

## IPG 2023-#0011

### "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 that YPF SA operates in Argentina. It evacuates part of the production from the Vaca Muerta field to one of the three crude oil refineries that the company operates 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 and that contributes to the Casa de Piedra dam, a source of water for several Patagonian provinces, so it is easy to interpret that a collapse of this pipeline would have had a strong ecological and business impact.*

*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 that after 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, of which about 4.40 meters had serious flaws in its lining.

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.



Geographic Location

### 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 Ministry of Mining-National Directorate of the Geological Service (1993). 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

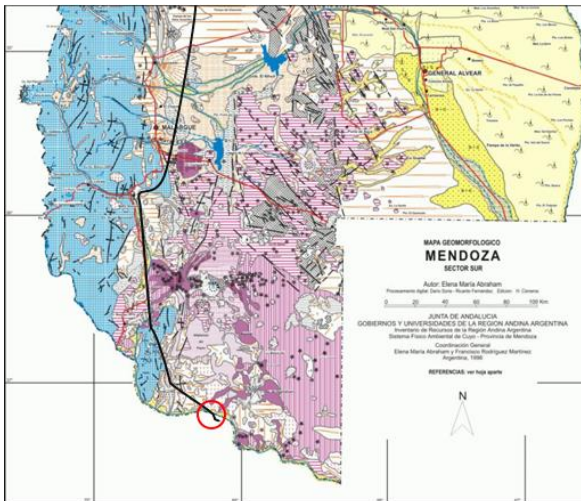



FIGURE 1. Geomorphological units of the study area 

### 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 Hidrogeológicas 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 Original state of affairs

The preceding figures show the state of the situation in the area, highlighting severe damage to the lining of the pipeline as a result of the violent impacts received.



FIGURE 2 – Exposed pipeline– Source: YPF SA



FIGURE 3 – Exposed pipeline– Source: YPF SA



FIGURE 4 – Damage caused – Source: YPF SA



FIGURE 5 – Damage caused – Source: YPF SA



FIGURE 6 – Aerial view of exposed pipeline – Source: YPF SA

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).



**FIGURE 7** – Location of pre-existing protections. – Source: YPF SA

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.



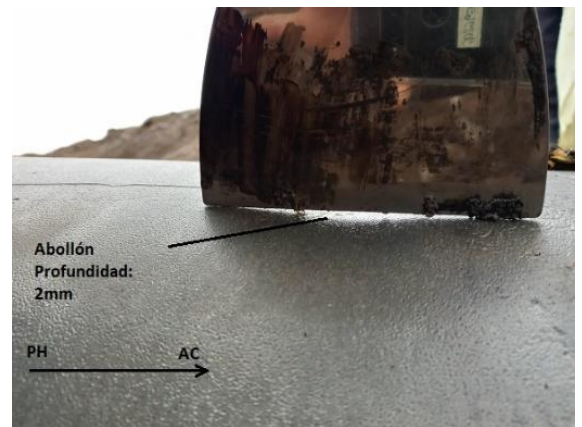
**FIGURE 8** – general view of the affected area – Source: YPF SA



**FIGURE 9** - Stone on the pipeline after the event - Source: YPF SA

### 1.9 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.



**FIGURE 10** – damage assessment. – Source: YPF SA

A mechanical evaluation of the project was then carried out:



FIGURE 11 – pipeline damage assessment– Source: YPF SA

### 1.10 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. A failure of the pipeline in the PK under study would cause a spill on this important river that divides the provinces of Mendoza and Neuquén with the consequent environmental, economic impact and damage to the company's image. It should be noted that the Colorado River downstream has an important dam that supplies water to three important Argentine Patagonian provinces (Casa de Piedra Dam).



FIGURE 12 – Location of the pipeline in relation to the Colorado River– Source: YPF SA– Google Earth

The nearest block valves are VB 2 pk 12 (9.1 km away) and VB 3 pk 88 (approx. 67 km away).

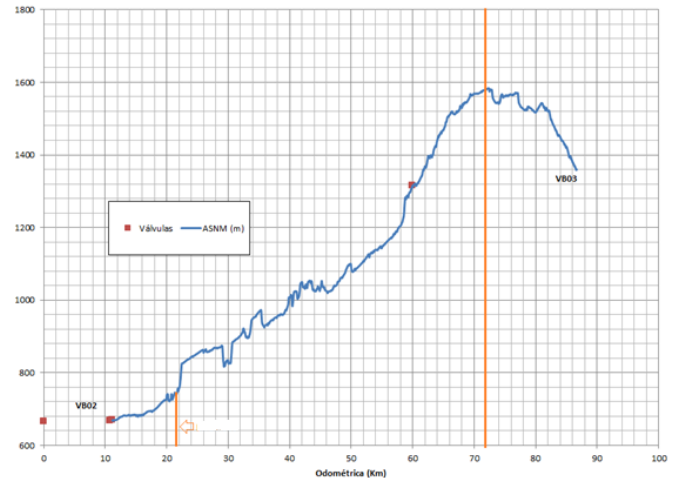


FIGURE 13 – Altimetry between VB – Source: YPF SA.

Depending on the altimetry of the area and the BVs present, a failure of the pipeline in the progressive in question would have meant a spill of more than 10,000 m<sup>3</sup> of crude oil.

### 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 part of the channel where the pipeline was most compromised 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 small breakwaters 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.14. After these tasks, the pipeline obtained a plug of approximately 0.80 meters.

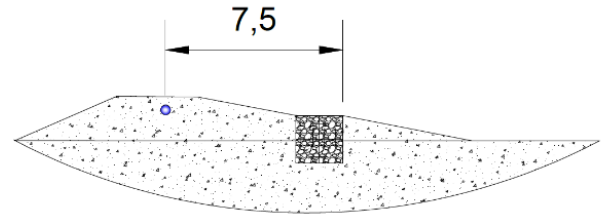
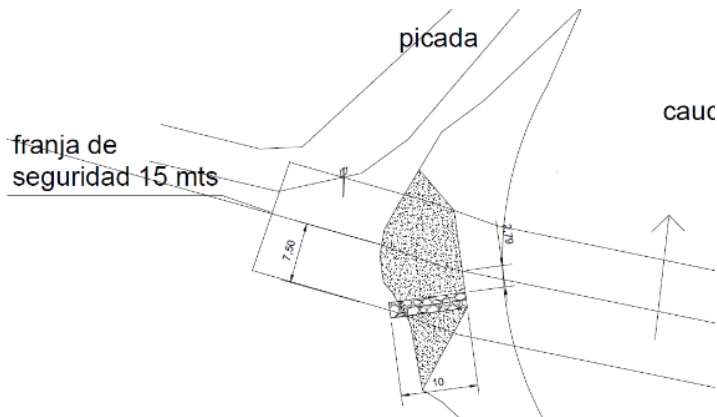


FIGURE 13 – Provisional work schematic plan – Source: YPF SA

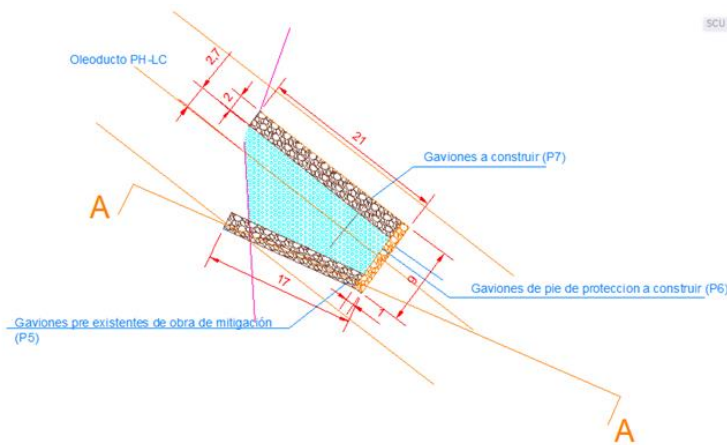


FIGURE 14 – Schematic plan of the final provisional work – Source: YPF SA



FIGURE 15 – Construction of temporary work with gabions and reinforcement tubing – Source: YPF SA



**FIGURE 16** – Construction of temporary work with gabions and reinforcement tubing – Source: YPF SA

## 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.

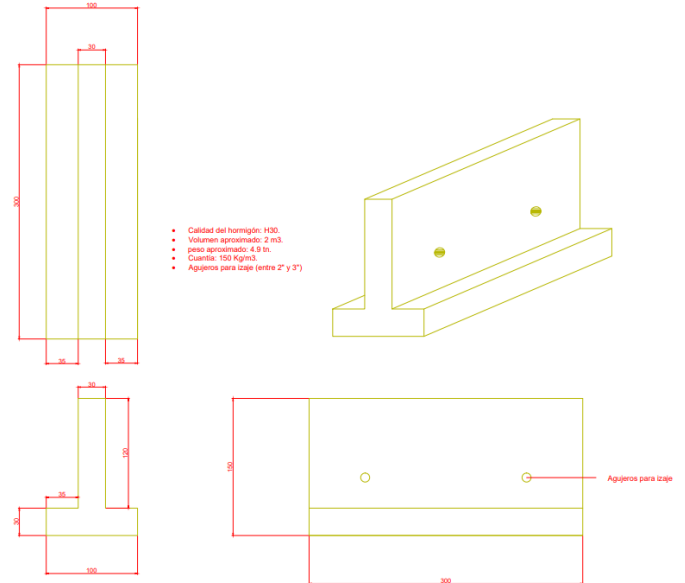
The aim was to restore the semi-permanent channels close as possible to its original morphology.

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 17 and 18

### 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.



**FIGURE 17** -Sleepers Plans – Source: YPF SA



**FIGURE 18** – On-site sleepers – Source: YPF SA

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.



**FIGURE 19** – Equipment moving a sleeper –  
Source: YPF SA

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 20



**FIGURE 20** – Construction of foot protections to prevent undermining - Source: YPF SA

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. 26)



**FIGURE 21** – Preparation of inclined surface for the placement of sleepers - Source: YPF SA

The concrete blocks were arranged in double rows (FIG. 26) 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.



**FIGURE 22** – Sleepers in final position - Source: YPF SA

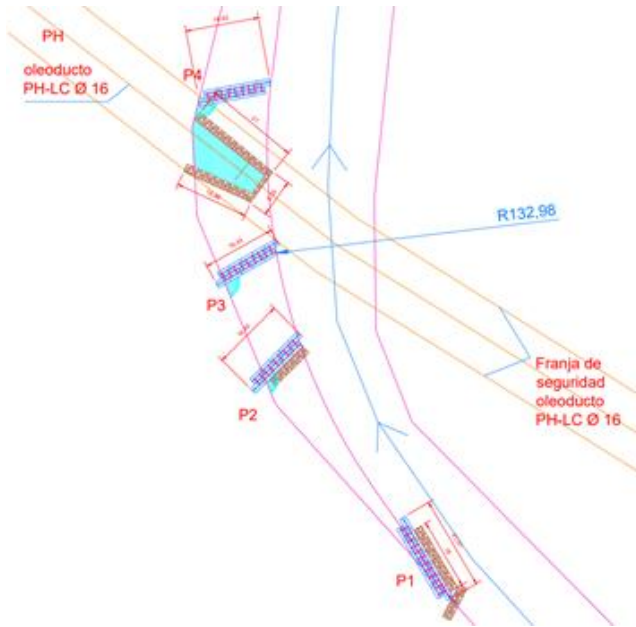
The breakwaters were calculated by determining restitution angles with respect to the tangent of the eroded bank of approximately 60° to 70° and taking care that the tip of these did not form erosion pots that could affect the riverbed. For this purpose, chapter 14 of the Manual of River Engineering – 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:



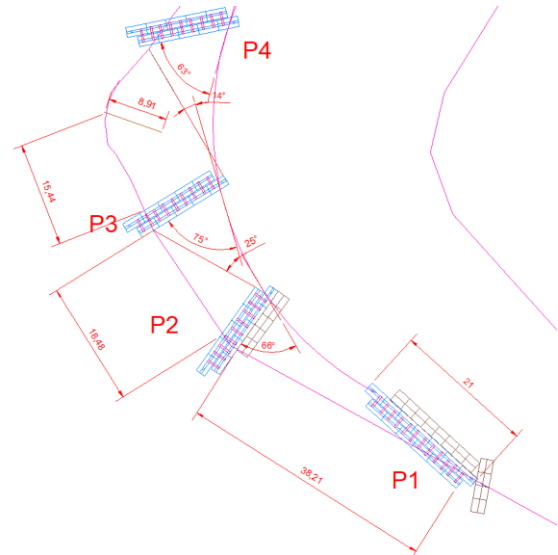
- Location of the breakwaters on the ground floor.
- Length of the breakwaters.
- Shape of the breakwaters in plan
- Spacing between breakwaters
- Longitudinal slope, elevation and width of the breakwater ridge.
- Orientation of the breakwaters.

And also fundamental concepts such as:

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



**FIGURE 23** – General Implementation of Protections - Source: YPF SA



**FIGURE 24** – General implementation of protections with indication of main angles and distances - Source: YPF SA

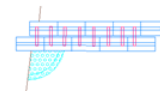


**FIGURE 25** – Aerial view of the construction site - Source: YPF SA

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



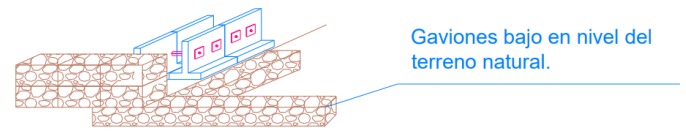
At the meeting between the slope and the P2, P3 and P4 protections, an erosion protection rockwall composed of stones of approximately 0.20 m<sup>3</sup> must be placed, previously placing a geotextile (only on the upstream side)



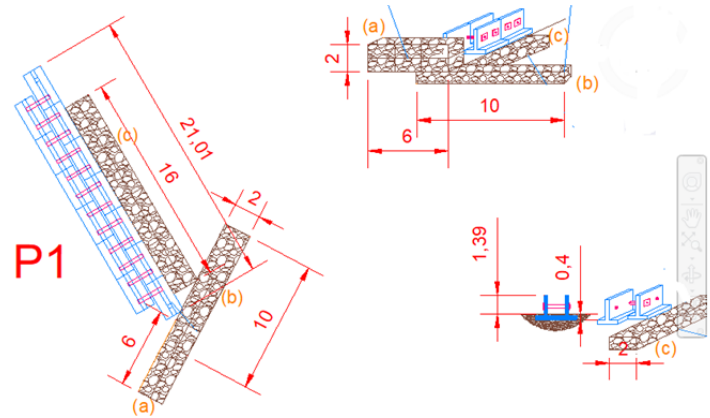
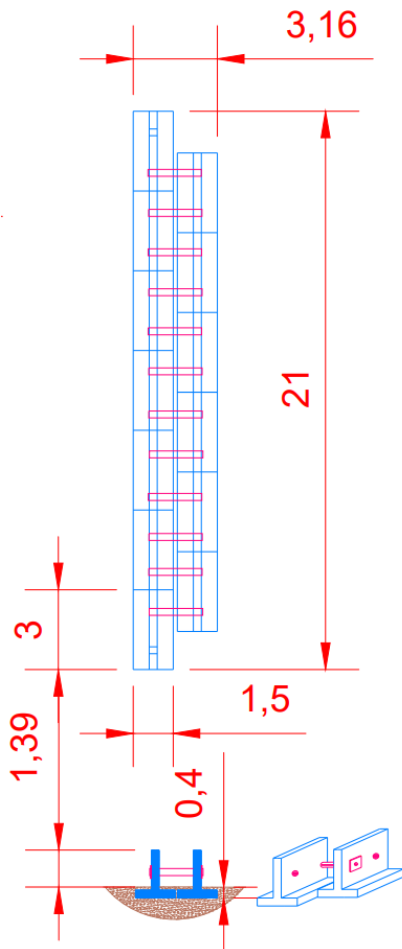
**FIGURE 26** – Plan details - Source: YPF SA



**FIGURE 27** – Materialization of erosion protection rocks - Source: YPF SA



**FIGURE 28** – Construction details – Riprap plant and foot protections - Source: YPF SA



**FIGURE 29** – 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 maintain its efficiency.

The riverbed has been backed on the north bank as planned and there have been no relevant developments at the moment.



**FIGURE 30** – Aerial view of completed work 1 – Source: YPF SA



**FIGURE 31** – Aerial view of completed work 2 - Source: YPF SA



**FIGURE 32** Aerial view of completed work 3 – Source: YPF SA

#### 4 CONCLUSION

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.



**FIGURE 33** - Aerial view of completed work with relative location of the pipeline - Source: YPF SA

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

This type of work was the first of its kind to be carried out in the Executive Management of Logistics, which means that it is a relevant milestone from a technical and human point of view, since some limits were challenged that exceeded the technical.

The tasks would not have been possible without the effort, dedication and commitment of **the Maintenance sector of the Executive Management of Logistics – AM Cuyo Region.**

I would also like to thank **Engineer Martín 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.

