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THE DEVELOPMENT OF A COMPUTATIONAL TOOL FOR GEORREFERENCED CLASS LOCATION ASSESSMENTS

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Abstract

The Class Location concept is adopted by most gas pipeline standards as a way to mitigate risk of third party damage in densely populated areas. These standards define a straightforward process to determine the Class Location, as well as the Maximum Allowable Operating Pressure (MAOP) based on the population living close the pipeline. While this process is well established, there are several challenges faced by pipeline operators when implementing it. These challenges include: (a) locating and classifying buildings close to the pipeline, (b) counting the number of buildings making use of the "sliding mile" concept and (c) correlating the geographic position of the identified Class Location segments with the pipeline characteristics such as diameter, wall thickness, material and pressure test level. This paper presents a method to perform Class Location Change assessments along pipelines using computational tool aided by georeferenced map imagery and counting algorithms. The tool also provides a framework where right-of-way inspection teams are able to locate and classify buildings near the pipeline. A building-based sliding mile have been implemented to appropriately count building and identify the current Location Class. Post-processing algorithms evaluate possible MAOP restrictions, such as pipe replacement and hydrotest. This methodology have proved to be effective by completing Class Location Assessments in 6500 km of gas pipelines.

Keywords: Gas Pipeline. Third Party Damage. Class Location.

1. Introduction

Third party damage is the prevailing cause of pipeline failures. Figure 1, extracted from the 10th Report of the European Gas Pipeline Incident Data Group [5], shows the distribution of accident causes in European gas pipelines.

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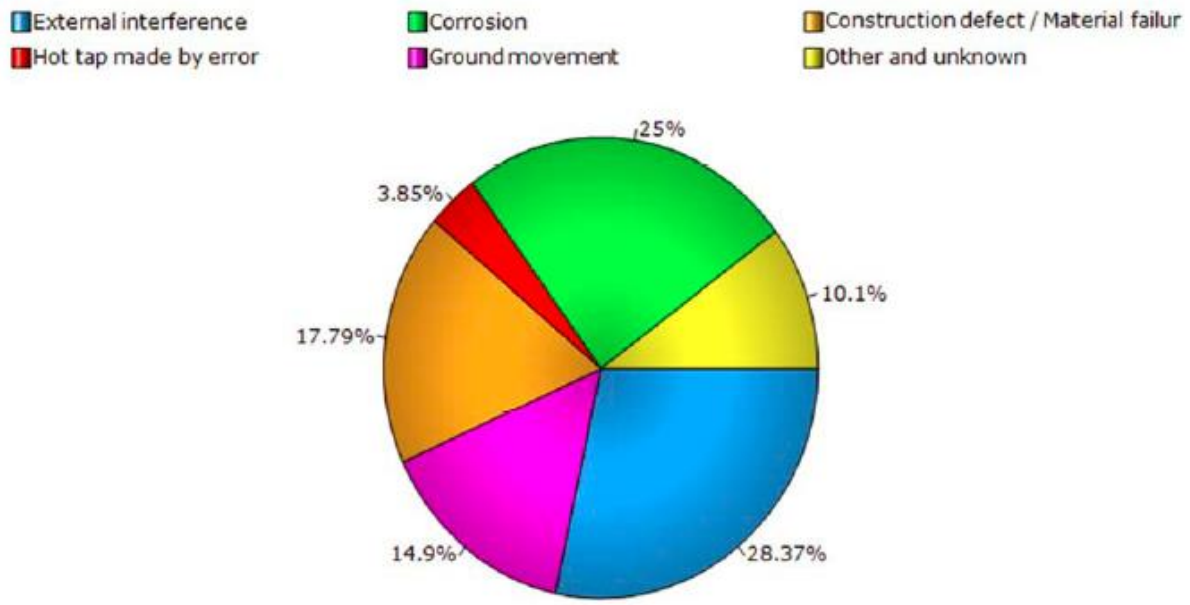

Figure 1. Incident distribution 2007-2016 (EGIG 2018)

The population density seems to be the generator of this failure mode, since in the low populated areas, third party damage is responsible for significant fewer cases than in highly populated areas [6]. In order to mitigate risks in highly populated areas, most gas pipeline standards like ASME B31.8 [1], CSA Z662 [2], ISO 13623 [3] and NBR 12712 [4] adopt the Location Class criteria. The location class system for gas pipelines was introduced in the USA in the 50's to prevent failures caused by human activities [5]. The ASME code [1] makes clear that intent in section 840.1 c:

> A pipeline designed, constructed, and operated in accordance with the requirements of Location Class 1 is basically safe for pressure containment in any location; however, additional measures are necessary to protect the integrity of the line in the presence of activities that might cause damage.

The ASME B31.8 [1] standard defines the location classes based on the number of dwelling units in the vicinity of a pipeline, being divided into four classes: 1, 2, 3 and 4. The number of buildings is counted in areas along the pipeline route, called the class location unit, which corresponds to a width of ¼ mile or 400 meters, with the pipeline on the centerline, by a length of 1 mile or 1600 meters.

The use of thick wall pipes to prevent third party damage is a solution for new constructions. After a gas pipeline begins to operate, the dwelling units near pipelines should be monitored. The buildings must be counted and typified to determine possible changes in the location class in accordance with current standards. Once the increase of buildings intended for human occupancy around the pipeline has been verified, the ASME B31.8 [1] standard determines a 6-months deadline for a new Location Class study, and then 18 months to confirm or revise the Maximum Allowable Operating Pressure (MAOP). These deadlines are justified because of the difficulty in obtaining the necessary data for the study and the possible solutions. If the solutions involves pipe replacement or new hydrotest, time is required for the procurement process.

While Class Location Change assessments are well established, there are several challenges faced by pipeline operators in order to implement this process. These challenges include:

- Locating and classifying buildings close to the pipeline;
- Counting the number of buildings making use of the “sliding mile” concept;
- Correlating the geographic position of the identified Class Location segments with the pipeline characteristics such as diameter, wall thickness, material and pressure test level.

This paper presents a method devised to perform Class Location Change assessments along pipelines using a computational tool aided by georeferenced map imagery and counting algorithms. The computational tool is a proprietary tool of Petrobras Transporte S/A - TRANSPETRO.

2. Summary of Location Class Criteria in ASME B31.8

The Location Classes along a gas pipeline are based on the population density in the vicinity of its centerline. The population density is indirectly assessed through the number of buildings of a Location Class Unit, that is, a rectangle of 1600m along the centerline and a width of 400m.

Gas pipelines are constructed and tested according to its Design Location Classes, but the movement and growth of human populations can alter the population density and cause changes in Location Class.

Table 1 shows 4 cases in which the increase in the number of buildings do not impact the Design conditions of a gas pipeline.

The major concern of gas pipeline operators are the cases in which the increase in the number of building impact the MAOP (Table 2), since the current Location Class demands changes in the hydrotest and design factor.

Table 1. Cases in which population growth do not alter the design condition (ASME B31.8) [1]

Design		**Current**	
Number of buildings	Location Class	Number of buildings	Location Class
0 - 10	1	11 - 25	1
11 - 45	2	46 - 65	2
46+	3	66+	3
Multistory	4	Multistory	4

Table 2. Cases in which population growth can change the MAOP due to more sever hydrotest and design factors (ASME B31.8) [1]

Current			
Number of buildings	Class Location	Hydrotest Factor	Design Factor
26 - 45	2	1.25	0.72
46 - 65	2	1.5	0.6
66+	3	1.5	0.6
Multistory	4	1.8	0.5

3. Methodology Devised for Location Class Change Assessment

In order to cope with the challenges faced by pipeline operators when conducting Location Class change assessment, a methodology has been devised combining georeferenced map imagery and computational algorithms.

To execute the assessment, the method undergoes the following steps:

1. Gathering pipeline data;
2. Locating and typifying buildings;
3. Counting buildings;
4. Defining the current location classes;
5. MAOP calculations.

3.1. Gathering Pipeline Data

The pipe tally coordinates are the bases for whole process, since the algorithm is design to count buildings defined over georeferenced map imagery. The following pipeline characteristics are also inputted, since they will influence the MAOP calculations.

a. Georeferenced pipe tally
b. Outside diameter
c. Material
d. Wall thickness
e. Design location class
f. Hydrostatic test pressure
g. Reference pressure for the assessment (usually the design pressure)

3.2. Locating and Typifying Buildings

With the pipeline route displayed over the satellite image, the computational tool provides a framework where right-of-way technician teams are able to locate buildings near the pipeline.

An important feature of this methodology is to display auxiliary parallel lines to the centerline, at a user-defined distance. It is usually useful to display auxiliary lines at 200m, which defines the boundaries specified by most standards. These parallel lines demarcate the area of interest and spare the technician from unnecessary work outside these borders.

Once a building is located, the technician is able to mark it with a click over the map, and by doing that, a georeferenced list of buildings along the gas pipeline is created. During this process, the technician is able to select among different types of buildings (Table 3), which, according to ASME B31.8 [1], will have different criteria in the Location Class Assessment.

Table 3. Types of buildings defined within the methodology

Label	Icon	Description
Simple	S	Building with human occupancy. Each separate unit in a multiple dwelling unit building is counted as a separate building.
Special	E	Building with concentration of people, such as: school, church, club, hospital, square, soccer field, theater or other public meeting place.
Multistory	P	Building for human occupancy with 4 or more floors.
Uninhabited		Uninhabited building or not occupied by humans.

Uninhabited buildings do not influence the Location Class Assessment. However, it has been observed that during process of marking building on the map it is helpful to register an icon over a uninhabited building for the purpose of showing that such building have been evaluated.

Figure 2 shows a pipeline segment with 3 auxiliary parallel lines (400m, 200m and 90m) where the technician has marked and typified all the buildings within 400m of a pipeline.

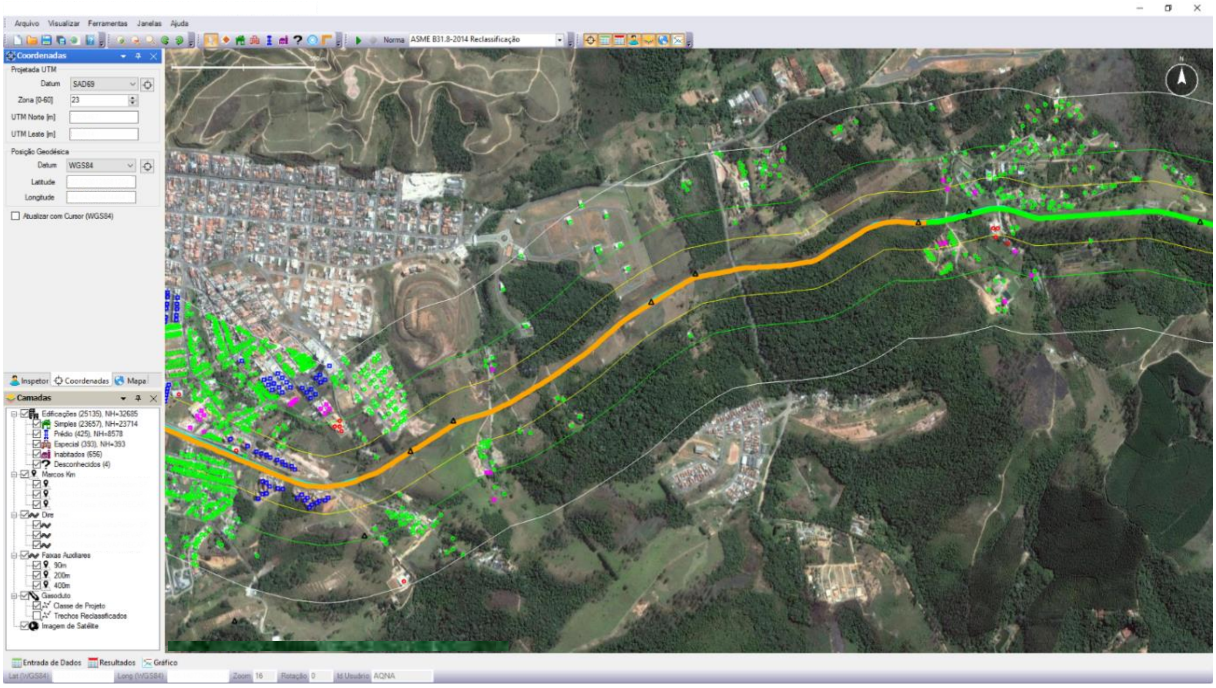

Figure 2. A pipeline segment where buildings have been located and typified

With the georeferenced pipe tally and the geographic location of each building at hand, the computational tool calculates the minimum distance (Y) to the pipeline axis (X), as depicted in Figure 3. Ultimately, the buildings list is completed with X,Y pairs, and from this point on, the analysis becomes unidimensional along the pipeline axis.

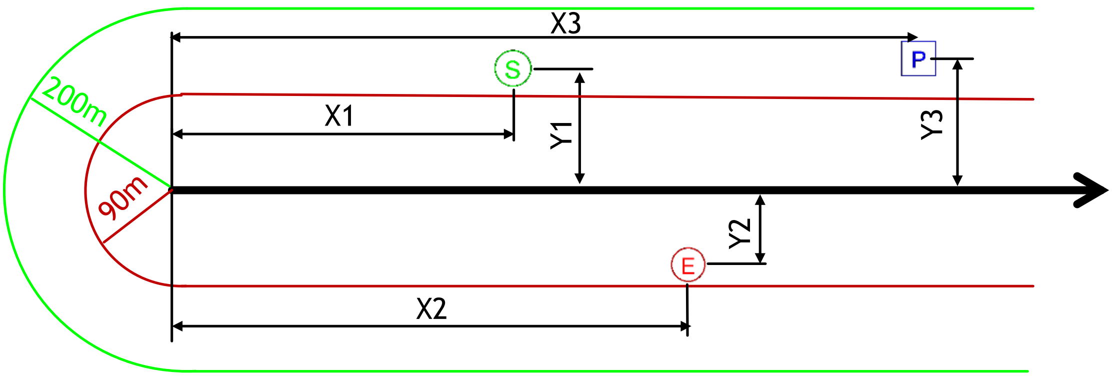

Figure 3. For each building is attributed the minimum distance to the pipeline (Y) and the respective pipeline length (X).

3.3. Counting buildings: a building-oriented sliding mile

The method used to count buildings is a key aspect in a Location Class Assessment. If the analysis considers a series of Location Class Units laid side by side, it is possible that a cluster of buildings is split in two parts, resulting in a lower count for each Location Class Unit (Figure 4a). According to ASME B31.8 [1] and CSA Z662 [2], the appropriate counting method is to register the largest possible count for each location (Figure 4b), and that can be achieved by sliding the Location Class Unit continuously along the pipeline. Figure 5 illustrates the "sliding mile" concept.

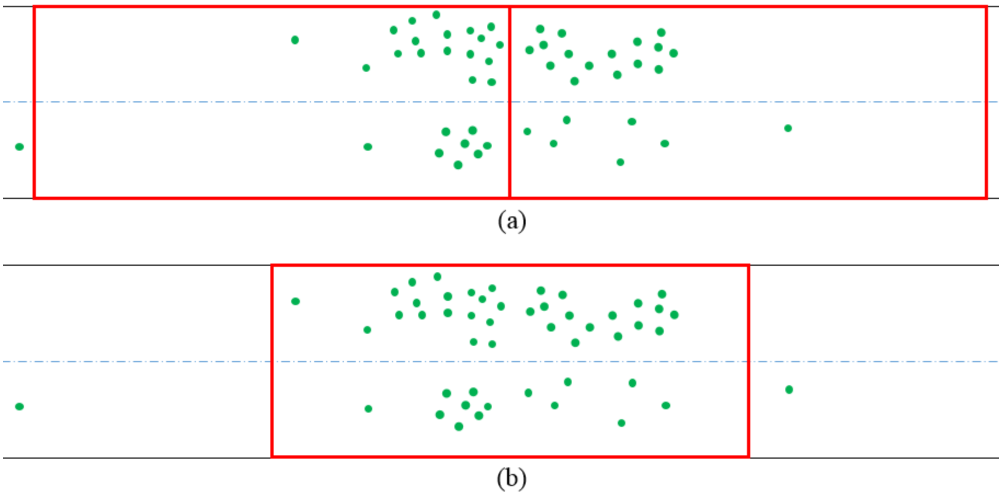

Figure 4. Example of building count where the Location Class Unit (a) splits highly populated area in two and (b) is properly positioned in order to register the maximum possible building count.

Implementing the sliding mile into a numerical algorithm is definitely one of the main challenges of the process. One possible solution is to advance to Location Class Unit by 1 pipe joint, which is the minimal discretization available from the pipe tally.

Another approach devised for this project is to position the border of a Location Class Unit at each one of the buildings that have been listed. Tests have proven that such building-oriented sliding mile can always capture the highest possible building count along a pipeline. Not only that, test have shown that this algorithm is less time consuming, since uninhabited areas are not screened by the mathematical routine.

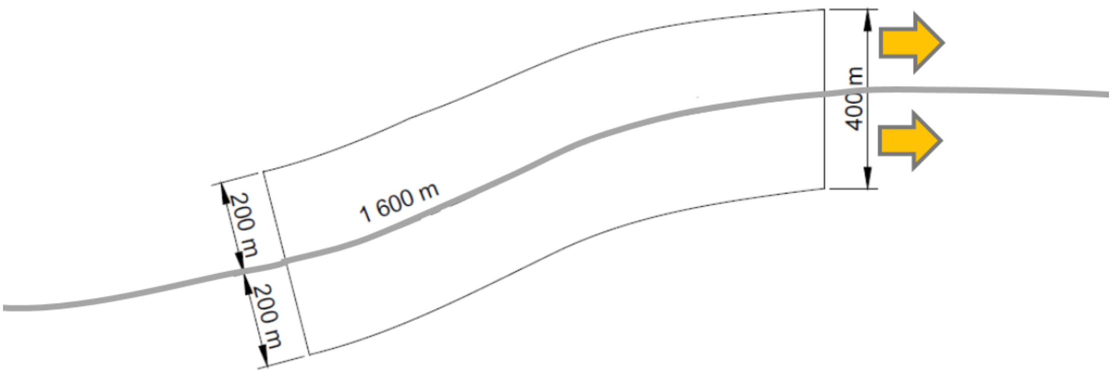

Figure 5. "Sliding mile" concept

3.4. Defining the Current Location Classes

As the building-oriented sliding mile registers its count and classifies a pipeline segment into Location Class 1 to 4, the next count potentially overlaps the previous assessed segment. The tool consolidates all the overlapped count, considering the highest building count number and by consequence the highest Location Class of each segment, shown in Figure 6. Figure 7 shows the overlapped zones over satellite images.

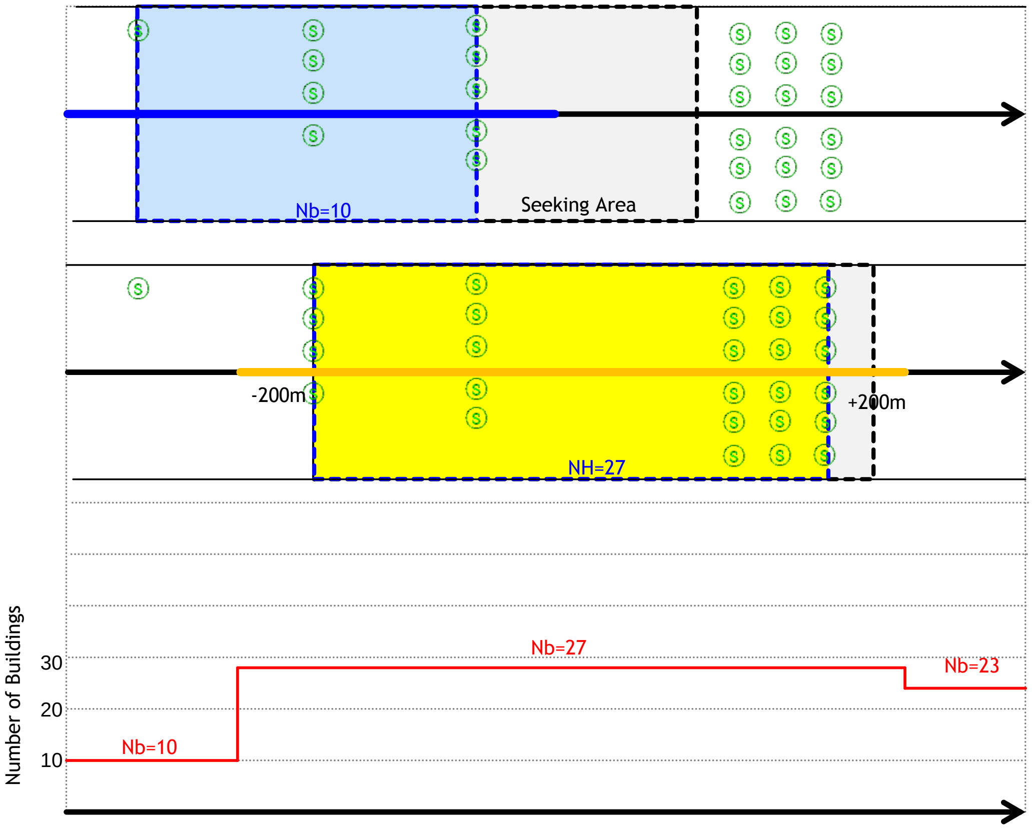

Figure 6. Consolidation of the overlapped Location Classes

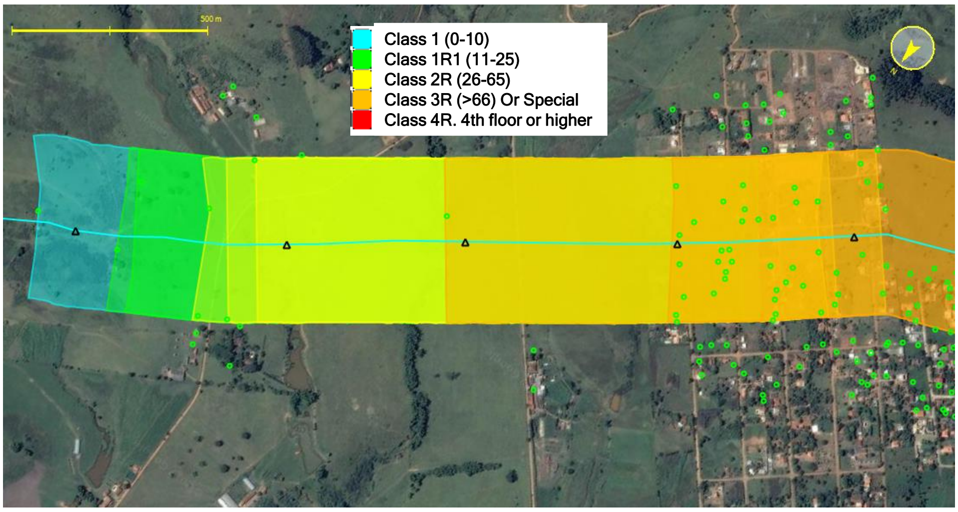

Figure 7. Overlapped location classes that must be consolidated

Figure 7 shows that the computational tool pre-classifies the Location Class Unit according to the building-oriented methodology, to be later compared with the Design Location Class of each section and thus update the increased Location Class.

A separate routine considers buildings typified as "Special" (when it is located less than 90 meters) and "Multistory" since they have specific criteria, which are not based on building count. Once more, a consolidation is applied to the overlapped segments.

This process concludes the consolidation of the Location Class Changes, by defining the Current Location Classes along the pipeline according to Figure 8.

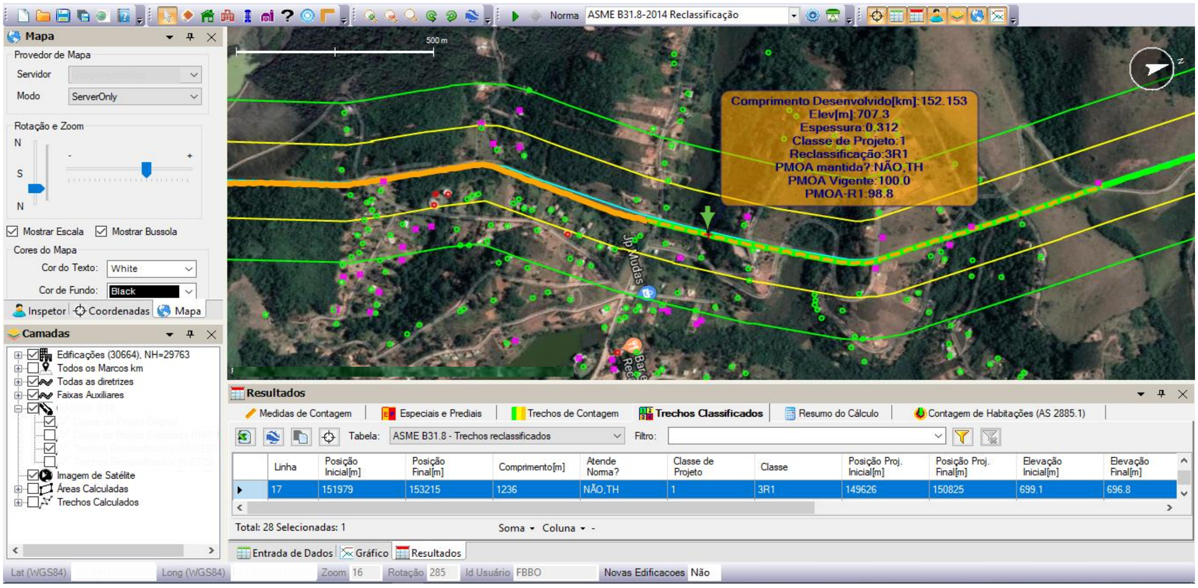

Figure 8. Consolidation of Changes Location Class

3.5. MAOP Calculations

On the pipeline segments with class location changes, the tool performs MAOP calculations in order to analyze possible restrictions based on the requirements of ASME B31.8 as shown in Table 2. In case of a MAOP restriction, the tool shows the segments that require hydrostatic retest or cut-outs in order to maintain the MAOP (Figure 9).

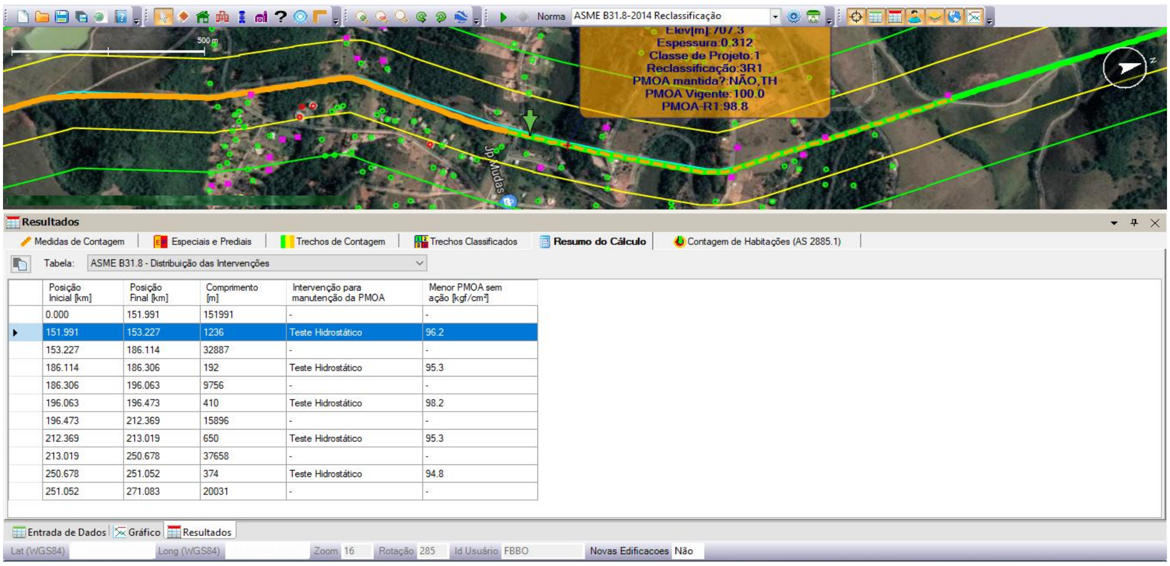

Figure 9. Consolidation of Location Class Changes

The results are presented in tables, graphics along the pipeline length and are also displayed over the satellite image as shown in Figure 10. The tables and profile graphics are linked to the map imagery, so when an specific point along the pipeline is selected on the table, it is also shown on the satellite image automatically.

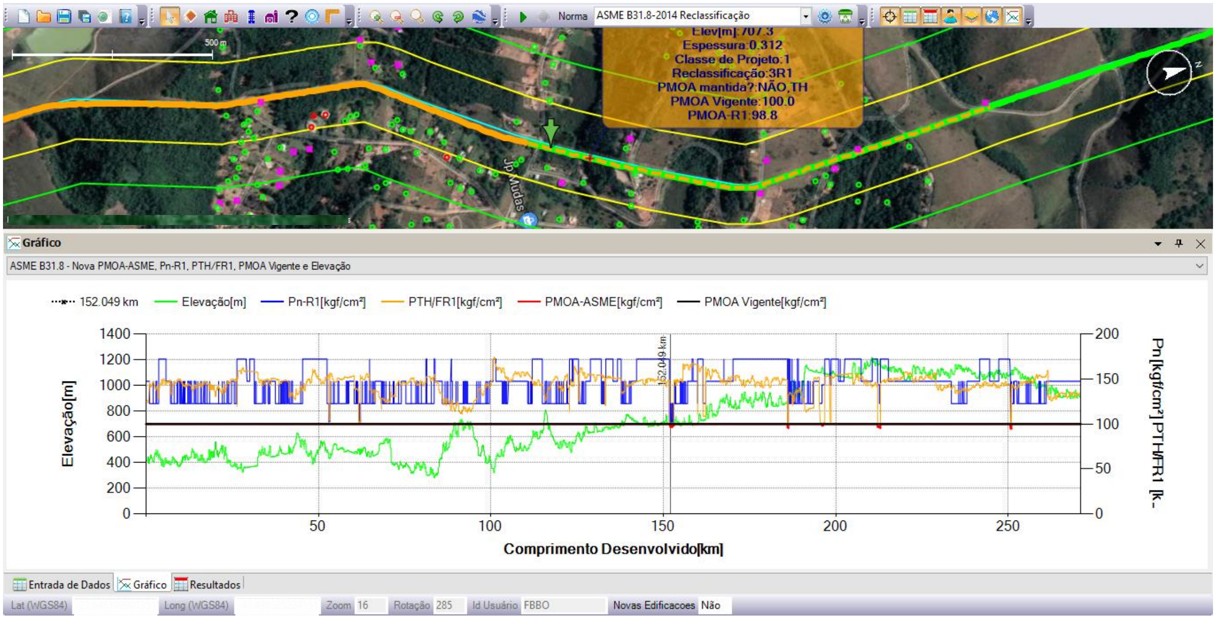

Figure 10. Pressure results displayed on a map and on a graph

4. Methodology Capabilities

The methodology described in this paper has been used to assess 6500 km of gas pipelines in Brazil. When considering the total project span, which includes data gathering (pipe tally, wall thickness, Design Location Class and Hydrotest Pressure), buildings typification, result analysis and reporting, the 6500 km of gas pipelines have been assessed for Location Class Changes in a matter of 2 years.

It has been found that, once having a proper methodology built in a computational tool, the data gathering is the most time consuming activity in such an assessment. Therefore, future revision of theses assessments are expected to be executed swiftly, since the hard work has already been accomplished.

As for the buildings survey, it can be said that the computational tool has successfully provided the right-of-way technicians with an intuitive interface to locate and typify buildings over satellite imagery that actually speeds up the process. In one specific pipeline, which extended for 320km, the team was able to register 25000 buildings located up to 400m of the pipeline axis, in a time spam of 3 weeks, including several site visits and even one aerial survey, which can be considered a very efficient undertaking. It is important to note that the satellite imagery is a feature to help speed up the process, nevertheless the right-of-way technicians rely heavily in their knowledge from previous field inspections and on additional confirmatory site visits.

Once having the building dataset available for the Location Class Change Assessment, different risk analysis have been conducted based on this dataset. The Risk Analysis team found that this pipeline-specific dataset is more reliable than the average census-based information. Becoming an ally for Risk Analysis was not anticipated and was revealed to be a positive side effect of the computational.

Furthermore, the methodology has provided the assessment with enhanced precision due to the georeferenced dataset. As a result, the decision making process in regards to the actions to restore the MAOP are facilitated and the results are traceable.

5. Conclusion

A methodology to support Location Class Changes Assessment has been presented. The described features for locating and classifying buildings close to the pipeline with georeferenced map imagery and automate building count, class location determination and MAOP calculations have been incorporated into a computational tool, which allowed the assessment of 6500km of gas pipelines. The computational tool is able to create a valuable dataset with pipeline information and the whole lot of buildings in vicinity of the pipeline. Furthermore, this dataset can be useful for other Risk Analyses in order to improve its inputs. The presented methodology provided an agile, reproducible and accurate results, being less subject to human error.

6. References

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