IPG 2025 7th International Pipeline Geotechnical Conference
IPG2025
6-7 November 2025, Bogota, Colombia

IPG2025-006

URGENT INSPECTIONS AND ACTIVITIES ON THE RIGHT-OF-WAY AFTER HEAVY RAINFALL IN RIO GRANDE DO SUL - BR

Marcelo Moya
TBG
São Paulo, Brasil

Gilberto Sanches Hernandes
TBG
São Paulo, Brasil

César Augusto Costa
TBG
Mato Grosso do Sul, Brasil

ABSTRACT

The paper aims to show the actions and inspections the TBG team carried out after an extreme rainfall event on the pipeline's Right-of-Way (RoW). At the end of April and first days of May 2024 heavy rains and floods occurred in the south of Brazil, in Rio Grande do Sul State. The Civil Defense declared a public calamity throughout the state. The RoW of the TBG gas pipeline crosses the State for approximately 200 km. The storms affected more than 2.3 million people by hitting 471 municipalities, equivalent to almost 95% of all cities in Rio Grande do Sul in addition to affecting 13.7 thousand kilometers of roads, including federal and state highways.

According to RTDT (Regulatory document-ANP, 2011), pipeline operators must inspect sensitive sites along RoW and their surroundings to verify RoW' conditions most susceptible to critical impacts on operational safety and procedures, especially after extreme rains, like happened.

These activities about RoW geotechnical surveys include Routine Inspection (by Track Technicians); Inspection of "Sensitive Sites" (by Track Technicians); Occasional Inspection (by our own Geotechnical Engineer); and Geological-Geotechnical Inspection (by Geotechnical Engineers special team). The inspections are carried out, among others, by on-site inspections or by special campaigns using helicopters, drones, diving and bathymetry.

Before that, In December 2023, a Geological-Geotechnical survey campaign was carried out. On Southern Pipeline Sector with 07 segments (652.3 km with approximately 840 water crossings and 470 geotechnical hazards - mitigated or not), that included the Rio Grande do Sul state segment, between km 1,002+000S and km 1,190+000S of the gas pipeline's RoW. Additionally, together with TBG Team, also eleven special regions (geotechnical hazards) were defined for aerial surveying using drones.

A new Geological-Geotechnical inspection campaign was provided after the event, and the paper shows the importance to review a recent inspection after a great event like happened in the South of Brazil.

Finally, will be shown a list of mitigation actions, projects, builds, and highlights the table of the geotecnichal risk before and after the event.

Keywords: Rainfall, Inspections, Heavy Rainfall, Right-of-Way.

1. INTRODUCTION

The Bolivia-Brazil Gas Pipeline is a facility operated by Transportadora Gasoduto Bolívia-Brasil (TBG) which is 2,593 km long in Brazil. It crosses about five thousand rural properties of 136 municipalities in the Mato Grosso do Sul, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul states. Along its RoW pipeline extension, crossing the lands with different geological-geotechnical features alluvial terrains from the Pantanal, of the central "Cerrado" (savanna) to the mountainous Serra do Mar south region, in addition to more than 2 thousand stream crossings, dozens of monitored slopes, among other landforms.

These situations require the operator to always maintain inspections and control situations of the adverse weather conditions that occur in Brazil along its route. TBG operates in accordance with its Integrity Management Program and its executive standards in compliance with the Renewed Operating License LO-081/2000 of the Bolivia-Brazil Gas Pipeline, with aspects of the ASME B31.8S Standard "Managing System Integrity of Gas Pipelines", also determined in the Technical Regulation for Land Pipelines (ANP No. 2-2011) - **RTDT** (ANP, 2011).

According to RTDT, pipeline operators, responsible for geotechnical corrective or mitigations interventions, must inspect sensitive sites along right-of-way (RoW) and its surroundings. Sensitive sites surveys must be carried out to verify RoW sites conditions most susceptible to critical impacts on operational safety and procedures, in accordance with written standards, including water crossings and geologically unstable areas, which must be followed with a certain periodicity, as established by carriers itself.

These RoW geotechnical surveys include: Routine Inspection (by Track Technicians); Inspection of "Sensitive Sites" (by Track Technicians); Occasional Inspection (by our own Geotechnical Engineer); and Geological-Geotechnical Inspection (by Geotechnical Engineers special team). The inspections are carried out, among others, by on-site inspections or by special campaigns using helicopters, drones, diving and bathymetry.

In December 2023, a Geological-Geotechnical survey campaign was carried out. On Southern Pipeline Sector with 07 segments (652.3 km with approximately 840 water crossings and 470 geotechnical hazards - mitigated or not).

Specifically in the Rio Grande do Sul state, between km 1,002+000S and km 1,190+000S of the gas pipeline's right-of-way (RoW) southern sector, this inspection initially planned 87.8 km of inspection by walking. Together with the TBG team, an additional 16.215 km were defined, thus totaling 104.015 km of inspection by walking for this segment.

For this segment, TBG provided a record of 152 known geotechnical phenomena and containment structures, all with "monitoring" risk levels. In addition to the geotechnical anomalies already in the TBG record, six sites with unknown geotechnical anomalies were also identified, two of which were classified as "monitoring" and four as "acceptable" level risk. Additionally, together with TBG Team, also eleven special regions (geotechnical hazards) were defined for aerial surveying using drones.

Therefore, in the 2023 Geotechnical Inspection campaign, only geotechnical phenomena with insignificant risk levels were present.

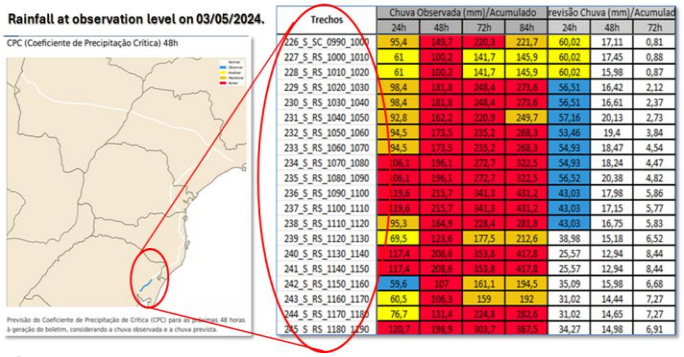
2. 2024 GEOTECHNICAL HAZARD PHENOMENA

TBG has a Meteorological Monitoring service that receives daily data on past and future rainfall for up to 84 hours, in order to assess the conditions or possibilities of landslides and to issue specific reports, in which anomalies are reported throughout the day.

The month of May 2024 began with heavy rain throughout the Rio Grande do Sul ROW pipeline, reached rain alert levels (400 mm / 84h) in the first month fortnight, determining the beginning of segment inspection services between km 1,000+000S and km 1,190+000S (Figure 1).

The May 2024 rainfall events and geotechnical hazards observed on TBG pipeline RoW were part of a major and historic "climate and environmental tragedy" in the Rio Grande do Sul state. The storms affected more than 2.3 million people by hitting 471 municipalities, equivalent to almost 95% of all cities in Rio Grande do Sul in addition to affecting 13.7 thousand kilometers of roads, including federal and state highways.

Collischonn et al. (2024) showed that the 2024 rainfall in the Guaíba watershed was concentrated over time. Between the end of April and May 3, 2024, the accumulated rainfall increased very rapidly. In just eight days preceding the flood peak on May 5, 2024, the accumulated rainfall in the basin increase of 444 mm, going from 209 mm to 652 mm. These rains were almost 10 times greater than the average rainfall typical for the month of April or May in this region.



Trechos	Chuva Observada (mm)/Acumulado				Previsão Chuva (mm)/Acumulad		
	24h	48h	72h	84h	24h	48h	72h
226_S_SC_0990_1000	95,4	149,7	220,9	221,7	60,02	17,11	0,81
227_S_RS_1000_1010	61	100,2	141,7	145,9	60,02	17,45	0,88
228_S_RS_1010_1020	61	100,2	141,7	145,9	60,02	15,98	0,87
229_S_RS_1020_1030	98,4	181,8	248,4	273,6	56,51	16,42	2,12
230_S_RS_1030_1040	98,4	181,8	248,4	273,6	56,51	16,61	2,37
231_S_RS_1040_1050	92,8	162,2	220,9	249,7	57,16	20,13	2,73
232_S_RS_1050_1060	94,5	173,5	235,2	268,3	53,46	19,4	3,84
233_S_RS_1060_1070	94,5	173,5	235,2	268,3	54,93	18,47	4,54
234_S_RS_1070_1080	106,1	196,1	272,7	322,5	54,93	18,24	4,47
235_S_RS_1080_1090	106,1	196,1	272,7	322,5	56,52	20,38	4,82
236_S_RS_1090_1100	119,6	215,7	341,3	431,2	43,03	17,98	5,86
237_S_RS_1100_1110	119,6	215,7	341,3	431,2	43,03	17,15	5,77
238_S_RS_1110_1120	95,3	164,9	228,4	281,9	43,03	16,75	5,83
239_S_RS_1120_1130	69,5	123,6	177,5	212,6	38,98	15,18	6,52
240_S_RS_1130_1140	117,4	208,6	353,8	417,8	25,57	12,94	8,44
241_S_RS_1140_1150	117,4	208,6	353,8	417,8	25,57	12,94	8,44
242_S_RS_1150_1160	59,6	107	161,1	194,5	35,09	15,98	6,68
243_S_RS_1160_1170	60,5	106,3	159	192	31,02	14,44	7,27
244_S_RS_1170_1180	76,7	131,4	224,8	282,6	31,02	14,65	7,27
245_S_RS_1180_1190	120,7	198,9	303,7	367,5	34,27	14,98	6,91

Figure 1. Accumulated and Forecast Precipitation Records on RoW TBG Pipeline Segment between km 1,000+000S and km 1,190+000S, referring to May 3, 2025. Prepared by the authors (2025).

TBG had just completed geological and geotechnical inspections in the region, which had been completed in this sector at the beginning of the year. Therefore, all important events, works, and geotechnical occurrences had been mapped, classified, and their geotechnical risks recorded, and recently photographed.

With this segment monitored meteorologically, the area most affected by the rains was identified and, considering these recorded sites, the field team was instructed to begin occasional inspections.

Immediately after these catastrophic events, TBG issued an internal alert and mobilized its teams of Track Technicians and Geotechnical Engineers to inspect the list of known sites in the region, including monitored slopes and to diagnose the damage (collapses) potentially caused by the heavy rains.

Access began to become increasingly difficult due to landslides on the roads, and also because many regions were flooded, making it difficult to cross bridges by car, for example.

When access was possible, field inspections were carried out at "Sensitive Sites" where faults in the terrain were noted, followed by an Aerial Geotechnical Inspection using a helicopter to assess the damage dimensions (Figure 2).

FIGURE 2. Field and Aerial May 2023 images of Geotechnical hazards on RoW Rio Grande do Sul TBG Pipeline segment. Prepared by the authors (2025).

On the other hand, given the lack of land mobility throughout the roads of state, it was decided that a helicopter inspection was necessary. The helicopter mobilized flew over the area recording all the abnormalities identified.

In these inspections, approximately 80 geotechnical anomalies were identified, of which 17 required reassessments and two were considered more critical (risk level “medium”).

3. PHYSIOGRAPHIC AND LANDFORM “SERRA DO MAR” CHARACTERIZATION

The most southern RoW TBG pipeline is situated at top of the “Serra Geral”. This landscape is characterized by high plains and rugged relief, with high slopes that intensify the erosion process.

The land in this region is predominantly based on rocks from the "Serra Geral Formation” (FSG), which is made up of a succession of lava flows, with a lower layer of basic composition, such as basalts, and the upper layers formed by acidic rocks, according to Rigo (2007) (Figure 3).

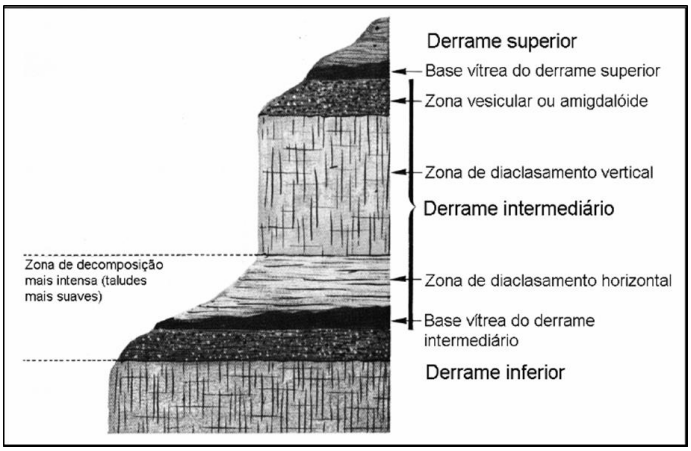


Figure 3. Schematic representation of the structure of basaltic flows of the "Serra Geral Formation" (FSG). Edited by Rigo (2007), adapted from Leins and Amaral (1978).

The occurrence of many intrusive bodies (sills and dikes) of basic and acidic composition is common, generally associated with structural discontinuities of the "Paraná Basin". The residual or saprolitic soils of the region are formed from rocks of the "Serra Geral Formation” and have physical and mineralogical characteristics that determine their geotechnical behavior.

This “Saprolitic – Neosols” (residual soils) has shallow depth, where the greatest limitation to root growth and water infiltration is the presence of lithic contact very close to the surface, or the presence of slightly fractured saprolite with density limiting roots.

According to Pinheiro et al. (2000), cited by Porto et al. (2019), specifically for residual soils of the FSG in RS, instability problems in these types of soil are often conditioned by the development of irregular alteration profiles. At the bases and tops of basaltic flows in the FSG, areas defined as horizontal jointing zones, the presence of glassy material and volcanic breccias ends up accelerating weathering processes due to the mineralogy of these materials and the accumulation of water in these locations. Therefore, it is common to find alternating profiles between sound rock, altered rock and thick layers of residual soils resulting from the alteration of volcanic breccias or rocks that have undergone hydrothermal alteration.

4. SPECIAL GEOTECHNICAL SURVEY CAMPAIGN

In September 2024, a special geotechnical survey campaign was carried out in this sector of the Rio Grande do Sul RoW TBG pipeline to evaluate the erosion process (Geotechnical Hazards) compared to it 2023 condition.

In these segments, 17 new geotechnical hazards and/or damage to geotechnical containment were identified and recorded by TBG itself Inspections after the heavy rains of April and May 2024. In the record of occurrences already listed by TBG, for the inspected segment, there were already 97 pre-existing geotechnical hazards, among them 76 that had already been 2023 Inspection and four were registered by the Geotechnical Geological Inspection Team during the 2023 campaign. Two existing geotechnical hazards had their geotechnical risk level increased to "Medium Risk".

5. RESULTS AND DISCUSSION

In this case presented after the extreme rains, it became clear that we must have some information and resources at hand to be able to deliberate urgent inspections, mitigating and planned actions and activities to correct the problem.

The mapping of areas with the most rainfall, with indicators for the range of pipelines above normal levels, is also very important for making quick and accurate decisions.

In this specific case, the team initially had an exact mapping of where the rains had reached levels above what can be considered normal for the pipeline range in that sector. As can be seen in figures 4 and 5, where the intensity of the rains was checked daily by sector, with accumulated rainfall for 24 hours, 48 hours, 72 hours, and 84 hours. Trends for the next 24, 48, and 72 hours were also monitored, providing a clear idea of the prioritization for field inspection.

Trechos	Chuva Observada (mm)/Acumulado				revisão Chuva (mm)/Acumulad		
	24h	48h	72h	84h	24h	48h	72h
226_S_SC_0990_1000	95,4	149,7	220,3	221,7	60,02	17,11	0,81
227_S_RS_1000_1010	61	100,2	141,7	145,9	60,02	17,45	0,88
228_S_RS_1010_1020	61	100,2	141,7	145,9	60,02	15,98	0,87
229_S_RS_1020_1030	98,4	181,8	248,4	273,6	56,51	16,42	2,12
230_S_RS_1030_1040	98,4	181,8	248,4	273,6	56,51	16,61	2,37
231_S_RS_1040_1050	92,8	162,2	220,9	249,7	57,16	20,13	2,73
232_S_RS_1050_1060	94,5	173,5	235,2	268,3	53,46	19,4	3,84
233_S_RS_1060_1070	94,5	173,5	235,2	268,3	54,93	18,47	4,54
234_S_RS_1070_1080	106,1	196,1	272,7	322,5	54,93	18,24	4,47
235_S_RS_1080_1090	106,1	196,1	272,7	322,5	56,52	20,38	4,82
236_S_RS_1090_1100	119,6	215,7	341,3	431,2	43,03	17,98	5,86
237_S_RS_1100_1110	119,6	215,7	341,3	431,2	43,03	17,15	5,77
238_S_RS_1110_1120	95,3	164,9	228,4	281,8	43,03	16,75	5,83
239_S_RS_1120_1130	69,5	123,6	177,5	212,6	38,98	15,18	6,52

Figure 4. The table shows the segments, the accumulated rainfall in mm/24 hours, (48, 72 and 84 hours), and the forecast of the accumulated rainfall for 24 to 72 hours.

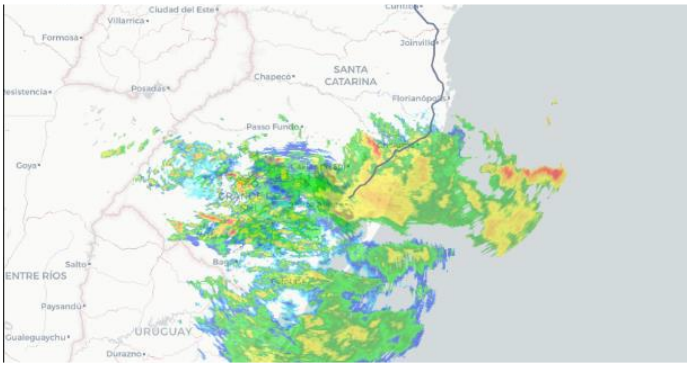


Figure 5. The rainfall maps helped to show the places with the most rain along the pipeline.

An important second point is the list of known geotechnical occurrences in that same sector, whether existing points with work, or monitored, or still with planned works. This list was made available to the aerial, helicopter, and ground teams for the initial inspections, as shown in figure 6.

	KM	PONTO SENSÍVEL	CARACTERÍSTICA	INSPEÇÃO VISUAL DATA :	SITUAÇÃO
1	1078+650S	Cruzam. e Trav.	Cruzamento e Travessias	02/05/2024	Estável - aguardar redução do nível de água
2	1079+000S	Travessia	Córrego	02/05/2024	Estável - aguardar redução do nível de água
3	1091+517S	Travessia	Obra prevista		
4	1092+500S	Travessia	Rio Santa Cruz	02/05/2024	Estável - aguardar redução do nível de água
5	1098+550S	Travessia	Rio do Pinto	02/05/2024	Estável - aguardar redução do nível de água
6	1099+250S	Reparo Programado	Reparo Programado		
7	1105+120S	Travessia	Obra existente		
8	1117+300S	Encosta	Encosta	03/05/2024	Trincas novas tranversais e paralelas à faixa
9	1118+200S	Encosta	Encosta	02/05/2024	Deslizamento de talude na estrada à montante do lado esquerdo
10	1118+300S	Encosta	Encosta	02/05/2024	Aterro sobre a faixa proveniente de deslizamento à montante - Lado Direito para Esquerdo
11	1119+510S	Travessia	Obra prevista		
12	1119+750S	Encosta	Encosta	02/05/2024	Deslizamento à 10 m Lado Esquerdo da Faixa
13	1117 ao 1119S	Região de Encosta	Região de Encosta	02/05/2024	Inspeção parcial
14	1120+900S	Encosta	Encosta monitorada	03/05/2024	Estável
15	1122+000S	Encosta	Encosta	03/05/2024	Acesso interrompido
16	1125+700S	Encosta	Obra prevista	03/05/2024	Pequeno aumento das trincas existentes afastadas da faixa
17	1127+384S	Travessia	Obra existente		
18	1135 ao 1136S	Região de Encosta	Região de Encosta		Inspeção parcial
19	1135+850S	Encosta	Obra prevista	03/05/2024	Sem alterações nas anomalias existentes
20	1139+950S	Travessia	Rio Paranhana	03/05/2024	Estável - aguardar redução do nível de água
21	1144+000S	Cruzamento	Cruzamento	03/05/2024	Estável
22	1146+100S	Cruzamento e Encosta	Cruzamento e Encosta	03/05/2024	Estável
23	1147+100	Cruzam. e Trav.	Cruzam. e Trav.	03/05/2024	Estável
24	1148+400	Cruzamento	Cruzamento	03/05/2024	Estável
25	1152+680S	Travessia	Obra existente DDVargas	03/05/2024	Estável
26	1156+100S	Travessia	Travessia	03/05/2024	Pequenas erosões
27	1159+300S	Travessia	Rio dos Sinos	03/05/2024	Estável - aguardar redução do nível de água

Figure 6. The table shows the occurrences of known geotechnical occurrences in black and the new ones in red to help the field team to list and classify.

This was important so that with the information from the field teams, aerial surveys, areas of heavier rainfall, and the list of existing occurrences, with that the group could, in meetings with the field team, geotechnical engineer, and specialists, make prioritization decisions in an objective manner, as shown in figures 7, 8, and 9. At this stage, it was possible to monitor the inspections, records, and risk classification using the ARCGIS system.

Finally, since there was the data from the last geological-geotechnical inspection, recently carried out months before the event, it was possible to compare how much the section was damaged by the rain, as shown in figures 10 and 11, where the number of known occurrences increased from 28 to 74.

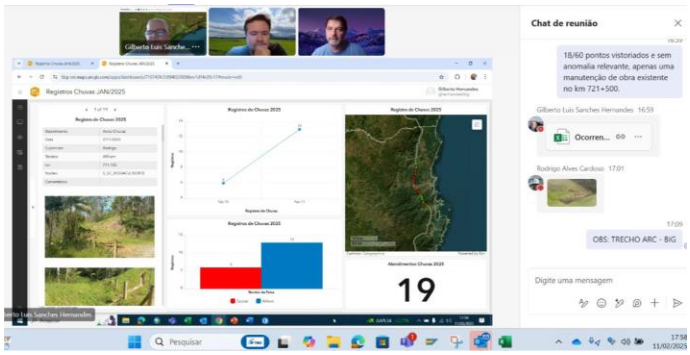


Figure 7. The team analyzes the points that should be prioritized for inspection.

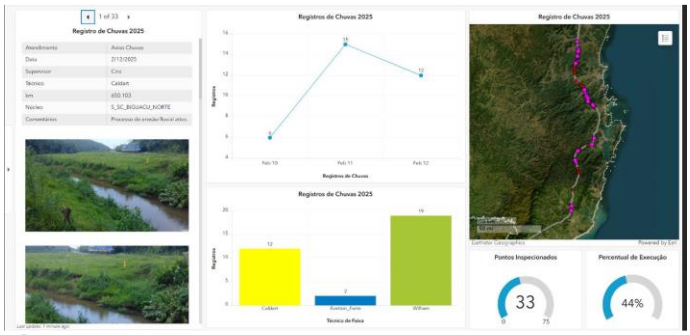


Figure 8. The team checks the productivity of field inspections, with field images coming just in time by ARCGIS.

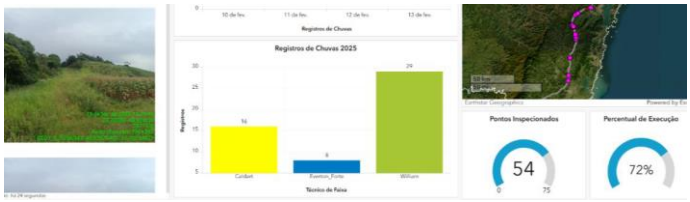


Figure 9. The result of the inspections with the assessed geotechnical occurrences and the productivity of the field team.

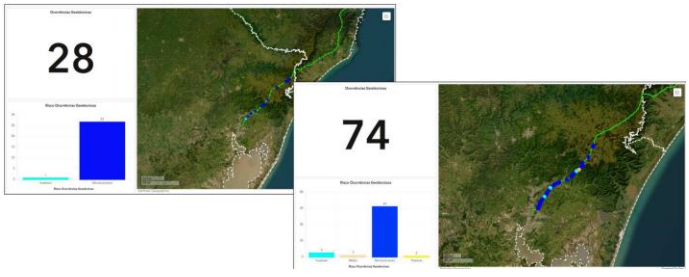


Figure 10 and 11. The result of the inspections before the events and after the events.

6. CONCLUSION

To maintain a high level of Pipeline Integrity, rapid responses from Geotechnical Hazard Management services are necessary, especially considering environmental disaster events.

After the heavy rains of April and May 2024, regarding the total number of occurrences, those classified with a "monitoring" geotechnical risk level predominate, with a total of 150 hazards. Of the remainder, four have an "acceptable" risk and two "medium". After the current geological-geotechnical inspection, seven occurrences were reclassified, with two of them aggravated.

REFERENCES

[1] ANP - Agência Nacional do Petróleo, Gás Natural e Biocombustíveis. (2011). Regulamento Técnico de Dutos Terrestres – RTDT. Available at: https://www.gov.br/anp/pt-br/assuntos/exploracao-eproducao-de-oleo-e-gas/seguranca-operacional-e-meio-ambiente/arq/res_anp_6_2011_anexoi.pdf

[2] CEPA - Canadian Energy Pipeline Association. (2014). Pipeline Watercourse Management. Recommended Practices, 1st Edition. Recommended Practices for Development and Implementation of a Pipeline Watercourse Management Program for Operating Pipelines. Calgary.

[3] Collischonn, W.; Ruhoff, A.; Cabeleira Filho, R.; Paiva, R.; Fan, F.; Possa, T. (2024). Chuva da cheia de 2024 foi mais volumosa e intensa que a da cheia de 1941 na bacia hidrográfica do Guaíba. Instituto de Pesquisas Hidráulicas – Universidade Federal do Rio Grande do Sul.

[4] Lima, G., Costa, C. A., Moya, M., Wosiacki. L. F. K., Costa-Cabral, M., Chilibeck, B. M., Walsh, B. W. (2025). Hydrotechnical Assessment of Pipeline Crossings under Climate Change (IBP4951_25). Rio Pipeline Conference & Exposition 2025, Rio de Janeiro. (in press).

[5] Porto. M. S; Bressani, L. A. & Silveira, F. G. (2019). Resistência ao Cisalhamento de Solos Residuais em Encostas da Formação Serra Geral no RS. In: XII Simpósio de Práticas de Engenharia Geotécnica da Região Sul GEOSUL 2019 – 17 a 19 de Outubro, ABMS, Joinville.

[6] U.S. Department of the Interior. (2019). Guidelines for Evaluating Pipeline Channel Crossing Hazards to Ensure Effective Burial. Sedimentation and River Hydraulics Group, 86-68240. Manuals and Standards. Bureau of Reclamation. Technical Service Center, Denver, Colorado. September 2019. Published online: March 17, 2023, in <https://www.usbr.gov/tsc/techreferences/mands/mands-pdfs/GuidelinesForEvaluatingPipelineChannelHazards_09-2019_Final508.pdf >