ANALYSIS AND CLASSIFICATION OF ENERGY GENERATION DAMS IN THE MUNICIPALITY OF COLATINA-ES: an application of the ANEEL method

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ABSTRACT

The aim of this article is to analyze and classify the dams used to generate electricity in the municipality of Colatina-ES. The study was carried out through exploratory research, an assessment that seeks to provide results on the risk classification of power generation dams in the city. The analysis of the calculations relies on ANEEL's matrix of dam classification indicators. These indicators provide various parameters for classifying the risk of dams. Thus, it can be concluded that the classification did not identify immediate risk factors/accidents.

Keywords: *Dams, Monitoring, Classification, Quality, Safety.*

1 INTRODUCTION

Earth dams are long-standing constructions. One of the oldest records is of a 12-meter-high dam built in Egypt approximately 6,800 years ago, which burst due to overflow (MASSAD, 2010 p.161). In Brazil, according to Vargas (1977), the first Brazilian earth dams were built in the Northeast at the beginning of the 20th century, as part of the plan to combat drought, and were designed on an empirical basis. The Curema dam, built in Paraíba in 1938, relied on new knowledge of soil mechanics.

Also according to Vargas (1977), the Vigário dam in the state of Rio de Janeiro was built in 1947 using the modern technique for designing and building earth dams in Brazil, where the vertical filter or chimney was used as an internal drainage element for earth dams.

Resolution No. 072, of December 19, 2018, of the STATE AGENCY FOR WATER RESOURCES - AGERH (2020), establishes the periodicity of execution or updating, the qualifications of the technical managers, the minimum content and the level of detail of the Dam Safety Plan, which will include the Special Safety Inspection and the Regular Safety Inspection.

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For what reason was an evaluation created on Resolution 072/2018 establishing safety and inspections in dams? This evaluation of the methods used to ensure the safety of the population around the dam will be assessed using the questionnaires in Appendix I and II.

With this in mind, the aim of this article is to study the safety and inspections of dams in the municipality of Colatina, Espírito Santo, by applying the Dam Safety Plan and Regular and Special Safety Inspections proposed by Resolution No. 696 of December 15, 2015 - Establishes criteria for classification, formulation of the Safety Plan and carrying out the Periodic Safety Review of dams inspected by the National Electric Energy Agency (ANEEL).

2 DAM

According to Raduns et al. (2020), hydroelectric plants are responsible for a large part of our country’s energy production, and are the main form of electricity production.

According to Borges Neto and Carvalho (2012), Brazil is the second largest producer of electricity from hydroelectric plants, a privilege only a few countries have.

Also according to Borges Neto and Carvalho (2012), the purpose of dams is to impound the river’s water to allow it to be captured and diverted, for hydroelectric use or for the river to be navigable, and to form reservoirs to regulate flows.

A dam should be seen as a unit or an organic whole in space, comprising the dam basin, the foundation soils which are like an extension of the dam on surfaces, the attached or auxiliary structures, the sounding instruments (piezometers, settlement meters), are important for observing the behavior of the work and maintenance (MELO, 1975).

According to (Massad, 2010), a large dam is any dam with a height of more than 15m, or with heights between 10 and 15m and which meets one of the following conditions:

a) ridge length equal to or greater than 500m;

b) reservoir with a total volume of more than 1,000,000 m^3;

c) spillway with a capacity of more than 2,000 m3/s;

d) dam with difficult foundation conditions;

e) dams with an unconventional design (Massad, 2010, p.120).

According to Chiossi (2013), the basic elements of a dam are simplified in figure 1.

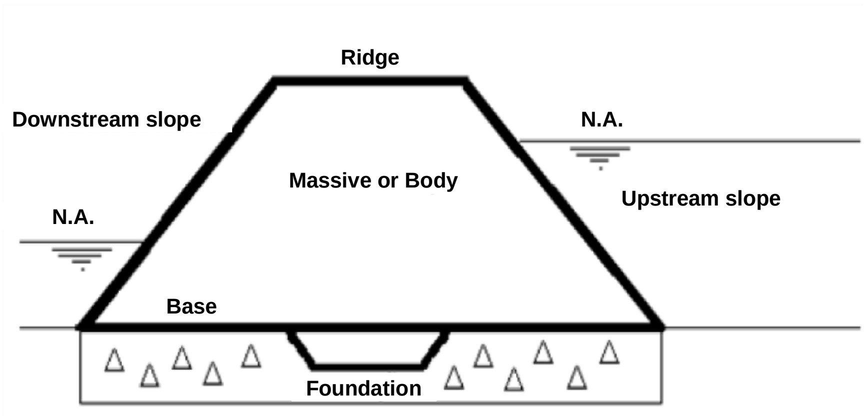

Figure 1: Basic elements of a dam
Source: Chiossi (2013)

Also according to Chiossi (2013), the structure of a dam, being subject to the action of a number of different forces, requires maximum precautions to avoid disasters on site.

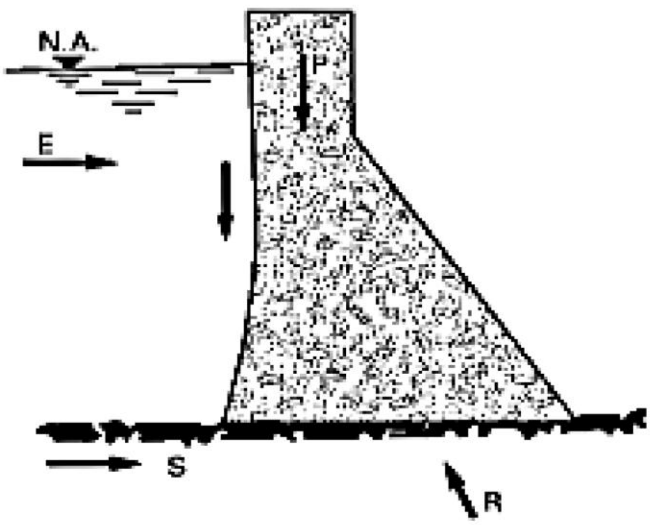

Figure 2: Forces acting on a dam.
Source: Chiossi (2013)

We have the following forces applied to a dam;

a) **P:** Weight of the dam: It depends on the volume of the dam and the specific weight of the materials used in its construction.

b) **E:** Hydrostatic thrust on the upstream face: in dams with a vertical upstream face, only the hydrostatic thrust on the upstream face will be considered. With an inclined face, the weight of the water on that face must also be determined.

> c) **S:** Water underpressure: Despite the measures taken during the design and construction of the dam to prevent percolation, some of the water will flow under pressure between the dam and the foundations. Because of this, the weight of the structure will be partially supported by the water, with a consequent reduction in the reaction of the foundations.
>
> d) **R:** Foundation reaction: Since V is the resultant of all the vertical forces and H is the resultant of all the horizontal forces acting on a dam, the composition of causes will give the overall result R. For a dam to be in static equilibrium, R must be absorbed by the reaction of the foundation, which must be equal and opposite to R, made up of a total vertical reaction equal to V and a resultant of friction. Same as H.
>
> e) **Other Forces:** The action of wind is rarely taken into account, as dams are built in sheltered locations. It is only felt on the downstream side, and is of little value in relation to the water pushing on the other side. In our country, we don't consider the effects of earthquakes or subsidence of the subsoil, which are taken into account in the United States, Japan, Chile, etc (CHIOSSI 2013 p.252).

Hydroelectric dams can be built with one or several types of materials in the same structure, including concrete, earth, rockfill, etc. (Massad, 2010).

2.1 HOMOGENEOUS EARTH DAM

The homogeneous earth dam is the most widely used, due to the topographical conditions, with very open valleys, and the availability of earthy material in Brazil, it tolerates more deformable foundations, and earth dams can be built on soft soils (Massad, 2010).

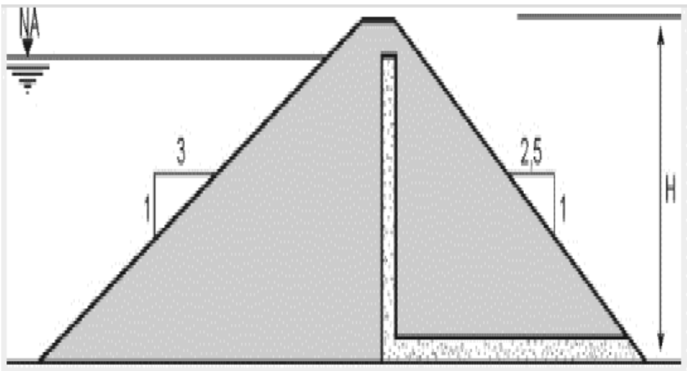

Figure 3: Homogeneous earth dam
Source: Massad, (2010).

Also according to Massad (2010), the slope of the upstream and downstream slopes is fixed in order to guarantee stability during the useful life of the dam, more specifically, at the end of construction, in operation and in situations of rapid lowering of the reservoir.

One of the problems that most concern the designer is piping or erosion. This phenomenon consists of soil particles being carried by flowing water, progressing from upstream to downstream over time, forming an erosion tube, which can develop into relatively large cavities in the body of the dams, leading them to collapse (MASSAD, 2010).

According to Massad (2010), in order to prevent the occurrence of collapse, percolation must be controlled, both by the foundations and by the body of the dam. In the embankment, the flow of water is intercepted in order to prevent it from exiting the faces of the downstream slopes or the downstream shoulders, by means of vertical (chimney-type) or inclined filters.

2.2 EARTH-FILL DAMS

According to Massad (2010 p.178), this type of dam is the most stable of the earth and rock-fill dams. The rock-fill material (stones) has a high friction angle, guaranteeing the stability of the upstream and downstream slopes, even when they are steep (slopes of 1:1.6 to 1:2.2).

The core of these dams can be central or inclined upstream, as shown in figure 2. When the clay and rockfill have comparable compressibility, the central core has the advantage of exerting greater pressure on the foundations, as well as on its base, which is beneficial in terms of controlling water losses (MASSAD, 2010).

According to Massad (2010), the core can be central (figure a) and has the advantage of exerting greater pressure on the foundations, as well as being wider at the base, thus controlling water losses, and the inclined core (figure b). One advantage of inclining the core is that there is no way of transferring its weight to the backstops, and another advantage of the inclined core is that a large part of the downstream rockfill can be lifted, saving time while the foundations are treated.

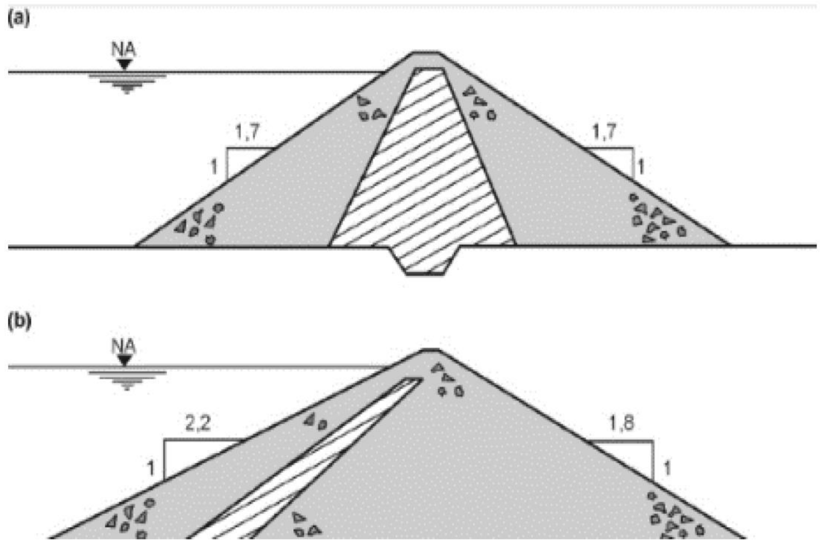

Figure 4: Earth-fill dam
Source: Massad, (2010).

2.3 ROCKFILL DAM WITH CONCRETE MEMBRANE

According to Massad (2010), dams with concrete membranes have concrete slabs as an impermeable septum on the upstream rockfill slope. These slabs are connected to each other by special joints, as they rest on a deformable medium, the rockfill, which can undergo significant settlements when it is first filled.

The great advantage lies in the construction schedule, as both the embankment and the concrete membrane can be built regardless of the weather, and rockfill embankments can be designed to withstand the detour of rivers through the rocks (MASSAD, 2010).

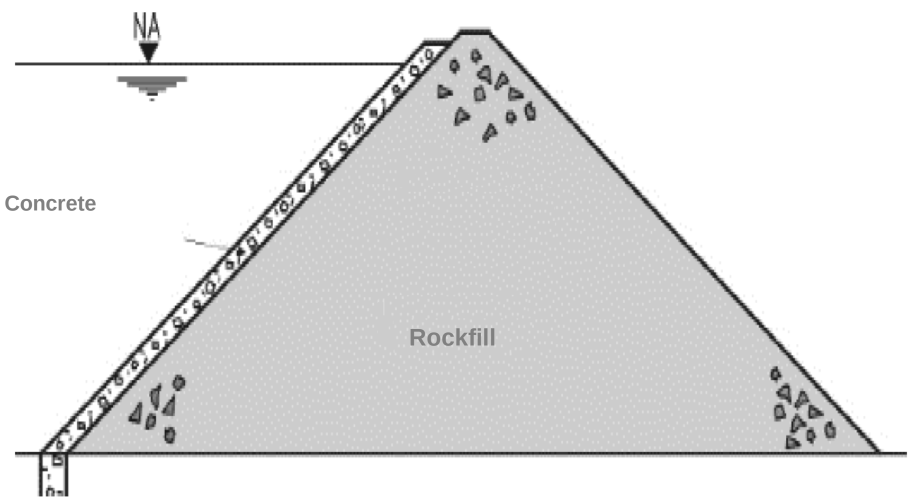

Figure 5: Rock-fill dam with concrete membrane.
Source: Massad, (2010).

2.4 HYDRAULIC EMBANKMENT DAM

According to Massad (2010), the soil is transported with water through pipes to the construction site. When it is dumped, the material segregates, separating the sands, which form the backfill, from the fines, which end up forming the core of the dam.

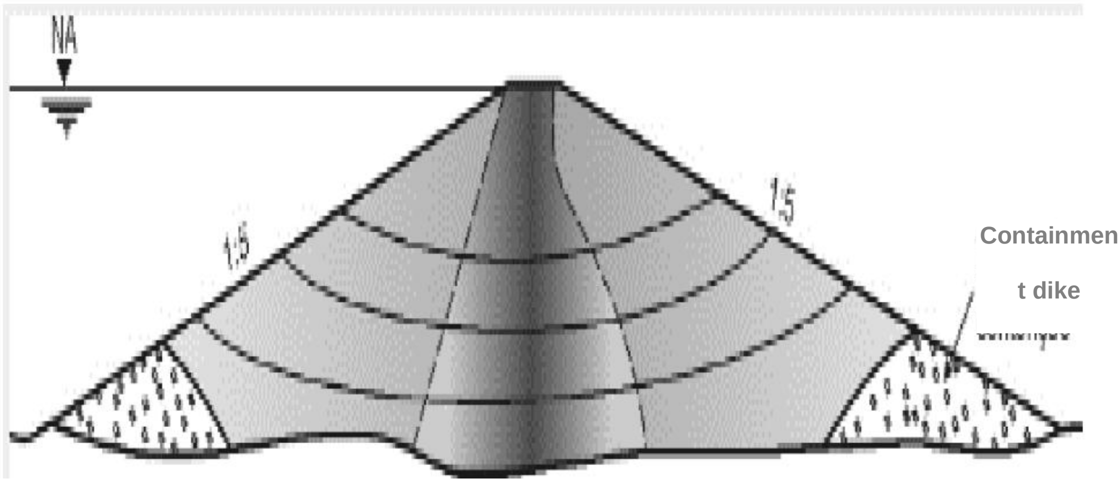

Figure 6: Hydraulic embankment dam.
Source: Massad, (2010).

3 DAM SAFETY PLAN

Resolution No. 696, of December 15, 2015, establishes criteria for classification, formulation of the Safety Plan and carrying out the periodic Safety Review of dams inspected by ANEEL (2015).

Complementary Law No. 912, of June 5, 2019, establishes the State Policy for the Governance and Safety of Dams, institutes the State System for the Governance of Water Infrastructure Projects and the State Information System on the Safety of Dams in the State of Espírito Santo. It mainly seeks to ensure that all dams in the state must have a Dam Safety Plan (PSB), where it is the responsibility of the developer to carry out this type of plan.

According to the National Water Agency - ANA (2016), in its practical guide to small dams, dam inspections are fundamental tools for managing dam safety and functionality, which must be included in the Dam Safety Plan. The inspection activity, although simple from a logistical point of view, is fundamental and must be carried out periodically and methodically. As a rule, whenever relevant anomalies are detected during inspections, corrective maintenance should be carried out.

ANA (2016) highlights Regular safety inspection A second level of inspection, known as regular inspection, corresponds to a higher level of detail, requiring a description of each of the aspects to be inspected and the measurement, whenever possible, of the dimensions of the anomaly,and a classification of the anomaly in historical terms (new, not evolving or evolving) and priority of intervention (alert or emergency situation, attention, potentially serious and not serious).

According to Massad (2010), the design of a dam should be based on two basic principles: safety and economy. The safety of the dam is obviously the overriding principle; human lives, community and individual assets depend on it.

Visual inspections are essential as part of dam safety control. In order to be effectively useful, they have to be carried out systematically and regularly. Three different types of inspection should be distinguished: routine, regular and special. Annex I contains a model of the regular inspection form for small earth dams (ANA, 2016).

3.1 ROUTINE INSPECTION

The regular safety inspection will be carried out by a Dam Safety team made up of trained and qualified professionals and should cover all the dam structures in the project and portray their safety, conservation and operating conditions (ANEEL, 2015).

Routine inspection is a frequent, faster activity designed to assess the general condition of the dam, detect the occurrence of new anomalies and monitor the progress of previously recorded anomalies. It should be carried out in conjunction with preventive maintenance activities, as provided for in the Planning of Routine Inspection and Preventive Maintenance Activities (ANA, 2016).

3.2 REGULAR SAFETY INSPECTION

The regular safety inspection will be carried out by a Dam Safety team made up of trained and qualified professionals and should cover all the dam structures in the project and portray their safety, conservation and operating conditions. (ANEEL, 2015).

According to the National Water Agency - ANA (2016), a second level of inspections, called regular inspections, corresponds to a higher level of detail, requiring a description of each of the aspects to be inspected, the measurement, whenever possible, of the dimensions of the anomaly, and a classification of the anomaly in historical terms (new, without or with evolution) and priority of intervention (alert or emergency situation, attention, potentially serious and not serious). The recommended frequency for these inspections is every six months, with one inspection at the start of the dry season and another at the start of the wet season.

3.3 SPECIAL INSPECTION

In addition to these regular inspections, whenever an exceptional event occurs, especially major floods, the operating conditions of the spillway(s) should be checked during the event and a very detailed inspection should be carried out afterwards, particularly of the spillway and the areas bordering it and the downstream foot of the dam, with a view to detecting erosion (ANA, 2016).

4 MATERIALS AND METHODS

4.1 CHARACTERIZATION OF THE STUDY MUNICIPALITY

Colatina is a city of 1,416 square kilometers, with around 123,000 inhabitants, 88% of whom live in urban areas and 12% in rural areas. Strategically located in the center of the state, the city has the greatest economic potential in the northern region. Located in the Rio Doce Valley, it is 130 kilometers from Vitória, the capital of Espírito Santo. The Vitória-Minas railroad, BR-259 and State Highway 080 pass through it (PREFEITURA MUNICIPAL DE COLATINA - PMC, 2020).

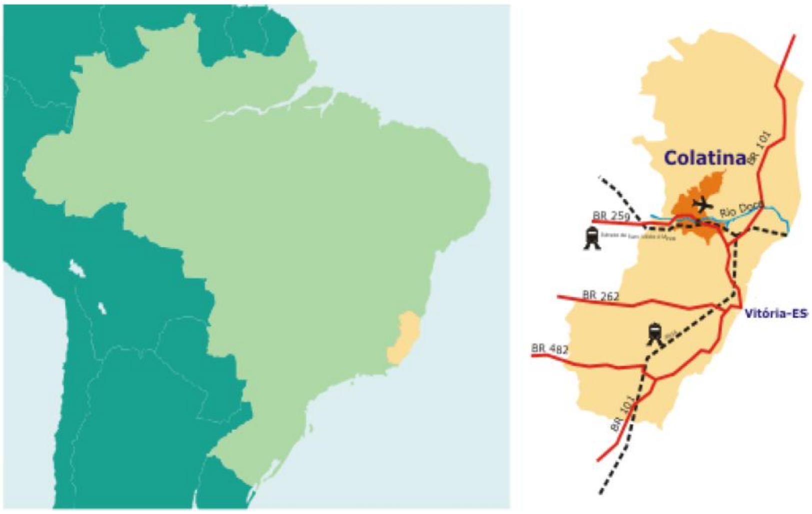

Figure 7: Location of the municipality of Colatina-ES.
Source: Colatina City Hall website (2020)2
[2]Available at < https://www.colatina.es.gov.br/> Accessed on: 20 Aug. 2020

The municipality of Colatina-ES has two dams for the purpose of generating electricity managed by the Santa Maria Light and Power Company, one located in the Córrego do Oito and Santa Maria districts. The dam developers are legally responsible for dam safety and must keep the information on their dams up to date with the respective inspection body (ANEEL, 2015).

4.2 DATA

The municipality of Colatina-ES has a Small Hydroelectric Power Plant (PCH), a concrete dam, located on the Santa Maria river, which is intended to generate electricity and is located at coordinates -19.6206 latitude and - 40.6150 longitude, with its operation authorized by the ANEEL supervisory body.

Photo 1: Santa Maria Dam
Source: Prepared by the authors

The Santa Maria dam, located in Colatina/ES, has been in operation since 1946 and is a small run-of-river hydroelectric power station with an installed capacity of 420 kW, two turbines, a gross drop of 13.61 m, a concrete dam with a maximum height of 5.30 m, a total crest length of 45 m and an open channel intake of 455 m, with a maximum turbine flow of 2.85 m^3/s.

The dams under study will be assessed in accordance with Resolution No. 696 of December 15, 2015, which establishes criteria for classification, formulation of the Safety Plan and carrying out the Periodic Safety Review of dams. (ANEEL, 2015)

According to ANEEL (2015), the method for evaluating and classifying electricity generation dams was based on the matrix for classifying water storage dams.

Also according to ANEEL (2015), this method assesses the dam according to Risk Category, such as: (Technical Characteristics, State of Conservation, Dam Safety Plan) and also the Associated Potential Damage, such as: (High, Medium, Low) and finally the final result will be calculated, informing the Risk Category and Associated Potential Damage.

Annex II of NR 696/2015 ANEEL contains the matrix for classifying water accumulation dams, where the following scores were assessed after photographic evaluation;

For the Risk Category according to the data in table 1, it was classified with a total score of 17 points, where its classification range was Low risk according to the classification in table 2.

TABLE 1: RISK CATEGORY

II.1 - RISK CATEGORY		Points
1	Technical Characteristics (TC)	11
2	Conservation Status (CS)	3
3	Dam Safety Plan (DSP)	3
TOTAL SCORE (CRI) = CT + EC + PS		**17**

Source: ANEEL (2015).

According to the total score in Table 2, if the Conservation Status (CS) is less than 8 points, the Low Risk Category band.

TABLE 2: RISK CATEGORY CLASSIFICATION

	RISK CATEGORY	**CRI**
CLASSIFICATION BANDS	HIGH	>= 60 or EC* >= 8 (*)
	MEDIUM	35 a 60
	LOW	<= 35

(*) A score (greater than or equal to 8) in any State of Conservation item automatically implies HIGH RISK CATEGORY and the need for immediate action by the person responsible for the dam.

Source: ANEEL (2015).

The Associated Potential Damage (APD) according to Annex II of NR 696/2015 ANEEL is classified according to Table 3.

TABLE 3: POTENTIAL ASSOCIATED DAMAGE

	POTENTIAL ASSOCIATED DAMAGE	**DPA**
CLASSIFICATION BANDS	HIGH	>= 16
	MEDIUM	10 < DPA < 16
	LOW	<= 10

Source: ANEEL (2015).

The Potential Associated Damage for the classification criteria was 5 points, and the dam was classified as having Low Potential Associated Damage.

5 RESULTS AND DISCUSSIONS

Based on a descriptive memorial, topographical and isometric plans and a site visit, a final assessment was made according to the risk classification matrix for the water accumulation dam for the purpose of generating electricity.

In a nutshell, the Risk Category obtained a total score in the Low classification range, due to the sum of the Risk Category being less than 35 points.

However, in the Potential Associated Damage - PAD category, there was a low score classifying PAD as a Low risk. The overall classification using the classification matrix was Low Risk Category and Low Potential Associated Damage.

Although no risk factors were identified during the on-site visual inspection, such as large erosions, extensive cracks, among others that could cause immediate incidents/accidents due to the dam being at its maximum height limit, as shown in photos 1 and 2.

However, the recommendations that new inspections and possible corrections be carried out during the dry season when the dam level is low should be followed as a way of preventing the anomalies from worsening and guaranteeing the future safety of the dam.

However, it should not be forgotten that anomalies, the cost involved in repairs and breakdown are correlated. As previously stated, academic literature shows that the costs related to dam failures are much higher than those that guarantee their safety.

With this work we can conclude that the Low Risk category was due to the fact that the Technical Characteristics (TC), State of Conservation (SC) and Dam Safety Plan (DSP) were satisfactorily accepted, but the verification of the technical evolution and biannual evaluations will certainly bring more safety to the Concrete Dam.

Despite the limitations of the work, since the upstream side of the dam was not inspected due to the high level of the Santa Maria River, all the proposed objectives were achieved by accurately reporting the physical conditions of the dams, and proposing biannual assessments and possible actions capable of confirming or minimizing anomalies.

In conclusion, the work is academically relevant in the sense that it contributes to research into ANEEL’s inspection methodology.

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APPENDIX I

ANNEX II
TABLE FOR CLASSIFYING WATER STORAGE DAMS

NAME OF THE DAM:	CGH Santa Maria
ENTREPRENEUR'S NAME:	Sta. Mª Geração e Trans, de Energia S/A
DATE:	30/05/2022

11.1 - RISK CATEGORY		**Points**
1	Technical Characteristics (TC)	**11**
2	Conservation Status (CS)	**3**
3	Dam Safety Plan (DSP)	3
TOTAL SCORE (CRI) = CT + EC + PS		**17**

	RISK CATEGORY	**CRI**
CLASSIFICATION BANDS	HIGH	>= 60 or EC* >=8(')
	MEDIUM	35 a 60
	LOW	<= 35

(*) A score (greater than or equal to 8) in any State of Conservation item automatically implies HIGH RISK CATEGORY and the need for immediate action by the person responsible for the dam.

II.2 - POTENTIAL ASSOCIATED DAMAGE		**Points**
	ASSOCIATED POTENTIAL DAMAGE (APD)	**5**

	POTENTIAL ASSOCIATED DAMAGE	**DPA**
CLASSIFICATION BANDS	HIGH	>=16
	MEDIUM	10 < DPA < 16
	LOW	<= 10

FINAL EVALUATION RESULT:

RISK CATEGORY	LOW
POTENTIAL ASSOCIATED DAMAGE	LOW

ANNEX I - RISK CATEGORY MATRIX AND ASSOCIATED POTENTIAL DAMAGE

RISK CATEGORY	**THE ASSOCIATED POTENTIAL**		
	HIGH	MEDIUM	LOW
HIGH	A	B	B
MEDIUM	B	C	C
LOW	B	C	C

Table 1: Table for classifying water storage dams
Source: ANEEL (2015).

APPENDIX II

1- TECHNICAL CHARACTERISTICS CT	POINTS
◉ Height	
○ Height <= 15 m (0)	0
○ 15 m < Height < 30 m (1)	
○ 30 m < - Height <=60 m (2)	
○ Height>60 m (3)	
b) Length	
◉ Length <= 200 m (2)	2
○ Length > 200 m (3)	
c) Dam type in terms of construction material	
◉ Conventional concrete (1)	1
○ Stone masonry / cyclopean concrete / CCR rolled concrete (2)	
○ Homogeneous earth / rockfill / rockfill earth (3)	
d) Type of Foundation	
◉ Healthy Rock (1)	1
○ Hard altered rock with treatment (2)	
○ Untreated altered rock / Fractured altered rock with treatment (3)	
○ Soft altered rock / saprolite / compact soil (4)	
○ Residual soil / alluvium (5)	
e) Dam age	
○ between 30 and 50 years (1)	4
○ between 10 and 30 years (2)	
○ between 5 and 10 years (3)	
◉ < 5 years or > 50 years, or no information (4)	
f) Design Flow	
◉ CMP (Probable Maximum Flood) or Decamillennial (3)	3
○ Millennial (5)	
○ TR = 500 years (8)	
○ TR < 500 years or Unknown / Unreliable study (10)	

TC (Total) 11

Table 2: Technical Features
Source: ANEEL (2015).

APPENDIX III

2- STATE OF CONSERVATION - EC	POINTS
g) Reliability of overflow structures	
◉ Civil and hydroelectromechanical structures in full working order / approach or restitution channels or spillway (free threshold type) unobstructed (0)	0
○ Civil and hydro-electromechanical structures ready for operation, but without emergency power supply sources / channels or spillway (free sill type) with erosions or obstructions, but without risks to the slope structure (4)	
○ Compromised civil structures or hydroelectromechanical devices with identified problems, with reduced flow capacity and with corrective measures being implemented / channels or spillways (free sill type) with erosions and/or partially obstructed, with risk of compromising the slope structure (7)	
○ Compromised civil structures or hydroelectromechanical devices with identified problems, with reduced flow capacity and no corrective measures / canals or spillways (free sill type) obstructed or with damaged structures (10)	
h) Reliability of Water Supply Structures	
◉ Civil structures and hydroelectromechanical devices in proper maintenance and operating condition (0)	0
○ Compromised civil structures or hydroelectromechanics with identified problems, with reduced flow capacity and corrective measures being implemented (4)	
○ Compromised civil structures or hydroelectromechanical devices with identified problems, with reduced flow capacity and no corrective measures (6)	
i) Percolation	
○ Percolation fully controlled by the drainage system (0)	3
◉ Moisture or emergence in downstream areas, walls, slopes or stabilized and/or monitored shoulders (3)	
○ Moisture or emergence in downstream areas, walls, slopes or shoulders without treatment or at the diagnostic stage (5)	
○ Outbursts in downstream areas, slopes or shoulders carrying material or with increasing flow (8)	
j) Deformations and settlements	
◉ Nonexistent (0)	0
○ Small cracks and subsidence with zero impact (1)	
○ Existence of cracks and subsidence of considerable impact, generating the need for additional studies or monitoring (5)	
○ Existence of significant cracks, subsidence or slippage with the potential to compromise safety (8)	
k) Slope Deterioration / Parameters (k)	
◉ Nonexistent (0)	0
○ Faults in the protection of slopes and walls, presence of small bushes and zero impact (1)	
○ Surface erosion, exposed ironwork, widespread vegetation growth, generating the need for monitoring or corrective action (5)	
○ Sharp depressions in the slopes, landslides and deep erosion grooves, with the potential to compromise safety (7)	
l) Lock	
◉ X No lock (0)	0
○ Well-maintained and functioning civil and hydroelectromechanical structures (1)	
○ Compromised civil structures or hydroelectromechanical devices with problems identified and corrective measures being implemented (2)	
○ Compromised civil structures or hydroelectromechanical devices with identified problems and no corrective measures (4)	

CE (Total) 3

Table 3: Conservation status
Source: ANEEL (2015).

APPENDIX IV

3- DAM SAFETY PLAN PS	**POINTS**
n) Existence of project documentation	
◉ Executive design and “as built” (0)	**0**
○ Executive design or “as built” (2)	
○ Basic design (4)	
○ Preliminary or conceptual design (6)	
○ No project documentation (8)	
o) Organizational structure and technical qualifications of the Dam Safety team professionals	
◉ Has an organizational structure with a technician responsible for dam safety (0)	**0**
○ Has a technician responsible for dam safety (4)	
○ Does not have organizational structure and technical responsible for dam safety (8)	
p) Safety inspection and monitoring routing procedures	
○ Has and applies inspection and monitoring procedures (0)	**3**
◉ Has and applies only inspection procedures (3)	
○ Has and does not enforce inspection and monitoring procedures (5)	
○ Does not have and does not apply procedures for monitoring and inspections (6)	
q) Operational rule for dam discharge devices	
◉ Yes or Free-standing spillway (0)	**0**
○ No (6)	
r) Safety inspection reports with analysis and interpretation	
◉ Regularly issues reports (0)	**0**
○ Issue reports without periodicity (3)	
○ Does not issue reports (5)	

PS (Total) 3

Table 4: Dam Safety Plan
Source: ANEEL (2015).

APPENDIX V

II.2. Table for classifying potential associated damage. DPA (Water Accumulation)	**Pts**
a) Total Reservoir Volume	
○ Small: <= 5 million m? (1)	**2**
◉ Medium: 5 million to 75 million m (2)	
○ Big: 75 million to 200 million m² (3)	
○ Very big: > 200 million m3 (5)	
b) Potential loss of human life	
◉ INEXISTENT: there are no permanent/resident or temporary/transit people in the area downstream of the dam (0)	**0**
○ NOT TOO FREQUENT: there are no people permanently occupying the affected area downstream of the dam, but there is a side road for local use (4)	
○ FREQUENT: there are no people permanently occupying the affected area downstream of the dam, but there is a municipal, state or federal highway or other place and/or enterprise where people may occasionally stay (8)	
○ EXISTING: there are people permanently occupying the affected area downstream of the dam, so human lives could be affected (12)	
c) Environmental impact	
◉ SIGNIFICANT: the area affected by the dam does not represent an area of environmental interest, areas protected by specific legislation, or is totally de-characterized from its natural conditions (3)	**3**
○ VERY SIGNIFICANT: the area affected by the dam is of significant environmental interest or protected by specific legislation (5)	
d) Socio-economic impact	
◉ INEXISTENT: there are no navigation facilities and services in the area affected by the dam accident (0)	**0**
○ LOW: there is a small concentration of residential and commercial, agricultural, industrial or infrastructure facilities in the area affected by the dam or port facilities or shipping services (4)	
○ HIGH: there is a high concentration of residential, commercial, agricultural, industrial, leisure and tourism infrastructure and services in the area surrounding the dam or port facilities or shipping services (8)	

DPA (Total) 5

Table 5: Table for classification of associated potential damage - DPA (Water Accumulation)
Source: ANEEL (2015).