PROTECCIONES GEOTÉCNICAS EN CRUCE DE RIOS, Pk 20,500 OLEODUCTO PUESTO HERNÁNDEZ – LUJAN DE CUYO ARGENTINA

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Documento: YPF-Público

01 Presentación del caso

El oleoducto de 16" Puesto Hernández – Lujan de Cuyo forma parte del sistema de 3000 km de ductos que se operan en la República Argentina. El mismo evacua parte de la producción del Yacimiento Vaca Muerta, corazón productivo del país desde el punto de vista energético.

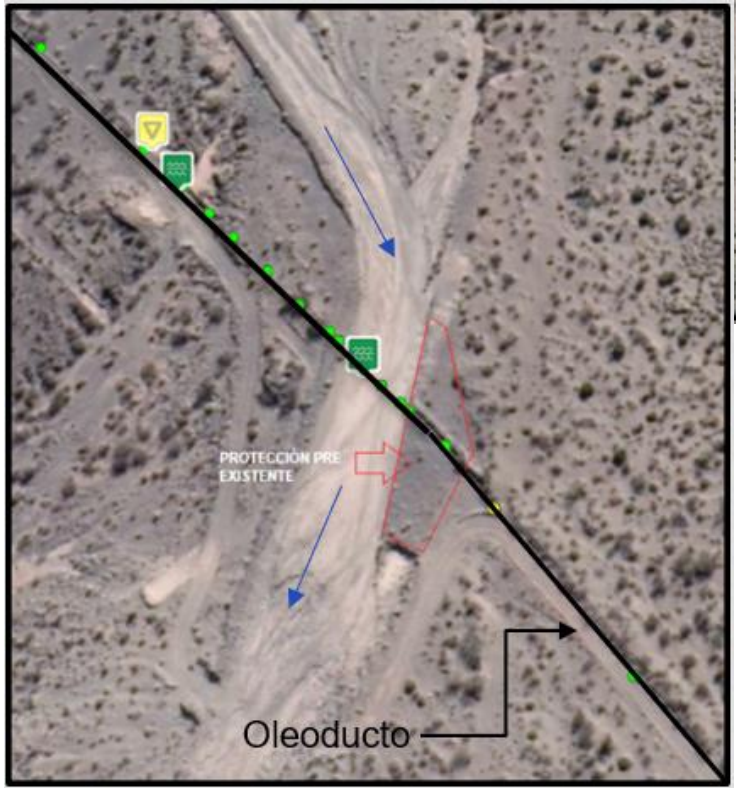
Debido a la caída de lluvias extraordinarias en el sur de la provincia de Mendoza, se produce el descubrimiento de aproximadamente 9 mts del oleoducto, en un cauce semipermanente a la altura de la progresiva kilométrica 20.500, quedando éste expuesto al impacto de piedras y demás elementos contundentes. El evento ocurre en una zona cercana al rio Colorado (2600 mts aproximadamente), un importante curso de agua que divide las provincias de Mendoza y del Neuquén

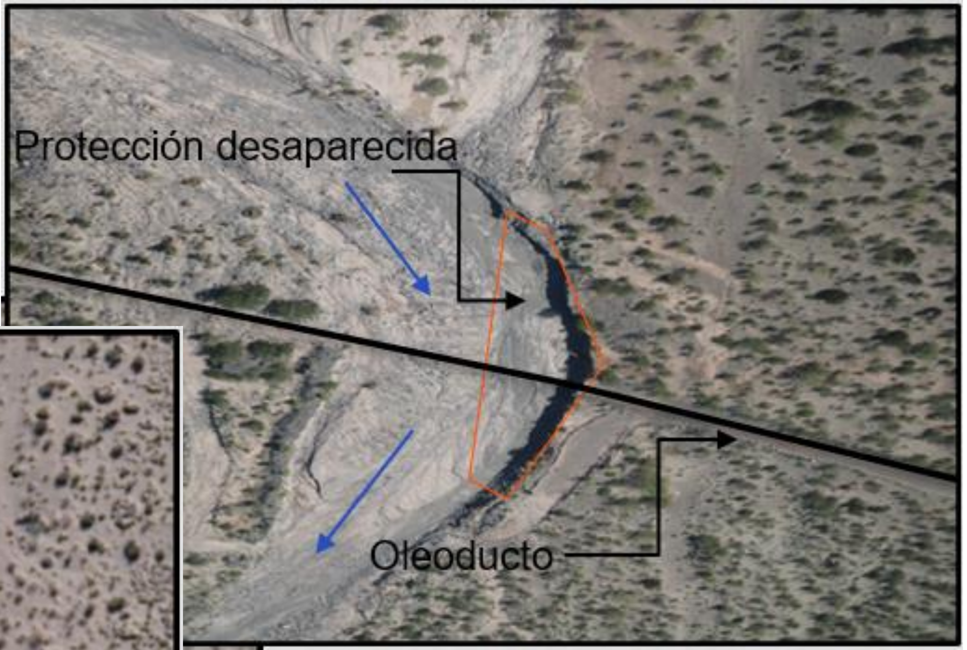
01 Presentación del caso

El ducto allí, se encuentra a aproximadamente 2600 m. del rio Colorado, el cual abastece al dique Casa de Piedra, fundamental fuente hídrica que sirve a las provincias de La Pampa y Rio Negro.

La situación encontrada fue considerada critica, ya que una falla de la línea en la pk en estudio, provocaría un derrame sobre esta importante rio que divide las provincias de Mendoza y la del Neuquén

03 Estado de situación





Situación del cauce pre existente vs situación post lluvias

La imagen de la izquierda muestra una obra de contención de antigua data y la de la derecha como quedó el cauce luego del evento.

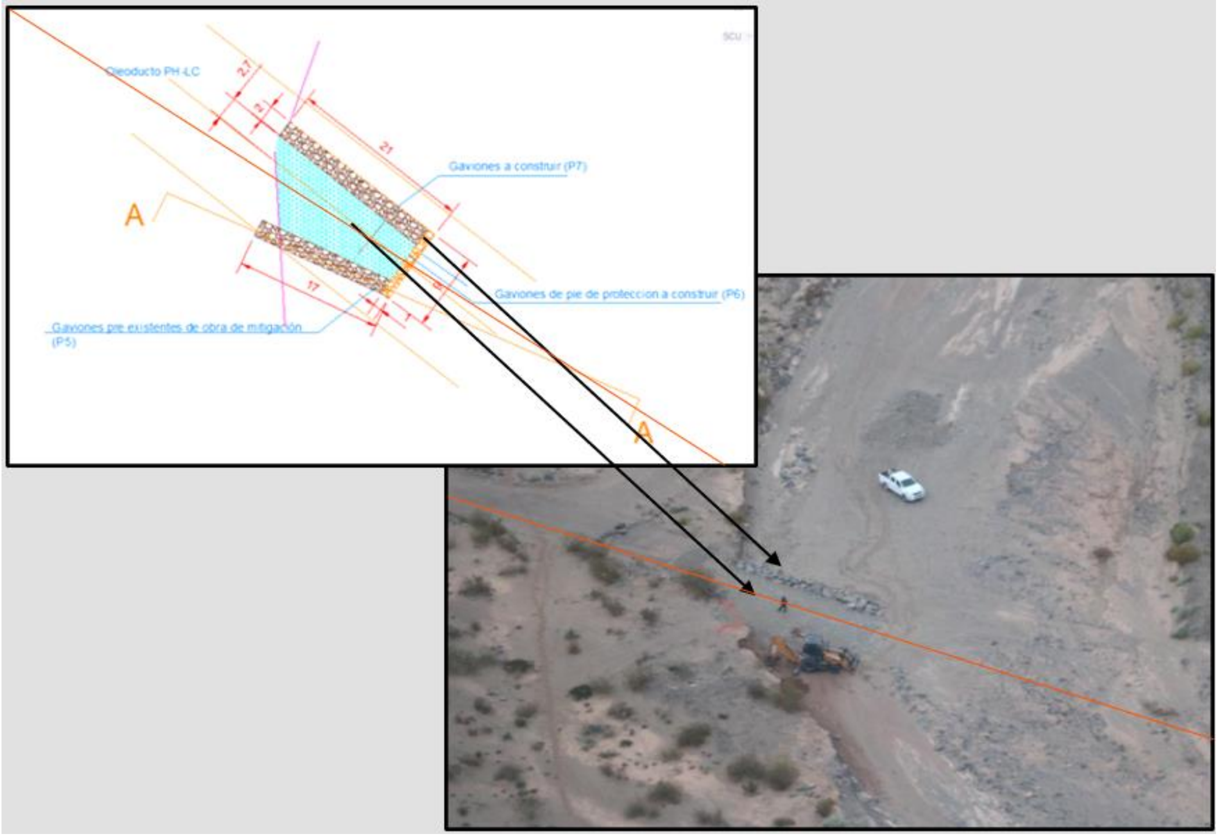
Como se puede apreciar, la obra anterior, no acompañaba la natural curva del cauce (radio lo que generó su colapso no obstante haber estado varios años en servicio.

Ante esta conclusión, lo que se buscó fue que la nueva obra, acompañara el natural escurrimiento de las aguas intentando generar un re encauzamiento de las mismas hacia la zona media del cauce donde el ducto tiene una tapada superior a los 3 metros.

03 Estado de situación

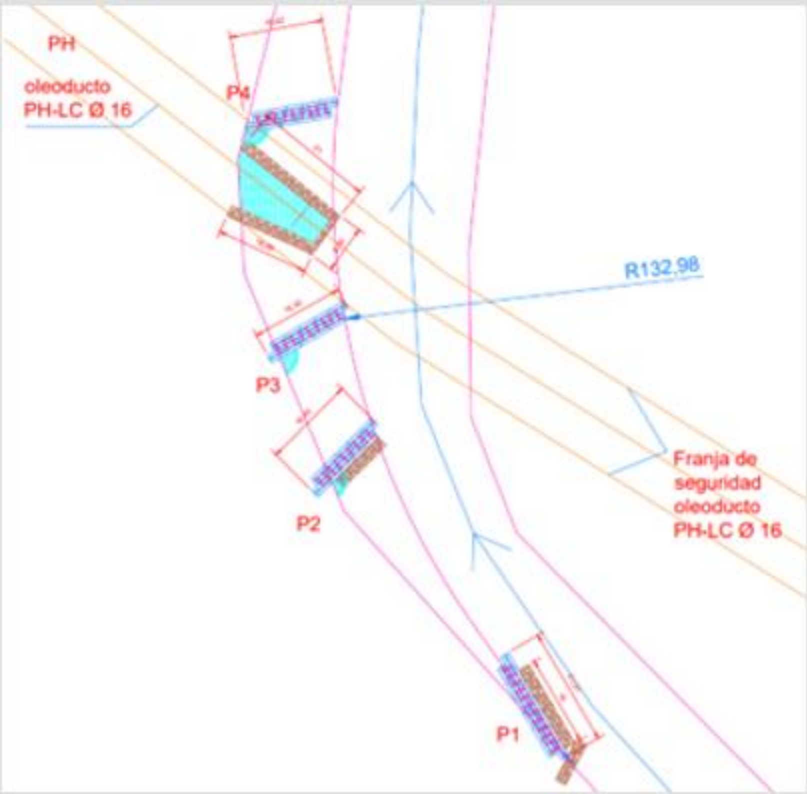
- Arribados al lugar, nos encontramos con el ducto descubierto y seriamente dañado en su revestimiento.
- El mismo presentaba el impacto de piedras menores (pérdida de revestimiento) y de elementos mayores que generaron abolladuras y perdida de material por arrastre.
- Se detallan en la imagenes una de las piedras arrastradas por la corriente y que generó un impacto sobre el ducto. Por otro lado se enseñan algunos de las evaluaciones mecánicas sobre la línea.
- **Es muy importante destacar que el lugar era pemanentemente monitoreado y que esta situacion se debio a una Lluvia de mas de 50 años de recurrencia**

04 Solución adoptada



Dado a que el diseño y la materialización de la obra definitiva llevaría un plazo para el cual que no era admisible dejar el ducto descubierto y a los efectos de salvaguardar al ducto de posible nuevos eventos, la primer tarea que se realizó fue la protección mitigatoria del mismo. Esta consistió en "abrazar" al tramo descubierto con una serie de gaviones de manera de generar una obra fusible ante un nuevo evento, hasta tanto se coordinaran las tareas definitivas

04 Solución adoptada



La obra final , consistió en diseñar una serie de escolleras materializadas con una doble hilera de sleepers de hormigón que acompañaran el escurrimiento natural de las aguas hacia el rio Colorado.
Se calcularon los ángulos respecto al terreno para lograr un radio del cauce adecuado, como asi también la cantidad y longitudes de cada una de las escolleras

04 Solución adoptada

El traslado y disposición en obra de los mismos fue un desafío logístico para el área Mantenimiento, ya que además de encontrarse la obra alejada de cualquier gran centro urbano, la topografía presento un nuevo reto, ya que hubo que cambiar la pendiente de un cerro para poder llegar con los camiones al lugar y disponer con equipos especiales de los sleepers en el cauce

04 Solución adoptada

Obra a punto de ser finalizada.
Las fotos aéreas tomadas por el patrullaje mensual, nos muestran la materialización de la obra a poco de ser finaliza en 2022

04 Solución adoptada

Situación actual.

Cauce completamente recostado hacia su margen de menor radio de curvatura debido al accionar redireccionador de las escolleras materializadas

05 Conclusiones finales

Conclusiones finales

- Si bien la obra fue calculada y diseñada especificamente para este cruce, es una leccion aprendida de otras operadoras a nivel Latinoamerica que pudimos rescatar y adecuar a nuestras necesidades.
- Las tareas fueron finalizadas en el mes de febrero 2022 y al momento se encuentra cumpliendo su función según lo estipulado, habiendose cumplido con los requisites legales y permisos de rigor.

¡Gracias!

ASME Proceedings 2025
International Congress of Pipeline Geotechnics
IPG 2025
November 6 and 7, **Bogota, Colombia.**

IPG 2025-#00--

"GEOTECHNICAL PROTECTIONS IN RIVER CROSSING, PK 20,500 PUESTO HERNÁNDEZ - LUJÁN DE CUYO - ARGENTINA OIL PIPELINE"

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ABSTRACT

The 16" Puesto Hernández – Lujan de Cuyo pipeline is part of the 3000 km pipeline system operates in Argentina. It evacuates part of the production from the Vaca Muerta field to one of the three crude oil refineries most important in the country.

Due to the extraordinary rainfall in the south of the province of Mendoza, approximately 9 meters of the pipeline were discovered, in a semi-permanent channel at the height of the progressive kilometer 20,500, being exposed to the impact of stones and other blunt elements. The event occurs in an area near the Colorado River (approximately 2600 meters), an important watercourse that divides the provinces of Mendoza and Neuquén.
To remedy this situation, several alternatives were evaluated, including a directed crossing which, due to the type of terrain, the complexity of the maneuver and the time it would take to carry it out, was discarded. Finally, the solution adopted was to design a series of breakwaters channelling the river, so that the waters flowing along the river would rest on the bank opposite the open conduit, where the plugging is adequate. In short, the aim was for the river to return to its original course.
To this end, a temporary protection of the line was first built and then 4 breakwaters whose angle with respect to the banks of the channel and their distance from each other were calculated so that future events do not affect the integrity of the pipeline again. To materialize the work, reinforced concrete sleepers were designed and sent to be built. This entailed complex logistics from several points of view, since the elements to be used had to be manufactured and moved from more than 400 km away, in addition to the difficulties of access, which included temporarily modifying the slopes of a hill so that the equipment could reach the work site.
Despite not having previous hydraulic studies, it was found thatafter two rainy seasons, the work, which is monitored monthly by both air and ground patrols, is working as planned, protecting this important pipeline from the aggressive meteorological events of Argentine Patagonia

NOMENCLATURE

Pk: Kilometric progressive.
Pipe: Pipeline.
Line: Pipeline.
VB: Block Valve.

1. INTRODUCTION

On a tour carried out during the month of February 2021, field personnel detected, after a series of heavy rains in the area, the pipeline completely exposed at Pk 20,510. A length of 8.80 meters of exposed pipe is observed.

The featured event took place in the south of the province of Mendoza, Argentina. The location has particular characteristics that will be detailed below in general and introductory ways. These were taken into account when finding the most appropriate technical-economic solution.

Image 1 - Geographic Location – Source : Google Earth

1.1 Geological features

Geologically, the area corresponds to the differentiated sector of the Neuquén Basin called "Engolfamiento del Atuel", which is located in the northern sector of the basin

The site in question is located in an area with outcrops of foothill sephitic deposits, according to the Geological Map of Mendoza made by the Ministery of Mining - National Geological Service Directorate.

It is located about 17.2 km NE of the Rio Grande on the northwestern slope of the Sierra de Chihuido. The area presents a geology rich in outcrops of sedimentary and volcanic rocks ranging from Jurassic to Quaternary units, with almost no interruption in the representation of lithostratigraphic floors

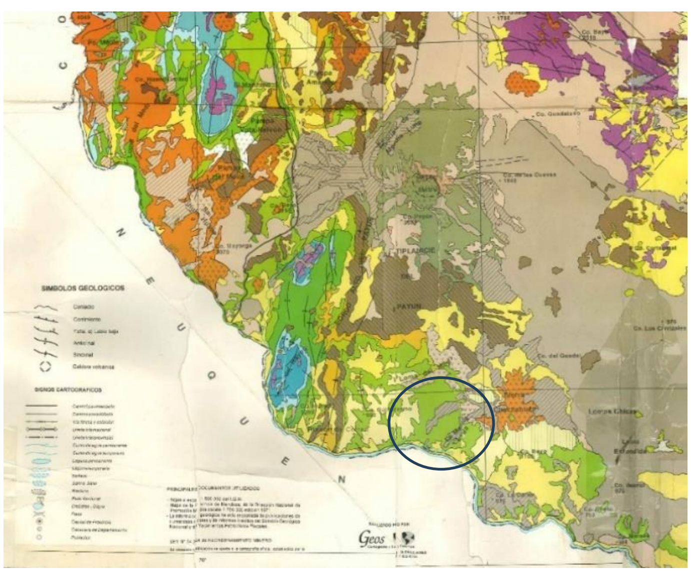


Image 2.1 Geomorphological units of the study area

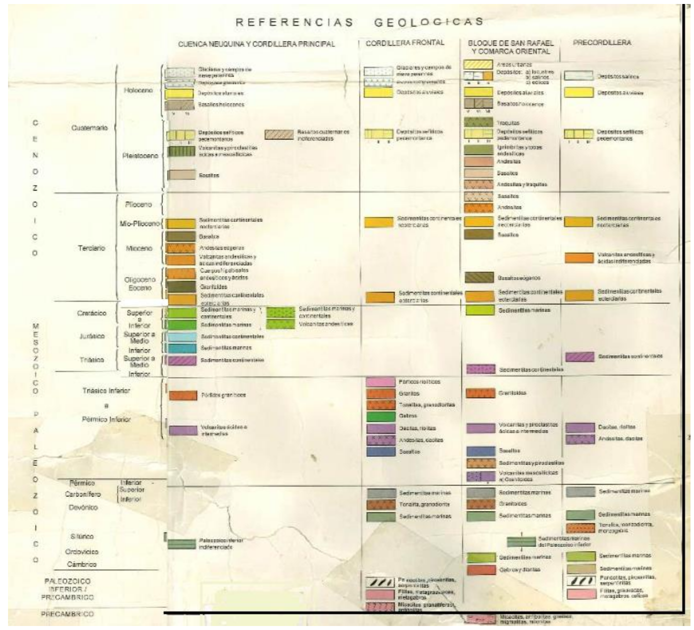


Image 2.2 Geomorphological units of the study area
Source: Ministry of Mining
National Geological Service Directorate
(Secretaria de Mineria
Direccion Nacional de Servicio Geologico)

1.2 Geomorphological features

The geomorphological characterization of the province of Mendoza is based on the general classification of units of clearly differentiated relief from west to east, the Mendoza landscape is integrated by a series of positive reliefs: the western mountains and mountain ranges and the plains, plains and depressions of the central and eastern area.

The area under study corresponds to the transition zone between the Cordillera Principal and the Payunia

1.3 Hydrological characteristics

The site is located 30 m from the center of the bed of a temporary alluvial channel running from N to S and 5.3 km north of the Colorado River.

1.4 Hydrogeológicas features

The study area is made up of Quaternary sediments that carry aquifers. It comprises filiform or mantiform, sometimes amalgamated, layers of permeable or highly permeable gravel, gravel and sand, with silt-clay intercalations. Locally, it has pyroclastic material in varying proportions. These sediments have accumulated in foothills (predominance of gravel), alluvial plains (predominance of sand and gravel), dune covers (loessic sands and silts) or river channels (gravels and clean sands).

1.5 Climatic characteristics

The province of Mendoza is governed by the action of the Pacific and Atlantic anticyclones and by the depression of northwestern Argentina, giving rise to an atmospheric circulation typical of the temperate zone. Variations produced by the influence of topography make it colder to the west and warmer and drier to the east. Despite the differences in height, structure and shape of the natural or mountain area, they have certain homogeneous climatic features that depend on the semi-permanent anticyclone of the Pacific Ocean. These features are: the glacial nature of the temperatures, the snowy winter rainfall and the violent and constant westerly winds.

1.6 Seismic risk

Seismic risk in the Province of Mendoza is high, so it must be addressed as a variable for project design and contingency plans. The National Institute for Seismic Prevention (INPRES) establishes a gradation of the type of seismic risk to which the province is subjected, which for the area of interest corresponds to a reduced hazard.

1.7 Environmental impact

Finally, it is worth highlighting the development of the corresponding environmental impact studies, which showed 39 positive and compatible impacts, vs. 24 moderate impacts and only 3 negative.

1.8 Basin

The watershed that supplies the study site covers an area of 18,186 hectares.

Image 3 shows its morphology, illustrated up to the point of the event.

Image 3 - Source IGN – National Geographic Institute Argentina – mapa.ign.gob.ar

Rainfall regime

Seasonality: Rainfall is concentrated mainly in the summer, between November and March, with greater intensity in December, January, and February.

Annual values

- Northeast: less than 100 mm/year, zone of maximum aridity.
- East: around 192 mm/year.
- South: up to 343 mm/year.
- Provincial average: approximately 220 mm/year

The ones we are concerned with are the southern region, Malargue, Pata Mora, La Puyania with 343 mm per year

Any rainfall that exceeds 10% of the annual rainfall in a single day is considered extraordinary.

The annual rainfall pattern in La Payunia varies between 200 and 500 mm.

Rainfall is concentrated in the summer, but is generally scarce and of low intensity.

In this context, extraordinary daily rainfall would be that which:

Exceeds 20-30 mm in a single day, which represents more than 10% of the annual total in some areas.

It can cause intense runoff, surface erosion, and temporary channel disturbances.

It is rare, but may be associated with summer convective storms.

Región	Precipitación Anual (mm)	Umbral de Lluvia Extraordinaria Diaria (mm/día)
Noroeste	100	10
Este	192	20
Centro	220	25
Sur	343	30
La Payunia	200 - 500	30

Table 1 – Thresholds of maximum extraordinary rainfall

In arid areas like La Payunia, rainfall of 5 to 10 mm/day is already significant.

Rainfall of 30 mm or more in 24 hours is considered extraordinary due to its impact on the volcanic soil, steppe vegetation, and local fauna.

Rainfall is concentrated in the summer, but is generally scarce and of low intensity.

In this context, extraordinary daily rainfall would be that which:

Exceeds 20-30 mm in a single day, which represents more than 10% of the annual total in some areas.

Can cause intense runoff, surface erosion, and alterations in temporary channels.

It is rare, but may be associated with summer convective storms.

1.9 Original state of affairs

The preceding figures show the state of the situation in the area.

Image 4 – Exposed pipeline – Source: Author of the paper

Image 5 – Aerial view of exposed pipeline – Source: Aereal patrol

In this position there was previously a protective work that had been completely destroyed by the meteorological event. (On many occasions, geotechnical protection works must be a "fuse" that acts as such in order to protect the pipeline so that the damage to it is as little as possible).

Image 6 – Location of pre-existing protections. – Source: Google Earth

On the other hand, it can be seen that the semi-permanent channel has a significant drag of stones and other blunt elements that are potentially risky for the pipeline, in fact, it was corroborated a posteriori, that the deterioration of the lining and the dents found were due to the impact of the transported elements.

Image 7 – general view of the affected area – Source: Author of the paper
Restricted area 7,50 m each side

1.10 Inspection

The first step was to perform a visual inspection of the pipeline for cracks or dents. Fortunately, the mechanical integrity of the line remained unchanged, but dents were found due to impacts.

1.11 Risk analysis

A risk analysis was carried out that showed the criticality of the pipeline. Within this analysis, design data, hydrological and tectonic hazards, among others, were included, and the possible environmental damage was also considered, since the pipeline is located approximately 2600 meters along the Colorado River.

Image 8 – Location of the pipeline in relation to the Colorado River – Source: Google Earth

1.11 Interim preliminary tasks

In view of the situation presented and as a first measure after the evaluations carried out, the rigorous mechanical and geotechnical repairs were carried out (the latter provisional), in order to protect the pipeline from another event. However, it was imperative to carry out the necessary permanent adaptation work to protect the facility from future natural events or geohazards, in addition to complying with the current regulations imposed and regulated by RES 120/17 of the SEN, the Argentine entity that regulates the activity.

2 PROPOSED SOLUTION

After studying the situation that had arisen and evaluating the failure mechanism of the previous existing protection, it was concluded that the defense work of the pipeline should contemplate adapting the current channel so that the runoff of the water and a potential impact of rocks would not affect it.

It is important to note that the pipeline did not have the same cover throughout its width, being this greater than 2.00 meters in the center of it.
In view of this, it was thought to make riprap-type defenses that would act as water rechannels in order to prevent erosion in the partof the channel where the pipeline was mostcompromised with respect to the clogged.
It should be remembered that the area has very violent seasonal rains and that action had to be taken quickly to protect the facility Next, each of the elements of the work will be presented, from the materials, the provisional work and the definitive implementation.

2.1 Temporary work

Due to the fact that the final work was going to take some time to carry out due to logistics and other operational issues, a first provisional protection was materialized, which consisted of making two smallbreakwaters of 10 meters in length with gabions and the accumulation of fine soil on the duct. First, the south gabion row was made and then completed as shown in FIG.8. After these tasks, the pipeline obtained a plug of approximately 0.80 meters.

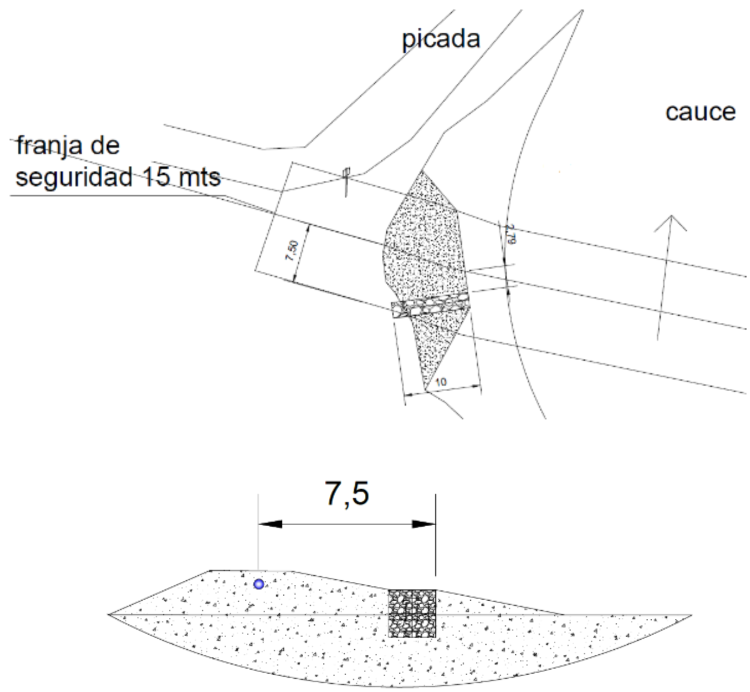


Image 9 – Provisional work schematic plan – Source: Author of the paper

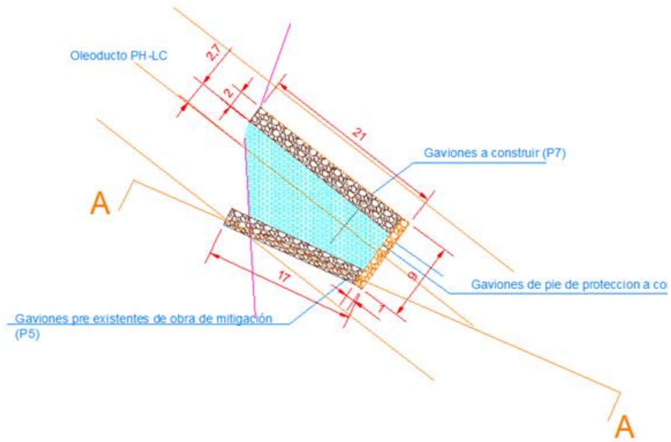


Image 10 – Schematic plan of the final provisional work – Source: Author of the paper

Image 12 – Construction of temporary work with gabions and reinforcement tubing – Source: Author of the paper

Image 11 – Construction of temporary work with gabions and reinforcement tubing – Source: Author of the paper

2.2 Definitive work

Originally, and at the time of the crossing during the laying of the line, the channel in question had a much smaller width than it had after the event. That is why, in the current middle area of the river, the pipeline has a depth of more than 2.0 0meters, having a cover protection that leaves it safe.

This is not the case in the outer part of the riverbed, which is where the pipeline was exposed after successive meteorological events.

The aim was to restore the semi-permanent channelas close as possible to its original morphology.

In view of this, it was determined to make a series of breakwaters materialized with concrete blocks (sleepers) located in the bed of the channel, in order to redirect the runoff to a safe area for the pipeline, always within the limits of the natural channel.

The materialization of the breakwaters was originally thought to be made using large stone blocks present in the place. As this was not possible, it was decided to make them with sleeper concrete blocks, which were detailed in FIGs 11 and 12

2.2.1 Materials

Once the solution had been chosen, it was necessary to study what material to make it with. This was limited to two options, which was to use large rocks similar to those used at sea or to use pre-cast elements of great weight and volume. Finally, he opted for the latter, which had to be manufactured so they had to be as robust and simple as possible. They were designed, calculated and sent to be built more than 400 km from the construction site.

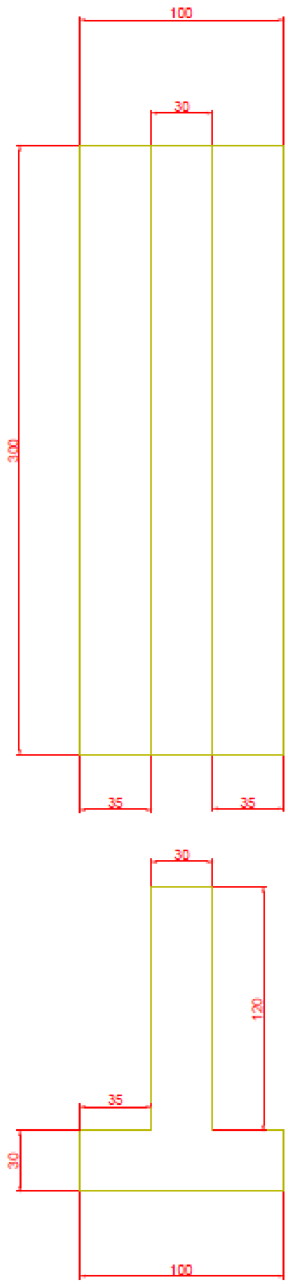


Image 13.1 -Sleepers Plans – Source: Author of the paper

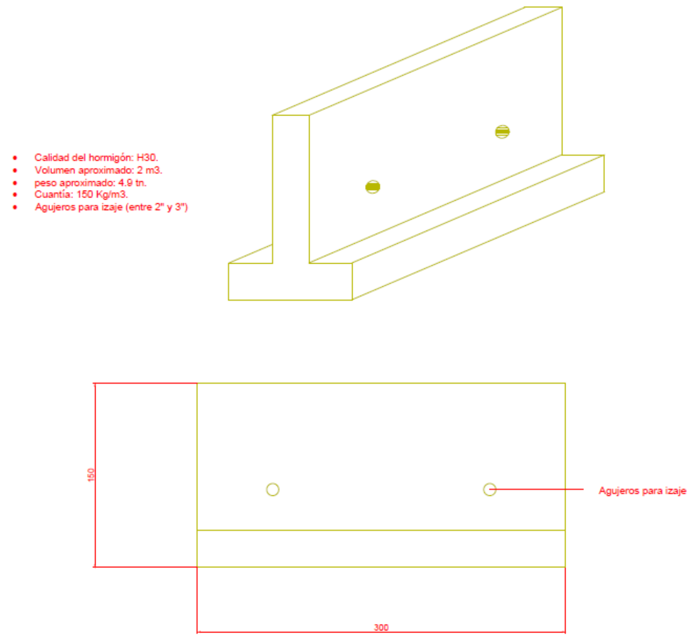


Image 13.2 -Sleepers Plans – Source: Author of the paper

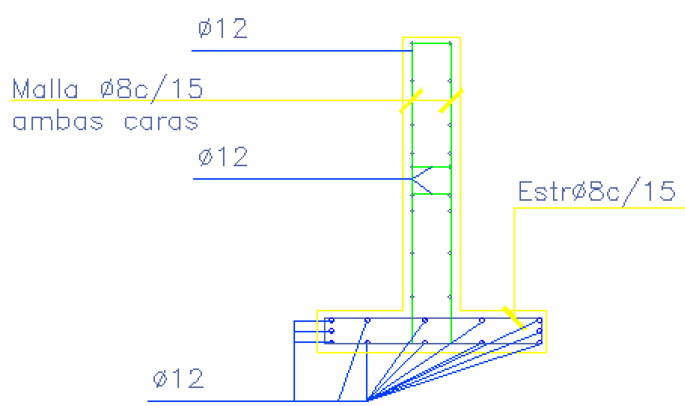


Image 13.3

- Concrete quality: H30
- Approximate volume: 2 m^3
- Approximate weight: 4.90 tons
- Quantity: 150 kg/m^3
- 2" lifting holes

Designed by the author of the papaer

Image 14 – On-site sleepers – Source: Author of the paper

The transfer of these elements was not a minor issue, not only because of the remoteness, but also because of the topography to access the work.
The slope of a hill had to be changed by providing material so that trucks and other equipment could get around it and reach the foot of the work with the concrete blocks and the equipment itself.

Image 15 – Equipment moving a sleeper – Source: Author of the paper

The construction process consisted of first making foot protections to prevent the washing of fines. This was done using gabions buried below the sleepers' line as seen in FIG 14

Image 16 – Construction of foot protections to prevent undermining - Source: Author of the paper

These tasks have been accomplished. The support base of the sleepers was compacted, giving it a slope such that at its end what protruded from the ground was 1.00 m. (see FIG. 16)

Image 17 – Preparation of inclined surface for the placement of sleepers - Source: Author of the paper

The concrete blocks were arranged in double rows (FIG. 20) to increase their strength and stability, also contemplating foot protections to prevent erosion, as mentioned above, and placing a fill of soil from the place in the space between them.

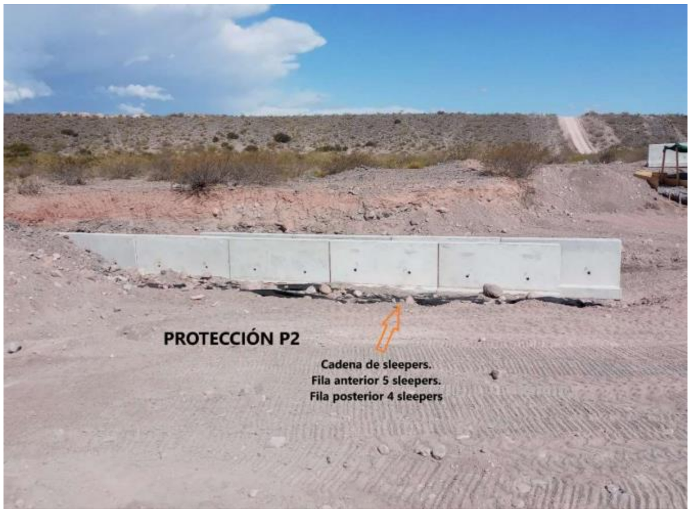


Image 18 – Sleepers in final position - Source: Author of the paper

The breakwaters were calculated by determining restitution angleswith respect to the tangent of the eroded bank of approximately 60° to 70° and taking care that the tip of these did not form erosion pots that could affect the riverbed.
For this purpose, chapter 14 of the Manual of River Engineering – Stabilization and Rectification of Rivers by Jose Antonio Maza Álvarez and Manuel Garcia Flores was used as a reference bibliography, from which the calculation equations were obtained for:

- Location of the breakwaters on the ground floor.
- Length of the breakwaters.
- Shape of the breakwaters in plan
- Spacing between breakwaters
- Longitudinal slope, elevation and width of the breakwater ridge.
- Orientation of the breakwaters.

And also fundamental concepts such as:

- E lesson of the building materials of these.
- Erosion on the foot.

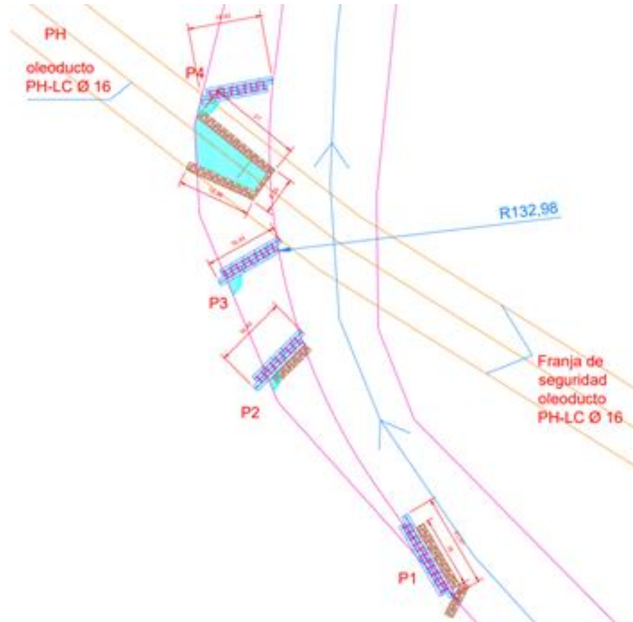


Image 19 – General Implementation of Protections - Source: Author of the paper

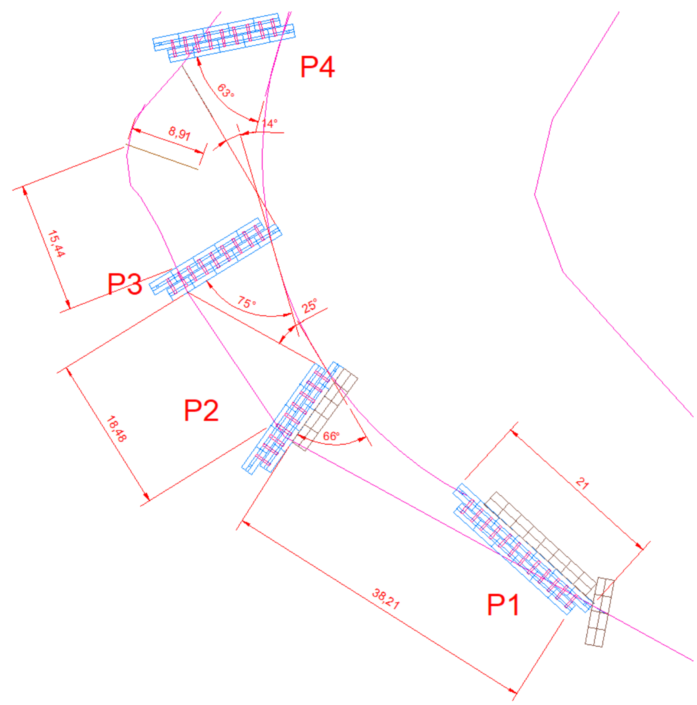
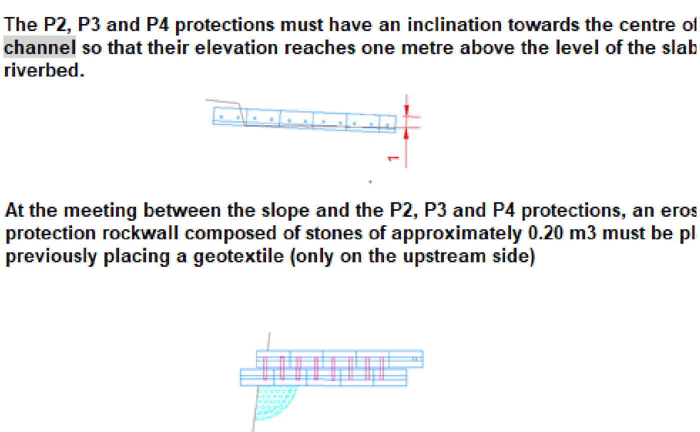


Image 20 – General implementation of protections with indication of main angles and distances - Source: Autor of the paper

Image 21 – Aerial view of the construction site - Source: Aereal patrol
Pipeline in orange



The P2, P3 and P4 protections must have an inclination towards the centre of channel so that their elevation reaches one metre above the level of the slab riverbed.

At the meeting between the slope and the P2, P3 and P4 protections, an eros protection rockwall composed of stones of approximately 0.20 m3 must be pl previously placing a geotextile (only on the upstream side)

Image 22 – Plan details - Source: Author of the paper

Image 23 – Materialization of erosion protection rocks - Source: Author of the paper

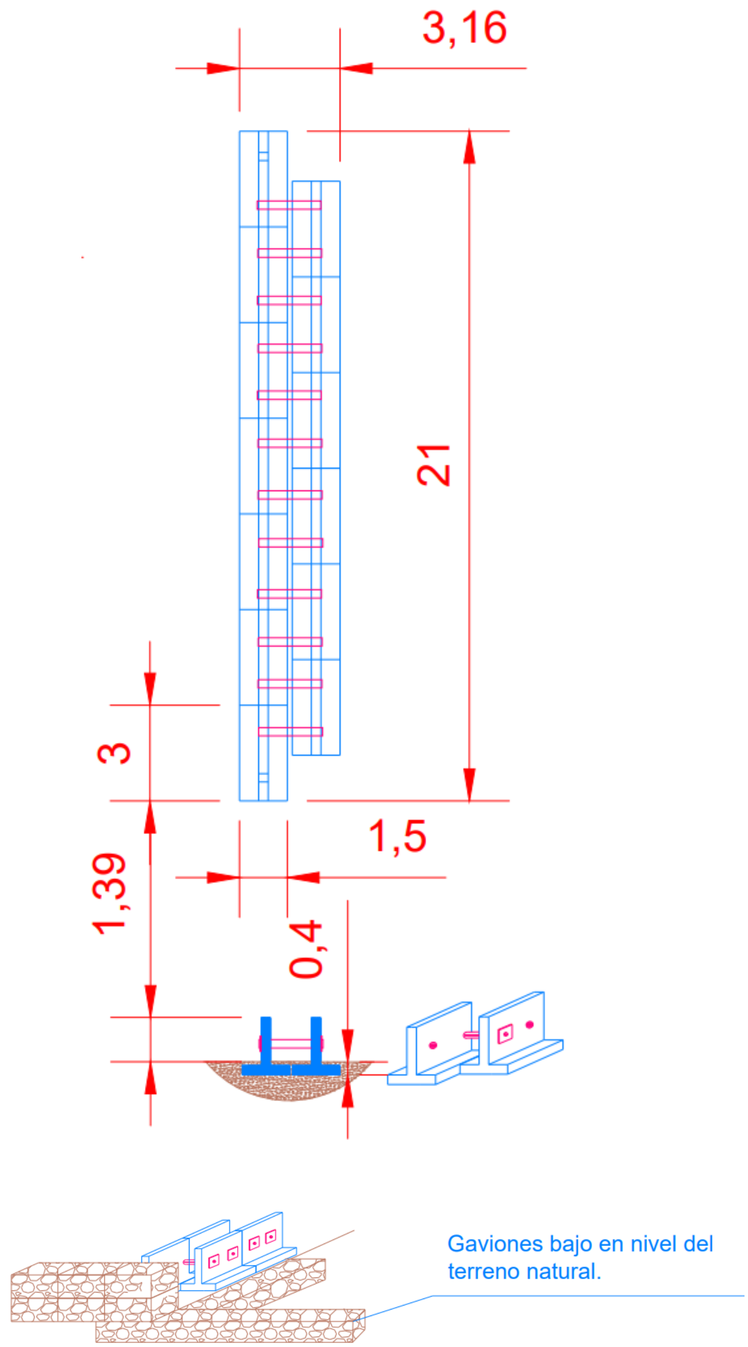


Image 24 – Construction details – Riprap plant and foot protections - Source: YPF SA

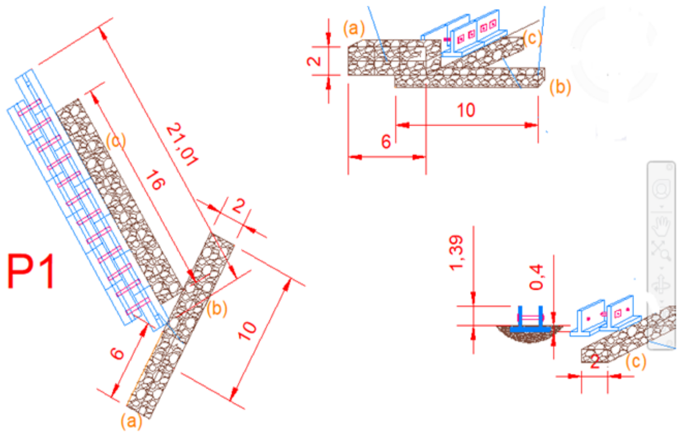


Image 25 – Plan Details - Foot Erosion Protection – Source: YPF SA

3 RESULTS AND DISCUSSION

The protection work was completed in February 2021. The most significant rainy seasons in the area are the period December – April, so to date, there have already been two summers in which the work has behaved successfully.

Like all civil works, it must be monitored continuously, evaluating the need to make maintenance corrections to maintainits efficiency.

The riverbed hasbeen backedon the north bank as planned and there have been no relevant developments at the moment.

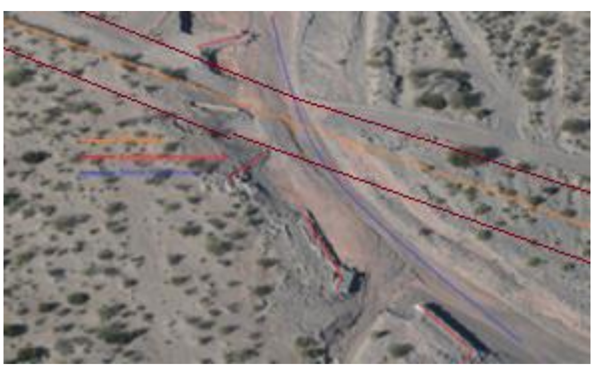


Image 26 – Aerial view of completed work 1 –
Source: Aereal patrol
Orange: Pipeline
Brown: Security zone

Image 27 – Aerial view of completed work 2 - Source: Aereal patrol

Image 28 Aerial view of completed work 3 – Source: Aereal patrol

4 CONCLUSION

This solution was chosen over a remote-controlled crossing. The latter posed logistical, cost, and economic complications that jeopardized its prompt implementation. Specifically, these types of riprap solutions have already been implemented in other channels, generating a soil deposit in the high-velocity zone generated by the designed protections, which have been highly effective. However, the specific project design must be calculated for each crossing.

The protections put in place have more than served their purpose. The original intention was that these breakwaters would be covered little by little, by the soil of the place, something that is beginning to be fulfilled, more than two years after its completion.

Image 29 - Aerial view of completed work with relative location of the pipeline - Source: Aereal patrol

The protective sleepers, arranged in double rows and with the floor arrangement between them, have generated an efficient barrier against erosion and the impact of large stones typical of the transport of this river, not having to intervene again in this area.
It is noteworthy that even though they are impacted, the sleepers that still remain with some exposed sector are intact.
The area is patrolled every 14 days (air and ground) and this monitoring has allowed us to closely monitor their behavior.

The pipeline in the center of the riverbed, which had a 2.20 meter cap prior to the work, has managed to increase it to 3.00 m and the originally discovered area has been left with a plug of just under a meter, but it has remained stable thanks to the protections that prevent the waters from generating unwanted erosion.

THANKS

I would like to thank **Engineer Martin Carnicero**, who selflessly evaluated my work and offered his contribution to the success of the project.

REFERENCES

Chapter 14 of the Manual of River Engineering – Stabilization and Rectification of Rivers by Jose Antonio Maza Álvarez and Manuel Garcia Flores.