

TECHNOLOGY AS AN EFFICIENCY TOOL: IMPLEMENTATION OF GIS PLATFORM AND CUSTOM APPLICATIONS IN OCP ECUADOR S.A

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ABSTRACT

OCP ECUADOR designed and deployed a GIS platform for information collection and processing regarding the maintenance of ROW, Pipeline Integrity and Risk Management, contributing to the times optimization and staff productivity improvement.

NOMENCLATURE

Place nomenclature section, if needed, here. Nomenclature should be given in a column, like this:

APP	Software application for mobile devices.
CP	Cathodic Protection.
ROW	Right of Way.
OCP	Oleoducto de Crudos Pesados.
GIS	Geographic Information Systems.
m.a.s.l.	Meters above sea level.
COTS	Commercial Off The Shelf Software.
KP	Kilometer Point

1. INTRODUCTION

OCP Ecuador, a private company, provides the service of transporting heavy and light crude oil for 485 km. The pipeline system is located in the northern sector of Ecuador and its route begins in the east of the country, within the Amazon region in Sucumbios, extends through the Andes Mountains, reaching 4060 m.a.s.l. and ends in the Ecuadorian coastal area in Esmeraldas. On its way it crosses 4 provinces (Sucumbios, Napo, Pichincha and Esmeraldas), 11 cantons and 33 parishes. OCP ECUADOR S.A. began its operation in November 2003 with a capacity to transport up to 450,000 barrels per day and to date has transported more than 800 million barrels of crude oil through its pipeline, of which more than 15 million come from Colombia, which has allowed to strengthen the regional hydrocarbon integration.



FIGURE 1: PROFILE OF THE HEAVY CRUDE OIL PIPELINE

OCP ECUADOR has always ensured to maintain a reliable and safe operation for which it has developed very demanding prevention plans that allow it to ensure the integrity of the pipeline and its right-of-way strip for which it has, in its organizational structure, an area responsible for the inspection and maintenance of the Right of Way (ROW) whose main objectives are:

- Maintain the geotechnical stability of the right of way.
- Maintain the relationship of good neighborliness with owners and communities.
- Monitor and control civil and industrial constructions in the ROW.
- Avoid the occurrence of accidents and protect the environment.

To meet these objectives, ROW staff carry out field activities focused on routine inspections, monitoring predictive and preventive maintenance and taking potentials to verify the status of the cathodic protection of the pipeline. All these tasks of gathering information in situ are carried out through a mobile application in GIS environment (Geographic Information Systems).

OCP Ecuador worked with Geoint Ltda., to develop of a mobile platform for offline and online use with a map-based user interface, to record all aspects of inspections in the Right of Way of OCP, in a first phase, and a second phase developed a mathematical-spatial model for calculating the Susceptibility

and Risk of the entire pipeline based on the methodology of risk and susceptibility assessment used by OCP but transformed to a spatial analysis environment using cost matrices and spatial clustering

This application has been used by the ROW Inspection staff from approximately 7 years, however, the changing technological world, made this application obsolete over time, which generated the need to migrate the equipment and the application to new technologies.

2. MATERIALS AND METHODS

2.1 Methodology

The work presented in this document depends on five main components if it is to function successfully.

First component, comprises People, distributed teams as Final Users, Platform Development, Platform Administration, and Technical Support.

Second component is workflow for data capture, quality control and ROW maintenance, using a methodology aimed at the identification and control of risks implemented in OCP.

Third component is the software platform that manages and processes field and cabinet data so that risk can be managed and quantified within OCP, whose development responds to an AGILE methodology for software development.

Fourth component is hardware, that comprises all the GPS, field tablets, IT infrastructure of servers and telecommunications.

Fifth component are Data and Data Management Processes regarding to data standardization, defined data flows by data owners.

2.2 Materials Used and Development Technology.

The entire deployed platform uses ESRI technology for GIS based applications and the OCP and SQL Server GIS as storage technology, detailed below:

- Database storage: SQL Server Spatial.
- Application Servers: ArcGIS Enterprise 11.0
- Content Management Server: Portal for ArcGIS 11.0
- ETL-Software: FME Form (aka FME Desktop).
- Data transmission technology: GIS Web Services REST, ESRI.
- Software Development Technology: ArcGIS Java Script API 4.x, ArcGIS SDK for WUP. .NET FOR UWP.
- Microsoft PowerBI

2.3 Software Platform Design Fundamentals

The complete software platform consists of:

- Mobile inspection app CPROW Data Logger
- Spatial Model of Risk Susceptibility
- GIS Portal for comprehensive visualization of Results.
- Geotechnics, Corrosion Risk Dashboards.

2.3.1 App CPROW Data Logger

This mobile application collects information on activities and events along the Right of Way including taking potentials. In backstage, the App sends the data to a spatial database with a hosted calculation engine directly, from where email notifications are generated, and the ROW maintenance matrix.

2.3.2 Susceptibility and Risk Model “MSR”

It is a mathematical-spatial model for calculating the Risk Susceptibility of the entire pipeline that evaluates and scores with a rating both the pipeline and the natural environment of the Right of Way.

This model has another App from where the parameters and weights of each variable are executed and controlled. From this interface the data is refreshed in addition to the possibility of creating scenarios to evaluate different calculation possibilities. This model has a dashboard for the expression of the results in an interactive cartographic and statistical way.

2.3.3 GIS Portal

It is a 2D / 3D GIS Web application integrating the official cartographic data of several OCP departments, as well as with the results of the inspections and with which the management of pipeline maintenance matrices is accessed.

2.3.4 Geotechnics, Corrosion Risk Dashboards

Visualization tools for results of geotechnical monitoring instrumentation as well as internal and external corrosion monitoring, allow specialists to make a comparison between techniques in different facilities and detect patterns as a function of time.

3. RESULTS AND DISCUSSION

3.1 OCP Workflow description

The overall workflow interrelates the four components as follows:

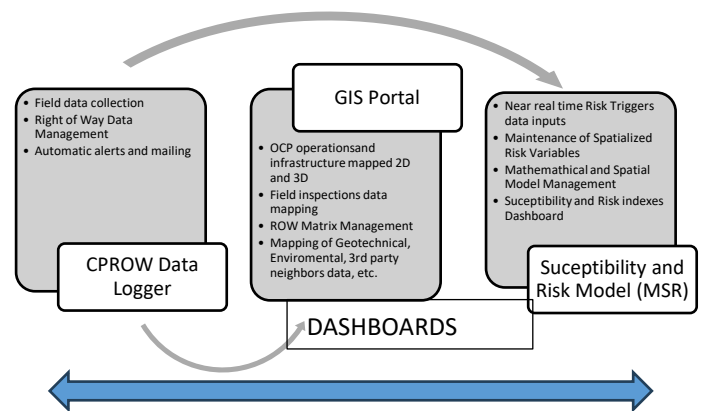


FIGURE 2: WORKFLOW OF THE PROJECT

3.1.1 Workflow of CPROW Data Logger

1. Field Staff captures inspections information in the field using the mobile device.
2. The device stores the data collected in the field that have fulfilled the validations during the capture of right-of-way inspection records and potential taking.
3. Connection to OCP Intranet using routers located at stations, bases or valves in the field.
4. The mobile device, through the app, connects to web services published to ArcGIS Enterprise to update data bidirectionally.
5. The data is downloaded to the provisional database (Stage Geodatabase).
6. Automatically Database procedures synchronizes the information between the Geodatabase Stage and the Production Geodatabase.
7. Finally, the staff synchronizes the photos taken in the field and they are stored on OCP file and web servers.
8. Processed field information and Right Of Way Matrices are published and accessed in GIS Portal Web application.

3.1.2 Workflow of MSR (Susceptibility and Risk Model)

1. “Static” variables are loaded as spatial data into Stage Geodatabase (Lithology, Soil Permeability, Crops, Constructions, Land Use / Land Coverage, Slopes, etc.). These variables don’t need a permanent update, and remains loaded. Pipeline Integrity variables are updated every semester.
2. “Dynamic” or “Trigger” variables – Pluviometry and Seismic Acceleration - are updated using MSR App with its respective frequencies. Pluviometry updated every day or weekly depending the rain intensity, and Seismic acceleration every seism reported by the official source (Geophysical Institute from National Polytechnics School).
3. Specialist remotely runs the model in OCP servers, using MSR App.
4. After every calculation cycle, data are published automatically in Susceptibility and Risk Dashboard web Application.

3.1.3 Workflow for Dashboards (Geotechnical and Corrosion)

1. Geotechnical Monitoring data is collected in the field by OCP personnel that includes all the geotechnical instrumentation implemented in critical sites along the pipeline in Excel.
2. Corrosion data standardized by proprietary users from their original formats that are internal and external

corrosion contractors (CIS, ILI, DCVG) and internal users (PC) from CPROW.

3. CIS, ILI and DCVG data are validated by a specialist who validates, reviews and places them in standardized forms.
4. In both cases, all the information is loaded into the spatial database through automatic ETL flows that take it from its original files, transform it and condition it so that it can be used directly in the GIS.

3.2. System Architecture

System architecture was designed to support client-server Corporate GIS applications in on premises OCP virtualized servers. All of the services, base platforms and servers was planned to be scalable if transactional request grows or if OCP needs other applications or integrations with its Corporate GIS.

In the architecture diagram below, the complete OCP Spatial Data infrastructure its organized in 3 layers listed from lower to upper level:

5. Data Layer: Storage Repositories and Databases.
6. Server Application Layer: Data processing, conditioning and web publication as web services, ready to be consumed.
7. Client Application Layer: Field and Modeling Management mobile Apps, Web Applications for Web GIS and ROW Data Management.

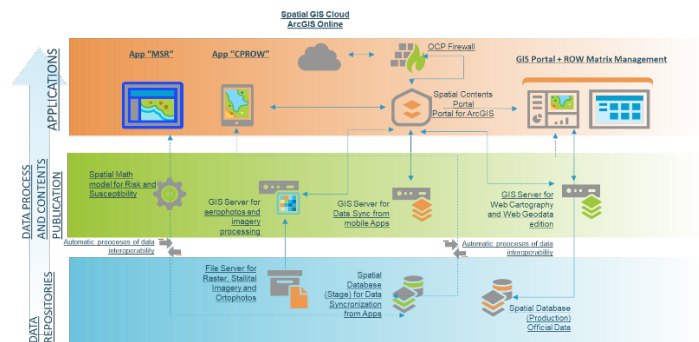


FIGURE 3: OCP SPATIAL DATA INFRASTRUCTURE ARCHITECTURE.

3.3 Components Detailed Description

3.3.1 App CPROW Data Logger.

CPROW Data Logger is the second version of Right Of Way (ROW) Field App for Windows 10. This last version incorporates Cathodic Protection (CP) Potential collection capacity to the Right of Way field inspections forms legacy functions.

For the sketch of the CPROW APP, User Interface / User Experience new design trends were used, totally coupled to the user experience, privileging ergonomics in the field, the current needs of users and business objectives.

CPROW is a Windows 10 App for tablets with GPS and touch screen capabilities. This App can run online or off-line and uses data synchronization capabilities to avoid data loses caused by internet intermittence or low signal quality, common problems outside cities.

The data collection functions are:

1. *Unstable Places* (Sitios Inestables) geotechnical inspection forms.
2. *Mitigation Activites for Geohazards* (Actividades de Mitigación por Fuerzas Naturales) inspections forms
3. *Incident Report* (Novedades) forms
4. *Minor Rivers and Creeks* (Ríos Menores y Quebradas) inspection forms.
5. *Third Party Incidents Mitigation* (Mitigación por Terceros) inspection forms.
6. Cathodic Protection Potential
7. Cathodic Protection hardware status.
8. Geocentric visualization, using an offline interactive layered maps cache in the mobile device.
9. Navigation Controls: Zoom, Pan for touch screen.
10. Map Query Controls adapted to touch screen.
11. Tools: Measure distances or areas, GPS Tools, Layer Control
12. Synchronization Tools to send and receive data from corporate GIS Geodatabase. Once each data Synchronization Process occurs, Database Server triggers an automatized reporting system to send field report mails to supervisors and mail report for synchronization status for field users.

Geographic Data Contents and Coverage

The memory capacity and resolution of mobile devices allows users to visualize the entire pipeline system, from the Amazonas Station in Lago Agrio to the monobuoys in the Ecuadorian coastal area.

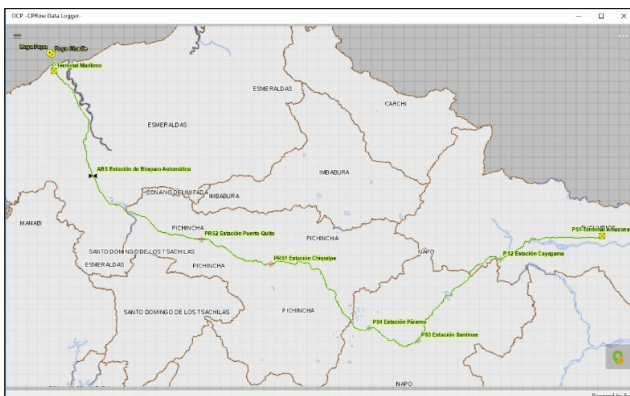


FIGURE 4: OVERVIEW OF THE CPROW APP NAVIGATION INTERFACE

In addition to the cartographic information of the OCP facilities, the field staff has topographic information from the Military Geographic Institute of national cartography at a scale of 1:50,000 and with a high-resolution aerial background photograph (10cm./pixel), all this under the same environment.



FIGURE 5: ENLARGED VIEW OF THE PIPELINE WITH AERIAL PHOTO AND CARTOGRAPHY 1:50,000

User Experience and User Interface

The CPROW APP has new forms formats for editing and entering more user-friendly information through which alphanumeric text, dates and photos can be included with an interface design aimed at minimizing typing by the user, allowing data collection to be faster and easier.

The expandable menu control allows the options to be used, once selected, to be retracted making the map area clear to maintain a "cleaner" visibility of the inspected site. On the other hand, the touch screen functionality of mobile devices makes date and pagination controls for images moldable to the user.

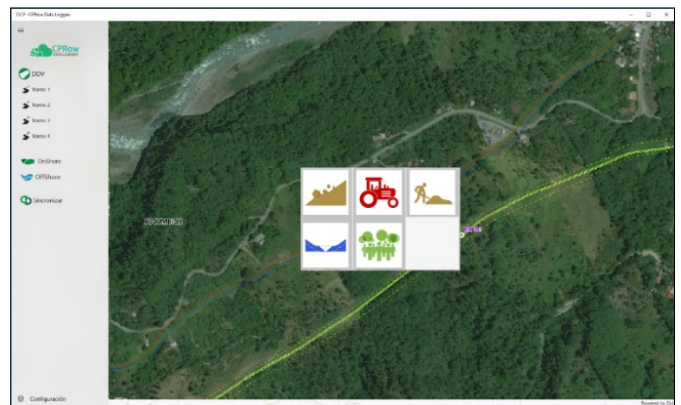


FIGURE 6: DISPLAY OF TWO RETRACTABLE MENUS IN THE NAVIGATION ENVIRONMENT.

Cathodic Protection Module

To the right-of-way inspection module, the potential intake module was incorporated along the main pipeline, onshore pipeline, stations, offshore facilities and rectifiers. In the field, through a traffic light symbology, the user can infer in the first instance whether the raised value is inside or outside criteria

based on NACE SP-0169. Subsequently, this information is analyzed in the office by the corrosion specialist through control panels.

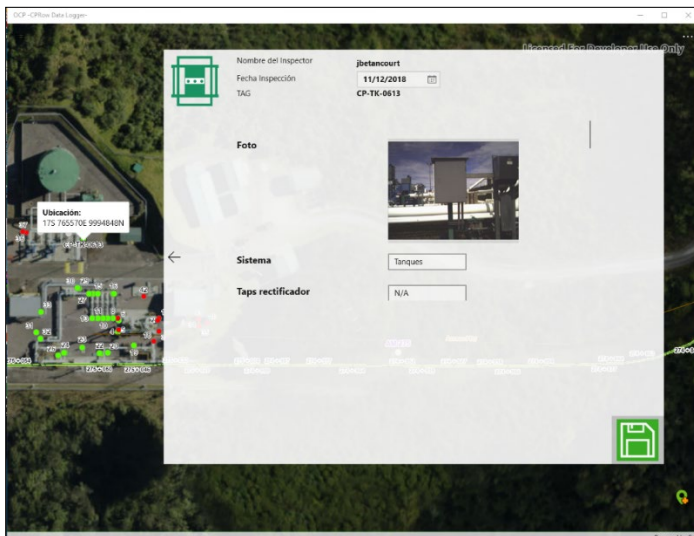


FIGURE 7: SURVEY OF POTENTIALS IN STATIONS WITH FORMULATION OF INFORMATION ENTRY.

Access Control

In order to improve the quality of the data, access controls have been incorporated into the final database, with this, any record that has incorrect, incomplete or filtered information according to business rules will be discarded and stored as historical in an audit log within the local database.

These improvements help optimize times from data collection in the field to the final analysis by the specialist. Prior to this module, the information was collected manually through a contractor and stored in formats that extended times for identification. of any novelty identified in the field.

Matrix and Daily E-Mail Report.

This functionality was deployed to send daily work reports, before data synchronization occurs from the mobile device to the production database, will be able to choose which records they want to send in the "Daily Inspection Report" email. All information is sent to the production database, regardless of whether it was chosen to assemble the daily report email or not.

Sincronizacion App movil ocurrido el 2018-12-11 a las 14H 35M

Tramo	Inspector	Fecha Toma	Tipo	KP-Numero	Fecha Sinc
3	RecorredorCVATR3-A	2018-12-11T15:27:55	C RIOS	289+434.934	2018-12-11 a las 14H 35M
3	RecorredorCVATR3-A	2018-12-11T17:48:20	RIOS MENORES	297894 + 478	2018-12-11 a las 14H 35M
3	RecorredorCVATR3-A	2018-12-12T03:06:32	ACCESOS	290+426	2018-12-11 a las 14H 35M
3	RecorredorCVATR3-A	2018-12-12T05:19:49	C VIAS	295+535.063	2018-12-11 a las 14H 35M

FIGURE 8:GENERAL STRUCTURE OF A SYNC EMAIL.

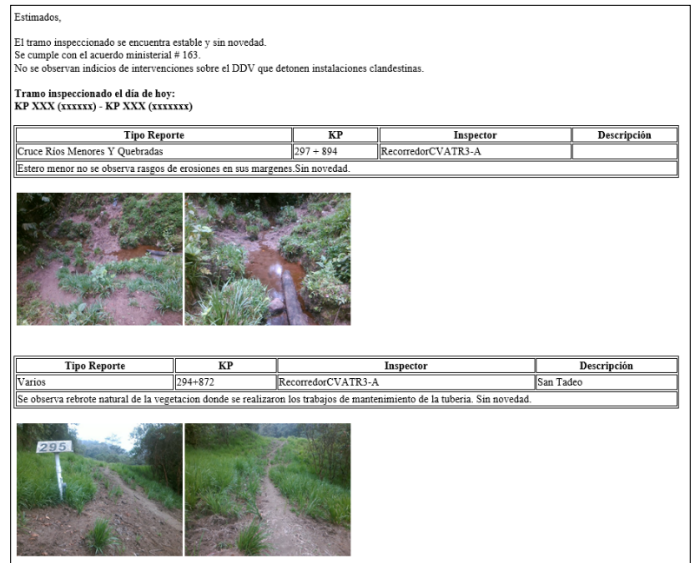


FIGURE 9: GENERAL STRUCTURE OF A DAILY REPORT EMAIL.

3.3.2 SUSCEPTIBILITY AND RISK MODEL (“MSR”)

This application has 3 main software components:

1. Backstage MSR Processing Engine, using Store Procedures in SQL Server and FME Desktop ETL Workflows.
2. App UI for Model Management, for recurrent variables data load, calculation scenario control (model algorithms, variable weighs, etc.) and model running control.
3. Geographic Dashboard Web Application, for final results key indicators, alerts and mapping risks.

Backstage Processing Engine.

When MSR was designed there were 2 processes related to data that will be solved to have an automatized model enrichment with low supervision needs. These processes were:

- 1) Data Load Automation,
- 2) Spatial Model Process and Algorithms Calculations.

Data Load Automation

There are variables related to Risk and Variables related to Susceptibility that must be loaded into OCP Corporate Geodatabase in order to have enough inputs to get the results. Most of this data was organized by data owners (geotechnical specialists / geologists) in standardized Excel worksheets with fixed column structure. Other datasets are geographic data normalized, processed by contractors or by geologists based in field surveys.

To data migration for geodatabase update FME Forms, ETL Workflows are running inside a server using automatic scheduled processes in Windows Server.

Spatial Model Process and Algorithms Calculations

Once data is loaded, using automatic processes, or user input by MSR App, the spatial model will be run to obtain an updated KPIs and alerts for out of permitted limits. Spatial model calculations are made using FME Forms data transformation capabilities.

Some of the calculations are made embedding R code inside FME ETL Workflows. FME Forms read inputs, process it using a simple interface to symbolize functions and after write the results back to Geodatabase. The spatial tables with the results are feeding maps published as GIS Web REST Services inside Geographic Dashboard, consequently the maps and KPI graphics are updated, too.

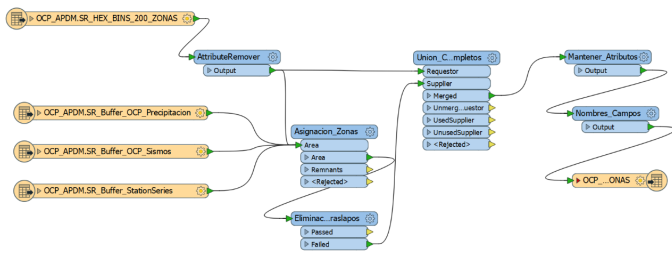


FIGURE 10: ETL WORKFLOW EXAMPLE INSIDE FME FORM INTERFACE.

MSR App

MSR App have a simple interface, designed to be used by specialists in a Windows 10 environment. App can be used connected directly to OCP corporate network or remotely via VPN.

MSR App accomplish two main objectives: 1) Manual Input data for risk event trigger variables that needs to be monitored by a specialist, these variables are Pluviometry and Seismic Acceleration; 2) Risk and Susceptibility Spatial Model Management.

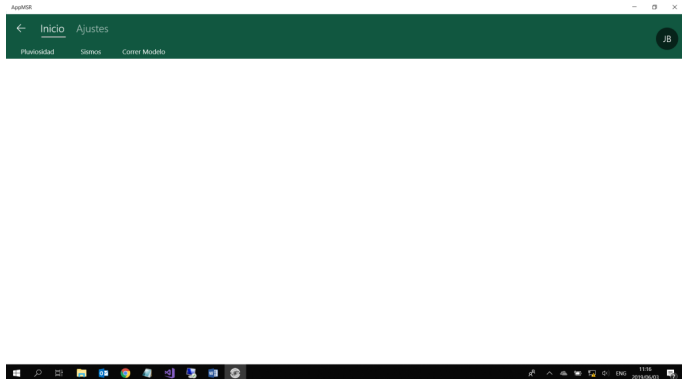


FIGURE 11: MSR APP USER INTERFACE.

Data Input Functions:

1. Daily and Accumulated Pluviometry input
2. Seism Input and graphic Seismic Acceleration calculation.

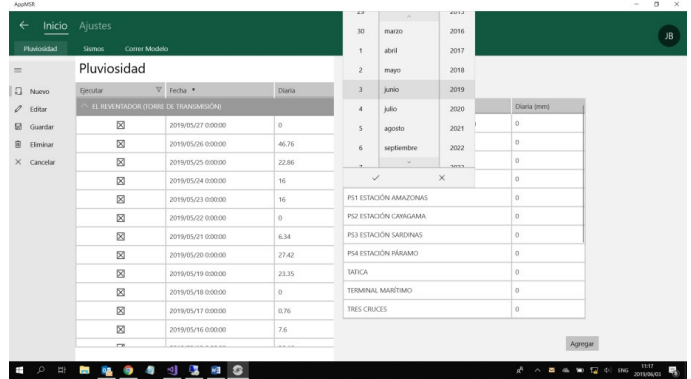


FIGURE 12: PLUVIOMETRY INPUT FORM USER INTERFACE.

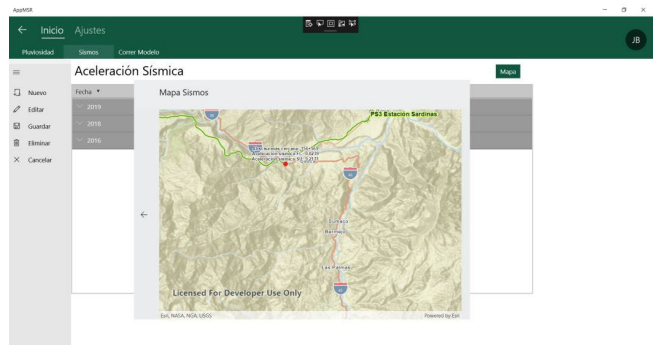


FIGURE 13: SEISMIC ACCELERATION INPUT UI.

Modeling Scenarios Management

Models are parametric. Scenarios are a set of parameters of formulas, variables, variables weigh in the model. There are one official MSR Model, but additional MSR Model scenarios could be created for training purposes or investigate different conditions influence in the results.

Model Running Management.

Once all is ready, MSR model can be executed totally or partially, in order to reduce processing time and obtain quick results. Partial model executions allowed are related to run Trigger Variables submodels only, that's only Precipitation submodel or Seismic Acceleration submodel; or Risk Data Load process.

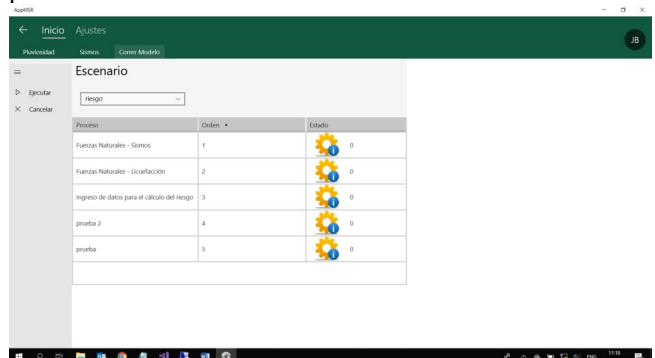


FIGURE 14: SCENARIO RUNNING MSR MODEL CONTROL INTERFACE.

Variable Adjustment Functions

Variable adjustments comprise creation or deletion variables and weighs modifications for each one, in order to create different risk scenarios, i.e. optimistic / pessimistic scenarios, personnel training scenarios, etc.

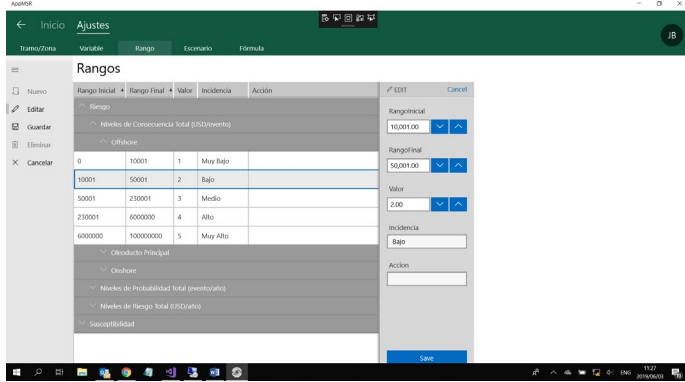


FIGURE 15: RISK AND SUSCEPTIBILITY FORMULAE EDITION FUNCTIONS.

With MSR App the user can modify risk or susceptibility KPI algorithms without to modify the App code. All calculation engines are based in parametric functions.

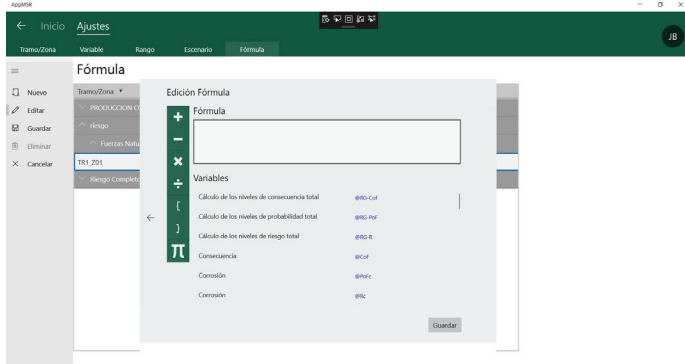


FIGURE 16: VARIABLE MANAGEMENT FORM UI.

3.3.3 GIS PORTAL

This is the final visible software component in OCP Ecuador. This is a responsive GIS Web Application developed in HTML5 with GIS functionality provided by ESRI ArcGIS Java Script API, release 4.0 and other third-party COTS components for JS.

Through GIS Portal, OCP Ecuador collaborators can consult georeferenced information on its main facilities, identify data regarding its emergency response plan, location of owners along the route of the pipeline, among others, and this information in turn contrast it with national cartography of Ecuador, such as protected areas, oil blocks, etc., providing the facility to make a visual analysis of specific or general problems.

GIS Portal has statistical information derived from environmental monitoring for legal compliance, which enables the user of these topics to identify trend patterns. It also presents monitoring information on the main threats to the pipeline (natural forces, third-party damage, and corrosion), providing

important support to specialists in planning and executing preventive or corrective actions.

Map Navigation, Data Layers and Cartographic Tools

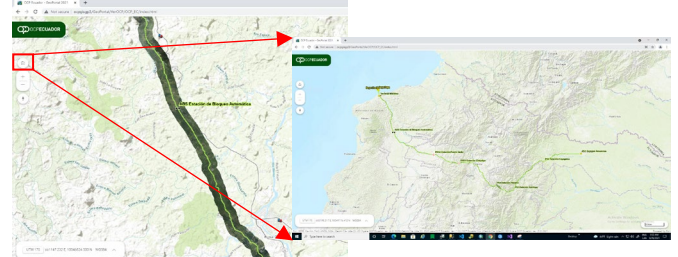


FIGURE 17: GIS PORTAL USER INTERFACE, SHOWING NAVIGATION TOOLS.

Coordinate System Management and Conversion functions.

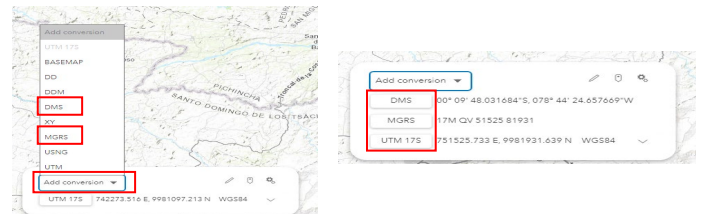


FIGURE 18: TOOLS FOR CORDINATE SYSTEM CONVERSIONS.

Customized cartography-linked photos and documents with informative pop-ups

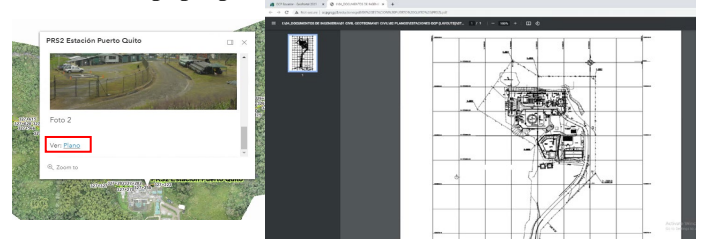


FIGURE 19: INFORMATION POP-UPS FOR ADDITIONAL DATA LINKED TO MAPS.

Measurement tools for surfaces, lengths expressed in different measuring units.

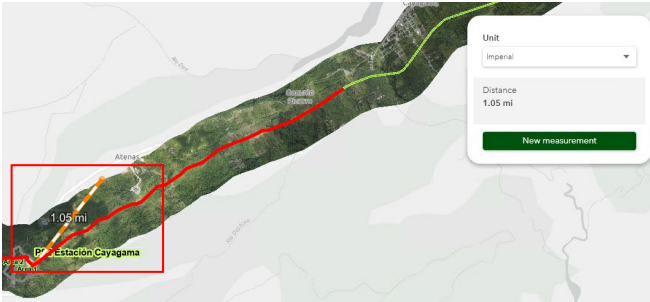


FIGURE 20: MEASURING TOOL FOR DISTANCES AND AREAS.

Statistical tools, for Environmental control data statistics.



FIGURE 21: STATISTICS FOR ENVIRONMENTAL COMPLIANCE SAMPLING.

3D rendering and measuring and topographic profile generation.

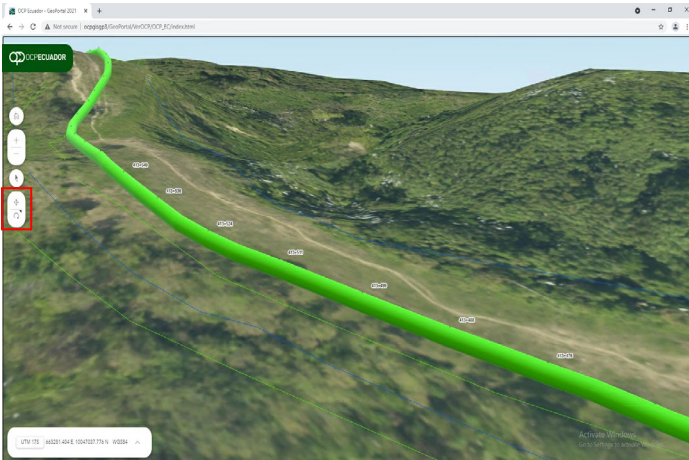


FIGURE 22: 3D VISUALIZATION WITH INFRASTRUCTURE RENDERING.

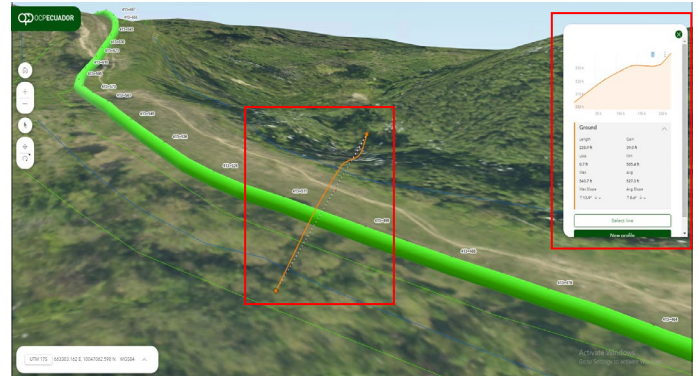


FIGURE 23: TOPOGRAPHIC PROFILE GENERATION TOOL

ROW Matrix Management Module:

There is a complete module that interacts with GIS Portal, to manage service matrices and incident following. This module can send daily e-mails with management work summary, matrices status, and alerts for users.

With this automatic notifications, it was possible to improve the management of collected points in the field, since it is based on service priorities, thereby prioritizing and assigning resources according to the identified need. Information tabulated in matrices facilitates the analysis of the data collected, identifying geographic and temporal patterns, thereby adjusting inspection plans year after year.

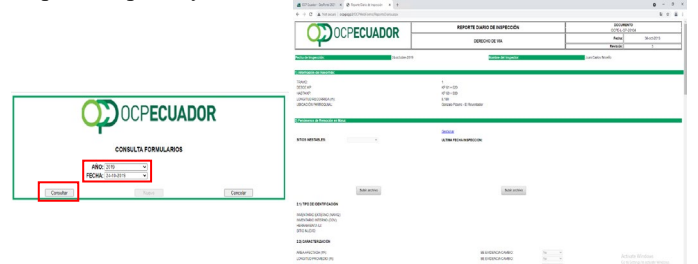


FIGURE 24: ROW MATRIX MANAGEMENT MODULE USER INTERFASE.



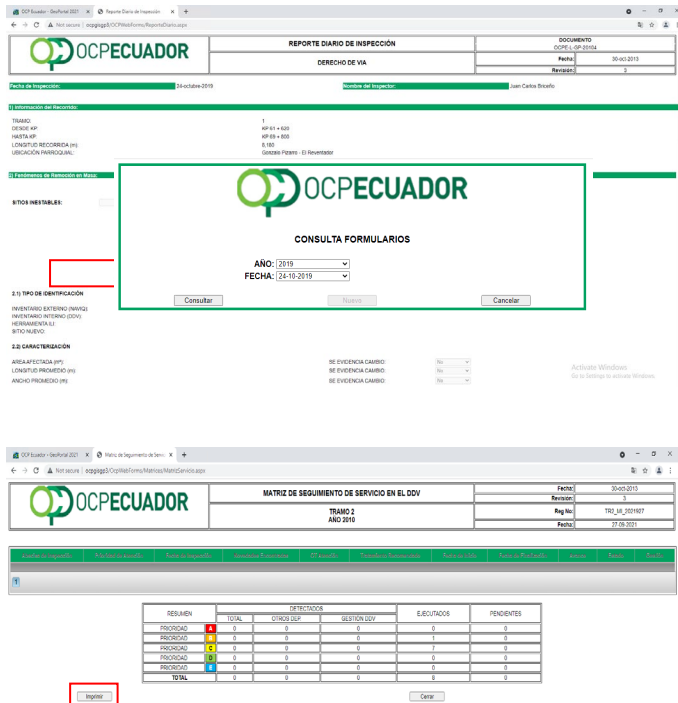


FIGURE 25: ROW GRAPHIC QUERY AND SERVICE MATRIX RESULTS

3.3.4. Geotechnical Dashboard

Geotechnical Dashboard was created in Power BI desktop with implementation of ArcGIS Maps for Power BI module, developed for the use of specialists in the analysis of geotechnical monitoring instruments through the comparison of displacements in North, East and absolute Elevation.

This dashboard is fed by FME workflows that allow the input of geotechnical field data for storage in OCP corporate database. The main functions are information filters by KP or element under monitoring, and geographic visualization through web services.

Geotechnical Dashboard can perform the following analyses which are located in separate tabs:

- Cumulative net displacement: Shows displacement in the three axes that the monitoring instrument has undergone with respect to the baseline.
- Partial net displacement: Shows displacement in the three axes that the monitoring instrument has undergone with respect to the previous monitoring.
- Cumulative vertical displacement: Shows vertical displacement that the monitoring instrument has undergone with respect to the baseline.
- Partial vertical displacement: Shows vertical displacement of the monitoring instrument with respect to the previous monitoring.

- Joint analysis: Shows the displacement of the horizontal and vertical axis that each monitoring instrument (joint) has undergone.



FIGURE 26: GEOTECHNICAL DASHBOARD INTERFACE – JOINT ANALYSIS

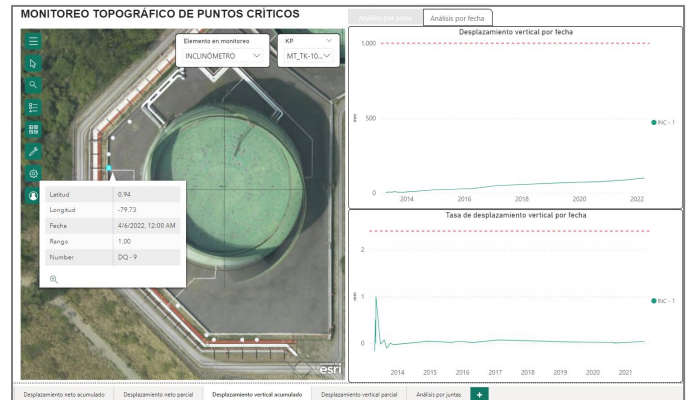


FIGURE 27: GEOTECHNICAL DASHBOARD INTERFACE – CUMULATIVE VERTICAL DISPLACEMENT

3.3.5 Corrosion Dashboard

Corrosion Dashboard was generated in Power BI Desktop in a Windows 10 environment using ArcGIS Maps module and statistical graphs. Then, it was published in Power service (Microsoft Fabric) for the organization's online visualization.

This dashboard is intended to support specialists and DDV supervisors in punctual and comparative multi-temporal analysis of cathodic protection and pipeline integrity issues: Loss of Thickness (ILI), Cathodic In-Step Protection (CIS), Post-Post Cathodic Protection, Coating (DCVG), pH and Resistivity.

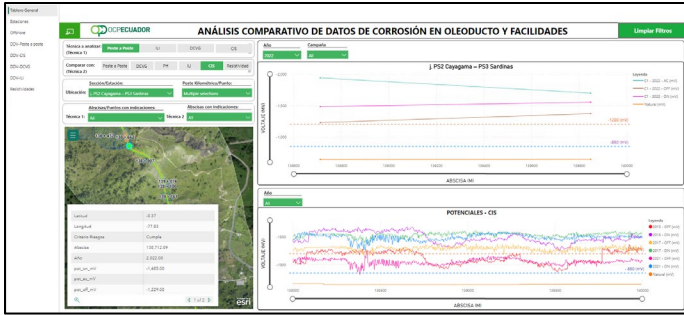


FIGURE 28: DASHBOARD CORROSION INTERFACE – GENERAL TAB.

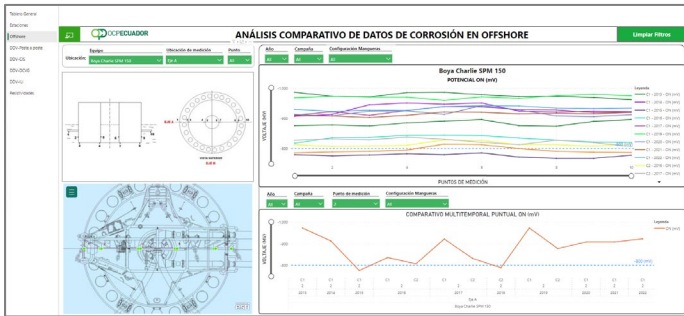


FIGURE 29: DASHBOARD CORROSION INTERFACE – OFFSHORE TAB

Prior to having this tool, the specialists in charge of information analysis and contrast it with relevant data from other monitoring techniques required at least one day to have the information centralized and standardized in databases and displayed on the control panel. , it is a matter of minutes to access it and analyze it for decision making.

3.4 Results Obtained

Stability and scalability

Being a native application, that is, it has been developed and created in a specific environment, makes its operation stable, intuitive to the user and can be used without the need for an Internet connection for its operation in the field. On the other hand, its modular structure makes it scalable over time, a feature that offers the possibility of incorporating new solutions to different needs or requirements of the company into its work interface.

Quality Control in the field

The new interface, forms and control buttons have been oriented to minimize the manipulation of the data collected in the field, to standardize the information from the taking through the use of drop-down selection lists (domains in databases) and to define validation criteria through the implementation of cartographic coverages whose traffic lights change depending on the values entered.

Data integrity and traceability

Its access control module prevents the entry of information to the final database without being filtered and created a reference LOG in the Stage database. Any record that is discarded for incorrect, incomplete or filtered information according to business rules will be stored in a backup LOG. In addition to user income, the temporality of their synchronizations and their georeferenced trajectories also have a LOG record.

Improved productivity

The synchronization of information from mobile devices to databases, is no longer an activity to be carried out exclusively in an office, now they can be executed from any facility that has access points to the corporate network. On the other hand, the incorporation of a reporting module allows the user to "assemble" and easily create the daily inspection report, selecting among all the observations raised in the field, which will be part of your report. These solutions have managed to reduce administrative times by 40% (approximately one and a half hours per day per inspector).

4. CONCLUSION

In the case of OCP, the implementation of geomatic tools proved to be a support for management, decision-making, and routine activities. Geomatic tools have been especially useful for providing a complete and comprehensive management of risk based in the best approaching of geoinformation.

OCP trusts in these tools for solving issues related to integrity of the pipe.

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