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CASE OF SUCCESS; INSPECTION ALERT FOR GEOTECHNICAL RISK DUE TO PRECIPITATION IN RIGHTS OF WAY IN THE PERUVIAN JUNGLE

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ABSTRACT

Gas and oil pipelines in the jungle are exposed to geotechnical threats due to frequent and intense rainfall. These natural conditions, and the alterations in the terrain due to the construction of the pipeline, demand adequate management of time and resources to maintain the integrity of the assets and reduce geotechnical risk. To manage these risks in maintenance services, the geotechnical risk management system (GRMS) was implemented. One of its technological tools is the ESTRATA 2.0 program, and its main functions include geotechnical risk assessment and the issuance of inspection alerts. Inspection alerts are based on a rain threshold model. The model was developed with data from mass removal phenomena, accumulated rainfall in 30 days and accumulated rainfall in the last 24 hours. Generating three types of alerts: monitoring, warning and critical. The alert is displayed on the ESTRATA web portal and is automatically sent by email to everyone involved in the SGRG. Since its implementation, the system has issued 485 inspection alerts, and 82 mass removal findings have been detected and addressed with different levels of affectation.

Keywords: Alert, risk, thresholds, inspection, geotechnical, management

1. INTRODUCTION

Oil and gas pipelines in the jungle are exposed to geotechnical threats caused by intense rainfall. These natural conditions, and the alterations in the terrain due to the construction of the pipelines, demand adequate management of time and resources to maintain the integrity of the assets and reduce geotechnical risk.

A part of the mass removal processes generated by rain occurs due to the increase in pore pressure in the slope (or the increase in the specific infiltration force). In the world, multiple rain-slide relationships have been proposed for early warning systems. In the global review in 2015, 244 functions were collected [1]. Some rain parameters investigated such as rain intensity, rain duration, accumulated rain, antecedent accumulated rain, or a combination of these [2] [3].

The selection of the parameters to consider to define the rain alert model depends on the characteristics of the precipitation in the study area and also, of the characteristics of the landslides that occur in this area.

In many cases, these rain-slide models establish critical thresholds defined as the minimum values of the selected rain parameters from which a landslide can occur.

To complete the model, the landslide events that occurred are analyzed and related to the rainfall that occurred.

In the maintenance services of rights of way (RoW) for gas lines in the Amazon jungle in Cusco, Peru, the Geotechnical Risk Management System was implemented to manage threats of this type. One of the fundamental tools of the system is the ESTRATA 2.0 software, from which early inspection alerts generated from a rain threshold model are issued.

This paper presents the result obtained in a gas line maintenance service by applying geotechnical risk inspection alerts in the period 2020 - 2023.

2. MATERIALS AND METHODS

2.1 Geotechnical Risk Management System

The GRMS is a management tool that integrates different technological developments and field work that improves the management of the maintenance service (FIG 1).

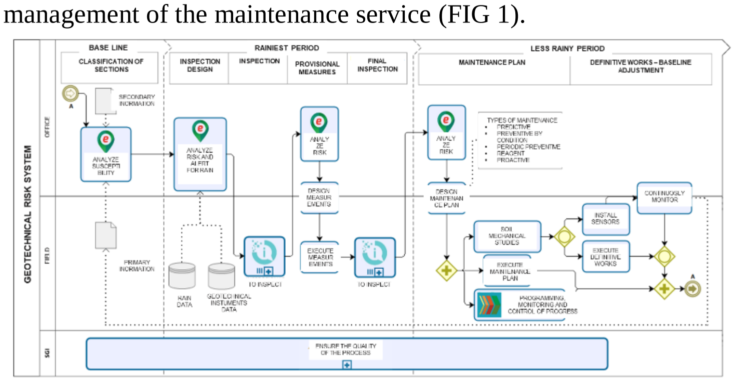

FIGURE 1: GRMS PROCESS FLOW

In the rainiest period in the jungle environment, the rainfall record of the entire network of automatic rain gauges is constantly fed to the ESTRATA software and produces two results automatically. One result is the analysis of the geotechnical risk due to landslides, scour at water crossings and erosion on the surface of the right-of-way. The other result is the issuance of inspection alerts for stretches of rights of way.

2.2 Rain Thresholds Model

The Rain Inspection Alert uses the Rain Thresholds model. This model was developed based on the historical data of the mass removal phenomena that occurred in the rights of way and the data of the precipitations preceding the identification of the geotechnical process. Both data sets correspond to the period 2018 – 2020.

The rain threshold model chosen and built considers two rain parameters:

a) Antecedent rainfall accumulated in 30 days

b) Accumulated rain in the last 24 hours > 20 mm

On the other hand, mass removal events were identified and classified using the INSPECTA digital application, another of the GRMS technological tools (FIG 1). This mobile application allows you to generate the MRPI Mass Removal Phenomenon Index, based on the registration and assessment of nine weighted variables.:

$$MRPI = \sum_{i=1}^{n} n.w \tag{1}$$

Where:

MRPI: Mass Removal Phenomenon Index
w: weighing
n: variable

Variables:

1. Affectation of the pipeline
2. Degree of slope – Type of soil
3. Level of vegetation cover
4. Presence of retaining works
5. Presence of erosion control works
6. Hold Point
7. Presence of water in the area
8. Stage of the mass movement
9. 9. Monthly precipitation

According to the MRPI value, each event was classified into one of the four classes:

MRPI	Class
≥ 42	High
≥ 32 y < 42	Moderately high
≥ 21 y < 32	Moderate
< 21	Low

With the events classified in the High and Moderately High classes, the critical threshold function was obtained, and with the events classified in the Moderate and Low classes, the lower threshold function called monitoring was obtained. In addition, with the entire set of events, a third function called referent or warning was obtained.

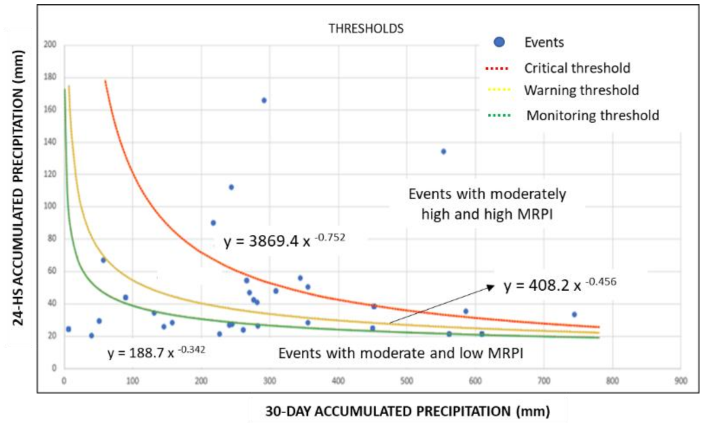

FIGURE 2: INSPECTION ALERT THRESHOLD MODEL

2.3 Segmentation of right-of-way sections

The rain registered in each automatic rain gauge of the network has a defined impact zone determined depending on the location of the rain gauge. This delimitation of the impact zone was generated using the Thiessen polygon method, where each rain gauge represents a point with defined coordinates.

These hit zones represent entire areas where any location within the zone is closer to its associated entry point than any other entry point.

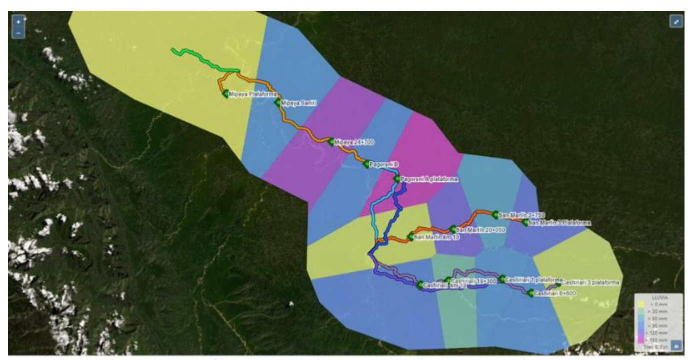

FIGURE 3: IMPACT AREAS OF THE RAIN REGISTERED IN EACH RAIN GAUGE OF THE NETWORK AND SEGMENTS GENERATED IN THE ROWS.

The generation of these areas produces the segmentation of the rights-of-way and then these segments are the sections of the right-of-way that must be inspected when an inspection alert occurs.

3. RESULTS AND DISCUSSION

The application of ESTRATA inspection alerts began on November 19, 2020 and to date the system has issued 485 inspection alerts.

Alerts can include one or more RoW sections and can be derived from one or more rain gauges in the network. For example, on February 17, 2022, ESTRATA issued an inspection alert for geotechnical risk of 19 RoW sections generated with rain data from 10 pluviometers, simultaneously. (FIG 4 Y FIG 5).

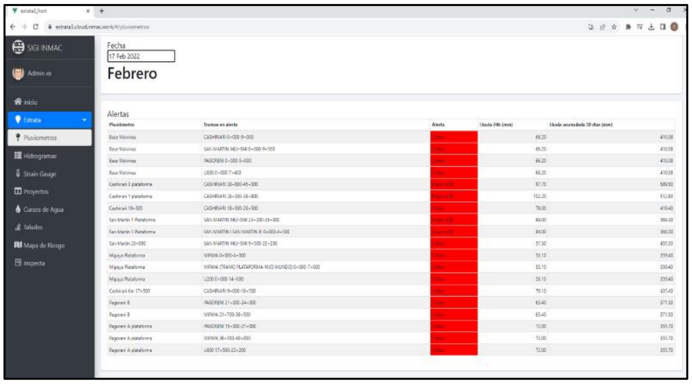

FIGURE 4: INSPECTION ALERTS ISSUED BY ESTRATA ON FEBRUARY 17, 2022

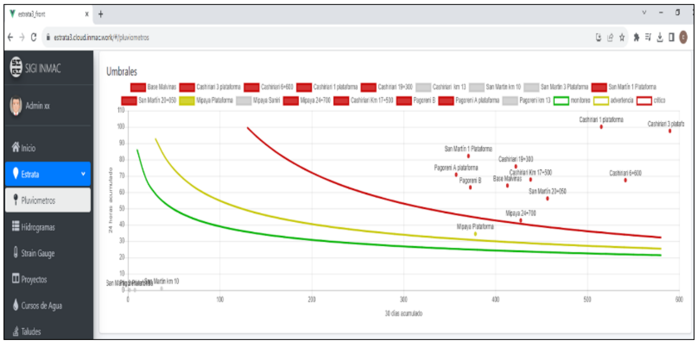

FIGURE 5: INSPECTION ALERTS VISUALIZED IN THE RAINFALL THRESHOLD MODEL ON THE ESTRATA WEB PORTAL ON FEBRUARY 17, 2022.

From the issuance of the inspection alert, the system automatically sends an email to all the participants of the GRMS and also to the personnel indicated by the client (FIG 6).

[PRUEBA] Alerta de lluvia estrata Inbox

inmac.idi@gmail.com Thu, Feb 17, 2022, 9:00 PM
to jcortez.grupoinmac, claudio.cruz, jose.barrientos, guillermo.murillo, arodrigo, emarquina, jbermeo, prodriguez, lsanchez, rptorres, lcolque, lrodriguez, cchoque, cjcampos, nancy.garcia, nchura, eherrera.inmac, ppiccar

Este es un mensaje de alerta automático. Puede ver el estado actual en: Estrata

Pluviometro	Tramos en alerta	Alerta	Lluvia 24h (mm)	Lluvia acumulada 30 dias (mm)
Base Malvinas	CASHIRIARI 0+000-9+000	Critico	66.20	410.38
Base Malvinas	SAN MARTIN MLV-SMI 0+000-9+500	Critico	66.20	410.38
Base Malvinas	PAGORENI 0+000-5+000	Critico	66.20	410.38
Base Malvinas	U600 0+000-7+400	Critico	66.20	410.38
Cashiriari 3 plataforma	CASHIRIARI 38+800-45+000	Mayor a 80	97.70	589.50
Cashiriari 1 plataforma	CASHIRIARI 26+500-38+800	Mayor a 80	102.20	512.80
Cashiriari 19+300	CASHIRIARI 18+500-26+500	Critico	78.00	419.40
San Martin 1 Plataforma	SAN MARTIN MLV-SMI 23+200-26+000	Mayor a 80	84.00	368.30
San Martin 1 Plataforma	SAN MARTIN I SAN MARTIN III 0+000-4+500	Mayor a 80	84.00	368.30
San Martin 20+050	SAN MARTIN MLV-SMI 9+500-23+200	Critico	57.30	455.30
Mipaya Plataforma	MIPAYA 0+000-4+000	Critico	53.10	359.40
Mipaya Plataforma	MIPAYA (TRAMO PLATAFORMA-NVO MUNDO) 0+000-7+000	Critico	53.10	359.40
Mipaya Plataforma	U200 0+000-14+000	Critico	53.10	359.40
Cashiriari Km 17+500	CASHIRIARI 9+000-18+500	Critico	70.10	435.40
Pagoreni B	PAGORENI 21+000-24+000	Critico	63.40	371.30
Pagoreni B	MIPAYA 21+700-36+500	Critico	63.40	371.30
Pagoreni A plataforma	PAGORENI 15+000-21+000	Critico	72.00	355.70
Pagoreni A plataforma	MIPAYA 36+500-40+000	Critico	72.00	355.70
Pagoreni A plataforma	U600 17+500-22+200	Critico	72.00	355.70

FIGURE 6: IMAGE OF THE MAIL SENT WITH THE INSPECTION ALERT TO THE PARTICIPANTS OF THE GRMS ON FEBRUARY 17, 2022.

The field´s work team receives the inspection alert and carries out the tour of the indicated sections of the RoW. The process continues with the survey of the sectors with deterioration or indication of deterioration and programs their priority attention. In the case of finding a mass removal process, the inspector uses the INSPECTA application to obtain the MRPI and define the level of affectation of the RoW and the pipeline. (FIG 7).

Since the beginning of the application of the inspection alerts, 82 findings of mass removal have been detected and addressed, with different levels of affectation, in 4 ROWs in charge of the maintenance service.

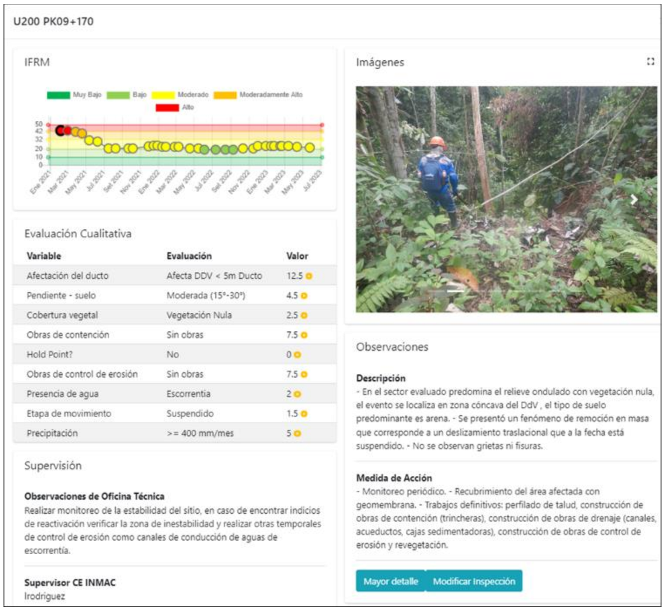

FIGURE 7: IMAGE OF THE INITIAL INSPECTION RECORD AT A SITE WITH MASS REMOVAL PROCESS.

After the emergency measures at the site, monitoring continues until the restoration work is carried out. In each new inspection, the complete evaluation of all the variables is carried out again. In this way, the result of the evaluation, comments, action measures and technical office observations are saved and added to the application database.

4. CONCLUSION

- The inspection alerts for geotechnical risk represent a determining tool for rapid and effective attention to mass removal processes that affect the RoW and even the pipeline.
- The inspection alerts generated by ESTRATA improve the efficiency of the service, due to the use of resources focused on areas with indications or with recently started mass removal processes.
- The integration and interaction of technological tools with the work of the field team and the technical office of the maintenance service have generated satisfactory results to manage of geotechnical risks.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Ramos-Cañón, Alfonso, Trujillo – Vela Mario Germán y Prada Sarmiento, Luis. *Rainfall thresholds for the initiation of landslides. a critical review*, 2015

[2] Guzzetti, Fausto, Peruccacci, Silvia y Rossi, Mauro. *Rainfall thresholds for the initiation of landslides in central and southern europe*, 2005

[3] Graciano, Patricia. *Estimación de umbrales de lluvia detonante de deslizamientos en las microcuencas de los corregimientos de Villa Restrepo y juntas de la cuenca Combeima Ibagué – Tolima*, 2015