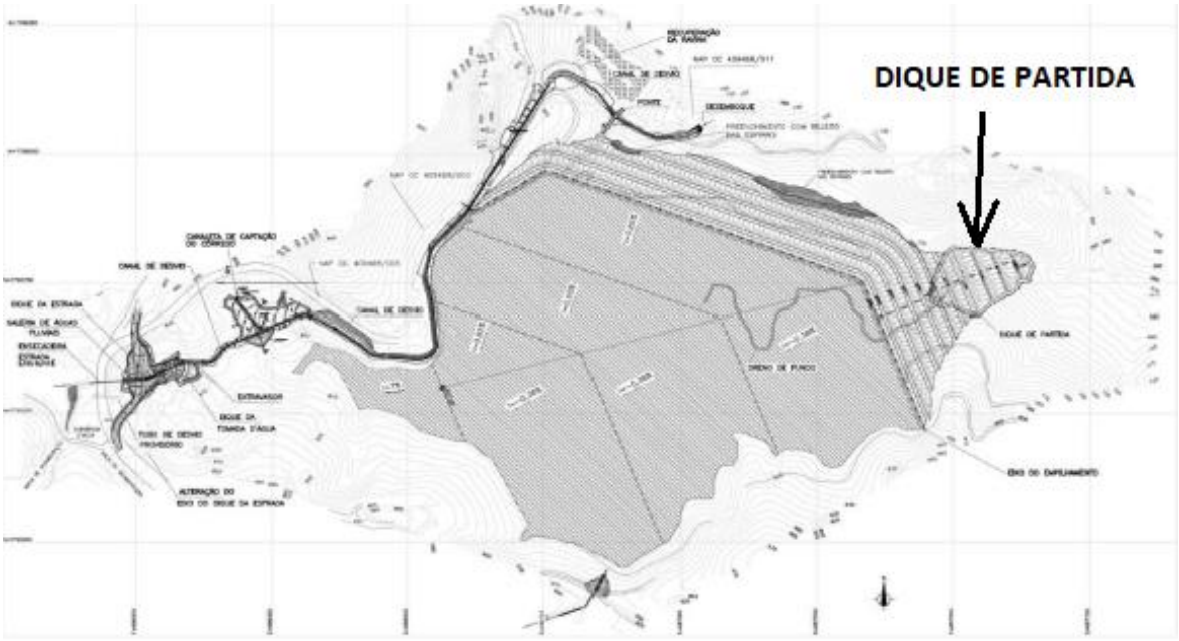
The Vale das Cobras drained pile is located in the Água Limpa Mine, MG. Its design, monitoring and stability analysis were reviewed by the Committee in July 2020. Currently, the pile is inactive and in the process of decommissioning in order to meet the current legislation.

Construction of the drained pile was initiated with a starter dike, with a height of approximately 55 m. A cofferdam was built upstream to divert the stream. The dike was built in 2010 and 2011, and consisted of a compacted soil embankment with a vertical filter and a drainage blanket. Its upstream face was protected with rockfill, which is separated from the soil embankment with transition materials interconnected to the

internal drainage system. The dike's downstream slope has three berms and forms a slope of approximately 1V:3H.

From this dike, the drained pile was raised utilizing coarse cyclone material. The predominantly fine fraction from the cyclone was deposited in the Diogo dam. Therefore, the pile consists predominantly of sand, with a volume of 20.8 x106 m³, discharged on the platform by spigots and spread by dozers to reduce the moisture to about 10%. The compaction was performed by the passages of these dozers. Currently, the pile is 105-m high, only 5 m below its original design level, presenting an external slope with 6-m wide berms at about every 10 m, forming an overall slope of 1V:3H.

The pile was originally designed to operate until 2021 and reach El. 810 m. The following figure shows the pile as designed.



Monitoring is performed by 11 piezometers, 9 water level indicators (INA's), 13 monitoring prisms and a flow meter. The instrumentation installed in the structure is fully adequate and well operated. The instrumentation indicates well controlled and very low water levels, which confirms the efficiency of the internal drainage system. Satellite monitoring was initiated and shows no movement of the slopes.

The phreatic surface is low, leading to satisfactory values of factors of safety for all scenarios. The table below indicates the results of static and pseudo static stability analyses, which meet all the requirements stipulated by ANM.

Vale das Cobras Drained Pile – Calculated Factors of Safety		
Analyzed Section	**Static Analysis**	**Pseudo-Static Analysis**
Reference FS	1.50	1.10
Section A-A - Global	1.55	1.32
Section A-A – Starter Dike	1.55	1.36
Section B-B - Global	1.51	1.32

Despite the above mentioned and the adequate characteristics of the drained pile in relation to stability, in 2019, after the collapse of Dam 1 of Córrego do Feijão, the ANM classified this tailings pile as raised upstream, regardless of the internal drainage condition, as subject to the same requirements of the tailings dams raised upstream. For this reason, despite the favorable characteristics of the Vale das Cobras drained pile, due to the legislation in force, Vale is planning the reclamation of the structure.

General Conclusions and Recommendations

In addition to the numerous specific recommendations mentioned above for all and each of the structures for tailings, sediments and/or water storage for various purposes, recommendations of broader scope associated with the various work contacts that the Committee had with Vale's teams over these two years are summarized in this chapter.

During all the contacts, the Committee members interacted with technical and management teams of high capacity and dedication. The following recommendations can complement the quality of these teams and support future decisions.

- A lack of design documentation was noted, even in some projects developed from the beginning by Vale or by one of its associated companies. This aspect is even more striking in mining structures acquired from third parties. This lack of technical documentation required efforts to obtain the characteristics of each structure through investigations and testing to obtain an *"as is"* document, whose accuracy is not as reliable as an *"as built"* document. Considering that in many cases mining activities occur over a long period of time, it is important to know how the construction was performed and under which criteria each structure was designed. Consequently, it is recommended that in future projects there should always be a sufficiently detailed and a well filed *"as built"* report.

- In all designs and construction and, most notably in the most urgent designs and in unconventional structures involving large concrete production, which is not common in mining projects, such as the admirable speed of execution since the first quarter of 2019 in the containment structure of Gongo Soco, impacted the technological analysis of the design. It is recommended that in work at a normal pace

of execution, the technological analysis of the design and construction methods should be performed more carefully.

- The containment structures of Gongo Soco and Mar Azul are completed and the containment structure of Fábrica is near to a successful completion. These three containment structures are large projects constructed under short schedules, involving high financial and intense human resources. These projects protect extensive downstream areas from economic, social and environmental impacts of the potential collapse of tailings dams that were at a high emergency level. With the construction finalized and one of them having already provided a significant benefit in attenuating the historically unprecedented severe flood wave that occurred on January 23 and 24, 2020, when it was still under construction, it is clear that these structures may continue to provide important contributions at least in flood control, an aspect practically abandoned in Brazil since the dissolution of the National Department of Sanitation Works (Departamento de Obras de Saneamento - DNOS) that occurred during the Collor de Mello government. Thus, if these structures are not affected by the collapse of Forquilhas I, II, III and IV, Grupo, Sul Superior, Sul Inferior and B3/B4 tailings dams before these dams are reclaimed, these structures have all the capacity to become excellent flood control dams generating safety and benefits to the downstream populations. Probably, for this purpose, in the current water intakes, only one sluice gate would be left in operation, and the others plugged with concrete. Vale could directly operate these structures or transfer them to the state or federal administration.

- In important dams under construction or undergoing raising, such as Itabiruçu, Maravilhas III and B-7, it was noted that lack of foundation basic investigation data generated costly interruptions in the construction activities, negatively impacting tailings disposal activities and, consequently, mineral processing. It is recommended that the investigations during the project design phase (basic design) be as detailed as possible, so that these interruptions during the construction of dams or pile raises are avoided.

- At the beginning of 2019, Vale had thirty-one geotechnical structures raised upstream, one of which, the B-1 dam in Brumadinho, collapsed on January 25, 2019. Shortly after, Vale began a program of reclamation of the other thirty geotechnical structures that had been raised upstream, which was later supported by the legislation that came into force about these structures. Vale's report issued in March 2021 to the US Security and Exchange Commission indicates that of the remaining thirty structures, five have already been completely reclaimed, leaving thirteen dams, ten dikes and two drained piles to be reclaimed. The Committee considers the reclamation program for dams and dikes that have been raised upstream appropriate.

- Since 2016, Vale has invested in the study and implementation of tailings disposal by dry stacking, which allows the disposal of dewatered tailings in piles without the need for construction of a dam. Between May 2016 and February 2018, Vale conducted a pilot filtration test and the construction of experimental stacks in the Pico Complex and, in December 2019, organized an internal workshop to discuss the dry stacking technology. A member of the Committee attended the workshop.

  Typically, for dry stacking, the tailings are initially thickened and then filtered to achieve a moisture content suitable for compaction and stacking of the dewatered tailings in a solid state. In some cases, the moisture content of the filtration may be too high to achieve adequate compaction and, in that case, an additional adjustment of the moisture by air-drying is performed on the stack prior to compaction. This technology allows the construction of stable piles that occupy less area than the conventional tailings storage facilities.

  In March 2021, in a report to the *United States Securities and Exchange Commission*, Vale announced an estimated investment of 2.4 billion US dollars between 2020 and 2024 for the construction of five tailings filtration facilities, four in the state of Minas Gerais using vacuum disc filters, one located in the Vargem Grande Complex (Pico Mine), two in the Itabira Complex (Conceição and Cauê mines) and one in the Brucutu Mine, with respective tailings filtration capacities of 28,429 t/day, 71,519 t/day, 45,338 t/day and 46,414 t/day. These plants will be the largest plants in the planet and in a humid climate (currently the largest is in Australia, in a dry climate, with capacity of approximately 35,000 t/day). These plants are scheduled for operation start-up between the first quarters of 2021 and 2022.

  The first filtration plant, located in Vargem Grande, gradually started operation in March 2021. Below is an image of the facility in Itabira, in the Conceição Mine.

A fifth plant that utilizes a filter press and with less capacity (1,424 t/day) has been scheduled to startoperation in Corumbá, Mato Grosso do Sul at the end of 2021.

The Committee supports the development and use of the dry stacking technology for tailings disposal and notes the large production rates for which the plants are being developed and the rapid implementation by Vale.

- Drained piles with good performance, such as Monjolo and Vale das Cobras, have extremely efficient drainage and high factors of safety, verified by monitoring of confirmed quality. For these structures it is not possible to perform a "*dam break*" analysis because they do not have a water reservoir. Although Brazil's National Mining Agency (Agência Nacional de Mineração - ANM) has classified these structures as being raised upstream and, under the legislation in force, they should be reclaimed, efforts are recommended with the indicated Agency to avoid the reclamation of these structures because they are proven not to have a collapse hazard.

- An interesting technological research on the liquefaction of saturated tailings, conceived by Vale, should be initiated in the very near future with the support of researchers and laboratories from COPPE/UFRJ (Alberto Luiz Coimbra Institute of Graduate Studies and Engineering Research of the Universidade Federal do Rio de Janeiro), UENF (Universidade Estadual do Norte Fluminense) and UFRGS (Universidade Federal do Rio Grande do Sul). The research will be conducted in two stages that can be performed simultaneously. In the first stage, a box model containing samples of the tailings to be studied will be utilized. The box will be subjected to vibrations simulating seismic events of different intensities, to evaluate the conditions under which liquefaction occurs. In the second stage, the liquefaction of the tailings will be investigated in two centrifuges, one located at COPPE/UFRJ and the other at UENF. The research will be conducted under the responsibility of the three universities. The Committee participated in the initial contacts to structure the research and recommends its continuation.

- In 2020, two fundamental documents were issued on technical governance guidelines for the design and operation of tailings storage structures. These documents are *"The Global Industry Standard on Tailings Management" (International Council of Mining & Metals et al)* and "*Safety Policy for Dams and Geotechnical Mining Structures"* (Vale). These two documents present the general guidelines to be followed regarding the studies, design, construction, operation, monitoring, closure and decommissioning of tailings dams. The Committee was consulted in advance and expressed its full support for the application of these guidelines for Vale dams and recommends that all Vale project designers, consultants and technical personnel follow these guidelines. These documents are briefly discussed below. In addition to technical engineering aspects, the following should be highlighted in the *"Global Industry Standard on Tailings Management"*:

i) Involvement and participation of the affected communities;
ii) Designation and institution of the *"Engineer of Record" (EoR);*
iii) Establishment and implementation of review levels as part of a quality and risk management system for all stages of the tailings storage structure life, including its closure;
iv) Promote the relevance of governance for the establishment of policies and systems that implement and verify compliance with these policies;
v) Implementation of emergency action plans.

In November 2020, Vale approved and published the Safety Policy for Dams and Geotechnical Mining Structures (POL-0037-G). The purpose of this policy, which is applicable to all types of dams, dikes, mines and waste rock piles, is to establish guidelines and commitments for the safety management of these structures, in order to correctly manage the critical aspects, as well as to meet the risk controls associated with the management systems that have been implemented. Having also been consulted, the Committee fully agreed to the formulation of this policy and recommended its implementation as soon as possible. The following are some aspects of this policy:

- Creation of the *"EoR, Engineer of Record"* role, which is the person responsible for permanent technical oversight throughout each structure life.
- Documentary record of historical technical analysis of the real physical conditions of all dams.
- Reclamation of all dams raised upstream.
- Alternative tailings disposal design in dams with increased solids content and humidity reduction.
- Implementation of the Safety Management System, so that the geotechnical structures are built and/or raised in accordance with detailed engineering design, under the oversight of the Engineer of Record - EoR and that the structures are operated in accordance with the operation, maintenance and geotechnical surveillance manuals.
- Contracting of engineering, external review and consulting services prioritizing the quality and the ethics, and not the cost of the services.
- Ensuring that all components of dams and mining waste storage facilities are designed with the best available technology and best practices, in accordance with the best practices of international institutions.
- Maintaining and distributing to the stakeholders a contingency preparedness plan for emergency response for the critical geotechnical assets.
- Implementing various controls aimed at managing the water present in the tailings storage facilities, from the project design phase to the operation, utilizing hydraulic structures to convey the surface water outside of the reservoir.

- Disposal of tailings considering, in the guidelines or operational parameters, the discharge sequence in order to ensure that the water is maintained away from the upstream slope of the tailings storage facility structure.
- Efficient reclaiming of water used in the production processes, with the use of tailings thickeners to reduce the amount of water to be transported with the tailings.
- Professional development of employees, so that they have the appropriate training for their key functions in geotechnical, hydrotechnical, mine operation and process activities.
- Performing at all stages of the asset life cycle, geotechnical risk controls and activities associated with geotechnical monitoring, identified based on the studied failure modes and their associated consequences.

The Committee has worked continously during these two years with Vale's management and technical personnel and has witnessed the successful implementation of the policies summarized above. It is noteworthy that the system of review levels is already in full operation, having designated the ”EoR” for the majority of the most important dams, as well as the "Independent Technical Review Boards” for the areas in which Vale operates.

An important Vale decision for the management of designs and construction was, therefore, initiating the implementation of the “design review” and the “EoR” since 2020 through consulting engineering companies, and enabling a better technical management of the structures reinforced by direct and continuous supervision.

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APPENDICES

Appendix A

List of Reports, Technical Notes and Technical Documents Issued by the Committee

Document Number	Subject / Structure	Material Receipt	Date Posted on the Portal
RL 01	Maravilhas III Dam	04/12/2019	05/06/2019
RL 02	Sul Superior Dam, Sul Inferior Dam, Laranjeiras Dam, Itabiruçu Dam and the Pontal System dams and dikes	05/04/2019	05/06/2019
RL 03	Itabirucu Dam	06/18/2019	06/18/2019
RL 04	Forquilhas I, II, III and IV Dams, Sul Superior, Sul Inferior, Cianita 2 and 3, Campo Grande, Borrachudo Dams 2 and 3, Portaria Dike, Doutor, Vargem Grande, Fernandinho and 8B dams	06/28/2019	06/28/2019
RL 05	Containment Structures Downstream of B3 / B4, Forquilhas e Sul Superior	08/07/2019	08/07/2019
RL 06	Structures of the Viga, Santanense, Esperanca and Serrinha mines	08/26/2019	08/26/2019
RL 07	Fourth Technical Visit to Dams and Downstream Containment Structures	09/09/2019	09/10/2019
RL 08	CCR structures for tailings containment	09/16/2019	09/17/2019
RL 09	Mello Small Hydroelectric Power Plant	09/28/2019	09/30/2019
RL 10	Fifth Technical Visit to Dams and Downstream Containment Structures	10/24/2019	10/30/2019
RL 11	Waste and Tailings Pile (PDER) at Esperança Mine	11/04/2019	11/04/2019
RL 12	Containment Structures -Sul Superior and Sul Inferior, Forquilhas and Grupo, B3/B4 tailings dams	11/28/2019	11/29/2019
RL 13	Containment Structures -Sul Superior and Sul Inferior, Forquilhas and Grupo, B3/B4 tailings dams	12/23/2019	12/26/2019
RL 14	Containment Structures -Sul Superior and Sul Inferior, Forquilhas and Grupo, B3/B4 tailings dams	01/08/2020	01/09/2020
RL 15	Containment Structures -Sul Superior and Sul Inferior, Forquilhas and Grupo, B3/B4 tailings dams	01/31/2020	02/03/2020

Document Number	Subject / Structure	Material Receipt	Date Posted on the Portal
RL 16	Pará Dams: Sossego, Mirim, Gelado, Geladinho, Pera Jusante	02/28/2020	03/02/2020
RL 17	B3 / B4 and Forquilhas Containment Structures	03/17/2020	03/18/2020
RL 18	B-7 Viga Dam	03/17/2020	03/18/2020
RL 19	Mina de Fábrica Dam - Notes on Monitoring	04/13/2020	04/14/2020
RL 20	Gelado Dam - Performance in Extreme Flood Scenarios	04/17/2020	04/20/2020
RL 21	Doutor Dam	04/20/2020	04/21/2020
RL 22	Containment Structure of Sul Superior e Sul Inferior, Performance in Extreme Flood Scenarios	04/26/2020	04/27/2020
RL 23	Forquilhas Containment Structure - Performance in Extreme Flood Scenarios	04/29/2020	04/30/2020
RL 24	Containment Structure B3/B4	05/31/2020	06/01/2020
RL 25	Mirim Dam	07/04/2020	07/06/2020
RL 26	Norte Laranjeiras Dam	07/20/2020	07/27/2020 (Rev.)
RL 27	Doutor Dam	07/27/2020	07/30/2020 (Rev.)
RL 28	Gongo Soco Containment Structure	07/29/2020	07/30/2020
RL 29	Santana Dam	07/30/2020	07/31/2020
RL 30	Taquaras Dam	08/18/2020	08/18/2020

Document Number	Subject / Structure	Material Receipt	Date Posted on the Portal
RL 31	Doutor, Campo Grande, Dicão Leste and Pilha Xingu dams	08/24/2020	08/25/2020
RL 32	Monjolo and Vale das Cobras Drained Piles	08/25/2020	08/25/2020
RL 33	Earthworks of the Santana Dam	08/27/2020	08/28/2020
RL 34	Maravilhas II Dam	08/31/2020	09/03/2020
RL 35	B3/B4 Containment Structures	08/31/2020	09/03/2020
RL 36	Itabiruçu and Borrachudo II dams	09/10/2020	09/11/2020
RL 37	Torto Dam	09/14/2020	09/15/2020
RL 38	Torto Dam	09/18/2020	09/22/2020
RL 39	B-7 Dam Flood Spillway	10/29/2020	10/30/2020
RL 40	Maravilhas III Dam	11/26/2020	11/27/2020
RL 41	Menezes I and II dams	11/28/2020	11/30/2020
RL 42	Capim Branco Dam	12/05/2020	12/08/2020
RL 43	Capitão do Mato Dam	01/11/2021	01/13/2021
RL 44	Nova Santarém Dam	01/17/2021	01/19/2021
RL 45	Paracatu Dike	02/07/2021	02/08/2021

Document Number	Subject / Structure	Material Receipt	Date Posted on the Portal
RL 46	Forquilhas Containment Structure	02/21/2021	02/22/2021
RL 47	Nova Maurício Hydroelectric Dam	03/17/2021	03/17/2021
RL 48	Concrete Technological Control - Forquilhas Containment Structure	03/19/2021	03/23/2021
RL 49	Concrete Technological Control - Forquilhas Containment Structure	04/13/2021	04/14/2021
RL 50	Maravilhas II Dam - Performance for extreme spillway inflow scenario	04/15/2021	04/16/2021
NT 01	General Recommendations for Design and Construction of Concrete Structures	05/25/2020	05/26/2020
NT 02	Factors of Safety in Dams and Tailings Piles	06/14/2020	06/15/2020
NT 03	Sul Superior e Sul Inferior Containment Structure	06/26/2020 (Rev.)	06/30/2020 (Rev.)
NT 04	Performance of Gravity Concrete Dams Constructed as Roller Compacted Concrete Structures in Earthquake Scenarios	06/30/2020 (Rev.)	06/30/2020
NT 05	Vertical Drilling in Dam Embankments	08/31/2020	09/03/2020
NT 06	EMESA Waste and Tailings Pile Stabilization	09/10/2020	09/11/2020
NT 07	B3/B4 Containment Structure Overflow	10/14/2020	10/14/2020
NT 08	Forquilhas Containment Structure	10/29/2020	10/29/2020
NT 09	Paracatu Dike	11/04/2020	11/05/2020

Document Number	Subject / Structure	Material Receipt	Date Posted on the Portal
NT 10	Comments on Meetings held between 9/28/2020 and 10/28/2020	11/11/2020	11/11/2020
NT 11	PCH Mello - Dam Reinforcement Project	11/19/2020	11/23/2020
NT 12	Dams of the Córrego do Feijão Mine	11/25/2020	11/26/2020
NT 13	EMESA pile	11/26/2020	11/26/2020
NT 14	Capitão do Mato Dam	12/14/2020	12/14/2020
NT 15	Forquilhas Containment Structure	12/18/2020	12/18/2020
NT 16	Foundation of the Maravilhas III Dam	01/06/2021	01/11/2021
NT 17	Capitão do Mato Dam - Stability of the Right Hillside	01/10/2021	01/11/2021
NT 18	Capitão do Mato Dam	01/12/2021	01/13/2021
NT 19	Norte Laranjeiras Dam	01/21/2021	01/22/2021
NT 20	Reclamation of the Germano Dam	01/21/2021	01/22/2021
NT 21	Settlement of the Itabiruçu Dam	02/16/2021	02/18/2021
NT 22	EMESA pile	04/09/2021	04/09/2021
Doc 01	Progressive Summary of Recommendations - Rev.0	-	05/04/2020
Doc 01	Progressive Summary of Recommendations - Rev.1	11/16/2020	11/16/2020

Document Number	Subject / Structure	Material Receipt	Date Posted on the Portal
Doc 01	Progressive Summary of Recommendations - Rev.2	02/08/2021	02/08/2021
Doc 01	Progressive Summary of Recommendations - Rev.3	03/23/2021	03/23/2021
Doc 01	Progressive Summary of Recommendations - Rev.4	04/21/2021	04/22/2021
Doc 02	Response to the Board's inquiries regarding Technical Note 02/20	07/04/2020	07/22/2020
Doc 03	Clarifications about Drained Piles Monjolo and Vale das Cobras	09/30/2020	10/01/2020
Doc 04.	Considerations about the questions raised by Vale (ENGCORPS)	03/23/2021	04/05/2021
Doc .05	Forquilhas Containment Structure - Minas Mais Consortium Comments	03/30/2021	04/05/2021
Doc 06	Forquilhas Containment Structure - Minas Mais Consortium Comments	04/14/2021	04/15/2021
Doc 07	Fábrica Containment Structure – Comments about CBR and Pinhole testing	04/30/2021	04/30/2021
Doc 08	Comments about Recommendations Status Tables	04/30/2021	04/30/2021

Appendix B

List of Virtual Meetings Held Since May 2020 Due to the Pandemia

Subject of meeting	Main participants by Vale	Date of Meeting
Relatorio_Resposta_CIAE-SB_CJS-REV.0	Deni and Decio	05/04/2020
B-7 Dam and EMESA Pile	Daniel Raposo and Cristiano Souza	05/08/2020
EMESA	Daniel Raposo	05/13/2020
Feedback with energy area	Ricardo Mendes and Leonardo Bretas	06/22/2020
Definition of 2.0 safety factor for VALE dams	Request Rafael Bittar and Diogo Costa	06/01/2020
Gongo Soco Analysis	Frank Pereira and Vagner Lima	06/04/2020
Forquilhas containment structure	Luiz Otavio Costa and Alexandre Valinhas	06/12/2020
Containment Minervino and Cordon Nova Vista	Romulo Guerra	06/15/2020
Norte Laranjeiras Dam	Wilson Lugão	06/18/2020
Action plan - Dams with negative DCEs	Ednelson Presotti	06/19/2020
Recommendation status tables | Energy	Leonardo Bretas	06/22/2020
Maravilhas III	Fernando Sgavioli and Ricardo Jeunon	06/24/2020
Campo Grande / Dicão Leste / Doutor / Xingú Pilha Dams	Felipe Campolina and Eduardo Brum	06/25/2020
Itabiruçu and Borrachudo II dams	Quintiliano Guerra	06/29/2020
Vale das Cobras and Monjolo Drained piles	Quintiliano Guerra	06/30/2020
Norte Laranjeiras Dam	Ricardo Leão	07/02/2020
Factor of Safety	Rafael Bittar	07/06/2020

Subject of meeting	Main participants by Vale	Date of Meeting
B3/B4, Sul Superior and Inferior and Vargem Grande Structures	Daniel Tibo and Vagner de Albuquerque	07/08/2020
Santana Dam	Quintiliano Guerra	07/09/2020
Maravilhas II Dam	Cristiano Santana and Talles Mendonça	07/14/2020
PCH Mello	Frank Pereira	07/15/2020
General Status of the Fábrica Containment Structure	Luiz Otávio Costa	08/04/2020
Technical note alignments 02 CIAE - SB	Rafael Bittar	08/12/2020
Torto Dam	Fernando Sgavioli and Ricardo Jeunon	08/13/2020
Mutuca Dam - Viga Dam 5 / Dam 7	Daniel Raposo	08/26/2020
Ferrosos Recommendation status tables	Daniel Tibo and Henrique Diniz	08/27/2020
Update on the Maravilhas III dam with an emphasis on foundations	Fernando Sgavioli and Ricardo Jeunon	09/25/2020
Paracatu Dike	Wilson Lugão and Igor Cicolani	09/28/2020
Update on the Maravilhas III dam with an emphasis on foundations	Fernando Sgavioli and Ricardo Jeunon	10/05/2020
Germano, Santarém and remnant of Fundão da SAMARCO Dams	Samarco	10/7/2020
Dam 6 and Dam 7A Structures / Patrimônio Dike	Fabrício Cardozo	10/09/2020
Dam IX, from the Fábrica mine. Dam IX, from the Fábrica mine	Felipe Russo	10/13/2020

Subject of meeting	Main participants by Vale	Date of Meeting
Dam IX, of the Fábrica mine	Arthur Duarte	10/13/2020
EMESA pile and B7 dam	Daniel Raposo	10/16/2020
Paracatu Dike	Renan Bezerra	10/28/2020
Corrego do Feijão	Eduardo Neves	11/11/2020
B1 and B6 Córrego do Feijão Dam	Eduardo Neves	11/25/2020
Capitão do Mato Dam	Gustavo Marçal / Henrique Penido	11/27/2020
Reinforcement projects for the Gelado, Geladinho and Estéril Sul dams	Bruno Campos	12/01/2020
Recommendation status tables	Daniel Tibo	12/02/2020
Forquilhas I, II, III and Group dams, from the Fábrica mine.	Luiz Otávio Costa	12/08/2020
Samarco - Nova Santarém and Germano dams	Samarco	12/12/2020
CIAE-SB Recommendation status tables - Update items in validation.	Henrique Diniz	12/16/2020
Clarification on Technical Notes	Rodrigo Marinaro	12/28/2020
North Dam / Laranjeiras Update	Ricardo Leão	01/5/2021
Germano Dam - Samarco	Luis Cervantes	01/07/2021
Itabiruçu Dam	Quintiliano Guerra	01/21/2021

Subject of meeting	Main participants by Vale	Date of Meeting
Questions about stress-strain analysis in ECJ-CCR - Gongo Soco	Vagner Lima	01/22/2021
Maravilhas III Foundation Treatment Project	Fernando Sgavioli	02/9/2021
ECJ Projects Phase 1 and Reinforcement of Dike 3	Celso Bora	02/22/2021
Fábrica containment structure	Alexandre Valinhas	03/18/2021
EMESA pile	Leandro Bruschi	03/29/2021