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RIVERSIDE DEFENSE AND RECOVERY OF THE RIGTH OF WAY AT 563.3 KILOMETER OF SECTION II OF THE NORTH PERUVIAN PIPELINE

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ABSTRACT

The North Peruvian Pipeline (ONP) represents a highly complex work in geotechnics. Its extension crosses the three regions of Peru, starting in the jungle (Loreto and Amazonas) and continues its journey through the mountains (Cajamarca), culminating in the Peruvian coast (Piura). This creates challenges in slope stabilization and recovery of the cover layer to protect the ONP and guarantee the proper functioning along 1106 kilometers of geologically diverse terrain. In its extension, the ONP crosses beds of creeks and rivers with morphological variety. In some sections it is parallel to the river banks, making it necessary in rainy seasons to attend to emergencies that put its operation at risk, as is the case of the section between the progressive Km 544 to Km 600 that is located on the edges of the Chamaya river, specifically the Km 563.3 sector of the ONP, which was affected by erosive processes due to the increase in flow derived from heavy rains. In this situation the solution was the construction of a riverside defense based on riprap to recover the right of way.

Keywords: The North Peruvian Pipeline (ONP), slope stabilization, river banks, erosive processes, river defense, recover the right of way (ROW).

NOMENCLATURE

ONP	The North Peruvian Pipeline
m	Meter
GM	silty gravel
Km	Kilometer
Dm	minimum rock diameter
t	thickness

1. INTRODUCTION

The ONP is one of the most important and large-scale works that has been carried out in the last 100 years in Peru, with an approximate route of 1,106 km comprised of section I with an extension of 306 kilometers and a diameter of 24”, the North Branch Pipeline (ORN) with 252 kilometers and a diameter of 16”, and section II with 548 kilometers and a diameter of 36”.

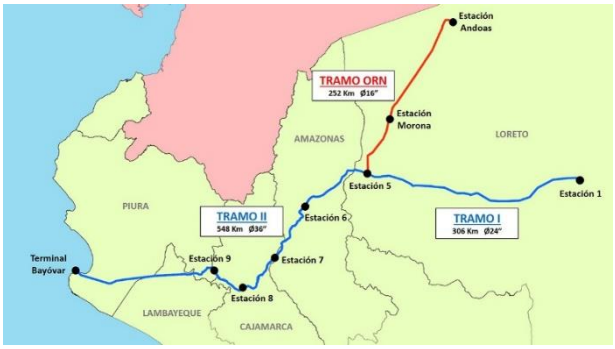

FIGURE 1: TOUR OF THE NORTH PERUVIAN PIPELINE (ONP).

The ONP transports crude oil from the Loreto oil exploitation zones across the Andes to the coast at the Bayóvar terminal, crossing the three natural regions of the country and five departments: Loreto, Amazonas, Cajamarca, Lambayeque and Piura.

During the first days of March 2022, the extraordinary rains caused an increase in the flow in multiple creeks and rivers in various regions of Peru, including the Cajamarca region and specifically in the Chamaya riverbed. The ONP Right of Way (ROW) is located between Km 544 and Km 600, on the banks of the Chamaya River, whose unforeseen increase on 03.03.2022 has caused multiple erosive processes along its route, putting the integrity at risk of the ONP in various sectors, one of them corresponding to Km 563.3 of the ONP.

FIGURE 2: SECTOR 1 OF 58 METERS OF 36” PIPE WAS FULLY EXPOSED.

FIGURE 3: SECTOR 2 OF 41 METERS OF 36" PIPE WAS FULLY EXPOSED.

The erosion produced at Km 563.3 ONP, has generated the following emergency conditions and immediate attention: Erosion-disappearance of the slope of the ROW approximately 330 m in length; Discovery of the 92 m long pipeline, leaving it exposed to a risk of rupture; accelerated eroding process that has been activated downstream of the last eroded point, of approximately 320 m, which compromises the ROW of the ONP; and instability of the asphalt layer in the upper part of the eroded slope, which is the natural access to the various ONP pumping stations.

FIGURE 4: EROSIVO PROCESS THAT GENERATED THE DISPLACEMENT OF THE CHAMAYA RIVER BED TOWARDS ITS RIGTH SIDE, AFFECTING THE RIGTH OF WAY OF THE ONP.

As a solution to the problems described above, the restitution of the ROW has been considered, through the construction of 753 m of river defense made up of riprap, riprap and fill material, in addition to the construction of a base terrace on the crown of the riprap. This solution intends to divert the waters to avoid the collapse of the eroded slope, protect the eroded slope, and restore the eroded ROW.

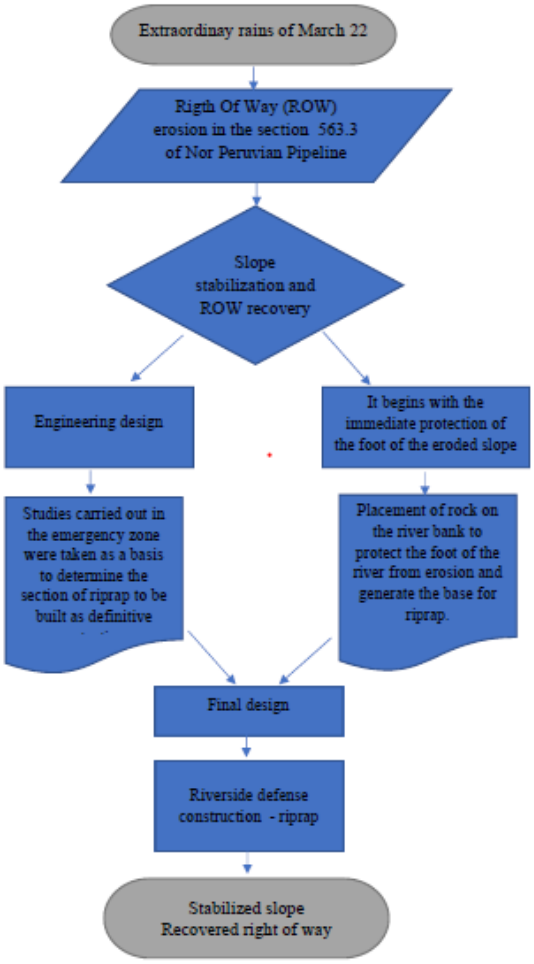

FIGURE 5: PROCESS FLOW DIAGRAM.

2. MATERIALS AND METHODS

After the event occurred, and given the dangerous condition of the North Peruvian Pipeline, the transportation operation has been suspended. The impossibility of pumping in the current conditions of disappearance (due to erosion) of the right of way where the pipeline is located, the high risk of pipeline rupture due to its current high-risk condition due to instability of the slope, and the consequences of contamination of the Chamaya River, affecting the environment and communities located on both banks of the river, were all cited factors. For this reason, it begins with the immediate protection of the foot of the eroded slope. In parallel, studies carried out in the emergency zone were taken as a basis to determine the section of riprap to be built as definitive protection.

2.1 Geographic and political location

ITEM	Description
Progressive ONP	563.3
East (m)	738466.0
North (m)	9341616.0
Zone	17S
District	Colasay
Province	Jaén
Department	Cajamarca

TABLE 1: GEOGRAPHIC AND POLITICAL LOCATION.

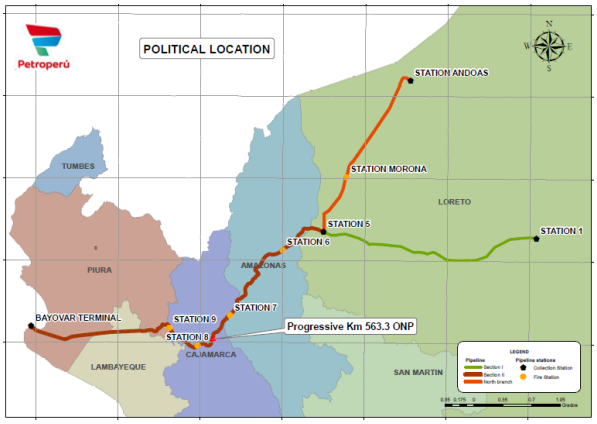

FIGURE 6: LOCATION KM 563.3 ONP.

2.2 Characteristics of the study area

The study area is located within the Chamaya river basin, a high basin predominantly composed of slopes and mountains. The riverbed presents characteristics of irregular haulage, with sub-rounded stones. Similarly, it presents a matrix of gravel with silty sand.

The eroded slope (right side of the Chamaya river) is made up of alluvial material (GM), corresponding to a combination of the natural slope and the cut material deposited during the construction of a section of highway (Fernando Belaunde Terry highway or marginal from the jungle). Due to the characteristics of the matrix, the slope is erodible in the presence of water flow.

2.3 Basin characteristics

The section of Km 563.3 of the ONP is located parallel to the Chamaya river and is located on the right bank of the Cuyca populated center. The area where slope erosion has occurred is within the area of influence of the Chamaya basin. According to the zoning of the tributary area, it has an approximate area of 6610.90 km2, representing 82% of the Chamaya basin.

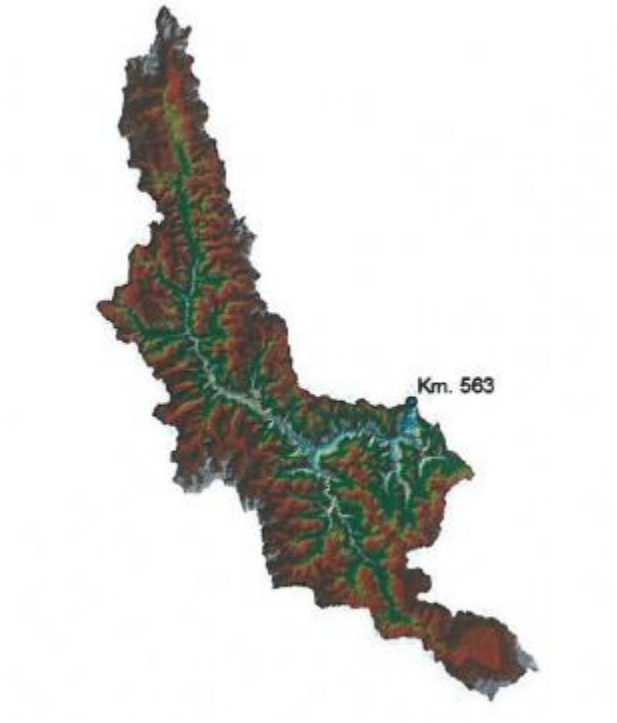

FIGURE 7: CHAMAYA BASIN.

ITEM	Description
Basin Code	49896
Basin Name	Chamaya
Basin area (Km)	6,610.9
Creek length (Km)	169
maximum height (amsl)	4150
Minimum height (amsl)	600
Incline (m/m)	0.0210

TABLE 2: GEOGRAPHIC AND POLITICAL LOCATION.

2.4 Design Parameters

The design of the riprap structure was carried out through the application of hydraulic calculations, for which parameters of the evaluation section were used, as well as the design flow for a return period of 140 years and 200 years.

The design made it possible to obtain the sizing of the riprap, as well as the rock gradation in accordance with the recommendations of the Design of Riprap Revetment (HEC 11) guide of the Federal Highway Administration.

ITEM	obtained value
Return period of 140 years	Flow 1607.3 m3/s
Return period of 200 years	Flow 1797.4 m3/s
stable width	90 m
riprap height	4.50 m
width crown	2.00 m
Scour depth	1.72 m
Riprap toe deptg	2.50 m
Stones diameter	1.50 m

TABLE 3: DESIGN PARAMETERS.

3. RESULTS AND DISCUSSION

With the parameters obtained, the typical section of the built riprap was determined, which allowed the restitution of the right of way. The construction of seven hundred and fifty-three meters (753 m) of river defense, made up of riprap and fill material, in addition to the construction of a base terrace on the crown of the riprap, served multiple purposes:

i) Divert the water to prevent the collapse of the eroded slope.
ii) Eroded slope protection.
iii) Restore the eroded right-of-way (which may allow the construction of a possible variant of the pipeline).

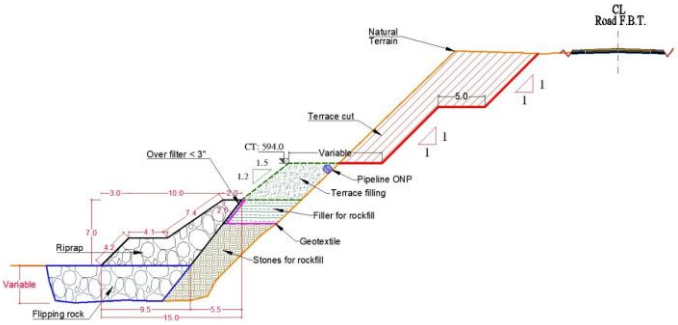

FIGURE 8: TYPICAL RIPRAP SECTION.

The activities that were carried out are described below:

3.1 Riprap

Structure made up of rocks (Dm >1.20m) placed or accommodated with the help of mechanical equipment, which has the purpose of:

- Protecting the eroded slope of the right bank of the Chamaya River, providing stability against erosive action and consistency against overflows, maintaining the initial course of the water

- Restoring the eroded right-of-way to allow the construction of a pipeline variant.

The riprap material was obtained from five (05) points located during the initial stage of the Service. The extraction was carried out by blasting and selecting the rock that meets the specified dimensions. The prepared rocks were placed in the toe and slope of the riprap following the geometric dimensions indicated in the respective plans. Due to the restrictions of the work area for the construction process, the slopes of the typical section were worked as aligned as possible, with the variations of the body of the riprap that were generated not less than indicated in the plans. For the interlock of the riprap between the large rocks, rocks of smaller than nominal diameter were used in order to reduce the interstices that form between rock and rock. Special care was taken to reach the crown levels of riprap.

FIGURE 9: CONSTRUCTIVE PROCEDURE OF RIPRAP.

FIGURE 10: CONSTRUCTIVE PROCEDURE OF RIPRAP.

FIGURE 11: CONSTRUCTIVE PROCEDURE OF RIPRAP.

FIGURE 12: CONSTRUCTIVE PROCEDURE OF RIPRAP.

FIGURE 13: CONSTRUCTIVE PROCEDURE OF RIPRAP.

FIGURE 14: CONSTRUCTIVE PROCEDURE OF RIPRAP.

FIGURE 15: CONSTRUCTIVE PROCEDURE OF RIPRAP.

3.2 Rockfill for riprap

Structure made up of rocks (1.20m>Dm>0.70m) placed or accommodated with the help of mechanical equipment, which has the purpose of restoring the material between the internal slope of the riprap and the slope of the land after erosion.

The riprap material was obtained from two (02) points located during the initial stage of the Service and the extraction was carried out by selecting the rock that meets the specified dimensions. The prepared rocks were placed between the riprap and the slope of the land after erosion following the geometric dimensions indicated in the respective plans. For the interlock of the causeway between the rocks, rocks of smaller than nominal diameter were used in order to reduce the interstices that form between rock and rock.

FIGURE 16: ROCKFILL CONSTRUCTIVE PROCEDURE FOR RIPRAP.

FIGURE 17: ROCKFILL CONSTRUCTIVE PROCEDURE FOR RIPRAP.

3.3 Geotextile

Its arrangement was at the rear of the riprap, with the purpose of controlling the escape of soil fines. The materials to be used can be made of non-woven synthetic polymers.

FIGURE 18: CONSTRUCTION PROCEDURE FOR GEOTEXTILE INSTALLATION.

FIGURE 19: CONSTRUCTION PROCEDURE FOR GEOTEXTILE INSTALLATION.

3.4 Rear fill of riprap

This work consists of the placement in strata, conformation and compaction of suitable materials coming from the same excavation, and cut material on the Right of Way or from the Quarries. The material for the formation of fills came from the cut material on the right of way and quarry material. The compaction depended on the area where it was carried out, special care was taken so that the instability of the slopes does not compromise the personnel and equipment that carry out the work. The equipment for spreading, accommodation, and compaction of the fill was an excavator, motor grader, tractor, and smooth vibratory roller. The placement of the fill was carried out using horizontal layers of no more than 0.40 m thick. The level of the crown of the rockfill, that is, the upper 0.40 m of the fill, was compacted in two layers.

FIGURE 20: CONSTRUCTIVE PROCEDURE OF REAR FILL OF RIPRAP.

FIGURE 21: CONSTRUCTIVE PROCEDURE OF REAR FILL OF RIPRAP.

FIGURE 22: CONSTRUCTIVE PROCEDURE OF REAR FILL OF RIPRAP.

3.5 Filter Layer (t=0.30m)

This work consisted in the construction of the filter layer behind the riprap and with the dimensions indicated in the project plans or indicated by the Supervisor.

FIGURE 23: FILTER LAYER PLACEMENT CONSTRUCTIVE PROCEDURE.

3.6 Filler for terrace

This work consisted of the placement in strata, conformation and compaction of suitable materials from the same excavation from cuts of the material on the Right of Way or from Quarries 1 and 4. The material for the conformation of fills came from the material of cut on the right of way. The compaction was carried out in the entire area, as long as the instability of the slopes did not compromise the personnel and equipment that carried out the work. The equipment for the spreading, accommodation, and compaction of the fill was an excavator, motor grader, and vibratory smooth roller tractor. The placement of the fill was carried out using horizontal layers of no more than 0.40 m thick. The level of the crown of the rockfill, that is, the upper 0.40 m of the fill, was compacted in two layers.

FIGURE 24: CONSTRUCTION PROCEDURE FOR TERRACE FILING.

FIGURE 25: CONSTRUCTION PROCEDURE FOR TERRACE FILING.

FIGURE 26: CONSTRUCTION PROCEDURE FOR TERRACE FILING.

3.7 Cut for terrace

This work consisted of the set of activities of excavating, removing, loading, the materials coming from the cuts required for the leveling, indicated in the plans and cross sections of the project. Materials from excavation were used to improve accesses, fill for riprap, and fill for the terrace

FIGURE 27: CONSTRUCTIVE PROCEDURE OF CUTE FOR TERRACE.

FIGURE 28: CONSTRUCTIVE PROCEDURE OF CUTE FOR TERRACE.

FIGURE 29: CONSTRUCTIVE PROCEDURE OF CUTE FOR TERRACE.

FIGURE 30: CONSTRUCTIVE PROCEDURE OF CUTE FOR TERRACE.

4. CONCLUSION

The great challenge was to start the erosion protection work in the rainy season and with high flows of the Chamaya River. Without having a defined design, it was decided to start the work with the protection of the foot of the eroded slope due to the unsafe state of the North Peruvian Pipeline.

Another great challenge was the large amount of rock needed and the few quarries close to the area. The construction of the river defense fulfilled the purpose of recovering the Right of Way at Km 563.2 ONP.

The following quantity were completed in each of the indicated activities:

ITEM	Unit	Quantity built
Riprap	m3	55,678.17
Rockfill	m3	20,616,95
Fill for riprap	m3	15,598.15
Geotextile	m2	5,600
Fill for terrace	m3	11,324.26
Cut for terrace	m3	49,123.58

TABLE 4: SUMMARY OF QUANTITIES OF MATERIAL IN THE RIVERSIDE DEFENSE BUILT.

FIGURE 31: CULMINATE RIPRAP.

FIGURE 32: CULMINATE RIPRAP.

ACKNOWLEDGMENT

To each of our families, for the unconditional support they give us.

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