ENVIRONMENTAL IMPACT STUDY FOR THE RUMICHACA-PASTO DIVIDED HIGHWAY PROJECT, PEDREGAL-CATAMBUCO SEGMENT, UF-4 AND UF 5.1, CONCESSION CONTRACT UNDER SCHEME PP No. 15 OF 2015.

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Chapter 5.1. Abiotic Media Characterization

San Juan de Pasto, March 2017

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5. INFLUENCE AREA CHARACTERIZATION

5.1. Abiotic Media

The influence area for the Rumichaca - Pasto divided highway project, Pedregal - Catambuco segmentby the abiotic media (described in Chapter 2 of this study) is framed within the charateristics of its diverse components, corresponding to geology, geomorphology, landscape, soils, hydrology, hydrogeology and atmosphere, which particular characteristics forthe abovementioned section are described hereafter.

5.1.1. Geology

This chapter describes the geologic, structural and evolutive characteristics of the influence area for the Rumichaca - Pasto divided highway project, Pedregal - Catambuco segment, as definedd from the compilation, analysis and integration of the existing secondary information, complemented with the ffield work and investigations performed on the subsoil.

The lithostratigraphic and structural descriptions presented hereafter at the regional level were made basedon the secondary information at the scale of 1:100,000 from the Colombian Geological Service – SGC, corresponding to the drawing 429 – Pasto. Based on the above, an identification was made for the different lithological units that outcrop within the study áreas andd the Homogeneous Zones were defined as of the similar lithological, structural and geomorphological characteristics.

The study area has outcrops of volcanic rocks, volcanic and volcano-sedimentary deposits, and igneous and metamorphic rocks. The oldest ones are Precambric from the la Cocha migmatite complex, which are part of the sector's basement; a series of volcanic, lava, ash, tuff, lahar and pyroclastic deposits can be superficially observed, which comprise the terciary-quaternary rocks and alluvial and colluvial quaternary deposits; these volcanic deposits are associated to extinct and active volcanoes' eruptions, such as the Galeras volcano.

In developing this numeral, we've used the information coming from the document "Colombian Geology" Galvis and Mojica 2014, (non-published literary product registry No.10-472465, Ministry of Interior), Generalized Geologic Map for the Nariño Department, compiled by Arango and Ponce INGEOMINAS 1982, geological drawing 429 at a 1:100.000 scale, the analysis of satellite images and the Ingetec Geology for Engineering No. CSH-4-VD-G-G-300-2.

- Field control

Based on the evaluation of the remote sensors and Pasto drawing 429, as well as from the abovementioned reports, we performed a cartographic ntory of the road corrridor, geological complementing and updating of the Project, which is an input for the development of a geological model that includes the regional and local description of the lythology, geomorphology, structural and tectonic geology and the weathering of hte rock units which outcrop in the road corridor.

Likewise, a detailed lithology and structural geology information acquisition was made for the area, corroborating the stratigraphic and tectonic data, identifying and/or corroborating the lithology reported in previous studies and the regional geology of the bibliographic base of the Colombian Geological Service.

Homogeneous areas were identified and characterized according to the geomorphological and geomechanical geological changes for the materials along the road alignment. The unstable areas reported in previous studies for the subject matter area were analyzed, and the processes for mass removal and erosion that may affect the road were corroborated and defined. An identification and mapping of areas of sources of materials and storage along the road corridor areas was made.

- Regional Geology

this road corridor is located in the Continental Crust, in the Colombian- Venezuelan Andean Plate. The western boundary of the plate is located in the Cauca-Patía Fault; this strike-slip type fault, serves as a contact with the Oceanic Crust of what is known as Chocó Plate. There is a satellite fault of it, sub-parallel to it, called the Ancuya fault.

within the Andean plate there is a great regional strike-slip fault, the Buesaco fault, NE-SW direction, which limits two kinds of Precambrian basements, to the NW there are schists surrounding the fault and a wide expanse of ancient ophiolites more towards the NW. To the SE of the mentioned fault there are some exposed migmatite in the basin of the Téllez river and in the vicinity of the la Cocha lagoon

There are large volcanic edifices with thick effusive deposits on top of the mentioned units. The predominant petrographic composition is andesitic, and basaltic to a lesser extent.

The geological evolutionary framework comprises an arc of Islands to the West, whose subduction zone is located tWest of the coastline; the arc comprises an outer arc represented in the Serranía de Gallinazo in the lower Patia and its continuation in Gorgona, an intermediate basin that constitutes the Pacific plain cut by the rivers Mira, Patía and Iscuandé , a magmatic or internal arc represented in volcanic outbreaks and intrusions that occur to the West of the Cauca-Patía Fault. The subduction corresponding to the islands arc continues to the SE of the Cauca - Patía fault, producing intense magmatism in the sialic crust which originated the Cenozoic volcanism which covered what is now the great plateau of Nariño.

At the regional level, there are rock outcrops with ages ranging from the Precambrian as the migmatitic complex of the la Cocha-rio Téllez (PRmgct), up to the upper tertiary, which is the predominant unit in the road layout and which correspond with the union of Lavas and pyroclastics (NQlp). In general, this last unit is comprised of interbedded lava flows and deposits of pyroclastic fall and of lava flows of andesitic and dacitic composition, occasionally rhyolitic. The terrain surface is dominated by pyroclastic fall deposits and pyroclastic flow deposits. These rocks originated by the predominantly volcanic action in the area of which there is stll current evidence (The Galeras volcano which is still active and the dormant active volcanoes Cumbal, Chiles - Cerro Negro, Azufral, Doña Juana and Animas). The main characteristic of the eruption of these volcanoes are the pyroclastic surges, which are turbulent flows with low concentration of particles and predominance of the gaseous phase (Figure 5.1.1). The volcanic deposits are also controlled by topography and gravity, although to a lesser degree than pyroclastic flows and may present a planar cross-bedding and low angle trough.

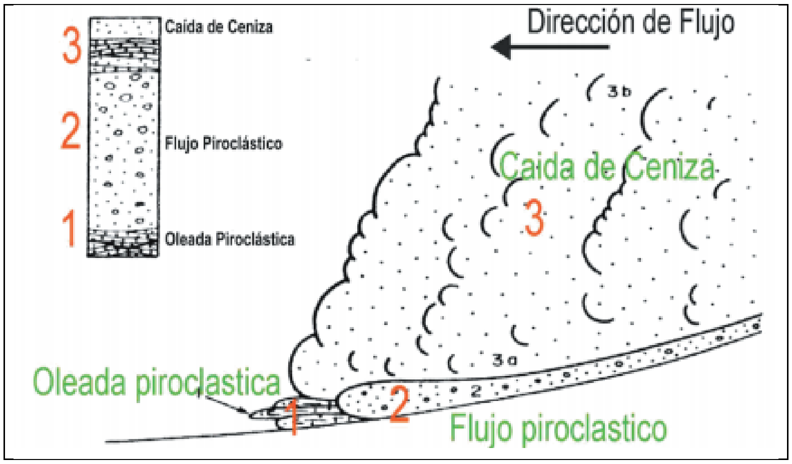


Figure 5.1.1 Generalized diagram of the geometry and position in the field of different , product of explosive activity. Modified from Cas & Wright (1988)
Source (Velandia, 2008)

At the regional tectonic level the Romeral fault and the Guáitara, Chiguaco, Iles and Guaimatan fault systems are outstanding. In addition, there are several satellite structures and baselines associated with branching from the main faults. It is worth highlighting that in the sector there is a convergence of great fault systems that geologically define towards the north the boundaries between these mountain ranges. The geological structures close to the study area evidence the tectonic activity that has given the current expression of the mountain system of the Andes of the North, especially the portion that corresponds to the differentiation between the Ecuadorian Andes and the Colombian Andes (Núñez, 2003)

in addition, the study area has been affected by compressive events mainly associated with the formation of mountain ranges and subsequent formation of volcanoes, the Figure 5.1.2 shows a tectonic-stratigraphic schematic of the southern end of the Colombian central and eastern mountain ranges (Cordilleras).

geomorphologically, the area displays landscapes with relief ranging from moderate hills and soft slopes caused by the denudational action upon deposits of ash covering the relief as if by tapes, aged Quaternary Neogene generating morphologies rounded to surrounded, to abrupt relief caused by a denudational - structural modeling on the toughest rocks such as lavas and consolidated tuffs, which are strongly affected by tectonism. In addition, there are denudational morphodynamical modelings, usually associated with processes of landslides associated with the undermining of waterways.

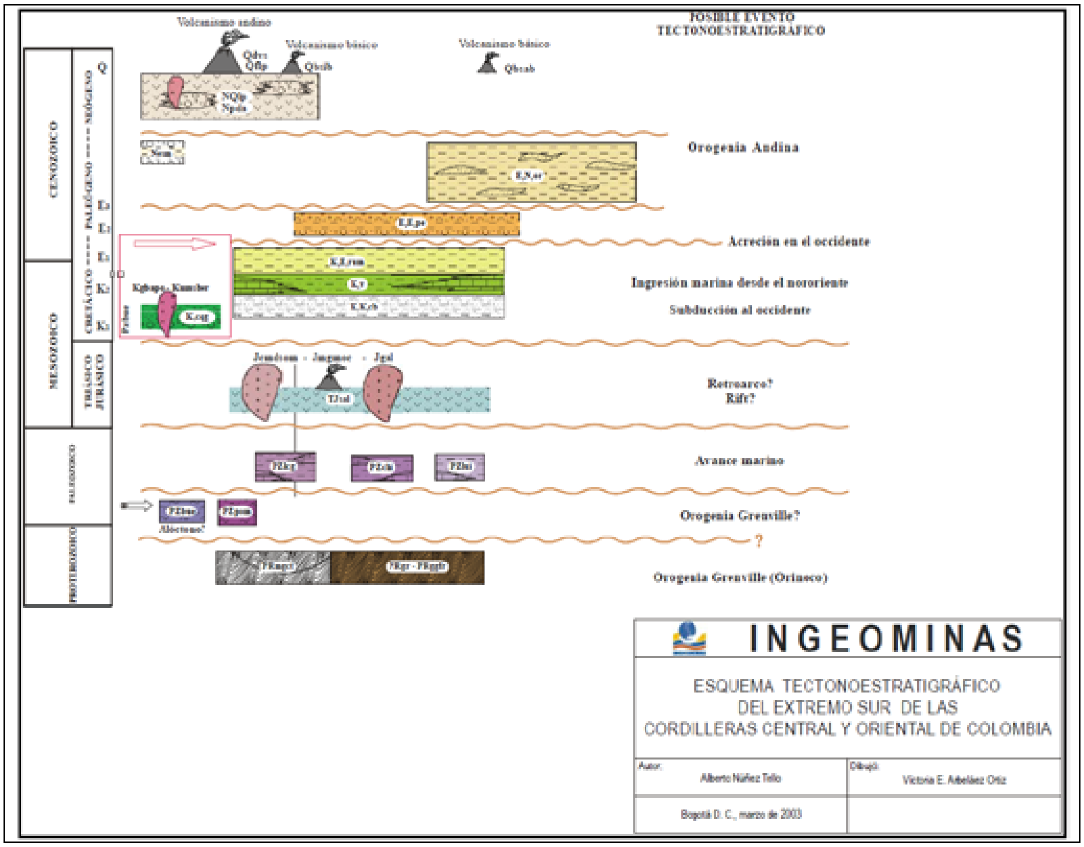


Figure 5.1.2 Tectonic-stratigraphic schematic of the southern end of the Colombian central and eastern mountain ranges

Source (Colombian Geological Service 2003).

The structural style of the region is complex. Dominated by high-angle faults of N-NE direction with a notorious deformation on the Eastern range produced by imbrication of wedges or scales of cortical fragments involved in a prism during a continuous process of accretion and subduction of an Ocean plateau.

In a more specific sense (Rodriguez, 2005) states that the tectonic events that fractured the lithologic units and affected some of the deposits exposed in the study area are manifested in two preferential directions of faulting; a longitudinal with a trend NNE - SSW and another transversal with sense NE - SW. Also, according to Rodríguez (2005) the Nariño Highland presents an intense tectonism which consists of numerous faults of Northeastern guidance affecting even the Plio - Pleistocene sediments; its eastern boundary is constituted by the Silvia - Pijao fault and the Western by the Cauca - Patía fault (Arango J, 1982). It is important to note that due to the very thick deposits of Neogene, a large amount of structural features have been masked, so if observed in the surface, it is due to recent tectonism.

- Local geology

The Pedregal - Pasto road corridor is almost in its entirety surrounding part or the Galeras volcano stratum, in its southern portion it falls within the Bobo river basin, and North in the Pasto river's hydrographic basin.

in this corridor, you can define some lithologic features. The units from the base of the volcanic deposits are lavas (TQI), these are exposed in the first segment of the corridor along the Guáitara river's canyon. These are particularly resistant to mechanical erosion, which is why you can observe negative slopes on the walls of the Canyon. Above the lavas the volcanic breccias of large angular and subangular blocks are predominant. Some sectors present scoria and pumice (NQlp). The scoriae present taluses of variable slopes in which frequent colluvium (Qc) are formed.

In the La Magdalena stream ravine and surrounding areas, comprised of mixtures of volcanites and sedimentary rocks there have been reports of instability problems, more than half of the photographs of geotechnical problems of engineering reports refer to the “Magdalena Formation"; this is a fault zone of remarkable proportions, which is referenced later. This chaotic mixing of lithologies, the presence of lagoons that appear to be "sag ponds", clays and "sandstone" are signs of a fault zone. (Figure 5.1.3)

The most superficial and most extended volcanic deposits are comprised in general of ash and volcanic sands and in some sectors of lapilli. These are soft and easily weatherable materials, thus construing the best agricultural lands in the region; such are present in flat or wavy surfaces such as those found on the lower slopes of the Galeras volcano towards the Pasto valley, in the watershed division of the Bobo river basin and the top part of it.

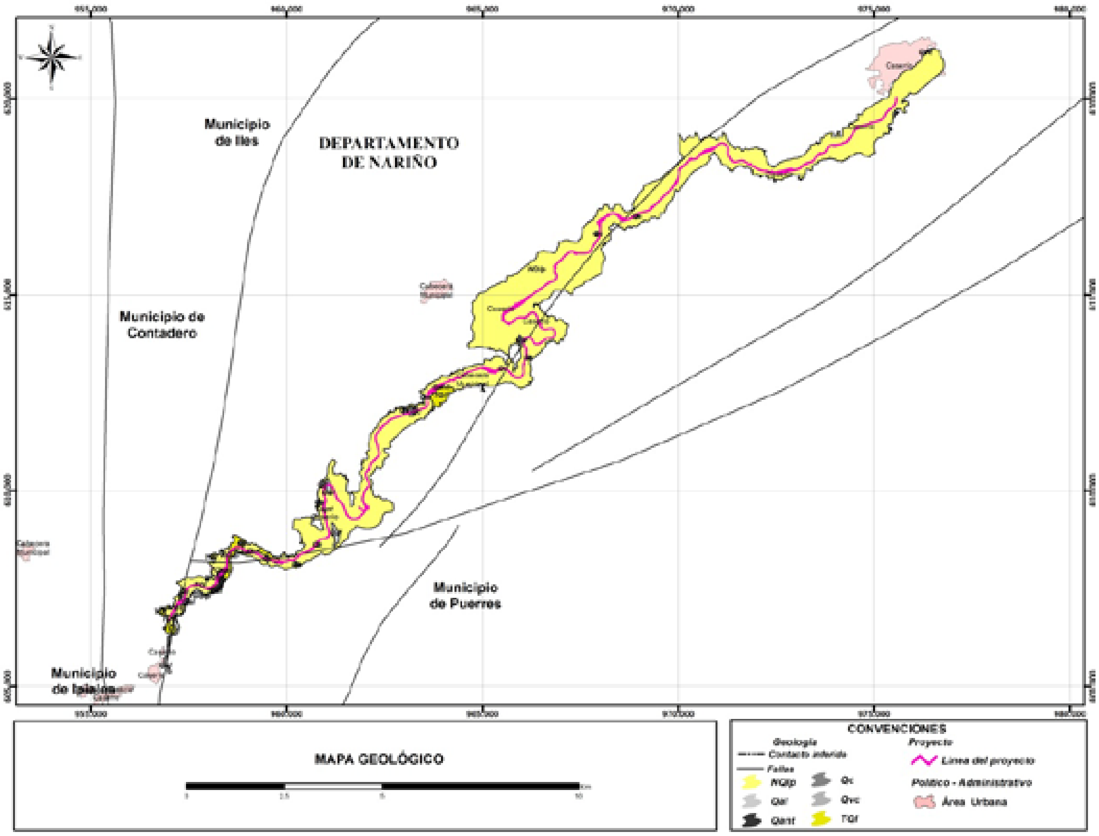


Figure 5.1.3 Geological map of the work area.
Source: M & M Team

The geological units found in the road layout are represented in **Table** 5.1.1 and correspond in general to a band formed by rocks of volcanic-sedimentary type, with a moderate to high degree of weathering, as well as alluvial Quaternary deposits.

Also in the table mentioned, we present their relationship with the Geology Units for Engineering which are mentioned in the Ingetec report; its difference is that the geological cartography groups the lithologic types according to the geological events that originated them, while the Geology for Engineering cartography groups them according to their homogeneity in terms of lithological types mechanical behavior.

Table 5.1.1 Geological units present in the study area and their relation to Ingetec's Geology for Engineering units.

Geologic Unit	Geological Description	Ingetec Nomenclature
TQI	Andesitic lavas with some levels of tuffs and volcanic breccias	TQvlc: Lavas and ash
		TQvl: Lavas
NQlp	Volcanic breccias with angular and subangular blocks; in some sectors with presence of tuffs, ash, scoria and pumice	Qvc: ash fall
		TQvf: Flows of ash and pumice
		TQvlc: Lahars and pyroclastic rocks
		TQsv: La Magdalena volcanic sedimentary set
		TQva: Burning avalanche and debris
Qant	Anthropic Filling.	Qant Anthropic Filling
Qal	Alluvial Deposits	Qal: Alluvial Deposits
Qc	Colluvial deposits	Qc: Colluvial deposits

Source (INGETEC, 2016)

Below we describe the stratigraphic units that comprise the study area:

Andesitic lavas with some levels of tuffs and volcanic breccias. TQI:

Dominantly very fractured andesitic lavas unit, probably due to the rapid cooling, ochre-coloured to Brown, presenting low primary porosity, usually overlayed by the NQlp unit. They outcrop in the initial part of the layout generating an abrupt topography, corresponding to lava flows from the Galeras volcano, happening with eventual levels of pyroclastic rocks and volcanic breccias of andesitic composition. This unit presents landslides with falling blocks (**Photography5.1.9, Photography5.1.9, and Photography5.1.9,**).

Photography 5.1.1: Andesitic lava outcrop in k 1 + 350, generating a strong morphology.
Source: M & M Team

Photography 5.1.2: Andesitic lava outcrop in k 1 + 700, generating a strong morphology.
Source: M & M Team

Photography 5.1.3: Andesitic lava outcrop in k 4 + 000, generating a strong morphology.
Source: M & M Team

- *Pyroclastics (NQlp)*

This is the unit of greater geographical expansion in the area of interest, corresponding to volcanic deposits caused by the Galeras active volcano. These deposits dominantly present brecciae with angular rock fragments of different sizes, of heterogeneous composition including andesitic lavas, volcanic scoria, fragments of pumice, ash and volcanic sands with sporadic levels of andesitic lavas; due to its origin these deposits are very irregular because they are conditioned to volcanic pulses energy as well as to the directions of the winds acting at the time of their deposition, they change qickly from breccia facies to ash, both laterally and vertically. There are usually ash deposits on the facies of the volcanic breccia which when meteorized produce andisols of high fertility, producing the typical landforms of very stable gently rolling uplands.

the slope generated in these volcanic deposits have the particularity of being stable in vertical cuts, in those cuts with minor slopes they are supremely unstable, since the action of the runoff waters produce a rapid weathering and intense erosions producing deep grooves which tend to be vertical; This condition generates frequent flows of debris and falling rocks that may reach metric dimensions, making the stability of works management both very complex and expensive (**Photography**5.1.9 and **Photography5.1.9**).

Photography 5.1.4: Pyroclastic deposits, volcanic brecciae in tuffy matrix in the k 3 + 510
Source: M & M Team

Photography 5.1.5: Volcanic ash in k 6 + 610
Source: M & M Team

- *Alluvial Deposits (Qal)*

In the study area, these are limited to alluvial deposits of the Bobo river, originating from erosion mainly of the recent vulcanite. The river presents bars where these deposits accumulate (Photography5.1.9).

Photography 5.1.6: Alluvial deposits of the Bobo river
Source: M & M Team

- *Colluvial deposits (Qc)*

The colluvial deposits usually form clast supported and matrix supported dejection cones and are comprised of heterometric and heterogeneous angled and sub-angled fragments arising mainly from landslides generated by the construction of the road (annex 5.1.1) (Photography5.1.9 and Photography5.1.9).

Photography 5.1.7: Colluvial deposit in k 0 + 600, clasts of andesitic lavas, volcanic scoria.
Source: M & M Team

Photography 5.1.8: Colluvial deposit generated by landslide in the toll area.

Source: M & M Team

- *Anthropic deposits (Qant)*

These correspond to the filling areas and road construction materials "dump sites". Usually there are commercial and housing constructions on top of them by the roadside; these present a flat morphology.

Inventory of landslides phenomena

Within the road layout we found twenty-three (23) landslide phenomena, which are presented in Table 5.1.2 (annex 5.1.2 landslides phenomena)

Table 5.1.2: Inventory of Landslides phenomena

CODE:	STAKED	OBSERVATIONS	GEOLOGY
1	K0 + 130 to K0 + 155	Colluvial deposit generated by landslide affecting the current road banking	Unit Qc, blocks and angular edges of andesites in a clayey matrix.
2	K0 + 540 to K0 + 740	Accumulation of debris at the foot of the slide.	Colluvial deposit as a result of a landslide which affected the NQlp unit composed of Lavas, brecciae and pyroclastic rocks
3	K0 + 820 to K0 + 960	Accumulation of debris and signs of debris flows due to road landslide.	Colluvil deposits Qc, affecting the NQlp geological unit
4	K2 + 780 to K2 + 920	Debris flows with rockfall, in the Magdalena creek canyon.	Colluvial deposit as a result of a landslide which affected the NQlp unit composed of Lavas, brecciae and pyroclastic rocks
5	K2 + 950 to K2 + 990	Debris flows with rockfall, in the Magdalena creek canyon.	Colluvial deposit Qc as a result of a landslide in the Magdalena creek fault zone.
6	K3 + 000 to K3 + 100	Landslide of ashes and tuffs, debris flows with rockfall. Magdalena creek fault zone.	Colluvial deposit as a result of a landslide which affected the NQlp unit composed of Lavas, brecciae and pyroclastic rocks.
7	K3 + 220 to K3 + 360	Geotechnical instability area in ash and volcanic brecciae, flows of washouts with rockfall, deep grooves due to drainage action.	Colluvial deposits affecting the NQlp unit comprised of ashes and brecciae.

CODE:	STAKED	OBSERVATIONS	GEOLOGY
8	K3 + 490 to K3 + 540	Colluvium matrix supported by angular fragments of intrusive volcanic rocks.	Colluvial deposit Qc affecting the NQlp unit, mainly volcanic brecciae.
9	K3 + 770 to K3 + 850	Landslide of ashes and volcanic breccia, debris flows with rockfall.	Colluvial deposit product of the flow of debris in unit NQlp composed of ash and brecciae.
10	K4 + 470 to K4 + 520	Zone of geotechnical instability in the lower part of the bank, compounded by erosion by fluvial action.	Colluvial deposits Qc affecting the NQlp unit comprised of ashes and pyroclastic rocks.
11	K5 + 100	Landslide crown in the lower part of the road alignment. Washout with rockfall flows is present.	Colluvial deposit Qc affecting the NQlp unit, volcanic brecciae.
12	K5 + 190 to K5 + 250	sliding in Brecciae with diverse size blocks. Washout with rockfall flows present and affecting the road.	Colluvial deposit Qc affecting the NQlp unit, volcanic brecciae.
13	K6 + 400 to K6 + 440	Sliding in brecciae with diverse size blocks. It affects the upper part of the road alignment.	Colluvial deposit Qc affecting the NQlp unit, volcanic brecciae.
14	K6 + 800 to K6 + 950	Sliding in brecciae with diverse size blocks. It affects the road alignment.	Colluvial deposit Qc affecting the NQlp unit, volcanic brecciae.
15	K8 + 300	Sliding in brecciae with diverse size blocks. It affects the lower part of the road alignment.	Colluvial deposit Qc affecting the NQlp unit, volcanic brecciae.
16	K11 + 580 to K11 + 680	Sliding of brecciae with different sized blocks, affecting the toll zone.	Colluvial deposit Qc affecting the NQlp unit, volcanic brecciae.
17	K11 + 760 to K11 + 960	Sliding of brecciae with different sized blocks, affecting the toll zone.	Colluvial deposit Qc affecting the NQlp unit, volcanic brecciae.
18	K12 + 410 to K12 + 470	Sliding of brecciae with different sized blocks, affecting the road's bank.	Colluvial deposit Qc affecting the NQlp unit, volcanic brecciae.
19	K14 + 670 to K14 + 700	Sliding of brecciae with different sized blocks, affecting the road's bank.	Colluvial deposit Qc affecting the NQlp unit, volcanic brecciae.
20	K15 + 730 to K15 + 770	Instability zone generated by landslide, the crown is close to the road's bank.	Colluvial deposit Qc affecting the NQlp unit, volcanic brecciae.

CODE:	STAKED	OBSERVATIONS	GEOLOGY
21	K16 + 160 to K16 + 290	Landslide scar, affects the road's bank.	Colluvial deposit Qc affecting the NQlp unit, volcanic material.
22	K22 + 660 to K22 + 720	Instability zone generated by water-saturation affecting volcanic ashes.	Colluvial deposit Qc affecting the NQlp unit, volcanic material.
23	K24 + 060 to K24 + 150	Sliding affecting the road's bank.	Colluvial deposit Qc affecting the NQlp unit, volcanic material.

Source: M & M Team

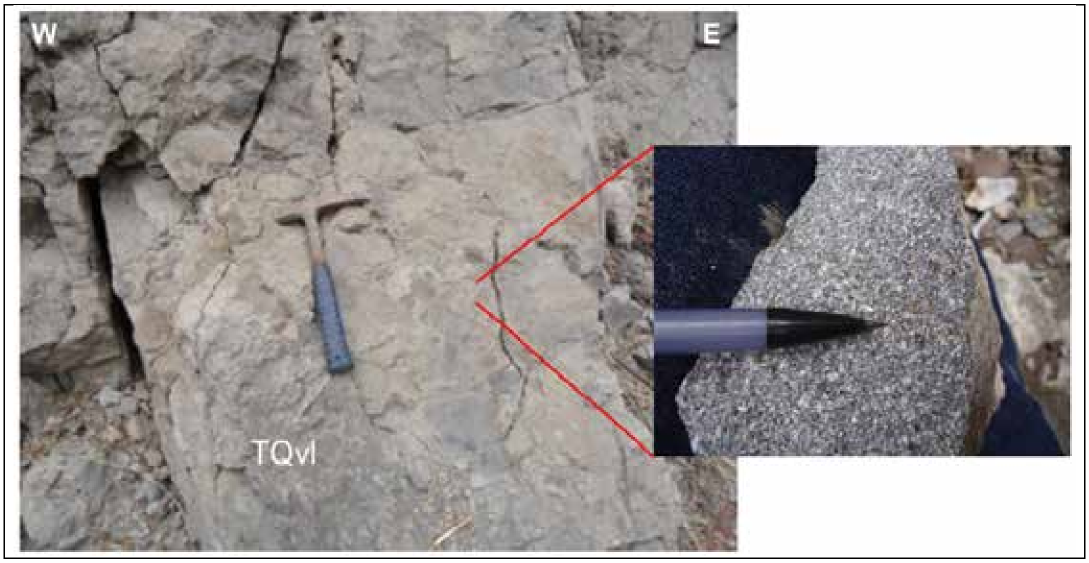
Engineering Geology units

- *La Magdalena volcanic - sedimentary set (TQsv)*

It is located between the municipality of Tángua and the Guáitara river, was mentioned by Royo and Gómez (1942) like "tuffy-volcanic-lacustrine rocks" that extend towards the south by the Valley of the Guáitara". The sedimentarypart of the set is represented by folssiliferous clays, siltstones, sandstones and thin levels of diatomites; andesitic scoria lavas are the essential volcanic component. Fascia changes in the vertical are observed as much as in the horizontal, its age is Plio-Pleistocene and it formed in a continental volcano-sedimentary atmosphere, with the presence of small lakes and/or damming of alluvial valleys as a result of calderic collapses and/or lava and pyroclastic emissions

- *Lavas (TQvl)*

They specially outcrop in the area of the volcanic complex of the Galeras; It is mainly of massive flows of tabular form and some scoriaceous, lavas aa' and lavas in blocks; they are usually interspersed with other volcanic materials; they are porphyritic rocks (**Photography5.1.9**), with phenocrystals which rarely exceed 2 mm in its larger diameter and which present evident flow textures. They are mainly andesites of two-pyroxenes and calcic plagioclase and dacites with amphibole and sodium plagioclase; they can also have microcrystalline quartz, olivine and biotite as accessory or xenocristals; the glass is present in the matrix or filling vesicles in varying proportions, corresponding to quartz - latite - andesites, quartz - andesites and dacites. (Source: (Colombian Geological Service 2003).



Photography5.1.9 Porphyritic Andesites ofthe TQvl unit, located in K1 + 820
Source (Gemini consulting S.A.S, 2015)

- *Burning and debris avalanches (TQva)*

These are mainly in valleys of the rivers Guáitara and Azufral, and in the Caballo Rucio Hill; these are rocks composed primarily of fragments of material formed at the time of explosion or fragments of a collapsed dome or lava ; the reddish color is due to the iron oxides in the eruption. The deposits are chaotic, given the turbulent and violent nature of the flow, and may or may not be bonded, depending on the thickness.

- *Flows of ash, pumice and scoria (TQvf)*

These volcanic deposits are observed in the last seven kilometers of the route, in the area where undulating to flat morphology is present. These are unconsolidated and chaotic deposits comprised primarily by fragments of pumice and/or scoria in an ash matrix or simply by ash sized clasts.

In the road alignment the flows of compounds by fragments of dacites and andesites of sizes up to 2m diameter can be observed in a matrix composed of lithic and fine pumice of sizes ranging from sand to silt (Photography5.1.10), alternating with deposits of ash of predominantly tan color (Photography5.1.11. You can see organic soils, residue from the weathering of these materials that reach thicknesses of up to 1m (Photography5.1.12).

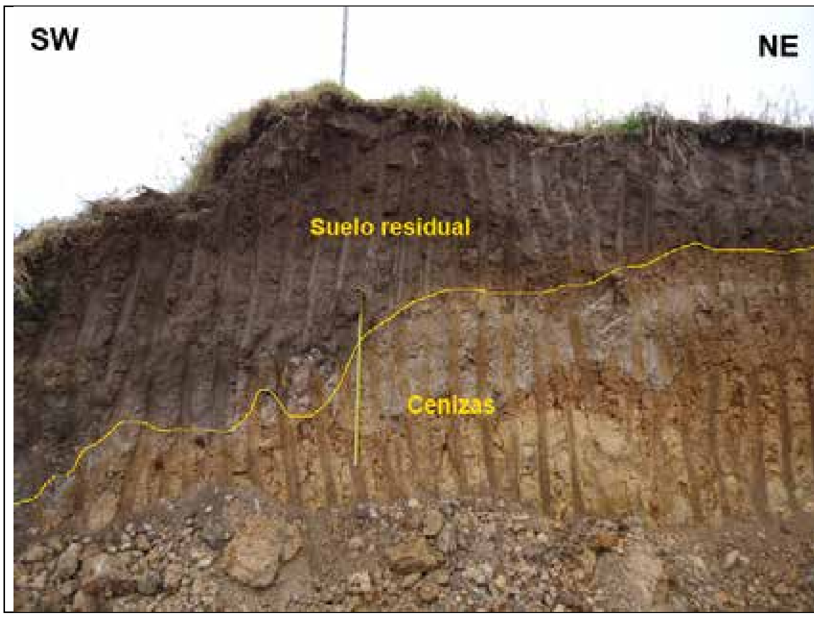
It is common to observe scoria and pumice layering in the pyroclastic rocks of the Galeras volcano, indicating magma mixing.

Photography5.1.10 Matrix pumice flows supported from unit TQvf, observed in the K30+300

Source (INGETEC, 2016)

Photography5.1.11 Deposit of ashes of the unit TQvf located in the K34+300

Source (INGETEC, 2016)



Photography5.1.12 Residual soils generated in ash deposits located in the K15+970

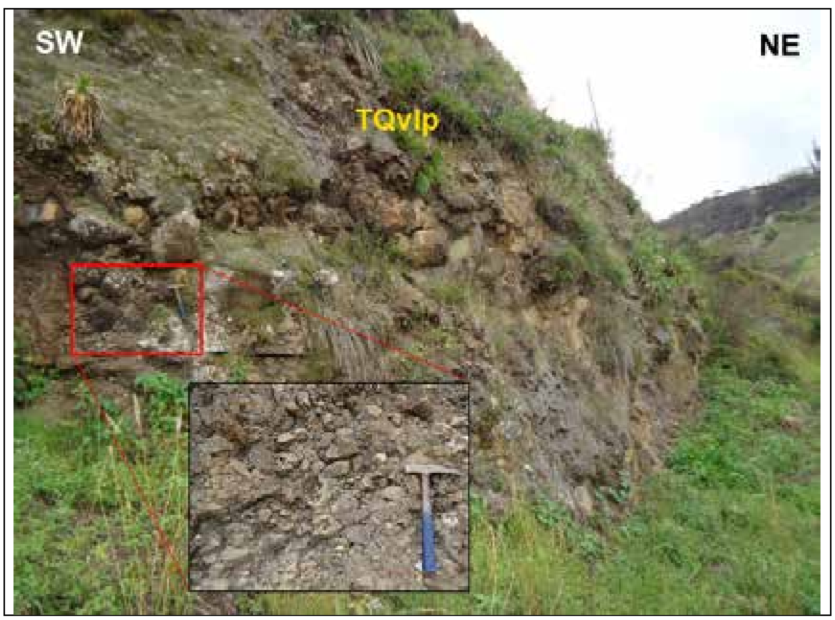
Source (INGETEC, 2016)

- *Lavas and ashes (TQvlc)*

These rocks correspond to lavas and flows and/or ash falls; usually there is a predominance of lavas that are covered by ashes or have collations of them.

- *Lahars and pyroclastic (TQvlp)*

These flows derived from the Galeras and Morasurco volcanos, are comprised of several deposits of lahars interspersed by pyroclastic flows. Lahar flows have fragments of andesitic rocks angularly shaped, with sizes up to 40cm in diameter; in a matrix that varies in percentage showing from supported matrices with a matrix generally of sand and silt to supported clasts. The pyroclastic flows are comprised of sub-rounded bombs of up to 8 cm in diameter in an ash and lapilli matrix (Photography5.1.13). These deposits can have up to 100m thickness.



Photography5.1.13 Deposits of the TQvlp unit located in K5+880
Source (INGETEC, 2016)

- *Quaternary deposits*

  - *Rains of ash (Qvc)*

These represent the explosive activity of different volcanic hot spots, are softening a pre-existing morphology and model, to a large extent, the current one. The deposits East of Pasto are important in the sector of Bomboná and Yacuanquer and the ones in Imues and Funes. They have a morphology of small, rounded, hills with typical structures of sedimentary deposits with gradient. These deposits consist primarily of glass, biotite, plagioclase, hornblende, quartz, potassium feldspar and pumice fragments. The dacitic and andesitic composition are predominant. (Source: (Colombian Geological Service 2003)

  - *Colluvial (Qc) and alluvial (Qal) deposits*

These deposits are located mainly in the city of Pasto, in the El Barranco river and in the San Ignacio area. Alluvial deposits are composed of gravels, sands, silts and clays associated with river channels and flood valleys. Colluvial deposits generally form dejection cones and are comprised of non homogeneous sized materials, and sometimes not even at origin (Photography5.1.14). These are Quaternary deposits, many of which are under formation.

Photography5.1.14 Colluvial deposit (Qc) between the abscissas K3 + 060 and K3 + 070
Source (INGETEC, 2016)

o *Anthropic fill (Qant)*

It is anthropic materials located in the margins of the current road, filled with products originating from slopes cuts and sometimes with waste and rubble material and terrain conformations for the road alignment in terrain depressed areas.

- *Homogeneous zones for the Pedregal-Catambuco stretch*

Along the section of the Pedregal-Catambuco stretch, we identified 4 Homogeneous Zones taking into account the lithological and geomorphologic characteristics, in order to know the mechanical behaviour of the rock in each one of them and the stability works to undertake in this road stretch.

For each Homogeneous Zone, these are precisely located and then a local analysis of the geological aspects is made, and a the regional level the geomorphology is presented, with its units and at the local level the mass removal processes which are made throughout the layout.

The delimitation and designation of Homogeneous Areas was carried out taking into account parameters based on textural elements of the rocks and the interpretation of the geological context in field.

- *Homogeneous zone I*

This homogeneous area is located along the Pedregal-Catambuco stretch in the section that corresponds to the K15 + 722.36 up to the K18 + 875.90. It flows through a geological unit of volcanic origin which corresponds to the unit of lahars and pyroclastic rocks (TQvlp).

There is also a small lens of a volcano-sedimentary unit corresponding to the La Magdalena Sedimentary Volcanic Group (TQsv) which is composed of siltstones, sandstones and thin diatomites levels; located between the abscissas K15 + 300 to the K16 + 000.

In this homogeneous area there have beensubsoil investigations by means of coring drilling PEPA-PT - MUR-9, PEPA-PT - TAL-16, PEPA-PT - TAL-17, PEPA-PT - TAL-18, PEPAPT - TAL-19, as well as the lines of seismic refraction PEPA-LSTAL-16, PEPA-LSTAL-17, PEPA-PT - LSTAL - 18, PEPA-PT - LSTAL-19; which were carried out in the unit of lahars and pyroclasts (TQvlp).

These investigations found residual soils that can reach up to 6 meters thick, followed by pyroclastic deposits formed by fragments of volcanic rocks of andesites and/ or rhyolites in a matrix composed of ash and lapilli of a soft and moist consistency.

- *Homogeneous zone II*

Homogeneous zone II comprises approximately 6,857 kilometers in length between the K18 + 875.90 to the K24 + 018, spanning volcanic rocks that correspond to lahars and pyroclastic covers (TQvlp) and rain of ash (Qvc).

Also present is a small lens which corresponds to Lavas and ashes (TQvlc) located between the abscissas K22 + 250 to the K22 + 540. In this homogeneous area there have beensubsoil investigations by means of coring drilling PEPA-PT-TAL-20, PEPA-PT-TAL-21, PEPA-PT-TAL-22, PEPA-PT-TAL-23 and PEPA-PT-TAL-24, as well as the seismic lines PEPA-LSTAL-20,PEPA-LSTAL-21, PEPA-LSTAL-22, PEPA-PT LSTAL 23 and PEPA-LSTAL-24; which were carried out in the unit of lahars and pyroclasts (TQvlp) and Ash rain (Qvc).

These investigations found organic residual soils in the Ash unit of between 1 to 3 meters thick, followed by ashes reaching thicknesses of up to 6.70 meters which cover the pyroclastic deposits formed by fragments of volcanic rocks of andesites and/ or rhyolites in a matrix composed of ash and lapilli of a soft and moist consistency. In the unit of Lava and ashes (TQvlc) residual grounds of up to 1,5m of thickness werefound, covering the volcanic rock within this unit.

- *Homogeneous zone III*

The homogeneous zone III encompasses approximately 6,012 kilometers in length between the K24 + 018 to K30 + 030, along the path there are volcanic rocks corresponding to Lavas and ashes (TQvlc) and rain of ash (Qvc), the area presents a morphology flat to semi-flat; in areas where the ash rains outcrop with an averaging slope slightly inclined with sectors slightly steep and low hills in the unit of Lavas and ash, with a morphology of low rounded hills with valleys in U whose average slopes are slightly steep with some strongly steep areas.

In this homogeneous area there have beensubsoil investigations by means of coring drilling PEPA-PT-TAL-25, PEPA-PT-TAL-26, PEPA-PT-TAL-27, and PEPA-PT-TAL-28, as well as the seismic lines PEPA-LSTAL-25, PEPA-LSTAL-26, PEPA-LSTAL-27, P and PEPA-LSTAL-28; which were carried out in the units of lavas and ashes (TQvlc) and Ash rain (Qvc). Where residual soils were found that can reach up to 3 metres thick, followed by deposits of ash and lava.

- *Homogeneous zone IV*

the homogeneous zone IV comprises approximately 7.948 km route between the K30 + 030 to the K37 + 947.96, of which 2.649 correspond to hte double lane and 5.269 to rehabilitation area. This homogeneous area traverses volcanic rocks that correspond to flows of ash and pumice(TQvf) and rain of ash (Qvc). There is also a small sector that corresponds to Lavas and ashes (TQvlc) located between the abscissas K34+326.24 to K34+360 with reference the left-hand side of the road, which will cut these rocks.

In this homogeneous area there have beensubsoil investigations by means of coring drilling PEPA-PT-TAL-29 and PEPA-PT-TAL-30, as well as the seismic lines PEPA-LSTAL-29, PEPA-LSTAL-30and PEPA-LSTAL-31; which were carried out in the units of ash flows and pumice (TQvf) and Ash rain (Qvc). These investigations found organic residual soils in the Ash unit of between 1 to 3 meters thick and fillups of up to 3.5m, followed by ash flows reaching thicknesses of up to 10 and 15 meters which cover the pumice flows deposits formed by fragments of volcanic rocks of lapilli tuffs in a matrix composed of ash of a soft and moist consistency. In the unit of Lava and ashes (Qvc) residual grounds of up to 2m of thickness were found.

- Structural geology

The Pedregal - Tangua section of the UF 4 is located betweenthe municipalities bearing their names. This corridor is framed in a complex tectonic given the convergence of the three Colombian mountain ranges, together with the tightening and rise of inter Andean depressions of the Magdalena Valley and the Cauca - Patía.

This is the sector where great fault systems converge northbound, geologically defining the limits between their mountain ranges. The nearby geological structures in the study area evidence the tectonic activity that has lead to the current expression of the mountainous system of the Northern Andes, specially the portion corresponding to the differentiation between the Ecuadorian Andes and the Colombian Andes (Núñez, 2003).

The structural style of the region is complex. There is predominance of high angle faults of N-NE direction with a notorious deformation over the Western Mountain Range produced by imbrication of wedges or thrust sheets from cortical fragments involved in a prism during a continuous accretion and subduction process of an oceanic plateau (González et al, 2002).

In a more specific sense, Rodríguez (2005) states that the tectonic events that fractured the lythological units and affected some of the exposed deposits in the study zone are manifested in two preferential directions of faulting: one longitudinal with a NNE - SSW trend, and another transversal with a NE - SW trend. Besides, according to Rodríguez (2005), in the Nariño highland plateau there is an intense tectonism comprised of numerous faults of northeastern orientation that affect even the Plio - Pleistocene; their oriental limitis construed by the Silvia - Pijao fault and the western by the Cauca - Patía Fault (Arango & Ponce, 1982).

Patía - Guáitara Fault

The Guáitara fault, located to the South of the city of Pasto, southwest of Colombia, itpresents a volcanic cover of Neogene age. This fault is interpreted as the continuation of the Romeral faults system. It is believed that it probably extends more to the South into the Republic of Ecuador.

It has been interpreted through aerial photographs, geomorphological field studies, and regional geological mapping . The geometry of the fault is dextral (right side), in accordance with the common behavior of other nearby Quaternary faults; compatible with the current field effort of compression WSW-ENE.

Its geomorphologic expression is well developed with deep V-shaped valleys, linear topographic features, controlled drainage, diverted streams and elongated hills (Paris et al, 2000; Paris,G., 1993, and Romero, J., 1994).

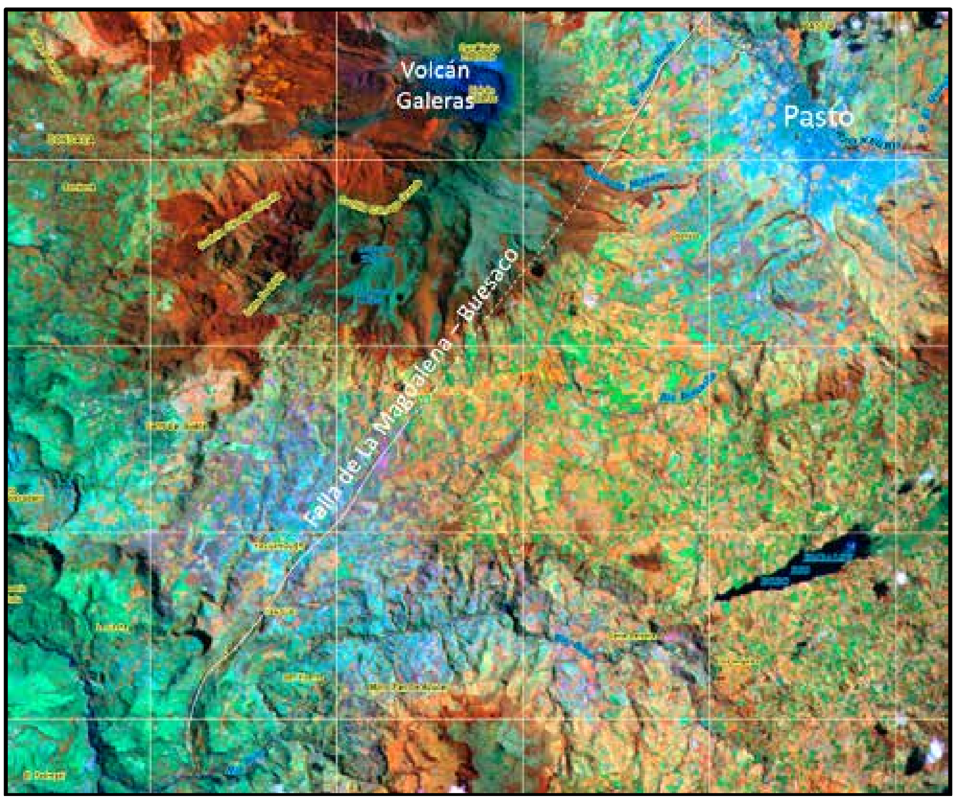


Figure5.1 .4: Satellite image of the area of interest; shows the path of the failure of the La Magdalena creek, in the direction of the fault of the Buesaco fault zone.
Source: M & M Team

San Ignacio fault

this fault is located E of the road alignment of the functional unit 4, at approximately 5km. It has a NE direction through the craters of ancient volcanoes, El Gallo, Ocoyuyo and San Fernando.

Romeral faults system

According to Paris et al., 2000, The Romeral faults System is one of the most active and continuous faults systems in Colombia. The literature has given this faults system a series of names as it traverses the country's length. The most ancient name is megashear Guayaquil-Dolores, which implies a whole series of parallel fractures in the Colombian west. The number of faults comprising the amplitude of this system varies between three and five kilometers, depending on their location in the country. Between latitudes of 1° and 5°N which correspond to the study area, the faults are known from north to south as Silvia- Pijao, Quebradagrande, Potrerillos, Guabas-Pradera, Cauca-Almaguer, Rosas-Julumito, Popayán, aispamba, El Rosal, and Buesaco (Figure 5.1.4).

Its main layout traverses the Galeras volcano, has a N45°E direction and, southbound tends to N10°E, where it continues its layout by the Guáitara river. The Buesaco fault is associated to this system, it is common to find calderitic complexes in these faults' layout.

Magdalena river faults System

At the regional level a layout parting from the Romeral faults system may be observed, with a EW direction and N30°E. This ramification starts approximately 1 km from the road layout in the sector K2 + 300. Cuts the UF 4 layout in the first 5 kilometres in three different sectors.

This system could be associated to the southern segment of the Chusma Faults System, but it is not cartographically well defined; likewise, the geological memory of template 429 mentions that this system limits the Central mountain range with the Magdalena valley.

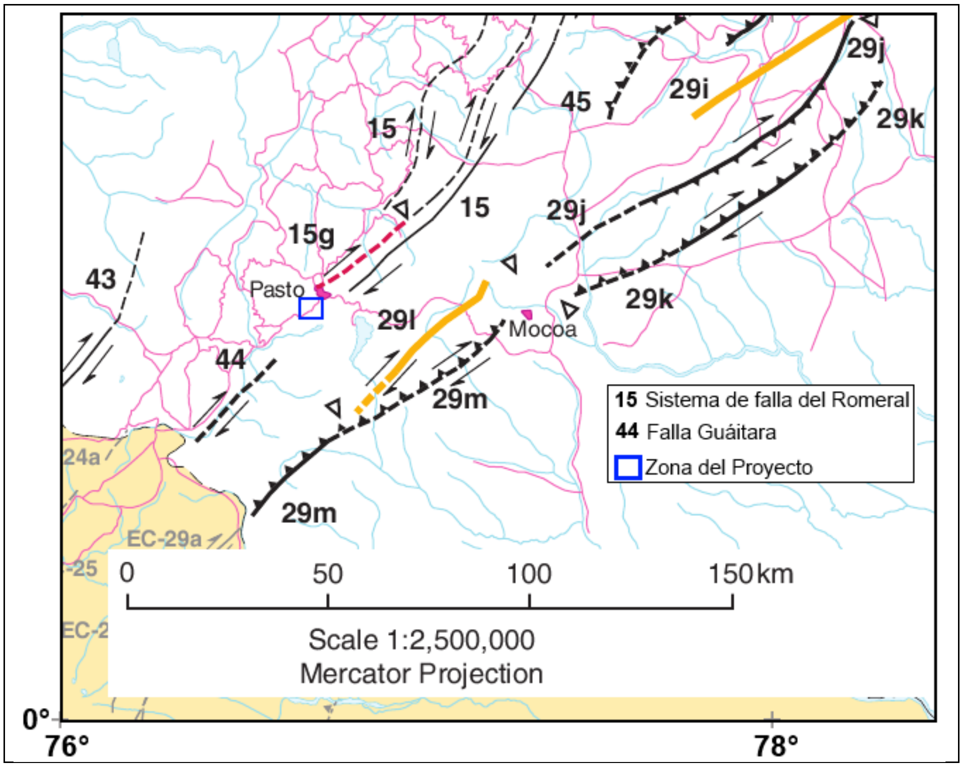


Figure5.1 .5: Main geological faults
(Source: (INGETEC, 2016)

Afiladores Fault

It is located approximately 18 km east from the layout. It was defined as an overthrust fault (Ponce, 1979) somewhat more to the south, and exscizes tectonic control over the La Cocha lagoon.

- Illustrative profiles

With the geological cartography based on the field surveys, the final maps and the lythological and geomorphological maps of the terrains crossed by the road project were made.

The information analysis allowed the acquisition of the geological and geotechnical model of the existing road corridor, both in plant and profile, identifying the diverse materials involved in it and their interaction with the scheduled road structure. See Annex 5.1.8.

5.1.2. Geomorphology

Geomorphologically, the area shows landscapes with features ranging from moderate with hills and crests originated on a denudational action upon the ash deposits covering the contour like tapes, of Neogene Quaternary producing rounded to sub-rounde morphologies up to abrupt landscapes originated by a denudational – structural modelling upon the most resitant rocks such as lavas and consolidated tuffs, which are strongly affected by tectonism. Additionally, there are some morphodynamic denudational models generally associated to landslides related with undermining of waterways.

- Regional Geomorphology

The Colombian mountain system is a part of the great Andes mountain range, a mountain range originating in Argentina and ending in Venezuela. In Colombia, the Andes enter by the south on the border with Ecuador, at the height of the Huaca massif known as the Knot of Los Pastos, highlighting in this site the plateaus of Ipiales, Tuquerres and Pasto, as well as numerous volcanoes such as those of Cumbal, Azufral and Galeras.

From the Los Pastos Knot, the Andes divide, giving rise to the western (left) and Central (right) mountain ranges (cordilleras), separated by the rivers Guáitara and Patía. The zone of study is located in the central mountain range that is the highest and volcanic of the cordilleras of Colombia and in turn, the one of smaller length. Its predominant morphologic characteristics are its great elevations, specially numerous volcanoes and wastelands. The volcanoes Galeras, Cumbal, Chiles - Cerro Negro, Azufral and the wasteland of Las Papas are several of their most outstanding geographical features.

The last phase of geological evolution that corresponds to the Pleistocene, a time in which the diastrophism and volcanism diminished in intensity, thus appearing drastic climatic modifications marked by the glaciarism and the erosion which are phenomena to which the present morphology of the landscape is due.

Volcanism is accentuated in the tertiary and early Quaternary periods by the activity of nearby volcanoes such as the Cumbal, Chiles and Troya, La Quinta, Cultún, French, Palacios and Tigre hills that somehow contributed with huge deposits of ash , Which filled the depressions and generally designed a semi-planar morphology characteristic of the areas of the Nariño highlands, where the expelled materials are presented with large deposits of clay, which can be observed in the sections formed by the -Pasto-Ipiales highway and in The canyon of the river Guáitara. The volcanic spills formed great plains and, as in other places, buried old slopes, clogged the flow and generally interrupted the erosive process of the rivers. This process can be observed in the Pun, Cultún and San Francisco valleys. From the above, it si then derived that the second component in modelling the landscape is the erosion produced by the drainage of rivers, which has produced profound interandean canyons such as the Guáitara canyon, dragging the materials expelled by the volcanoes, still unconsolidated materials, without reaching metamorphism and facilitating the vertical excavation. (Source: Muncipality of Ipiales Territorial Ordering Plan (POT), 2010).

The third factor that has influenced the modelling of the landscape is the sedimentation of cancavities formed due to orogenic movements which gave rise to the Andes cordillera to its current hgeight; during this process folds, ruptures and fauts formed which gave place to great concavities , which later turned into interandean lakes.

Some lagoons disappeared due to the slow accumulation of drag materials due to rain waters, and this phenomenon was increased during the interglacier periods where the defrosting increased, then the erosion coming from the surrounding cordilleras filled up, forming the flatlands of Túquerres and Ipiales.

The morphology towards the high borders of the plateau is characterized by the footprint left by the glaciers, specially the presence of conglomerates and mud flows. It is common to watchalluvial cones, soem as result of the sudden avenues, other from a fluvial-glacier origin, judging by the very heterogeneous morain material.

In general, the fluvial and volcanic materials are predominant fillers of the depressions upon which the erosive processees have recently acted. In this case, the cold streams are more stable and the landslides or soil alterations are not present, since they're always covered by vegetation, reason that makes infiltration prevalent over water drag.

· Morphogenetic environments

Fluvial Environment: This category encompasses the geoforms originated by processees due and/or associated to the diverse fluvial origined processes, whether old or current, caused mainly due to erosion or lateral undermining of banks and caused mainly due to rivers' and streams' currents draining the area and in compliance to the old and current sediment and colluvial materials accumulation processes in the neighboring areas to these currents, both in times of great torrential avenues causing lateral undermining of banks, together with outbanking and flooding, as evidenced all throughout the rivers and streams' paths which present their own fluvial dynamics for current currents both during we periods as during dry periods. This way and with the aid of satellite imaging and the shadows model, it was possible to interpret the diverse geomorphological units of accumulation in ther active beds and the erosion of the nearby areas to the rivers and streams paths, and in the bedding of the current waterways, whose deposits were transported and accumulated when these currents lost their materials drag capability and deposited them in their current active beds.

These processees carry the formation of the fluvial system characteristic geoforms , mainly the colluvium-alluvial small valley of a profound disection and the pronounced alluvial valley. For the previous geoforms, the composition of the sediments varies significantly, aspects that can be analyzed for the reconstruction of the accumulation environments (Walker, 1984).

Colluvium-alluvial valley (Fvca)

V-shaped colluvium-alluvial valleys product of water erosion on slopes and hills in the area, producing dissections or deep cuts , alluvial producing transportation of material and fall of rocks.

Pronounced alluvial valley (Fvap)

V-shaped alluvial valley with high slopes product of fluvial processes that mainly cause erosion on the lithology of the area even though it also includes lenticle bodies and erosion processes caused by runoff. They also involve aggradational processes.

Volcanic environment*:* The volcanic environment is characterized by constructed landforms from magmatic eruptions of lava and/or explosive character and their products. The volcanic landforms are presented in all sizes from metric size craters up to thousands of kilometres of lava plateaus. Also, the different types of magmas affect the volcanic behavior, differentiating large explosive trends from calderas (rhyolitic) and lava of the shield volcanoes (basaltic) and mixed processes from the stratovolcanoes (andesitic) . The most notorious sub-environments relate to the interaction of volcanic processes and denudational processes, resulting in the geomorphology of pyroclastic deposits slopes, pyroclastic mantled hills and small valleys in pyroclastic deposits. Also, the geological formations can result in combined processes such as pyroclastic flows and volcanic fluvial - or "lahars" (Walker, 1984).

Hills of pyroclastic deposits (Vldp)

Landforms of volcanic and denudational origin which exhibit wavy to flat outlines, with low slopes. Their genesis is a product of deposition and subsequent erosion of a pyroclastic mantle which covered the outline in the past. It presents dendritic drainage patterns and may be predisposed to be affected by erosion due to its geological composition.

Pyroclastic mantle denuded hills (Vcmp)

Landforms of volcanic and denudational origin which exhibit wavy to flat outlines, with low slopes. Their genesis is a product of deposition and subsequent erosion of a pyroclastic mantle which covered the outline in the past.

Denudational Environment*:* The dissection of the landscapes by exogenous processes is manifested via water and gravitational erosion processes or a combination of the two. Under dry weather conditions, the erosive forms related to soil loss and dissection generate erosion phenomena of a laminar shape, furrows and gullies, i.e. lands wastelands. On the other hand, wet conditions favor the weathering of the subsoil and gravitational movements with their landslides and soil and debris flows. Undoubtedly, the two processes interact to produce an endless number of combinations. Even so, the water erosion processes and landslides are the two dominant sub-ambients of the Denudational Environment.

Within the Sub-environment of landslides we may differentiate the denuded hills with abrupt slopes (Dlpa), sometimes represented in a linear way, the colluvium and greater landslides phenomena (Dmya) or less active associated to crowns and concentrated erosion (Ddma). Also notorious are the variable stability cones, sometimes difficult to distinguish from the hillside deposits except for their typically filler shape and lesser slope. This morphology is also related to a complex drainage of two or three secondary channels separated by the recent flows within the lower valley itself.

Denuded slopes of steep slope (Dlda)

Landform of denudational origin over deposits of lavas and pyroclastic rocks which form steep hills, with high slopes prone to landslide phenomena and advanced erosion.

Denuded slopes of medium slope (Dlpm)

Landform of denudational origin over deposits of lavas and pyroclastic rocks which form gently inclined hills, with medium slopes, with greater stability than the previous unit. There are lesser landslides and concentrated erosion.

Landslides, crowns and erosion (Dmya) phenomena

These correspond to minor landslides, mud flows, landslides and erosive surfaces phenomena.

Colluvium (Dqc)

Sedimentary bodies of irregular shapes topographically located in low and intermediate areas with regard to the outline of the area. They exhibit a topography from inclined to relatively flat as a result of the accumulation of material due to mainly gravitational effects reworked by alluvial processes.

Anthropic environment. This environment is characterized by landforms generated by significant alteration of the Earth's surface by the action of men. Within these processes are artificial landfills, landfills and cuts often associated with infrastructure works and in some sectors of clay mining operations. Although urban areas also represent a remarkable change in the Earth's surface, especially the permeability of urban land, for the time being these are considered as a secondary alteration of the basic morphology of the terrain, looking to deal with these in more detailed surveys.

Anthropic bodies (Antr)

Anthropic bodies which exhibit flat outlines with slopes less than 12%.

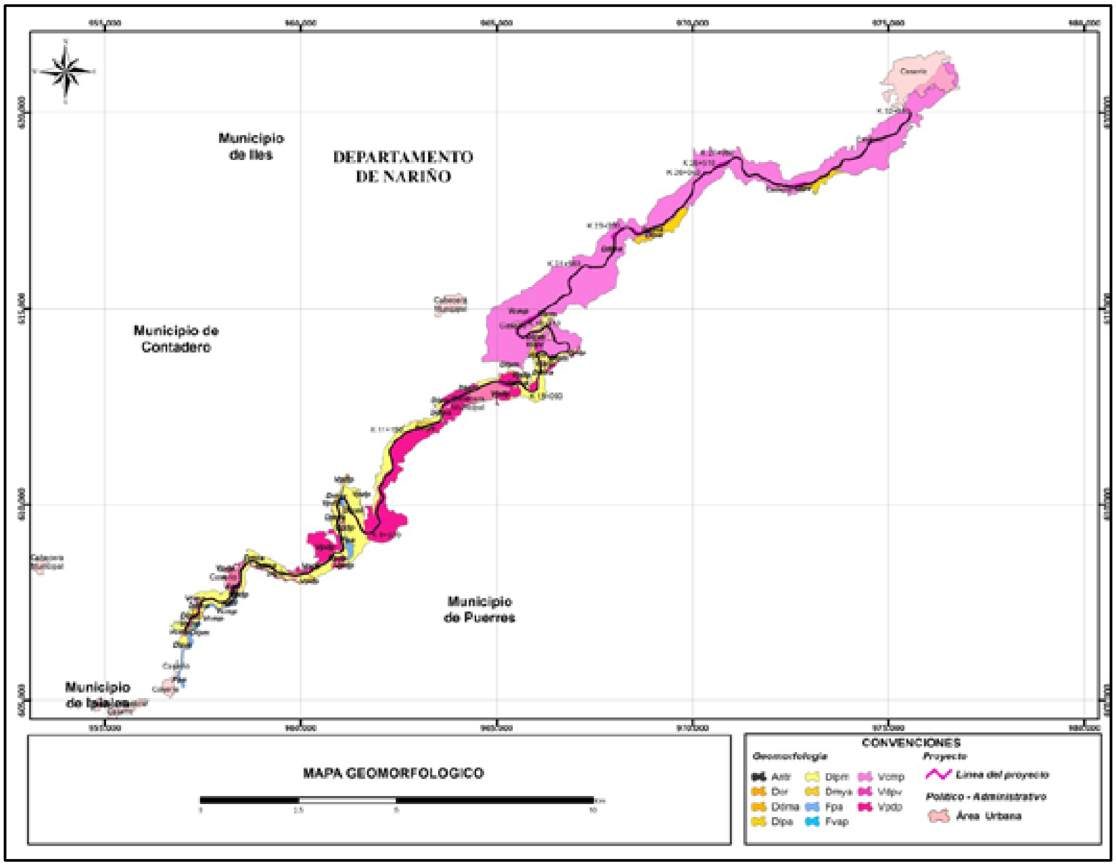


Figure5.1 .6: Geomorphological Map
Source: M & M Team

The Table 5.1.3 presents the areal and percentage distribution of each one of the differentiated geomorphologic units in the project's influence area.

Table 5.1.2: Areal and percentage distribution by geomorphological unit

SYMBOL	AREA ha	%
Antr	10,362935	0,535935522
Dcr	0,196066	0,010139862

SYMBOL	AREA ha	%
Ddma	3,902182	0,201807494
Dlpa	46,984076	2,429855565
Dlpm	380,990282	19,7035131
Dmya	20,184746	1,043885962
Fpa	24,199443	1,251512347
Fvap	1,185861	0,061328671
Vcmp	1087,129395	56,22261061
Vdpv	8,373266	0,433036652
Vldp	350,107749	18,10637421
SUM	1933,616001	100

Source: M & M Team

In accordance with table 5.1.3, the unit presenting the greatest coverage is the Vcmp (unit of pyroclastic mantles denuded hills) with a 56,22%, equivalent to 1087,112 hectares, followed by unit Vldp (unit of pyroclastic deposits hillocks) with an 18.19%, representing an area of 350,10 hectares. These two volcanic origined units represent 74,32%, which is in line with the origin of the rocks in the area. Other representative unit is the Dlpm (unit of denuded slopes of average falling gradient), with 19.7% equivalent to 380,99 hectares. This unit is of depositional origin.

- Slope ranges

The following homogeneous ranks of slopes were taken as base elements for the analysis of the geomorphologic component, which are those adopted by FAO and for the Colombian case by IGAC, Table 5.1.4 describes each one of the used slope ranges.

The slope ranges were determined according to the IDEAM guidelines, which is divided into nine (9) ranges, coresponding to the hilliness coefficient of a plane with regard to the horizontal plane, being the inclinations of 45 degrees the ones that correspond to a 100% slope.

The inclination value of the terrains was estqablished using a 12 meter DEM Palsar (digital terrain model) associated to the geomorphology of the GDB parameter.

table 5.1. 4: Classification by surface slope

SLOPE	AREA ha	%
Leveled, 0 - 1%	481,984689	24,9265981
Slightly flat, 1-3%	0,00000000	0
Slightly inclined, 3-7%	190,371481	9,84536128
Moderately inclined, 7-12%	324,536059	16,7838939
Strongly inclined, 12-25%	521,728348	26,9820041
Slightly sheer or slightly steep, 25-50%	402,599794	20,8210831
Moderately sheer or moderately steep, 50-75%	12,3956300	0,64105955
Strongly sheer or strongly steep, 75-100%	0,00000000	0
Totally steep, > 100%	0,00000000	0
SUM	1933,616001	100

Source: M & M Team

Based on the established ranges, a slopes map was produced; the colors used for this purpose are based on the spectrum, so the lighter colors correspond to the softer slopes while the dark correspond to escarpments; the homogeneity in the work and nomenclature of the slope ranges ensure an adequate articulation of the different maps; initially, the slopes map shows the distribution of this morphological expression; the same ranks are used in the description of the physiographic units and, consequently, how these positions are that ones that affect the evolutionary development of the soils.

According to Table 5.1.4, we may deduce that the slope ranks that cover a greater area are the interval between 12-25% (Strongly inclined) with an area of 521,72 hectares, followed by the rank between 0-1% (Leveled) with a 24.92%, which is equivalent to 481.98 hectares; the rank between 25-50% (Slightly sheer or slightly steep) has a 20.82%, equivalent to an area of 402.6 hectares. These three intervals represent the 72,73% of the overall area.

It is important to note that ranges between 1-3% (slightly flat), 75-100% (strongly sheer or strongly steep) and > 100% (Fully sheer) have no areal representation within the area of influence of the project.

- <u>Instability</u>

- *Homogeneous zones for the Pedregal-Catambuco section*

- Homogeneous Zone I

It presents a low hills morphology with valleys in U whose slope inclinations vary from abrupt to strongly inclined. The slopes in this area vary from slightly inclined (3-7%) to totally steep (> 100%) especially in the areas of talus cuts on the current road and in the El Quelal creek canyons (Figure 5.1.6).

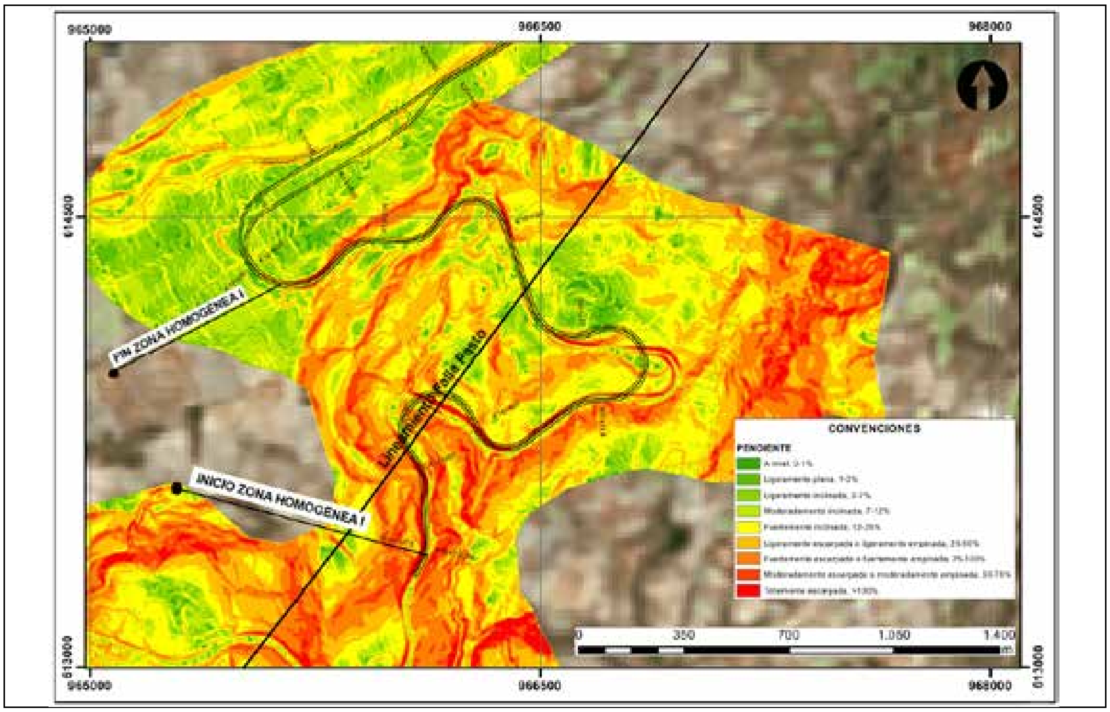


Figure 5.1.7 Slopes map for the homogeneous zone I.
Source (INGETEC, 2016)

- Landslides and erosion processes

The unstable areas identified in the homogeneous zone I were analysed in compliance with their lithology and associated processes to each one of them, making the relevant classification in erosion, falls, landslides or flows and their possible causes, mobilized material, type and speed of the movement.

These were located according to the journey undertaken in field, 9 sectors with instability along the corridor of the Homogeneous Zone I. These sectors have instability due to erosion, rock slides and to the action of gravity, depending on the materials present in the area mainly volcanic materials mostly ash, lahars and pyroclastic Llocal Geological Maps, scale 1:5.000).

The slopes in these designated sections vary from moderately inclined (7-12%) to totally steep (100%), which corresponds to lahars and pyroclastic rocks (TQvlp) and to a lesser extent to the unit Volcanic Sedimentary Set of La Magdalena (TQsv). Below is the registry of the unstable areas according to the abscissas, with their respective lithology and explanation of the phenomenon or current process. (See annex 5.1.1)

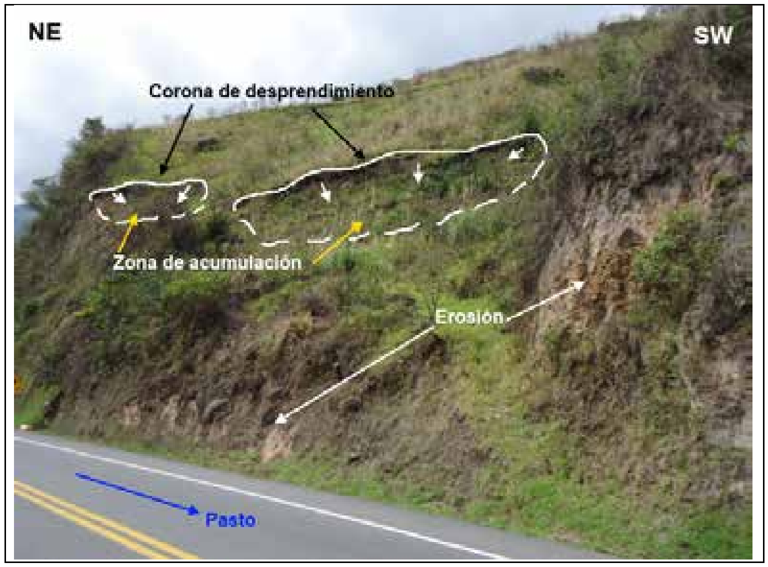
PD 5-1

In the area K16 + 100, coordinates 966. 060E and 613741N, we observed the presence of low magnitude ancient gravitational movements over the road cut talus in the unit of lahars and pyroclastic rocks (TQvlp), associated with highly weathered materials that reflect a level IIA. Was also observed diffuse erosion by runoff that disperse the finest materials of the pyroclastic deposit (Photography 5.1.15).

PD 5-2

In the left talus of the current road that leads to the municipality of Pasto, at K16+520, coordinates 966.273E and 613768N, we observed evidence of material rupture in the upper part of the talus in the unit of Lahars and Pyroclastic rocks (TQvlp).

It can be observed in Photography 5.1.16 that the detachment does not cover the whole cut of the road talus, terefore it only corresponds to the accommodation of the pyroclastic deposit after intervened. There is a deposit of erosion naturally removed talus pyroclastic material at the lower part of the talus.



Photography5.115 Scar from a stabilized landslide process, currently there is erosion on the exposed rock.
Source (INGETEC, 2016)

Photography5.116 Scar from a landslide process, the removed material deposit due to the process may be observed in the lower part.
Source (INGETEC, 2016)

PD 5-3

In the road talus at K16+620, coordinates 966.368N and 613709E, we observed detritus flows that fall along the talus from the top of it. These rocks, corresponding to the Lahars and Pyroclasts (TQvlp) unit, are released due to the erosion of the pyroclastic deposit matrix (Photography 5.1.17), which leaves the volcanic rock blocks without support, generating detachment of the blocks, causing the flows.

Photography5.117 Landslide process in the lahars and pyroclasts unit identified in the talus of the current road at K16+220

Source (INGETEC, 2016)

PD 5-4

In the K16+804.43, coordinates 966.532N and 613801E, a talus of pyroclasts of the Lahars and Pyroclasts unit (TQvlp) is observed, which is composed of blocks of volcanic rock in a fine matrix with ash composition. A diffuse erosion was identified which is taking place by the removal of runoff particles, which accumulate in the lower part of the talus developing a deposit of materials removed by erosion (Photography 5.1.18).

Photography5.118 Talus on the current road evidencing active erosion processes

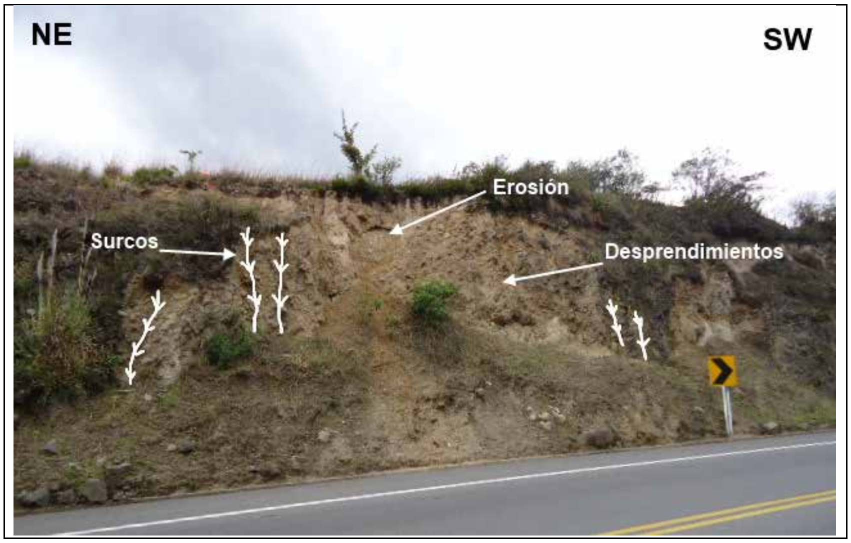
Source (INGETEC, 2016)

PD 5-5

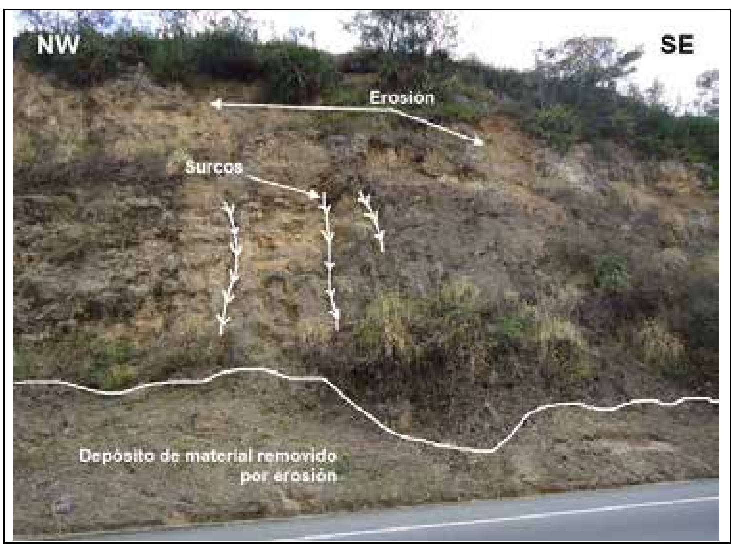
In K17+400, coordinates 966869E and 613890N, in the unit of Lahars and Pyroclasts (TQvlp). Locally we observe a rock talus composed of blocks of volcanic rock in a fine matrix with ash composition. A diffuse erosion was identified which is taking place by the removal of runoff particles, which accumulate in the lower part of the talus developing a deposit of materials removed by erosion.

PD 5-6

In the left slope of the current road leading to the municipality of Pasto, from K17+500 to K17+560 (coordinates 966.592E and 614.076N) there is a cut on the talus of approximately 120 m in length, where moderate erosion was identified with appreciation of grooves, some detachments of blocks which loose their support due to erosion of the fine materials that make up the pyroclastic deposit matrix (Photography 5.1.19 and Photography 5.1.20)



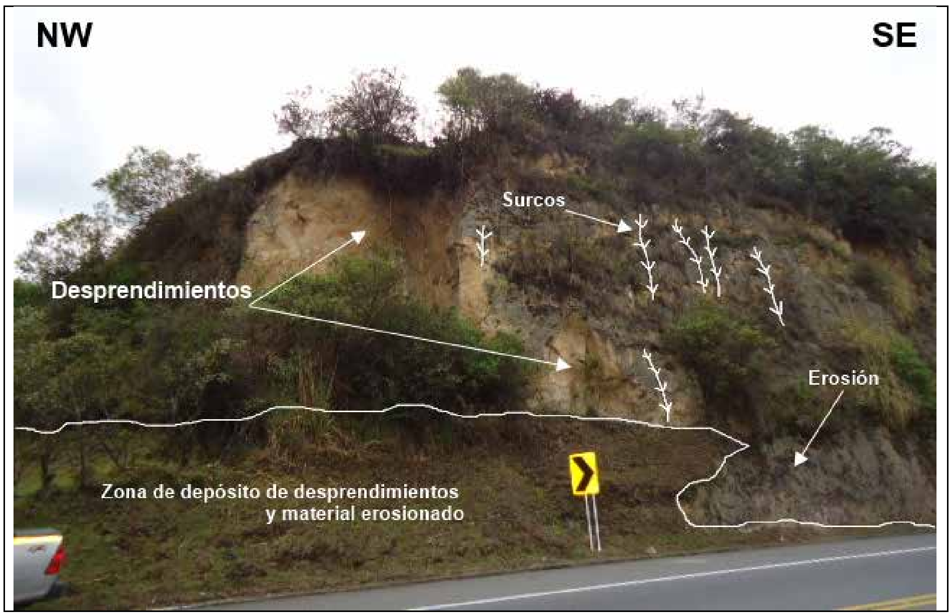
Photography5.119 Lahars and pyroclasts unit with presence of mild erosive processes as grooves and denudatory processes as detachments.
Source (INGETEC, 2016)



Photography5.120 Lahars and pyroclasts unit with presence of erosive processes.
Source (INGETEC, 2016)

PD 5-7

At a height of K18+100, coordinates 966.335E and 614560N, there is a cut in the talus of approximately 12 m height in the Lahars and Pyroclasts unit (TQvlp), where moderate erosion is observed, grooved erosion occurs when The superficial flow begins to concentrate on the terrain's surface, due to the natural irregularity of the same and some detachments of blocks that loose their support due to the erosion of the fine materials that make up the matrix of the pyroclastic deposit (Photography 5.1.21).



Photography5.1 2 1 Lahars and pyroclastic unit exhibiting grooves in the outcrop and detachments.

Source (INGETEC, 2016)

PD 5-8

At the height of K18+195, coordinates 966.240E and 614573N, there is a cut in the talus of more than 10 m height, in the Lahars and Pyroclasts unit (TQvlp), where moderate erosion is observed and the start of a grooved erosion due to the uneven cutting of the terrain (Photography 5.1.22).

Photography5.1 22 Lahars and pyroclasts unit with presence of grooves.
Source (INGETEC, 2016)

PD 5-9

At the height of K18+600, coordinates 965.876E and 614415N, there is a cut in the talus of the current road in the in the Lahars and Pyroclasts unit (TQvlp), where moderate erosion is observed, with accumulation of removed material deposited at the base of the talus.

- Homogeneous zone II

The zone presents a flat to semi-flat morphology and low hills with rounded ridges, with slopes varying from slightly flat to strongly inclined (Photograph 5.1.23).

Photography5.1.23 Morphological expression of low hills with rounded crests in unit Qvc
Source (INGETEC, 2016)

The homogeneous zone II presents in the flat to semi-flat morphology in the unit of Ash rains (Qvc), slopes ranging from 1-3% slightly flat and 25-50% slightly sheer or steep identified at the edge of the road in the current cut slopes (Figure 5.1.6).

- Landslides and erosion processes

In the Homogeneous Zone III some sites were identified that present landslide processes which are related to the superficial units or layers of unconsolidated pyroclastic deposits. These processes are classified as erosives, falls, landslides or flows.

Six sectors with instability were identified along the corridor of the Homogeneous Zone. These sectors present instability mostly towards erosion, rocks detatchment and action by gravity, taking into account the materials that are present in the area, mainly volcanic materials mostly ash, lahars and pyroclasts.

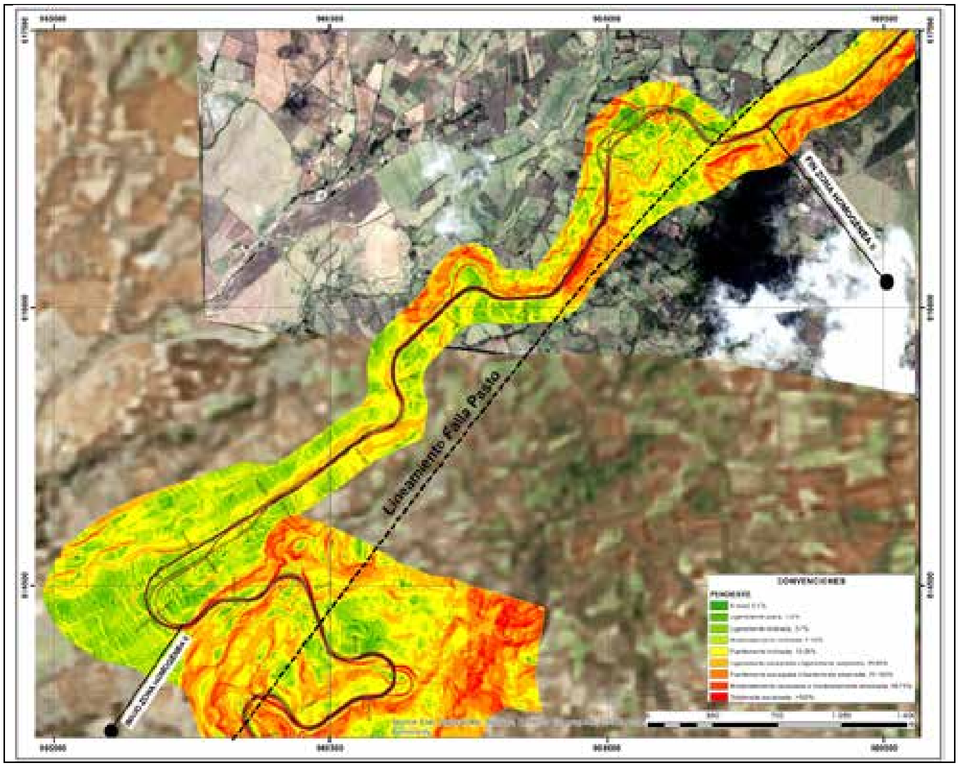


Figure 5.1.8 Slopes map for the Homogeneous Zone II
Source (INGETEC, 2016)

The slopes in these marked sections vary from moderately inclined (7-12%) to strongly sheer (75-100%), the flatest areas correspond to the Ash Rain (Qvc) unit and the larger ones tothe lahars and pyroclasts (TQvlp) and lavas and ashes (TQvlc) which are in lesser exposure. They are described according to the field journey, their lithology and explanation of the current phenomenon or process.

PD 4-09

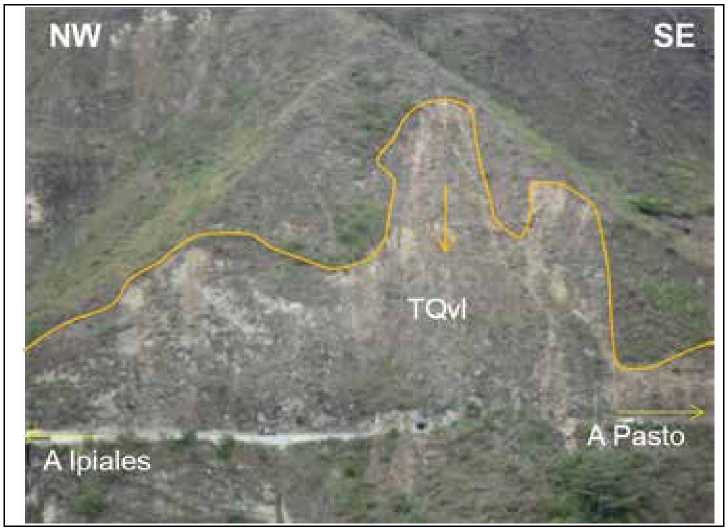
It is located at coordinates E 958618; N 608566; 1746msnm, abscissa K2+800 on the talus of the current road. The landslide process is generated by detritus flows, in the Lavas unit (TQvl) tuffs (Photograph 5.1.24). The talus has an approximate slope of 80 °. This process was identified on the talus on the left side of the current road. It should be taken into account that the projected road alignment for the expansion does not intervene this talus.

Photography5.1.24 Detritus flow in TQvl at the height of K2+800

Source: (INGETEC, 2016)

P D4-10

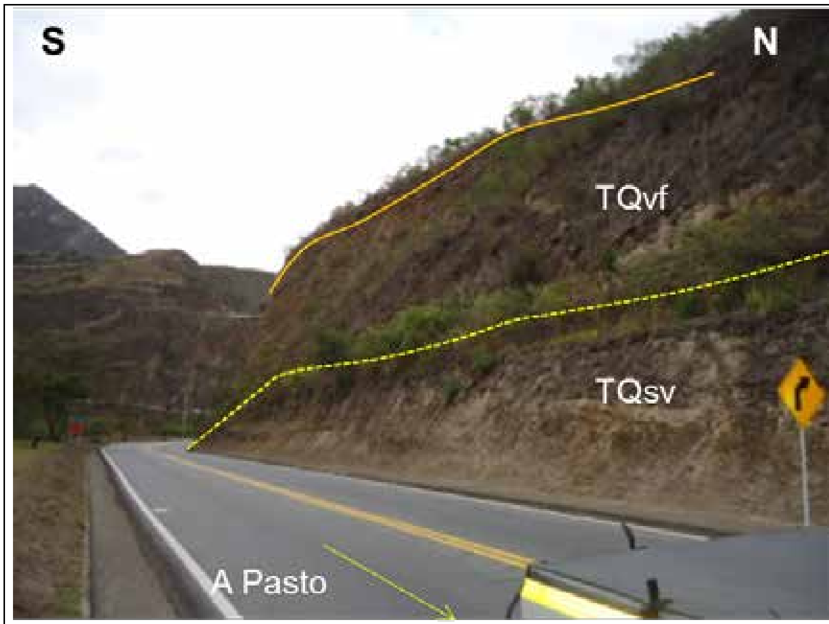
Located at coordinates E 958847; N, 608533; 1747msnm, abscissa K2+960 in the talus of the current road, which presents superficial erosion in the Lavas unit (TQvl) (Photography 5.1.25). The expansion of the projected road will not intervene this talus.



Photography5.1.25 Surface erosion in rocks of the TQvl unit in K2+960
Source: (INGETEC, 2016)

PD4-11

Located at coordinates E 959015; N 608545; 1758msnm, abscissa K3+040 on the talus of the current road. The landslide process is generated by superficial and slight erosion with the presence of furrows in the unit of ash and pumice flows (TQvf). The lower talus is in rocks of the Sedimentary Volcanic Complex of La Magdalena (TQsv) which only presents surface erosion (Photograph 5.1.26).



Photography5.1.26 Surface erosion and slight erosion with presence of furrows in the talus of K3+040

Source: (INGETEC, 2016)

PD4-12

It is located at coordinates E 959210; N 608447; 1775msnm, abscissa K3+100 in the talus of the current road, presents superficial and slight erosion with presence of furrows in the unit composed of siltstones, arcillolites and finely laminated diatomites corresponding to La Magdalena Volcanic Sedimentary Unit (TQsv)Potography 5.1.27).

Photography5.1.27 Surface and slight erosion with presence of furrows in the TQsv unit in K3+100

Source: (INGETEC, 2016)

PD 5-10

In the right talus of the current road, on K21+480, coordinates 967.080E and 615982N, a rotational slide is observed in the ashes of the Lahars and Pyroclasts (TQvlp) unit. The slide is very punctual and the talus of its surroundings presents stability (Photography 5.1.24).

Photography5.1.28 TQvlp unit with denudative processes.
Source (INGETEC, 2016)

PD 5-11

In the Lahars and pyroclastic unit near K21+480, coordinates 967.143E and 616072N, erosion was identified in the lahar deposits, which generate the detachment or collapse of materials that collapses due to gravity.

PD 5-12

In the Lahars and pyroclasts unit (TQvlp), K22+050, coordinates 967.596E and 616063N, a fine materials collapse scar was identified which falls with a sudden rotational movement supported at the base, which is deposited at the lower part of the talus.

PD 5-13

In coordinates 967.709E and 616082N, in K22+160, a scar of fine materials collapse corresponding to the Lahars and pyroclasts unit was identified.

PD 5-14

At coordinate 967.826E and 616.226N, on the talus of the road at K22+340, a diffuse erosion of fine materials was observed in the Lavas and Ashes unit (TQvlc) corresponding to ash (upper part of the talus), which is deposited in the lower part (curb area) (Photo 5.1.25).

Photography5.1.29 Talus with erosive processes in the TQvlc unit
Source (INGETEC, 2016)

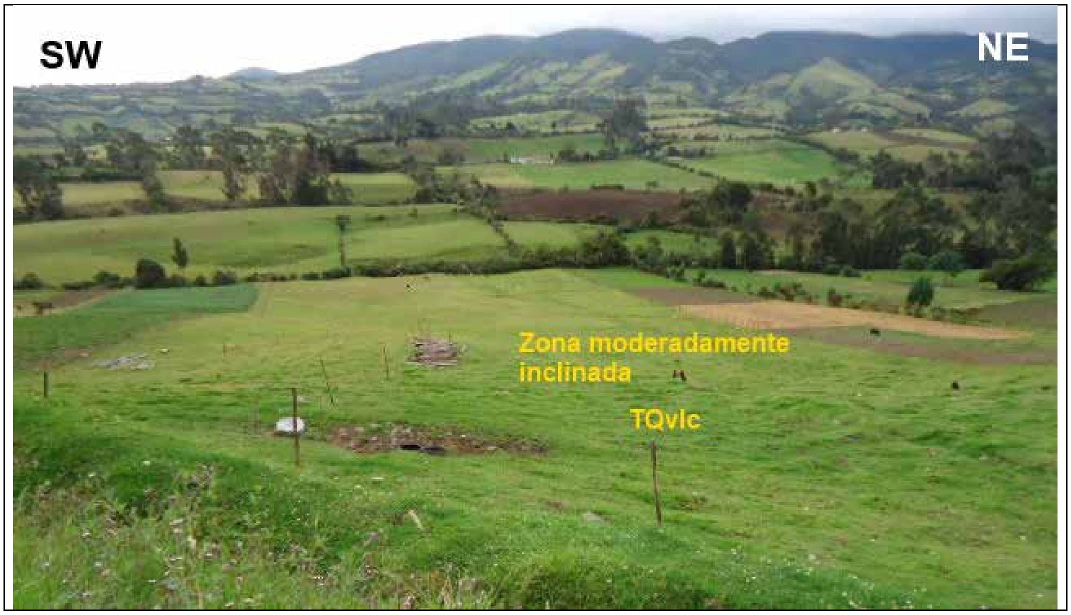
PD 5-15

In the coordinate 968.010E and 616614N the talus of the current road on K22+800 shows erosion in the materials corresponding to laharic flows interspersed with ashes and pyroclastic flows. Due to this erosion, volcanic rock blocks detachments corresponding to pyroclastic materials are taking place (Photography 5.1.26).

Photography5.1.30 Talus with landslide processes.
Source (INGETEC, 2016)

- Homogeneous zone III

The slopes in this area range from moderately inclined (7-12%) in the flatest areas corresponding to the Ash rain (Qvc) unit and moderately inclined (7-12%) to strongly sheer (75-100%) (Figure 5.1.7) in the unit consisting of lavas and ashes (TQvlc) which are in lower exposure (Photography 5.1.27).



Photography5.1.31 Moderately inclined morphology.
Source (INGETEC, 2016)

- Landslides and erosion processes

The Homogeneous Zone III presents landslide processes which are related to the superficial units or layers of unconsolidated pyroclastic deposits. These processes are classified as erosives, falls, landslides or flows.

Eight sectors with instability were observed along the corridor of the Homogeneous Zone. These sectors present instability mostly towards erosion and collapse of materials by gravity, taking into account the materials that are present in the area, mainly volcanic materials mostly ash, pyroclasts and lavas (Local Geological Maps, Scale 1: 5000). They are described according to the field journey, their lithology and explanation of the current phenomenon or process.

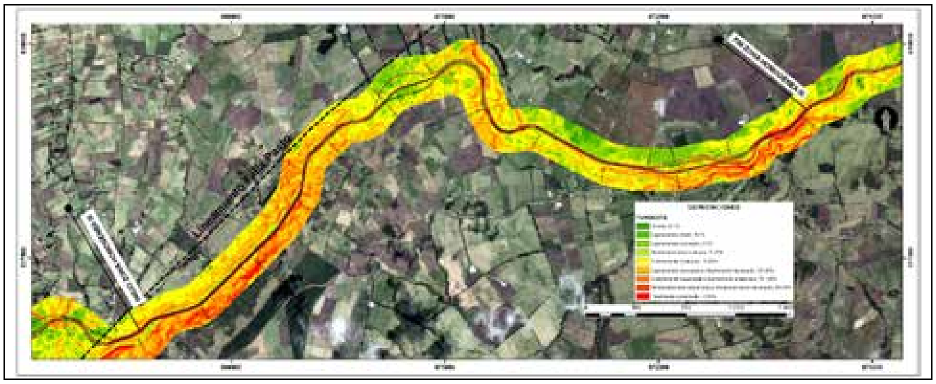


Figure 5.1.9 Slopes map for the Homogeneous Zone III
Source (INGETEC, 2016)

PD 5-16

On the right side of the road that leads to Pasto in K24+140 (968. 902E, 616956N) within the colluvial deposits (Qc) a zone with wavy morphology was observed as presenting surface erosion and terraces (cow's feet).

PD 5-17

On K24+590, coordinates 969. 345E, 617. 227N, alongside the right side of the road (Tangua - Pasto) it was observed that the current talus presents a small sector with erosion on the Lavas and ashes unit, presenting erosion in the ashes (Photography 5.1.28).

Photography5.1.32 Talus on the current road with erosive processes

Source (INGETEC, 2016)

PD 5-18

On the talus of the current road in the coordinates 969. 516E, 617. 400N, at the height of K24+60 of the new road layout it was observed erosion processes in the Lavas and ashes (TQvlc) unit, which do not generate risks of instability in the area.

PD 5-19

In the current path in the coordinates 969. 682E, 617. 562N, at the height of K25+455 of the new road layout, we identified a scar from an old collapse of material from the Lavas and ashes (TQvlc) unit, where the fine materials corresponding to ashes due to their consistency are susceptible to weathering and to present this type of gravitational processes (Photography 5.1.29).

Photography5.1.33 Talus of the current road with collapse of fine material scar from the TQvlc unit.

Source (INGETEC, 2016)

PD 5-20

At the coordinates 970. 335E and 618. 458N, located on the K26+235 of the new road alignment, we identified erosive processes on both sides of the road in the rain of ashes (Qvc) unit, which are mild and do not present greater instability that may affect the road (Photography 5.1.30).

PD 5-21

In the sector of the road that corresponds to K27+340 of the new road alignment, in coordinates 971. 267E and 618. 762E, a small falloff of ash was detected in the talus of the current road, from the Ash Rain (Qvc) unit.

Photography5.1.34 Current road talus with erosive processes.
Source (INGETEC, 2016)

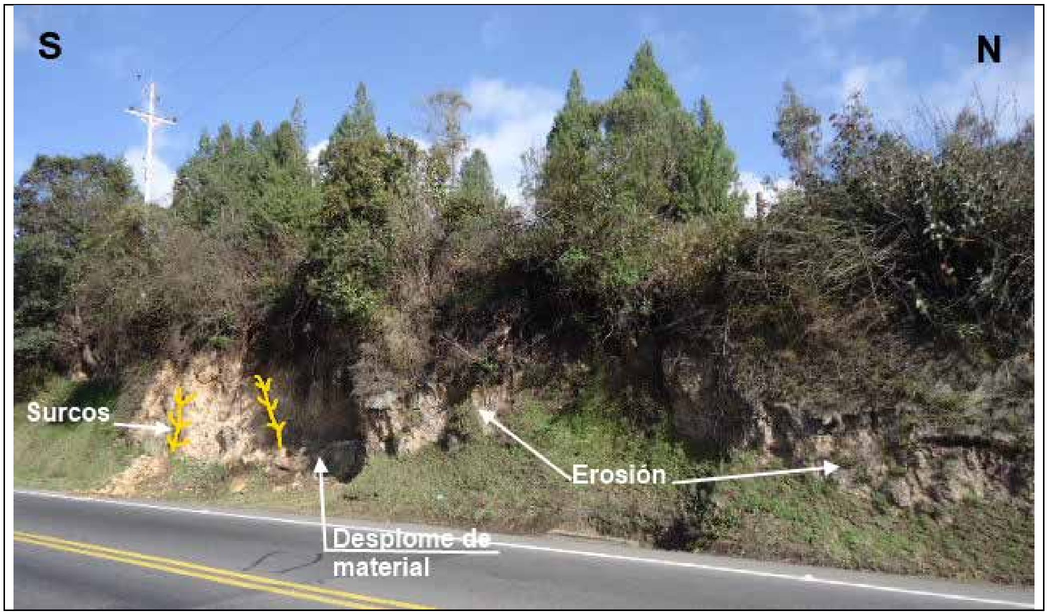
PD 5-22

On the current road alignment, where the right lane for the Pedregal - Catambuco is being projected, at the K29+240 of the new layout, was identified erosive and collapse of pyroclastic material in the talus, which respond to the response of high precipitation, seismic events or human intervention. Formation of small furrows and collapse of material fines that correspond to ashes which may contain fragments of volcanic rocks are observed.

You can see that in general the area is stable without major magnitude processes that may affect the new road (photography 5.1.31).

PD 5-23

On the talus of the current road, in coordinate 973. 518E and 618495N, projected to the K30+010 of the new road, erosive and gravitational processes were identified. These processes are considered minor according to the current conditions of the terrain and the involved materials. Slight erosion and small material collapses are observed.



Photography5.1.35 Road talus showing furrows and material collapse.
Source (INGETEC, 2016)

- Homogeneous zone IV

in the Homogeneous Zone IV the morphological contrast where slope changes are identifiable can be observed. In the sector K30+030 to K32+700 there are generalized strongly inclined slopes in the area and in the talus cuts and the riverbeds and creeks moderately sheer or moderately steep (50-75%) (Figure 5.1.8).

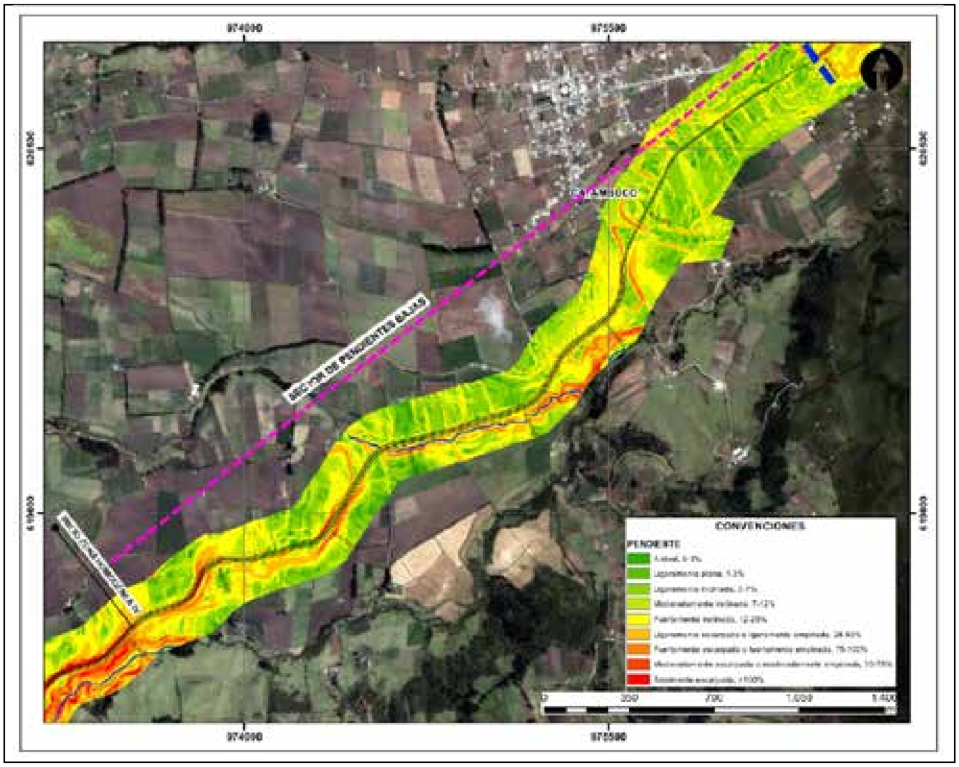


Figure 5.1.10 Slopes map for the homogeneous zone IV, sector of low slopes.
Source (INGETEC, 2016)

- Landslides and erosion processes

The Homogeneous Zone IV presents landslide processes which are related to the superficial units or layers of unconsolidated pyroclastic deposits. These processes are classified as erosives, falls, landslides or flows.

Six sectors with instability were observed along the corridor of the Homogeneous Zone. These sectors present instability mostly towards erosion and collapse of materials by gravity, taking into account the materials that are present in the area, mainly volcanic materials mostly ash, pyroclasts and lavas (Local Geological Maps, Scale 1: 5000).

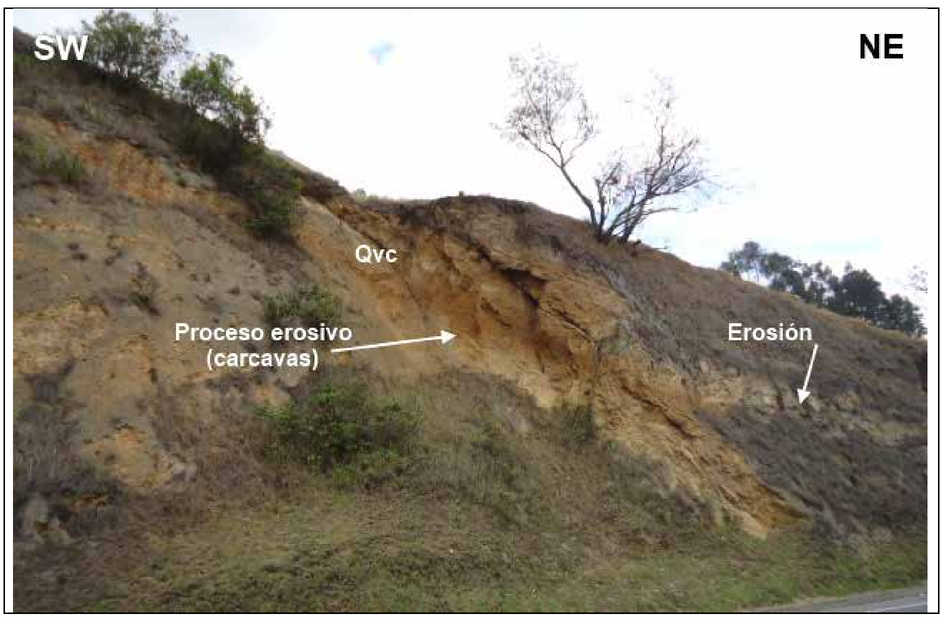
They are described according to the field journey, their lithology and explanation of the current phenomenon or process.

PD 5-24

On the talus of the current path in the coordinate 973.779E and 618638N, projected to K30+335 of the new road, gravitational and erosive processes in the ash flows and pumice (TQvf) unit were identified. These processes are considered minor according to the current conditions of the terrain and the involved materials. A slight erosion and small blocks falls are observed.

PD 5-25

in the rehabilitation zone an erosion process was identified in the current talus of the road, where there is a wide gully due to erosion, furthermore, there is diffuse erosion in the rest of the talus, which implies a protection to it in order to prevent the advancement of the process (Photography 5.1.32).



Photography5.1.36 Talus in the current road presenting gully erosion.
Source (INGETEC, 2016)

5.1.1. Landscape

For the identification process and/or evaluation of the area of intervention of the project's landscape it is important to remember that the European Landscape Convention understands or perceives this component as any part of the territory as perceived by its population, whose character is the result of the action and interaction of natural and/or human factors; that is why it is both a physical reality and at the same time the representation that we culturally make of it, being very substantial the individual and social perception that this generates.

therefore, with this assessment and/or study we're not only seeking the identification of the scenic values of the landscape units with which the project interacts, but also as another instrument for the protection, ordering and management of the same, as well as of the other components or aspects required by the standard. The realization of this assessment and/or evaluation of the landscape units that demand the project is within a line or object of establishing some principles, strategies and guidelines so that together with the other studies that encompass the whole EIA, the measures of cataloguing, valuation and protection within the framework of the standard are adopted.

For this process in the area of influence of the project we recognize and take into account the physiographic and/or geomorphologic components, the perception of landscape as required and contemplated in Resolution 751 of 2015, but at the same time complemented with physical-biotic analysis.

In order to determine the landscape in the area of influence of the project, we took into account the geomorphologic aspects, the visual quality of the landscape and the perception of the communities on its territory. Hereafter is a graphic display of the physical-biotic influence area, defined from the interaction of the abiotic and biotic elements of the territory, on which the characterization of the landscape was made.

in Nariño Department there are three distinguishable physiographic regions corresponding to the Pacific Region, Andean Region and a small part of the Amazon Region. For the Rumichaca Pasto project, the influence area is located in the Andean region or also called the masiff of Los Pastos because of the concentration of the Andes mountain range, where two branches can be distinguished as is the part of the Western Cordillera and the Center - Oriental, where it denotes a high influence of volcanic activity in particular the Galeras volcano and therefore it can be defined generally , that the landscape corresponds to a hilly undulating terrain with some mountain areas with high levels of landslides processes due to the abrupt slopes in the landform, as well as different types of valleys affected by runoff, fluvial processes and expansion of the agricultural frontiers.

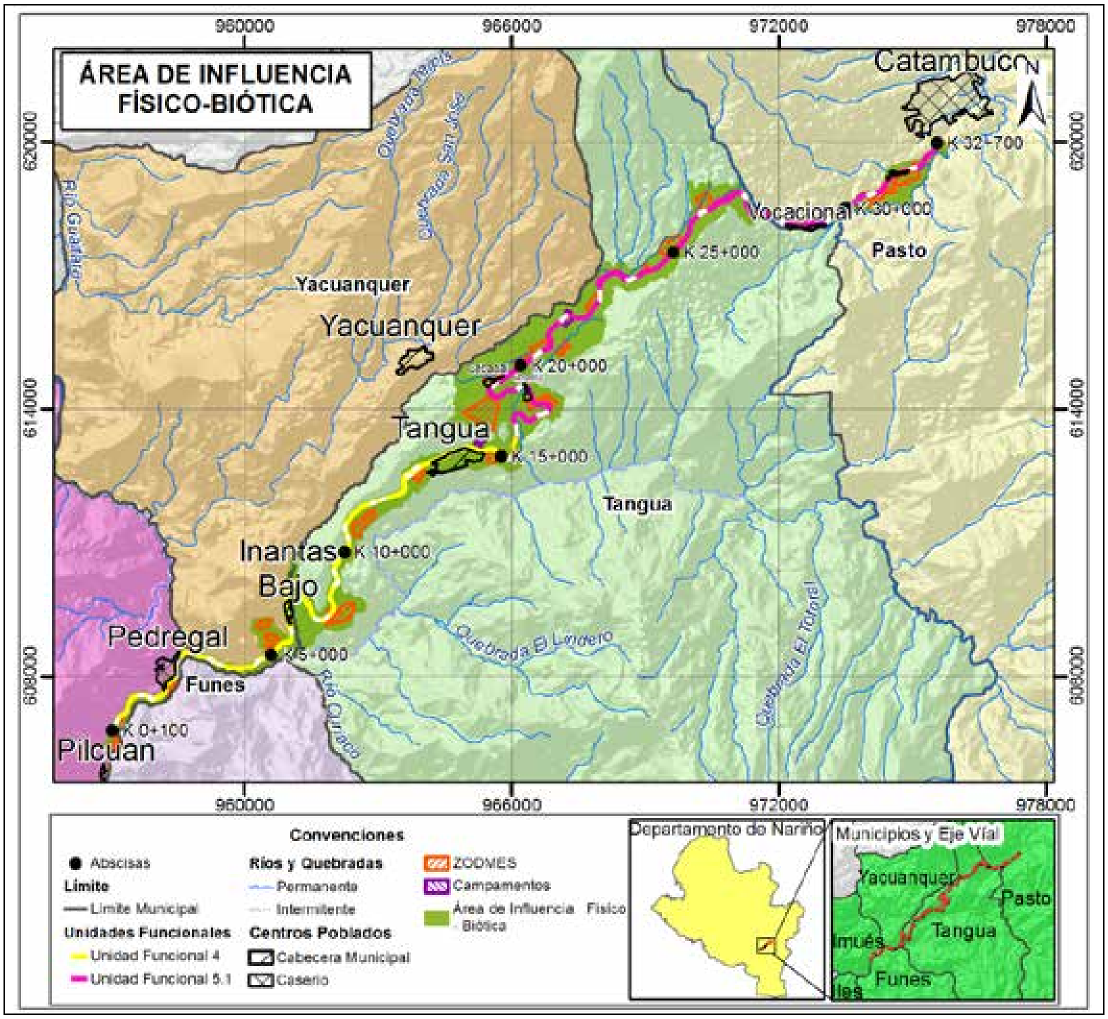


Figure 5.1.11 Area of physical biotic influence defined for the Pedregal - Catambuco section

Source Google Earth adapted by Gemini environmental consultants

5.1.2.1. Morphologic characteristics of the landscape

The types of landscapes present in the study area are quite varied implying that they were generated by different volcanic, denudational, fluvial and even anthropic types morphogenetic processes, the structural control is not very relevant since there were no forms generated by structural processes.

The volcanic activity has been a main factor in the geomorphologic aspect of the study area because the lava , lahars and ash falls molded the preexisting hills and mountains. This volcanic landscape was in turn modified by fluvial, denudational and finally anthropic activity that altered the aspect of this net volcanic landform and added some more.

The dissection of the landscapes by exogenous processes is manifested via water and gravitational erosion processes or a combination of the two. Under dry weather conditions, the erosive forms related to soil loss and dissection generate erosion phenomena of a laminar shape, furrows and gullies, i.e. barren wastelands. On the other hand, wet conditions favor the weathering of the subsoil and gravitational movements with their landslides and soil and debris flows. Undoubtedly, the two processes interact to produce an endless number of combinations. Even so, the water erosion processes and landslides are the two dominant sub-ambients of the Denudational Environment. These processes are those which would be taking place in the study area generating this type of landscapes. As you can see in the schematic profile that is similar to the study area.

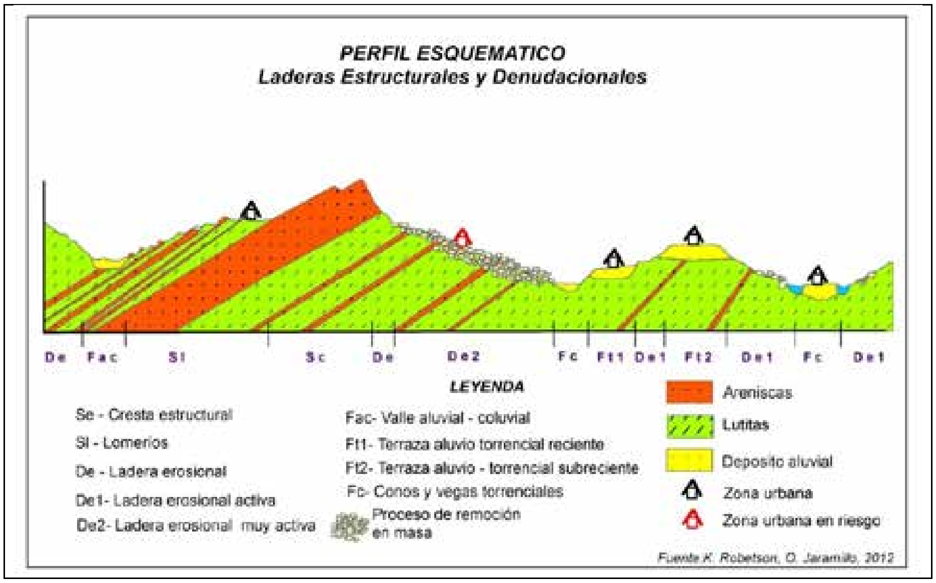


Figure 5.1.12 Schematic profile with denudational slopes and structural mountains, as well as other types of units.

Source (Robertson, 2013)

According to the field observations supported by satellite images, there are three types of landscape units (UP) for the area of influence of the project, as follows:

- UP 1: Low hills
- UP 2: Mountain
- UP 3: Valley

From formations identified in the landscape, each type of landscape was associated with the coverage in the area of influence of the project Rumicahca - Pasto, Pedregal - Catambuco section, which correspond to agricultural areas, transformed areas, forests, pastures, secondary vegetation, and herbaceous vegetation.

From this interaction 4 types of landscape are identified, distributed in 14 units, which are presented in the following table:

No.	Landscape Unit	Area (ha)
1	Heterogeneous agricultural areas in low hills	956,65
2	Heterogeneous agricultural areas in mountain	315,72
3	Areas transformed in low hills	14,45
4	Areas transformed in mountain	29,51
5	Areas transformed in valley	9,26
6	Urban areas in low hills	39,81
7	Urban areas in mountains	64,54
8	Forests in low hills	44,92
9	Crops in low hills	33,76
10	Pastures in low hills	229,38
11	River in low hills	20,89
12	Herbaceous or shrubby vegetation in low hills	5,54
13	Herbaceous or shrubby vegetation on mountain	159,43
14	Secondary vegetation in low hills	9,74

Source: Geminis Environmental Consultants

Hereafter in Figure 5.1.11 and Figure 5.1.12 we present a cartographic location of the different landscape units identified in the area of influence, as well as the description of these.

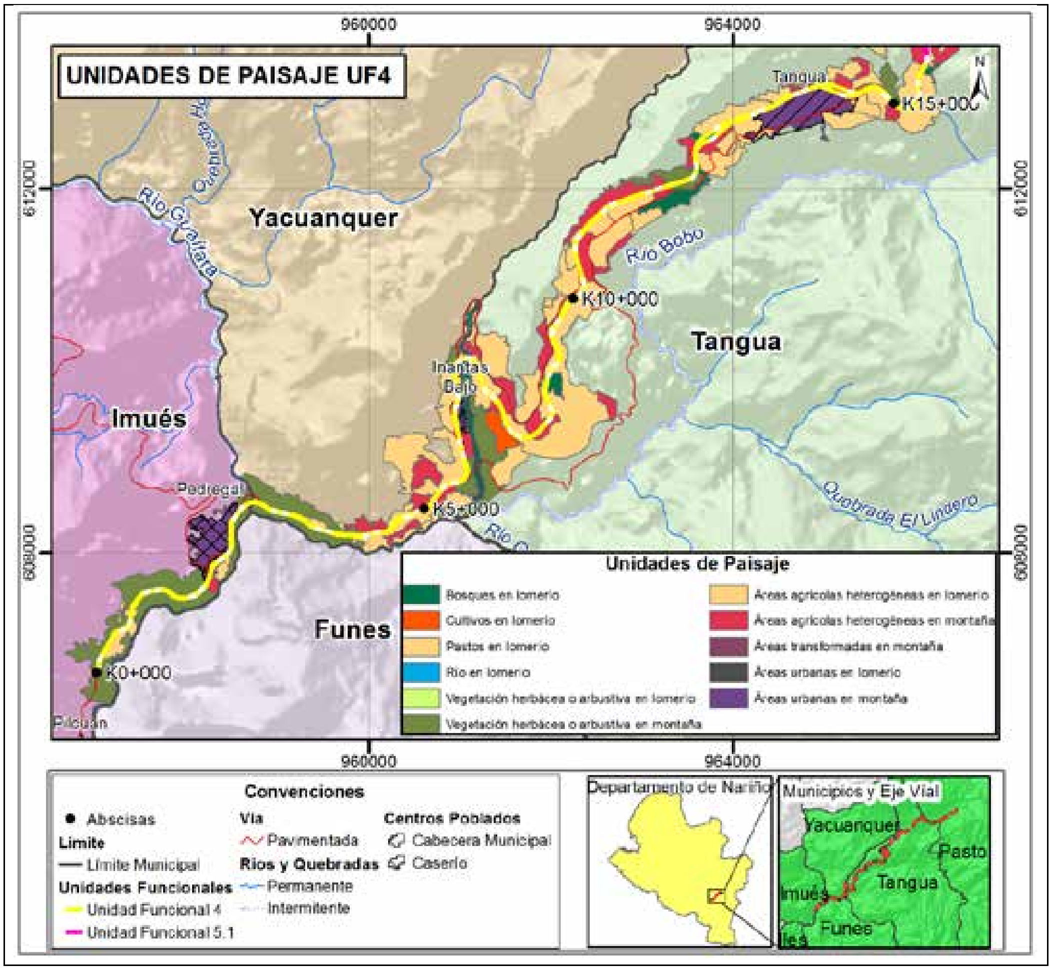


Figure 5.1.13 Landscape units for UF 4

See details in GDB/Cartografía/PDF/ EIADCEDP_TC_008

Source: Geminis Environmental Consultants, 2016

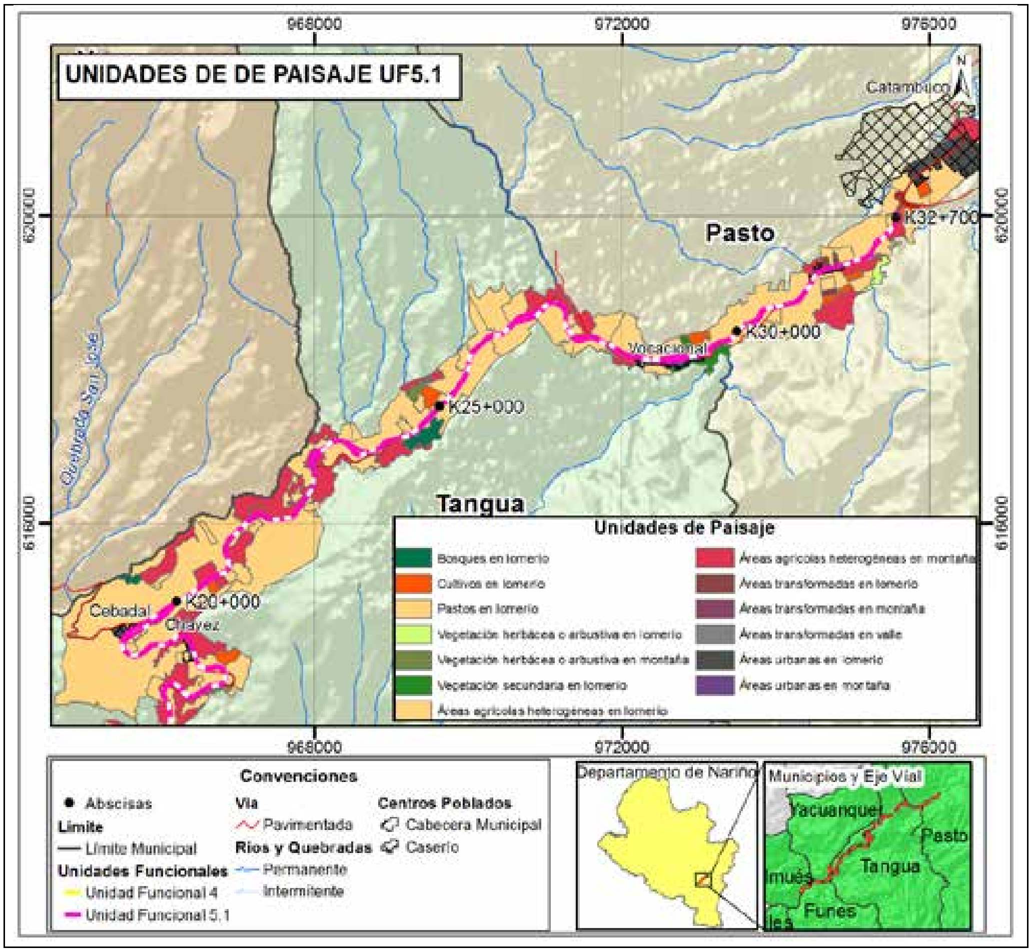


Figure 5.1.14 Landscape units for the UF 5.1

See details in GDB/Cartografía/PDF/ EIADCEDP_TC_00**8**

Source: Geminis Environmental Consultants, 2016

- *UP 1: Low hills*

The landscape of the low hills groups landforms of pyroclastic mantles hills and pyroclastic deposits hills, therefore it comprises a large part of the area of influence of the project, the topography is undulating to slightly steep with convex and short slopes, they present a dissection from low to moderate with a dendritic pattern.

The low hills are affected by landslides and laminar type water erosion processes , in some areas there's little vegetation top coat which causes a high impact both in the landscape and in stability. This type of landscape area of influence represents 70% of the territory and is associated with the following units:

- Heterogeneous agricultural areas in low hills
- Areas transformed into low hills
- Urban areas in low hills
- Crops in low hills
- Pastures in low hills
- River in low hills
- Herbaceous or shrubby vegetation in low hills
- Secondary vegetation in low hills

Of the above units, teh one with greater representativity in the influence area corresponds to the heterogeneous agricultural areas, which is predominant due to the degree of intervention in the territory associated with agricultural and livestock activities that determine the economic dynamics in the municipalities that comprise the project. Within these areas the spaces with forest vegetation correspond mainly to hedgerows of introduced species which divided the land into parcels of relatively small sizes (which at a cultural level gives a connotation to the region of "patchwork carpet", which it is). In the next phtography you can see the presence of low hills in the area of influence of the project.

Photography5.137 Low hills landscape - heterogeneous agricultural Areas in low hills (UP1)
Flat Coordinate N 618128,4274 - Y 972332,0131
Magna Sirga Origin origin West
Source: Geminis Environmental Consultants, 2016

- *UP 2: Valley*

The valley landscape can be seen all throuhout the entire Guáitara river, forming slopes that vary from low to steep in some sectors. The high runoff and hydric erosion activities causes dissection in the landscape which can be very deep in some areas generating material transport and falling rocks. This landscape is very rare in the area of influence, occupying less than 1% of the territory and is associated to transformed areas, in the municipality of Tangua, municipal rural settlement of Cebadal.

- *UP 3: Mountain*

this landscape is characterized by its abrupt slopes generated via different denudatinal processes that were shaping these structures over time. These denudational processes took place over rocks (lava deposits and pyroclastic rocks) but even so since the high slopes are prone to falling rocks and material transport.

in the area of influence of mountain areas the main event is heterogeneous agricultural areas, with a predominance of livestock vocation areas. This type of landscape represents approximately 30% of the influence area and is associated with the following units:

- Heterogeneous agricultural areas in mountain
- Areas transformed in mountain
- Urban areas in mountains
- Herbaceous or shrubby vegetation on mountain

Due to the steep slopes in the mountain landscape, the agricultural activities are less with regards to the low hills landscape, however it is frequent to find presence of zones with livestock activity. In areas of greter slope the dominant areas are those of herbaceous vegetation, which represent the greatest coverage within the mountain landscapes. Photography 5.1.26 presents an area of mountain landscape associated with the area of influence of the road corridor, with slopes exceeding 30%, covered by pasture vegetation.

Photography5.138 Mountain landscape - herbaceous or shrubby vegetation on mountain (UP3)

Flat Coordinate N 613702,413 - Y 966345,127

Magna Sirga Origin origin West

Source: Geminis Environmental Consultants, 2016

5.1.2.2. Visual quality of the landscape

the characteristic vegetation in the area of influence of the project Rumichaca - Pasto, Pedregal - Catambuco section is dominated by mosaics pastures and crops such as potatoes and corn due to the smallholding and microholding allotment level, characteristic of the area. Within these areas the natural spaces are reduced, there are frequent relicts of eucalyptus plantations that have been abandoned and upon which there is no technical management. As mentioned above the dominant landscape corresponds to mountainous areas of low hills, followed by mountainous territories, associated with coverage of human intervention such as agricultural and livestock areas.

the visual quality is defined as the degree of excellence or merit presented by a certain landscape and is defined on the basis of the analysis and evaluation of its biophysical attributes (including the visual expression of biotic components such as flora and fauna, and physical, such as outline, soil, and water), aesthetic (include the expression of the aesthetic traits perceived visually, (in terms of shape, color and texture) and structural (includes the expression of the diversity and uniqueness of attributes present and the natural or anthropic condition of the landscape). It should be borne in mind that around the world there are different definitions of quality of the landscape and therefore a variety of methods have been proposed for the evaluation of them. For the evaluation of the landscape in the stretch Pedregal - Catambuco of the road corridor Rumichaca Pasto, the visual quality of the landscape was determined from its attributes, taking as a reference the parameters suggested in the methodology proposed for the determination of the landscape value of the SEIA. (SEIA 2013).

- *Characteristics of the visual attributes*

For their identification characteristics related to the biophysical, structural and aesthetic components, which were obtained asof the field journeys and the defined observation points for all the project and which are cartographically represented in Figure 5.1.13.

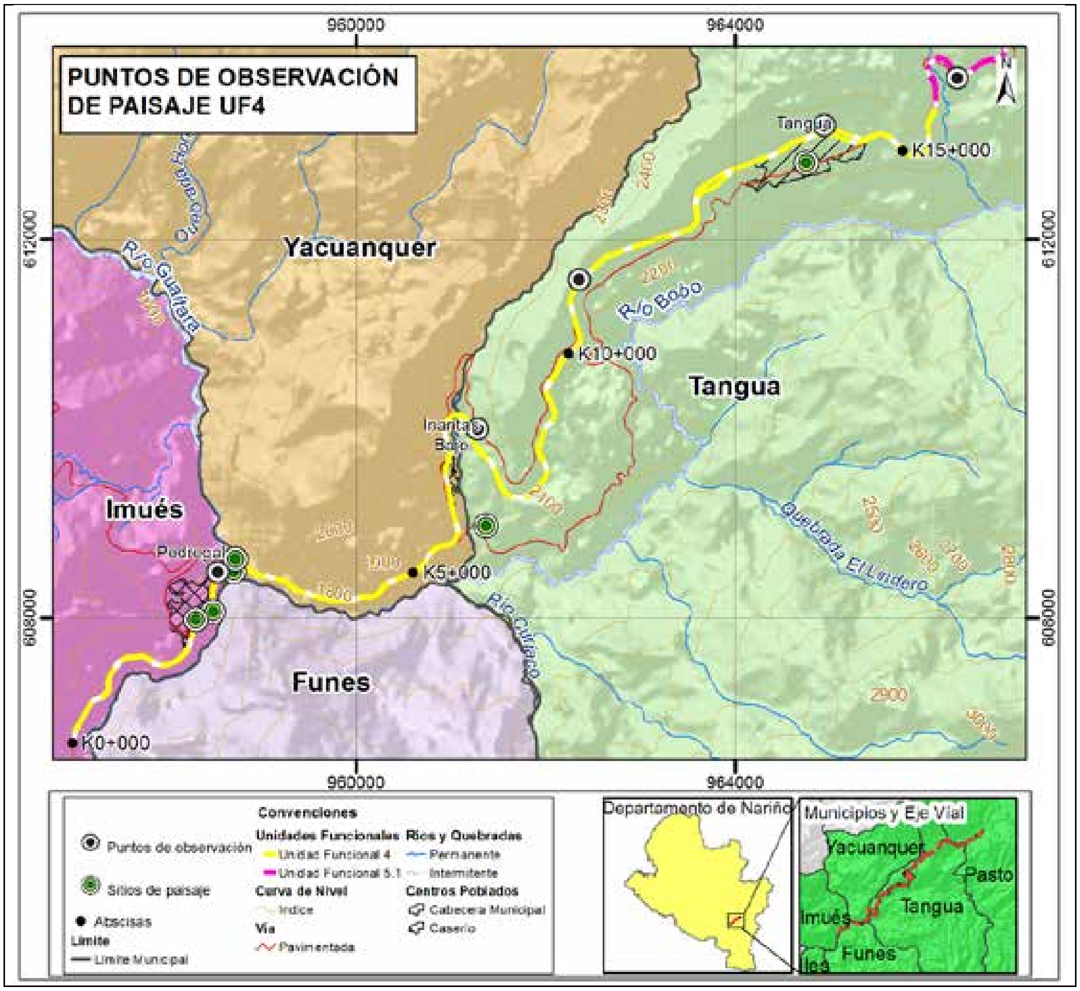


Figure5.1 .15: Location of observation points for landscape (UF5.4)

Source: (Geminis Consultants S.A.S, 2016)

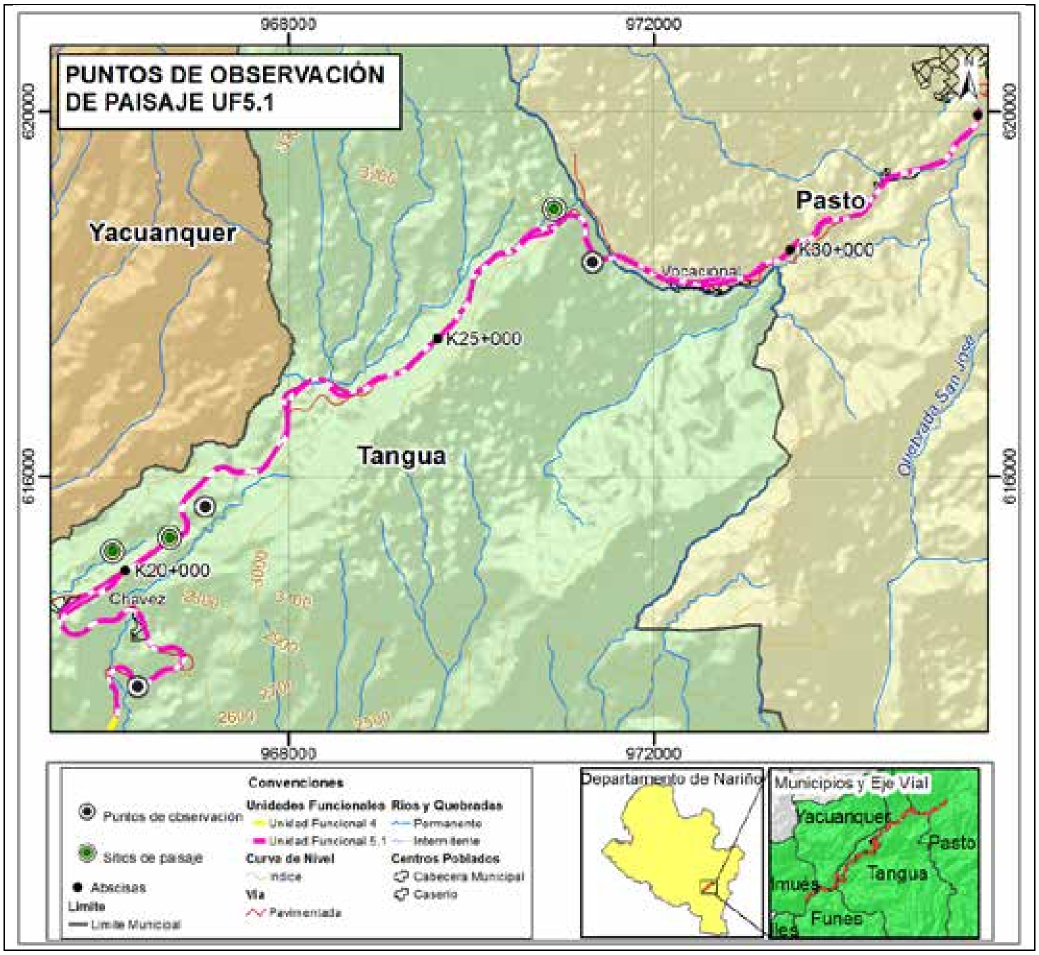


Figure5.1 .16: Location of observation points for landscape (UF5.1)
Source: (Geminis Consultants S.A.S, 2016)

The visual range obtained from the observation points was taken into account for the definition of visual basins. The visual basin may include the intersection of several water basins depending on the scope of the observation points, in the case of the area of influence of the project, the mountainous landscape features from a given point allow for a visual overview of several basins, mainly in the sectors associated with inter-Andean canyons where the modeling of the landscape is the erosion produced by the rivers drainage, in this case, the Guaitara River.

Table 5.1.5 presents the landscape observation points from where the visual basins were identified, as well as the hydrographic basins that comprise eaach point in its visual basin.

Table 5.15 Observation points for Landscap

OBSERVATION POINT	COORD. X	COORD. Y	HYDROGRAPHIC BASINS
PO1	976306	620835,5	Taminango Creek, Af. Miraflores River 02
PO2	975831,5	620517,2	
PO3	975756,1	620437,4	
PO4	971331,2	618351,5	Piquisiqui Creek
PO5	967087,5	615675	El Cebadal Creek
			El Quelal Creek
			Af. Unión Creek 03
PO6	966345,1	613702,4	El Quelal Creek
PO7	964943,9	613203,9	Af. Bobo River 03
PO8	962355,6	611571	Af. Bobo River 03
			Af. Bobo River 02
PO9	961285,6	609994,3	Af. Magdalena Creek 04
			Af. Magdalena Creek 05
PO10	958539,3	608487	Af. MI Guáitara 18
			Af. Bobo River 01

Source: Geminis Environmental Consultants, 2016

Once the observation points were defined, the visual quality for the area of influence was analyzed as of the biophysical, structural and aesthetic attributes of the landscape, the variables that are presented below were analyzed:

table 5.1.6 Variables for analysis of the biophysical attributes of the Landscape

Name	Variable	Values or types
Outline	Type	Valley
		Hill - Low hills
		Rocky Outcrop
		Mountain
		Volcano

Name	Variable	Values or types
	Slope	from 0 to 15
		From 15 to 30%
		More than 30%
	Orientation	Sunny Spot
		Shady Spot

Source: Geminis Environmental Consultants, 2016

Table 5.1.7 Variables for analysis of the structural attributes of the landscape

Name	Variable	Range or type
Landscape diversity	heterogeneity	Low
		Medium
		High
	Singularity	Null
		Low
		Medium
Anthropic Naturalness	Anthropic Quality	Null
		Low
		Medium
		High

Source: Geminis Environmental Consultants, 2016

Table 5.1.8 Variables for analysis of the aesthetic attributes of the landscape

Name	Variable	Range or type
Form	Diversity	Low
		Medium
		High
Color	Diversity	Low
		Medium
		High
	Contrast	Low
		Medium
		Thick
Texture	Grain	Fine
		Medium
		Thick
	Diversity	Low

Name	Variable	Range or type
		Medium
		High

Source: Geminis Environmental Consultants, 2016

As of the observation points and the landscape attributes, similar basins were determined by their attributes and were grouped in the following way:

- Landscape Set 1. Mountains dominated landscape

It is comprised by the visual basins of 6 observation points: PO5 PO6 PO7, PO8, PO9 and PO10. THe sector is predominant in mountain formations with diverse coverages in mosaic and with formations and low level faunal presence, natural vegetation is reduced, mainly associated with water bodies.

Name	Type of attribute and Characteristic that gives value
Outline	Type: It is mountainous, with small areas of rocky outcrops.
	Slope: More than 30%
	orientation: Shady as a result of the mountainous formations that make it up
Soil	Medium roughness – Due to the terrain slopes which generate affectations to the air currents, decreasing their speeds.
Water	Type: River, including the main water body that is part of the project: The Guáitara river.
	Bank: In it you can appreciate a riparian zone from minimal to null, because of the river's canyon and therefore the presence of vegetation is scarce.
	Movement: It is fast, with falling or waterfalls.
	Abundance: It presents a high abundance of water bodies..
	Quality: With presence of turbidity due to landslides caused by runoff waters due to the little or no vegetation in the riparian zone, as well as by effect of the agricultural activities carried out in the middle and upper basins.
Vegetation	Coverage: Because of the naturalness and the anthropic intervention, it can be evaluated as null, but considering that the anthropic intervention is associated with agricultural and livestock production keeping vegetable layers of crops and pastures, we can then consider a coverage level above 70%
	Temporality:It is permanent, given the fact that the area of influence is found in the tropical region and does not experience any seasonal changes that may cause changes in the vegetation type.
	Diversity: It is medium, because the outline and climatological variables do not favor it and some sectors are being intervened with crops.

Name	Type of attribute and Characteristic that gives value
	Layer: Most of the vegetation is characterized by being arboreal type with presence of some shrubby species mainly as part of the early succession process.
	Foliage: It is perennial, but there are also some deciduous species and therefore it is determined as with a slight tendency to mixed.
Fauna	Presence: Since these are relatively little intervened areas given the topographic conditions, it is determined as a trend from medium to high.
	Diversity: its trend is medium
Snow	Coverage: NOT APPLICABLE
	Seasons: NOT APPLICABLE

Source: Geminis Environmental Consultants, 2016

Name	Type of attribute and Characteristic that gives value
Landscape diversity	heterogeneity: Since this is an area with a variety of biophysical attributes and easy recognition and identification, it demarks the landscape as having a high heterogeneity.
	Singularity: Given its heterogeneity makes it high.
Naturality	Human quality: is evidenced in two ways, the presence of human settlements as well as from agricultural projects, but due to the characteristics of the outline this attribute is determined on a medium value with a tendency to a low value.

Source: Geminis Environmental Consultants, 2016

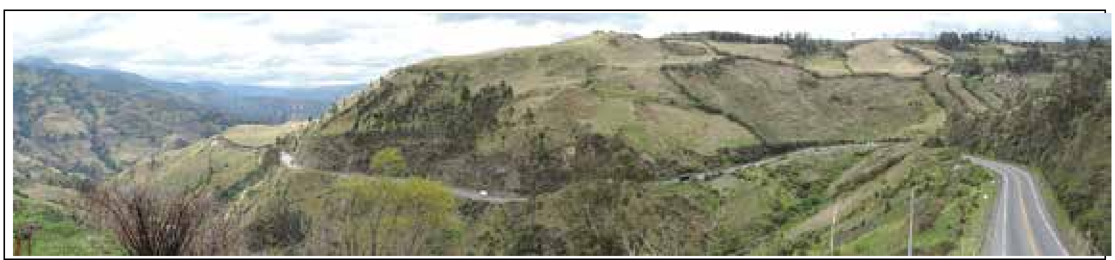
Name	Type of attribute and Characteristic that gives value
Form	Diversity: by the characteristics of the outline is high, since it presents a great scenic variety.
Color	Diversity: It presents a high variability of color shades.
	Contrast: the effect of notable differences between colors and shades is high.
Texture:	Grain: Fine (determined by dispersed elements, or grouped in mozaic zones and herbaceous vegetation, heterogeneously present due to the terrain's topographic variations)
	Diversity: Low (the presence of elements that define the texture of the landscape are homogeneous in the evaluation section)

Source: Geminis Environmental Consultants, 2016

Herafter are the panoramic images taken in the observation points, which allowed in field to assess the quality of the landscape:

Photography5.139 Landscape Set 2, PO 9
Flat Coordinate N 609994,3 - Y 961285,6
Magna Sirga Origin origin West
Source: Geminis Environmental Consultants, 2016

Photography5.140 Landscape Set 2 - PO 7
Flat Coordinate N 613203,88 - Y 964943,87
Magna Sirga Origin origin West
Source: Geminis Environmental Consultants, 2016



Photography5.141 Landscape Set 1 - PO 6
Flat Coordinate N 613702,41 - Y 966345,12
Magna Sirga Origin origin West
Source: Geminis Environmental Consultants, 2016

- Landscape Set 2. Landscape dominated by Low hills

It is comprised by the visual basins of 4 observation points: PO1, PO2, PO3 AND PO4. There is a predominance in the sector for low hills formations with diverse coverage at the mosaic level. It has herbaceous vegetation in areas of greater slope and dominated by pasture zones in less abrupt slopes, the plant composition is dominated by introduced species and to a lesser extent native, typical of early succession processes.

Name	Type of attribute and Characteristic that gives value
Outline	Type Low hills (dominant) with presence of Valleys
	Slope: between 15% and 30%
	orientation: Dominated by sunny spots due to the outline formations
Soil	Roughness: low – given the not very marked slopes of the terrain, the air currents affectations do not diminish their speeds significantly.
Water	Type: Rivers (due to antropic intervention and weather conditions drains are mostly intermittent, which is reflected in the result of the abundance)
	Bank: With vegetation (elements characteristic of intervened vegetation, with presence of exotic species in some cases and secondary riparian vegetation)
	Movement: Meander
	Abundance: Low
	Quality: Dirty - murky
Vegetation	Coverage: Because of the naturalness and the anthropic intervention,it can be evaluated as null, but taking note that the anthropic intervention is associated with agricultural and livestock production keeping vegetable layers of crops and pastures, we can then consider a coverage level above 70%
	Temporality: it is occasional because of the agricultural activity.
	Diversity: At the coverage level it is presented as a high level of diversity since these are landscapes dominated by mosaics, with different anthropic elements as diverse products crops and pastures. Regarding the vegetation composition, the introduced species are dominant in plantation systems (without technical management) and as part of the livestock system.
	Layer: Most of the vegetation is characterized by being a shrubby type with some herbaceous type plants. .
	Foliage: It is outdated and therefore is determined with a slight tendency to mixed.
Fauna	Presence: The degree of intervention and the topography condition that favors anthropic action, it is determined as a downward trend.
	Diversity: its trend is low.
Snow	Coverage: NOT APPLICABLE

Name	Type of attribute and Characteristic that gives value
	Seasons: NOT APPLICABLE

Source Geminis Environmental Consultants, 2016

Name	Type of attribute and Characteristic that gives value
Landscape diversity	heterogeneity: For being an area with little variety of biophysical attributes it demarcates the landscape as having a medium heterogeneity with a low trend.
	Singularity: For having a heterogeneity with a medium to low trend, it makes its singularity be within the same values.
Naturality	Anthropic quality: there is a clear evidence of two forms, the presence of human settlements as well as from agricultural projects, but given the characteristics of the outline, the areas are heavily intervened with crops, which makes the naturality trend be from low to nil.

Source Geminis Environmental Consultants, 2016

- Aesthetic landscape attributes

Name	Type of attribute and Characteristic that gives value
Form	Diversity: by the characteristics of the outline is medium, since it presents a single scenic trend.
Color	Diversity: It presents a high variability of color shades because of the crops.
	Contrast: the effect of notable differences between colors and shades is high.
Texture	Grain: Thick (determined by elements grouped in zones of mosaics, which generate medium levels of shade over the landscape)
	Diversity: Low (the presence of elements that define the texture of the landscape are homogeneous in the evaluation section)

Source Geminis Environmental Consultants, 2016

Hereafter are the panoramic images taken in the observation points, which allowed in field to assess the quality of the landscape:

Photography5.1.42 Landscape Set 2: PO 3
Flat Coordinate N 615675,0 - Y 967087,4
Magna Sirga Origin origin West
Source: Geminis Environmental Consultants, 2016

Photography5.1.43 Landscape Set 2, PO 4
Coordinate flat N 618351,5 - Y 971331,2
Magna Sirga Origin origin West
Source: Geminis Environmental Consultants, 2016

5.1.3.3. perception of the community on the landscape

in order to identify the perception of the community on the landscape and the most representative sightseeing interest sites in the area, was implemented with the community in the area of socio-economic influence. The workshop was developed with participants from the communities of the area of influence of the municipalities of Tangua, Pasto. Yacuanquer and Imués. Part of the procedure involved the development of a talking map, on which the community identified the sites of sightseeing interest present in their territory.

Photography 5.1.44 Identification of landscape workshop: location of places of scenic interest with community municipality of Yacuanquer
Source: Geminis Environmental Consultants, 2016

Starting from the identification of the sites of sightseeing interest over the talking map an assessment of each site was made in order to determine its representativeness as per the criteria defined in the following table. (See Table 5.1.8)

Table 5.1.3. Criteria for the assessment of sites of sightseeing interest

VARIABLE	Assessment		
	5 to 4	**3 a 2**	5 to 4
Plant cover	Wide variety of types of vegetation, with different shapes and textures, and high density	**Plant cover**	Wide variety of types of vegetation, with different shapes and textures, and high density
Degree of intervention	Free of aesthetically unwanted acts or with modifications that favorably affect the visual quality	**Degree of intervention**	Free of aesthetically unwanted acts or with modifications that favorably affect the visual quality
Water bodies	Dominant factor in the landscape, clean, clear,	**Water bodies**	Dominant factor in the landscape,

VARIABLE	Assessment		
	5 to 4	**3 a 2**	5 to 4
	white waters, rapids and waterfalls, or sheets of water at rest, permanent		clean, clear, white waters, rapids and waterfalls, or sheets of water at rest, permanent
Outline	Very mountainous, prominently marked, either an outline of great superficial variety or very eroded or dune systems or presence of any singular or very dominant traits	**Outline**	Very mountainous, prominently marked, either an outline of great superficial variety or very eroded or dune systems or presence of any singular or very dominant traits
Cultural elements	Presence of culturally significant items or sites of scenic interest	**Cultural elements**	Presence of culturally significant items or sites of scenic interest
Liveness	High variety of elements in harmony, with relative degree of unity, as well as balance and coherence with the scenic background, evoking feelings of curiosity and well-being	**Liveness**	High variety of elements in harmony, with relative degree of unity, as well as balance and coherence with the scenic background, evoking feelings of curiosity and well-being

Source: Adapted from Ecopetrol, 2015

Photography5.1.45 Landscape dentification workshop: assessment of landscape with community, municipality of Imués

Source: (Geminis Environmental Consultants, 2016)

The workshop allowed us to identify with these communities the representative sites of scenic interest, as well as to know their perception of the quality presented at these locations with respect to the assessment criteria defining the landscape.

From the workshop, the communities recognized the following sites of scenic interest with their respective name assigned by them as well as with its distinctive characteristic, as shown in the following tables:

Table 5.1.4: Scenic interest sites for the Municipality of Tangua - Municipal Rural Settlement of Tablón de Obraje

Sites identified		
No.	**Name assigned by the community**	**Site distinctive**
1	Mag Creek	Irrigation
2	Forest	Firewood
3	Coffee cultivation	Sale and self-consumption

Sites identified		
4	Beans cultivation	Sale and self-consumption
5	Peas cultivation	Sale and self-consumption
6	Maize cultivation	Sale and self-consumption
7	Mountains	Cultivate
8	Fruit trees	Sale and self-consumption

Table 5.1.5: Scenic interest sites for the Municipality of Tangua - Municipal Rural Settlement of San Pedro de Obraje

Sites identified		
No.	Name assigned by the community	Site distinctive
1	Forest	Without Distinctive
2	Water source	Without Distinctive
3	River	Without Distinctive

Table 5.1.6: Scenic interest sites for the Municipality of Pasto - Municipal Rural Settlement of San José de Catambuco

No.	Name assigned by the community	Site distinctive
1	Cascade	Irrigation
2	Forest	Firewood
3	Miraflores River	Storage Tank
4	Crops	Potato single crop
C	Home gardens	Sale and self-consumption
6	Mountains	Grass
7	Water source	Self-consumption
8	Hot springs	Private

Table 5.1.7: Scenic interest sites for the Municipality of Pasto - Municipal Rural Settlement of La Merced

No.	Name assigned by the community	Site distinctive
1	Hot springs outcrop	Human consumption
2	Puiquisiqui Creek	Irrigation

No.	Name assigned by the community	Site distinctive
3	High Cubiján creek	Irrigation
4	Planted forest	Particular
c	Mountains	Without Distinctive
6	Vegetable gardens	Human consumption
7	Crops	Potato single crop

The perception of quality of these sites according to the assessment criteria given by the community of each of the places mentioned above and which are reflected in the following charts:

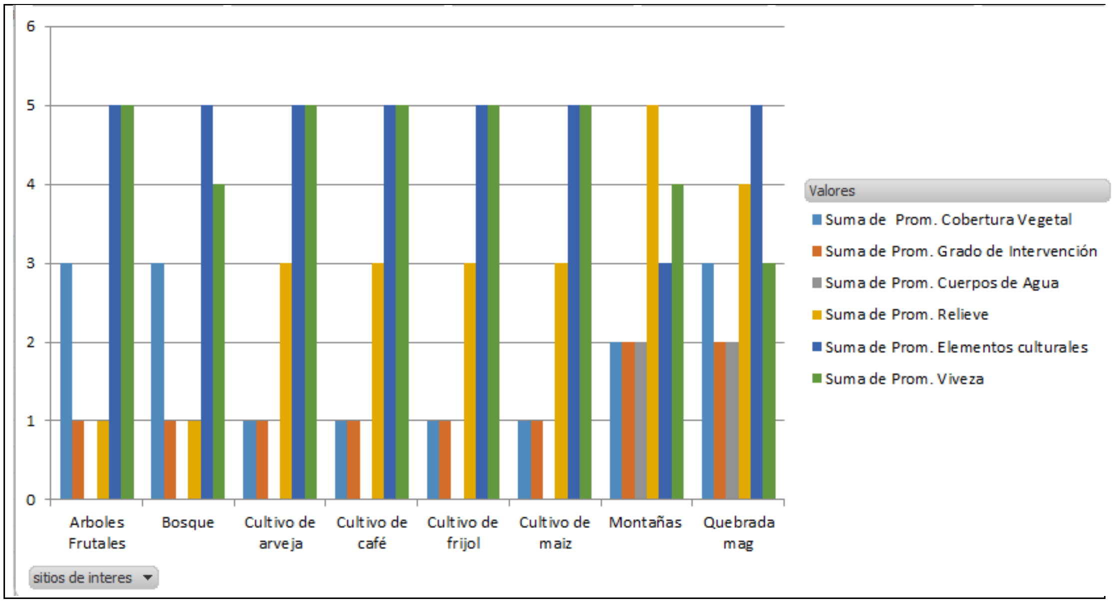


Figure5.1 .17: Matrix Evaluation of Scenery for the Municipality of Tangua - Municipal Rural Settlement Tablón de Obraje

Source: (Geminis Environmental Consultants, 2016)

When analyzing the Figure 5.1.15 itclearly identifies that for the community allocated to each of the sites identified the most representative variable on average was the cultural elements, where the vast majority remained with average of 5, it being the most favorable, which refers to the presence of culturally important elements or interesting scenic sites, being the only variation to this variable on the site called Montañas, which ranked it within the moderately favorable range. Another one of the variables with high average values oscillating between 4 and 5 is the vividness, which means to say these landscaping scenarios have a high variety of elements in harmony, with relative degree of unity, as well as balance and coherence with the scenic background, summoning feelings of curiosity and well-being. But in relation to other variables it is concluded that, from their perceptions, these are not as relevant or important because the scores produced relatively low averages. In this order of ideas, the conclusion on this chart is that the most representative zone from the landscape importance is the Magdalena creek, followed by its mountains.

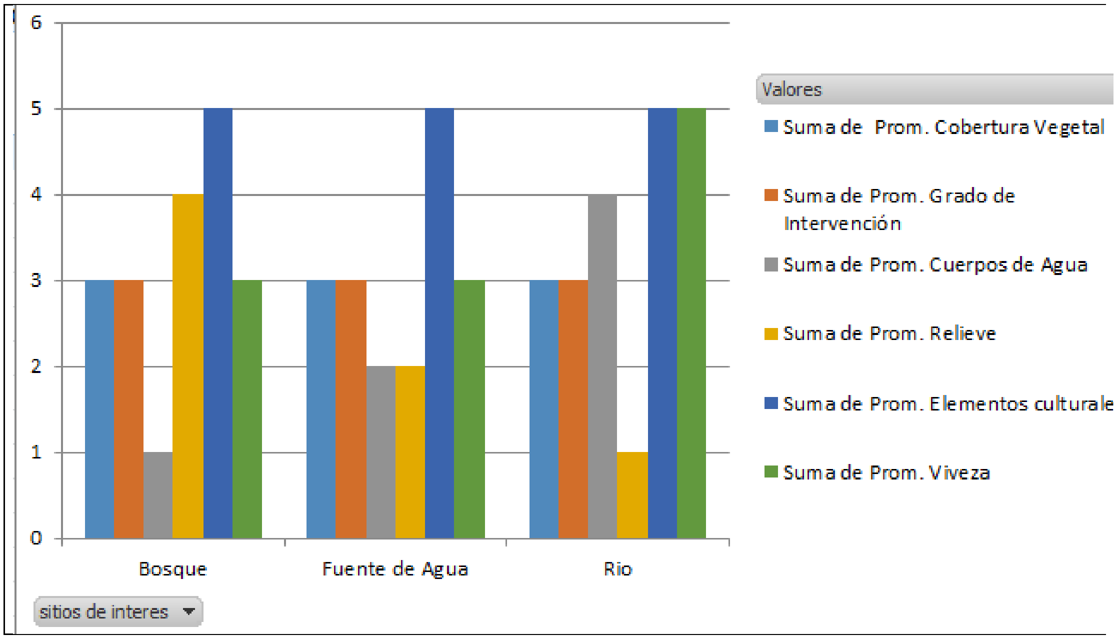


Figure5.1 .18: Matrix Evaluation of Scenery for the Municipality of Tangua - Municipal Rural Settlement of San Pedro de Obraje

Source: (Geminis Environmental Consultants, 2016)

in this graph IT is also perceived that the best valued variable was that of cultural elements in each of the sites identified by the community, i.e., demonstrating that there are a variety of elements in harmony with relative degree of unity, as well as balance and coherence with the scenic background, evoking feelings of curiosity and well-being. But in general terms, each of these sites according to the averages thrown by the values given by the community is or they consider it in a moderately favorable range, since they range from 2 to 3 and the sum of each of the variables averages obtained for each scenario concludes that the most representative is the river.

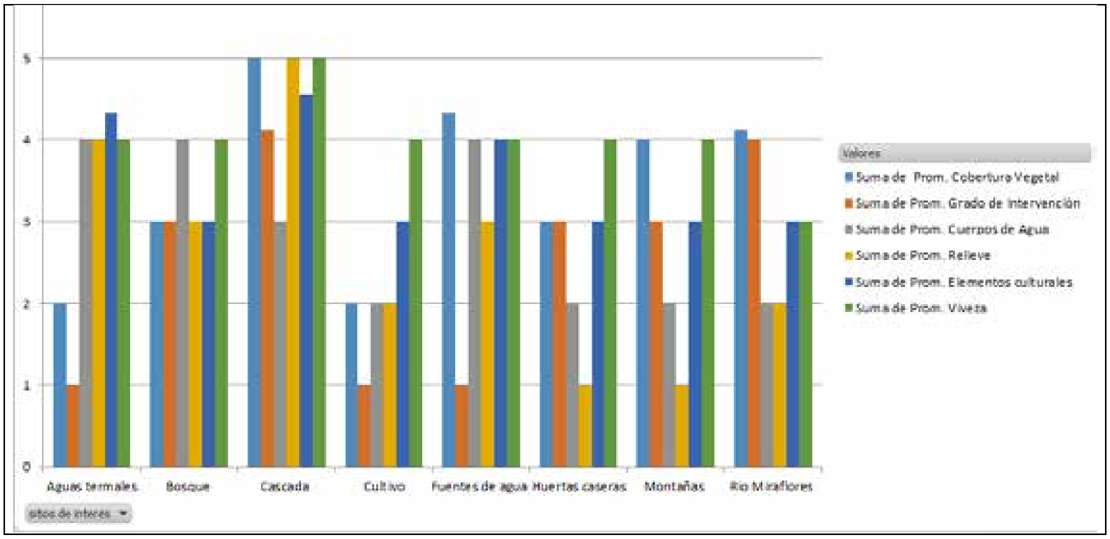


Figure5.1 .19: Matrix Evaluation of Scenery for the Municipality of Pasto - Municipal Rural Settlement of San José de Catambuco

Source: (Geminis Environmental Consultants, 2016)

With respect to these results, the inhabitants of this sector also considered the cultural elements variable as very important or favorable from the landscape perception for each of the sites identified, by the arguments that this summons. Another variable that was within this same denomination was the vividness emanating each of the sites. Finally it is concluded for this chart that the identified sites are by its averages in a trend from medium to most favorable, i.e., ranging from 3 to 5 in average and the best scenically valued is the cascade, followed by its forests and the Miraflores river.

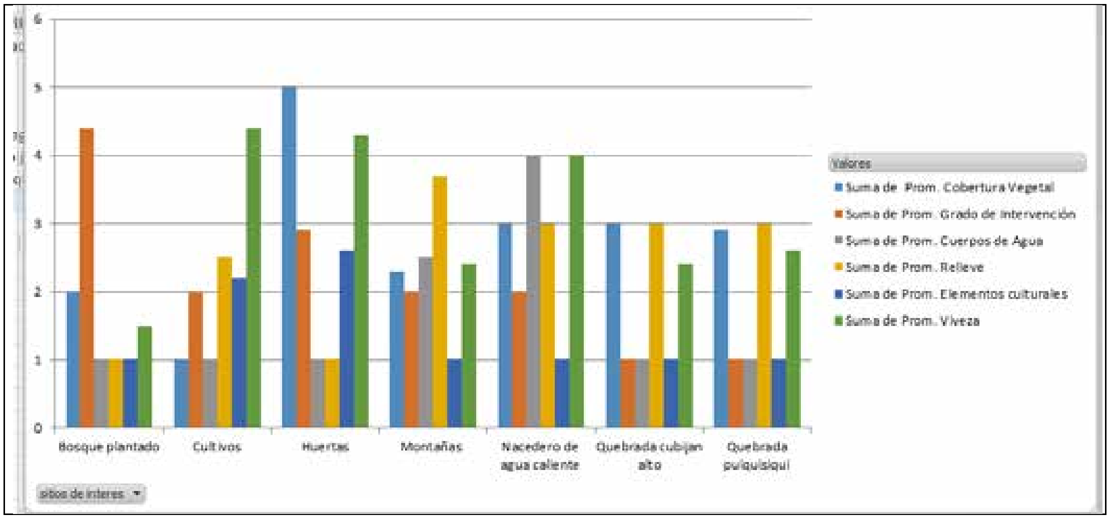


Figure5.1 .20: Matrix Evaluation of Scenery for the Municipality of Pasto - Municipal Rural Settlement of La Merced

Source: (Geminis Consultants S.A.S, 2016)

To finalize with the analysis of these graphs, it is evidenced with the sum of each one of the averages obtained for each variable, that the most important scenic zone, is the springs of hot water followed by the vegetable gardens which houses the visual that is generated by and speaking of variables, the best rating in the sum of all the averages in each of the sites is the vividness, due to the variety of elements though interventions, subdivisions or disorders and an imbalance between elements are observed,, followed by the vegetation cover variable for its variety of one or two types of vegetation

5.1.4. soils and land use

In this chapter we describe the soil component soil from the viewpoint of current use of soil and use conflict identified in the area of influence of the Rumichaca - Pasto divided highway project, Pedregal - Catambuco segment.

The soils study aims to characterize, describe, classify, and make spacial allocations to the landscape through a zoning (functional units) that allows the identification of the potentialities and limitations of the soil.

5.1.4.1. Soils cartographic units

The landscape unit is defined as a portion of the terrain surface that has a homogeneous morphology as a result of anthropic and biological activity. This unit is the fundamental basis for the analysis that allows the identification of the parameters that affect the use of the land.

Likewise, the landscape behaves as an integrated spatial and temporal entity. The study of the landscapes assumes an interdisciplinary approach that allows a real understanding of the soil and the proper formulation of management policies and occupation of the territory.

Equally, the soils study is divided by functional units throughout the road corridor Rumichaca - Pasto Pedregal Catambuco segment. In this study, the place of origin and completion, landscape, parental material, cartographic unit, taxonomy, agrological classification, nomenclature and area of influence are described by functional unit, as described in Table 5.1.13.

Table 5.1.8 Location of functional units

FUNCTIONAL UNIT	PLACE OF ORIGIN	PLACE OF DESTINATION
4	Pedregal 0+000	Tangua 15+750
5	Tangua 15+750	Catambuco 32+700

Source: (Geminis Environmental Consultants, 2016)

The description of the soils cartographic units is presented according to the order of the functional units and area of influence in the Ttable 5.1.14 .

Table 5.1.9 Soils classification

HEAT FLOOR	HUMIDITY PROVINCE	GEOMORPHOLOGY	Association	CARTOGRAPHIC UNIT	TAXONOMIC UNIT	AGROLOGICAL CLASS	AREA (HA)
Temperate	Arid	Low hills	Indifferenciated	ARCf2,g2	Typic Ustorthents 30%, Ashes miscellaneous 30%, Entic Haplustolls 30%, Typic Argiustolls 10%	VIIItc6	208,80

HEAT FLOOR	HUMIDITY PROVINCE	GEOMORPHOLOGY	Association	CARTOGRAPHIC UNIT	TAXONOMIC UNIT	AGROLOGICAL CLASS	AREA (HA)
		Mountain	Indifferenciated	ARCf2,g2	Typic Ustorthents 30%, Ashes miscellaneous 30%, Entic Haplustolls 30%, Typic Argiustolls 10%	VIIItc6	19,98
		Low hills	Consociation	ARBb, c	Typic Haplustolls 50%, Cumulic Haplustolls 35%, Typic Argiustolls 15%	IIIsc6	8,25
		Low hills	Consociation	ARDd2, e2	Entic Haplustolls 90%	VItec6	3,58
		Low hills	Indifferenciated	ARCf2,g2	Typic Ustorthents 30%, Ashes miscellaneous 30%, Entic Haplustolls 30%, Typic Argiustolls 10%	VIIItc6	2,87
Cold	Humid	Mountain	Consociation	MLAb,c,d,e,f,g	Acrudoxic Melanudands 50%, Acrudoxic Hapludands Acrudoxic Placudands 20% 30%	IIIsc3	1,57
		Low hills	Indifferenciated	AMEf2, g2	Typic Haplustepts 30%, Typic Ustorthents 30%, Ash miscellaneous 25%, Vitrandic Dystrudepts 15%	VIIItc4	30,11
		Low hills	Consociation	ALBc	Pachic Melanudands 40%, Typic Hapludands 30%	IIIt3	8,33
		Low hills	Consociation	MLAb,c,d,e,f,g	Acrudoxic Melanudands 50%, Acrudoxic Hapludands Acrudoxic Placudands 20% 30%	IIIsc3	44,81
		Low hills	Consociation	AMBa, b, c	Vitric Haplustands 90%	IIIc4	342,30
		Mountain	Consociation	AMBa,b,c	Vitric Haplustands 90%	IIIc4	1,83
		Low hills	Consociation	ARBb,c	Typic Haplustolls 50%, Cumulic Haplustolls 35%, Typic Argiustolls 15%	IIIsc6	78,86
		Low hills	Consociation	ARDd2, e2	Entic Haplustolls 90%	VItec6	29,67
		Low hills	Indifferenciated	ARCf2,g2	Typic Ustorthents 30%, Ashes miscellaneous 30%, Entic Haplustolls 30%, Typic Argiustolls 10%	VIIItc6	110,75
		Low hills	Association	AMDd, e	Vitrandic Dystrustepts 45%, Typic Haplustalfs 40%	VIIts5	177,37
		Mountain	Association	AMDd, e	Vitrandic Dystrustepts 45%, Typic Haplustalfs 40%	VIIts5	139,34
		Valley	Association	AMDd, e	Vitrandic Dystrustepts 45%, Typic Haplustalfs 40%	VIIts5	9,44
		Low hills	Indifferenciated	AMEf2, g2	Typic Haplustepts 30%, Typic Ustorthents 30%, Ash miscellaneous 25%, Virtrandic Dystrudepts 15%	VIIItc4	127,22
		Mountain	Indifferenciated	MMAf, g	Entic Haplustolls 40%, Humic Dystrustepts 40%	VIItsc4	2,46

HEAT FLOOR	HUMIDITY PROVINCE	GEOMORPHOLOGY	Association	CARTOGRAPHIC UNIT	TAXONOMIC UNIT	AGROLOGICAL CLASS	AREA (HA)
Very cold		Low hills	Consociation	ALBc	Pachic Melanudands 40%, Typic Hapludands 30%	IIIt3	53,17
		Low hills	Consociation	AMBa,b,c	Vitric Haplustands 90%	IIIc4	60,41
		Low hills	Consociation	MLEd, e, e2	Acrudoxic Fulvudands 50%, Typic Fulvudands 30%, Typic Palehumults 20%	IVts3	14,62
		Low hills	Association	AMDd, e	Vitrandic Dystrustepts 45%, Typic Haplustalfs 40%	VIIts5	0,95
		Low hills	Indifferenciated	AMEf2, g2	Typic Haplustepts 30%, Typic Ustorthents 30%, Ash miscellaneous 25%, Virtrandic Dystrudepts 15%	VIIItc4	0,84
		Low hills	Consociation	ALBc	Pachic Melanudands Pachic Fulvudands 30% 50%	IIIt3	207,44
		Low hills	Consociation	MLAb,c,d,e,f,g	Acrudoxic Melanudands 50%, Acrudoxic Hapludands Acrudoxic Placudands 20% 30%	IIIsc3	137,07
		Low hills	Consociation	AMBa, b, c	Vitric Haplustands 90%	IIIc4	18,67
		Low hills	Indifferenciated	AMEf2, g2	Typic Haplustepts 30%, Typic Ustorthents 30%, Ash miscellaneous 25%, Vitrandic Dystrudepts 15%	VIIItc4	18,99

Source: (Geminis Environmental Consultants, 2016)

The description of soils is made according to the order of the legend of the soils map according to types of outlines in every landscape, which are characterized by similar conditions in terms of climate, topography, and parental materials.

Each classification is represented by a symbol that is related in order to landscape, climate and soils. These letters are accompanied by alpha-numeric subscripts that indicate ranges of slope, erosion and rockyness, as shown in the following tables: Table 5.1.15, Table 5.1.16, Table 5.1.17, Table 5.1.18 and Table 5.1.19.

Table 5.1.10 Symbolism of the landscape units

LANDSCAPE	
SYMBOL	DESCRIPTION
M	Mountain
L	Knoll
P	Foothill
R	Plain

LANDSCAPE	
V	Valley

Source Cortolima, 2005.

Table 5.1.11 Symbolism of the climate unit.

CLIMATE	
SYMBOL	DESCRIPTION
E	Extremely cold damp
H	Very cold damp and very damp
L	Cold damp and very damp
M	Dry cold
Q	Medium damp and very damp
R	Medium dry
V	Warm damp and very damp
W	Warm dry

Source: Cortolima, 2005.

Table 5.1.12 Symbolism of the slopes unit

SLOPE	
SYMBOL	DESCRIPTION
a	Slightly flat, 1-3%
b	Slightly inclined, 3-7%
c	Moderately inclined, 7-12%
d	Strongly inclined, 12-25%
f	Moderately steep (50-75%)
g	Strongly sheer (<75%)

Source: Cortolima, 2005.

Table 5.1.13 Symbolism for the erosion unit.

EROSION	
SYMBOL	DESCRIPTION
No Symbol	There is none or it is light
2	Moderate
3	Severe

Source Cortolima, 2005.

Table 5.1.14 Symbolism for the rockyness unit.

ROCKYNESS	
SYMBOL	DESCRIPTION
p	Rock coatings

Source: Cortolima, 2005.

Below is a description for the most representative landscape units including climate information. In the Cartographic units it is worth highlighting the geological material, outline, vegetation, current use, and limitations of use. Finally, the physical and chemical characteristics are commented.

- *Soils of low hills landscape in a dry cold weather - UF4*

Geomorphologically, it cooresponds to low hills, formed by stretched and short hills with different gradients, of a moderately flat and undulating outline. It has broken zones with short slopes and flat transepts with a lowly influent area influence. The soils corresponding to this unit are derived from moderately fine and fine sandstones, shales, siltstones, claystones and limestone rocks; well drained floors, of median texture, strongly acid, pH from 5 to 5,2, low to moderate fertility. High contents of phosphorus unavailable due to the high contents of iron and aluminium. Most are affected by water erosion and landslides from a light to moderate degree. Rockyness levels are severe.

o Consociation - Functional Unit 4

This unit corresponds to a low hills profile with lithology claystones and volcanic tuff, with a moderate slope of 7-12%, a moderately inclined to moderately wavy topography . In this unit you can find homogeneity in the mountainous ondulations, of a slightly flat outline and a moderate level of erosion.
These are soils with transition from dry cold to very damp, medium fertility, acid pH, superficial horizon susceptible to frosts. We recommend an integrated soil resource management and crop rotation to improve its fitness for use, as well as improving the irrigation techniques. The recommended crops are wheat, barley, peas, corn, and pastures. This unit presents a current use in livestock, with improved pastures, sand mines, transitory crops, very superficial effective depth and presence of superficial rock fragments.

These form the soilconsociation Typic Ustropepts 35%, Typic Ustorthents 35% and Entic Haplustolls 30%.

Characteristics of the taxonomic Ustic Dystropepts components: distributed in the middle sectors of the unit; their profile is type A-B-Cr, where the A and B horizons are light-colored (yellowish brown and strong brown) and clayey texture; the Cr horizon is composed of weathered claystones rock. They are well drained; superficial, limited by paralytic contact; very strong to strongly acidic; with low contents of calcium, magnesium, potassium and phosphorus; high saturation of aluminum and low fertility.

characteristics of the taxonomic Typic Ustorthents components: distributed in the low and middle sectors of the slopes; their profile is type A-C, where the A horizon is brown grey dark, with loam texture and abundant content of coarse rock fragments; the sequence of C horizons has very dark grayish brown colors and loam textures and sandy loam, with abundant rock fragments. They are well drained; superficial, limited by rock fragments; moderately alkaline; with a change complex called by calcium and magnesium, high contents of phosphorus and moderate fertility.

Characteristics of the taxonomic Entic Haplustolls components: they are distributed in the low sectors of the unit; their profile is of loam clayey textures, very dark brown grayish color with clear brown yellowish spotting in depth; its nomenclature is A-AC-Cr. They are well drained; superficial, limited by paralytic contact; acid to slightly acid, with a with a change complex called by calcium and low contents of phosphorus; fertility is high.

- *Soils of mountain scenery in a very cold damp and very damp climate - UF5*

formed by dimensions and short hills with different degrees of slope, moderately steep and undulated profile. It has broken zones with short slopes. The corresponding soils are derived from sandstones, shales and volcanic tuffs; they are well drained soils, with thick textures, strongly acid, with high contents of aluminum and iron; It ranges from the 2,600 to 3,200 meters above sea level These soils are affected by water erosion and landslides from a light to moderate degree. They form the soil sssociation Typic Humitropepts 60%, Oxic Dystropepts 20% and Typic Troporthents 20%.

o Miscellaneous area - Functional Unit 5

the landform corresponds to mountain outline, consisting of sedimentary rocks and high content of organic matter due to the height above the sea level which allows the decomposition processes to be slower. This is mixed with fine sediments (clays), the topography is undulating with pronounced breakdowns, with slopes of 7, 12 and 25%, featuring frequent coarse rock fragments on the surface.

This unit presents current use in livestock, unmanaged pastures, with drainage issues in the lowlands, very superficial effective depth, fragments of rock in surface and above all area covered by infrastructures in the Catambuco village and entrance to the city of Pasto, corresponding to the urban area, therefore its agrological classification is U and III.

Characteristics of the taxonomic Typic Humitropepts components: These soils are located in the upper part of the unit, in altitudes greater than 2,300 m.a.s.l. They are characterized by presenting moderate radicular depth, well drained; they are developed from sandstones and shales. The morphology of the profile is type A/B/C. The A horizon is deep (varies between 25 and 50 cm), black loam texture, granular structure; the B horizon is greyish Brown, loam clayey texture, subangular block structure; the C horizon is pale grey with yellowish-brown spottings, clayey texture, massive structure. The reaction is strongly acid, the organic matter content is high in the first horizon and low in the rest of the profile.

characteristics of the taxonomic Oxic Dystropepts components: This soils unit is distributed in the middle and upper sectors of the unit, the nomenclature profile is A/B/C, where the upper horizon is brown, sandy loam texture, resting on a B-C sequence of mixed red and yellow-red colors, With clayey textures, well drained, moderately deep, with low fertility, strongly acidic pH.

Characteristics of the taxonomic Typic Troporthents components: this type of soils occupy the upper part of the unit, are characterized by little genetic development, a thin horizon A, brown color with loamy texture, resting on a horizon C with yellowish brown with loam clayey sandy texture, with fine pebbles, these are well drained, superficial soils, pH 5.3.

5.1.4.2. Current soil use

The study of the current use of soils entails the interaction between the vegetable cover and the different human activities that are carried out on this resource, it is a fundamental element to know the present situation and to evaluate, in time, the transformations that have been happening and which will continue to happen both in natural vegetation as in cultural, a product of the dynamics of land occupation, evolution of the country's productive system, population growth, development policies and strategies and natural global changes, among others. (See Figure 5.1.19 and Figure 5.1.20)

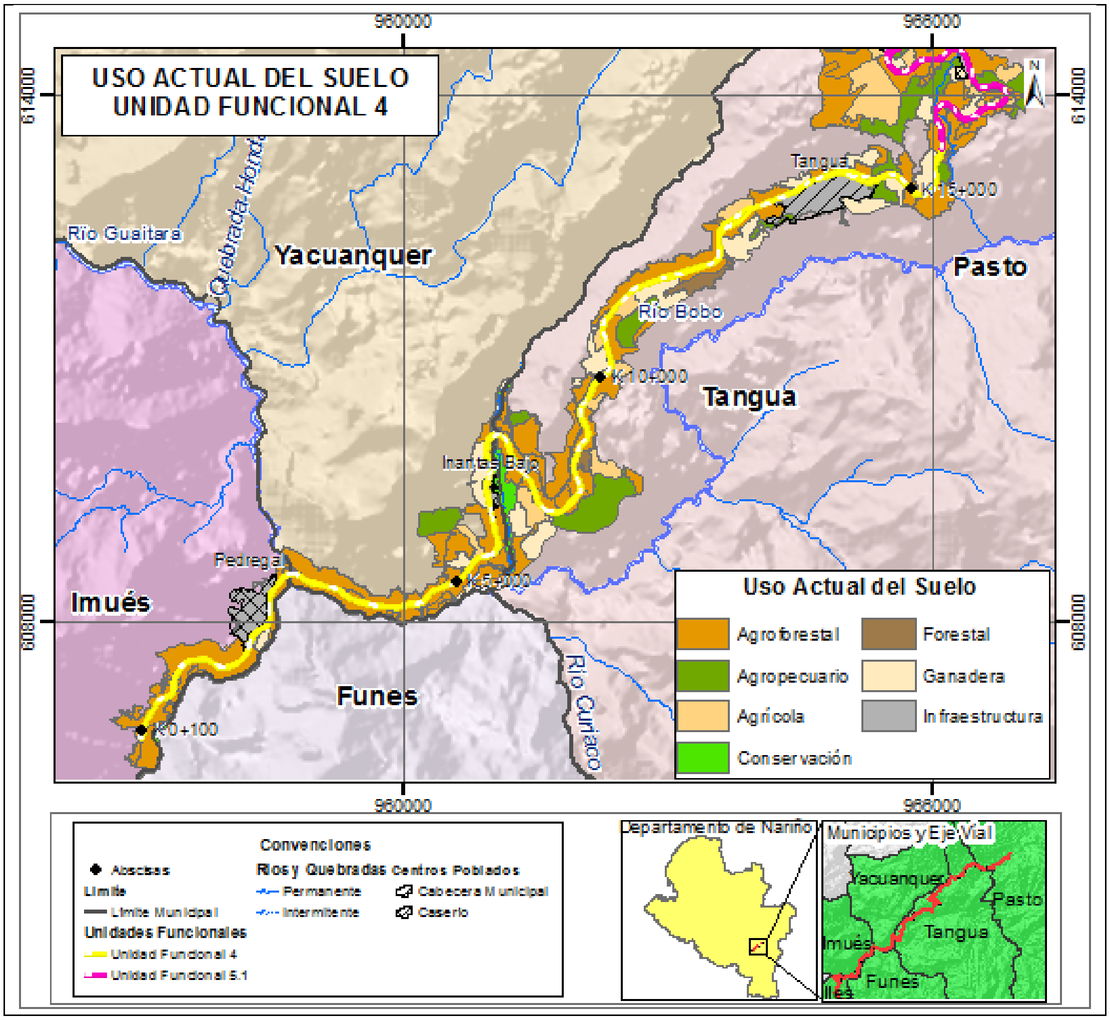


Figure5.1 .21: Current UF 4land use

Source: (Geminis Environmental Consultants, 2016)

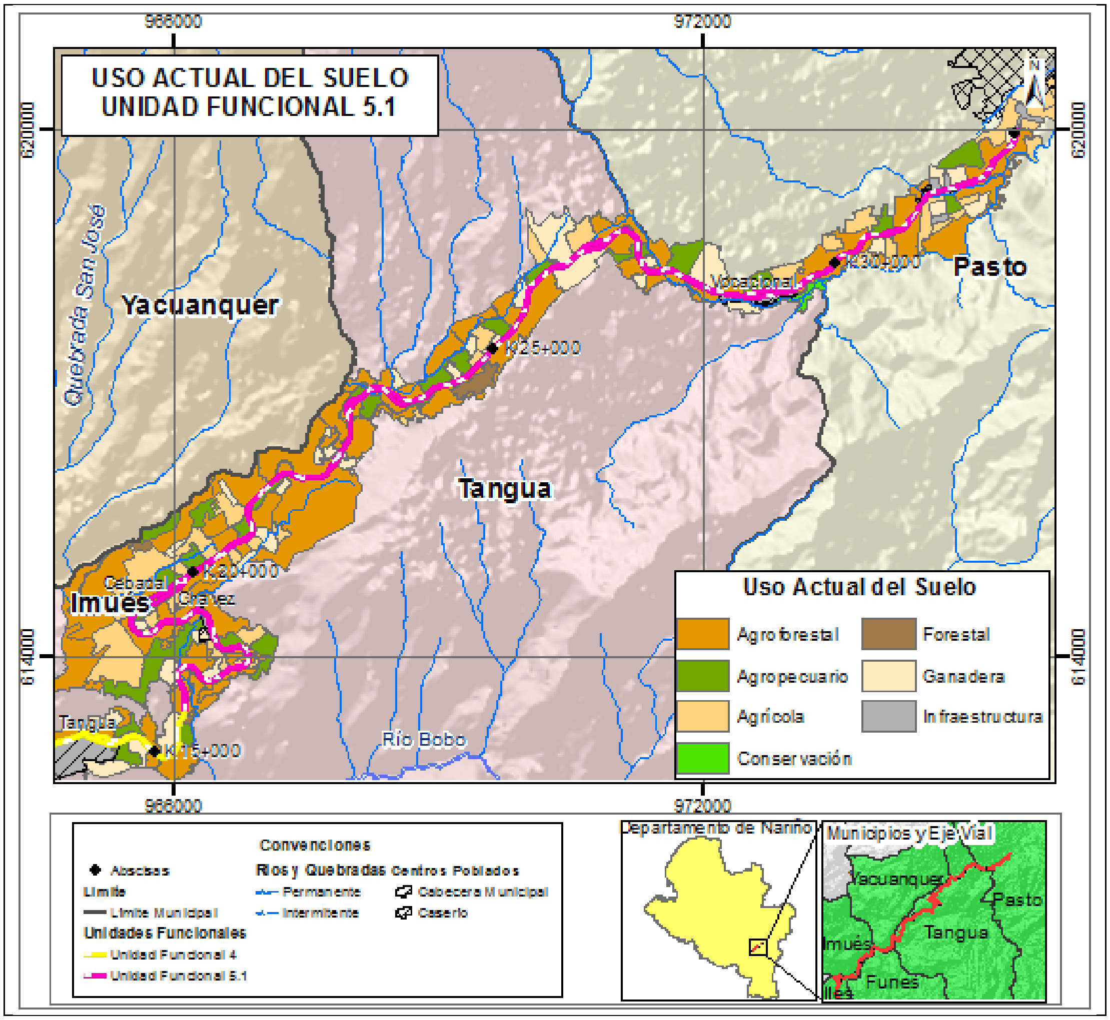


Figure 5.1.22 Current UF 5.1 land use

Source (Geminis Environmental Consultants, 2016)

The soils found in the study area (see Table 5.1.20) occupy sectors that are broken to steep, little evolved with great intervention of crops, little technified which causes the degradation of the same.

Table 5.1.15 Present use of the land in the area of influence of the Rumichaca - Pasto divided highway project, Pedregal - Catambuco segment

CURRENT USAGE				
USE	TYPE OF USE	NOMENCLATURE	AREA (ha)	%
Agricultural	Transient intensive farming	CTI	12,03	0,62
Agricultural	Transient semi-intensive farming	CTS	15,11	0,78
Agricultural	Intensive semi-permanent and permanent crops	CSI	210,42	10,88
Agroforestry	Forestry-Agricultural	SAG	61,50	3,18
Agroforestry	Agro-Forestry-Herding	SAP	480,40	24,84
Agroforestry	Forestry-herding	SPA	455,01	23,53
Cattle ranching	Semi-intensive and intensive grazing	PSI	236,09	12,21
Forestry	Production	FPR	25,30	1,31
Forestry	Production-protection	FPP	4,20	0,22
Conservation	Protection	CFP	29,32	1,52
Conservation	Water resources	CRH	20,89	1,08
Agro-herding	Traditional agro-herding	AGR	225,88	11,68
Infrastructure	Roads	ROAD	48,54	2,51
Infrastructure	Urban	URB	108,92	5,63
TOTAL			1933,62	100,00

Source: (Geminis Environmental Consultants, 2016)

The current predominant land use is agriculture and livestock. These uses are directly related to the existing vegetation cover, where transient crops and pastures predominate with mainly wooded natural spaces.

As regards to agricultural use, such is present throughout the whole section presenting semi-intensive transitional crops (barley, wheat and vegetables), intensive semi-permanent and permanent crops (peas and beans), and intensive transitional crops (potato).

Agroforestry land use occurs in certain sectors of the road corridor, as is the case in the municipality of Imués, observing that new environmentally friendly production systems have been incorporated, such as forestry-herding systems, where an interaction between the animal and the arboreal component is sought. On the other hand, in different sectors of the road, the practice of intensive and semi-intensive grazing is observed, causing erosion of the soils.

In addition, throughout the Pedregal - Catambuco segment, forest plantations of the species *Eucalyptus globulus* can be seen, as well as secondary vegetation. The plantations are established, without silvicultural management and without design, because the distances found in the field, do not favor the development and growth of the individuals. Trees presenting irregular growth, crooked and inclined.

- *Urban*

Infrastructures and roads. It is a composition determined by concrete structures and housing foundations, roads, parks, planks, premises, among others.

- *Stockbreeding*

It is the main and dominant use in the area of influence of the variant extensive cattle ranch, this type of grazing is characterized by animals that remain a prolonged period in the same pasture. This system is generally used in natural pastures in which, due to their poor production and growth, subdivision of pastures is not justified. As a general rule, the load capacity of these systems is relatively low, the paddocks are sub-grazed during the rainy season and are used excessively during dry seasons, with the consequent deterioration of the forage cover. This system favors the propagation of weeds, re-infestation of ecto and endo animal parasites, inadequate distribution of feces and urine in the pasture and especially, a poor use of forage. The performance of management practices is reduced to null and the intensity of their use prevents the presence or development of other coverages.

- *Agroforestry*

Agroforestry, silvopastoral and agrosilvopastoral systems
Corresponding to the UF4; Given its agrological characteristics, it presents little agronomic management that has allowed the ecological interaction of woody plant species, generating a mosaic of pastures, stubble and forest relics, some transitional crops such as beans, peas, potatoes, presenting natural spaces that allow the use for grazing.

- *Protection*

Forestry for protective forestry

This use is found in areas with relics of natural forest, generally associated with bodies of water, such as births or wetlands, in these forests there have been selective use of the species, and have also been felled to generate livestock activity nearby, Which affects its coverage as it tends to reduce.

Transition between protective forestry activity and extensive grazing

This transition refers to the patch found in Functional Unit 4, 0+000 - 15+750, where the existing vegetable cover of fragmented natural forest was burned, to give way to future use in livestock with clean pastures.

5.1.4.3. Potential lands use

The potential use of land is defined as the most intensive use that such land can support, ensuring sustainable agricultural production without deteriorating natural resources.

The units of soil, slope, susceptibility to erosion and flora were analyzed, so that alternatives to the limitations and potentialities of the lands of the study area were constructed. The classification that is presented allows the adequate exploitation of lands in the area. The evaluation of the lands to determine the suitability of potential use was made taking into account the most important agrological characteristics such as climate, slope, erosion, natural fertility, effective root depth, drainage, possibility of mechanization and especially those units of protection . See Figure 5.1.21 and Figure 5.1.22

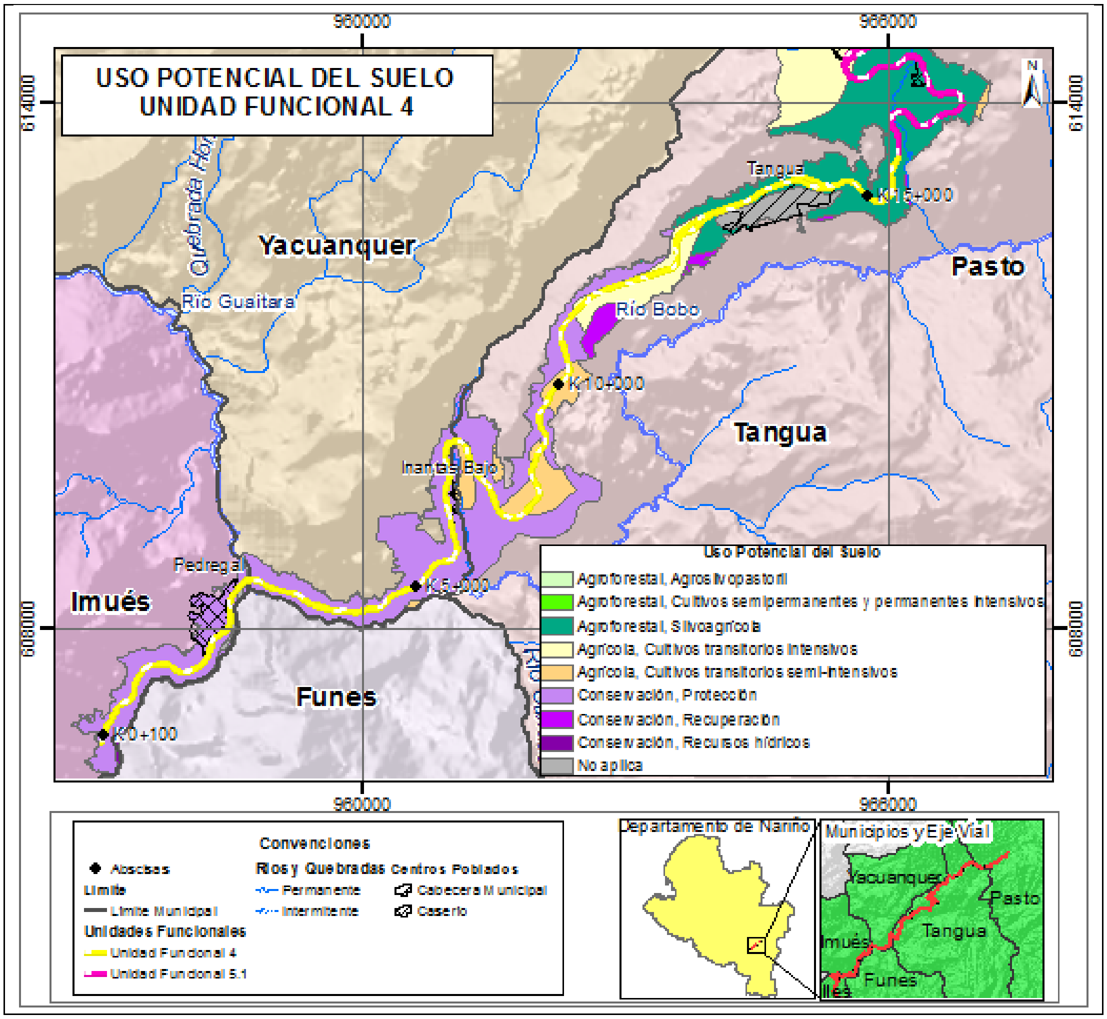


Figure 5.1 .23: Cartographic representation of the potential use for the UF 4 influence area

(Source: (Gemini consulting S.A.S, 2015)

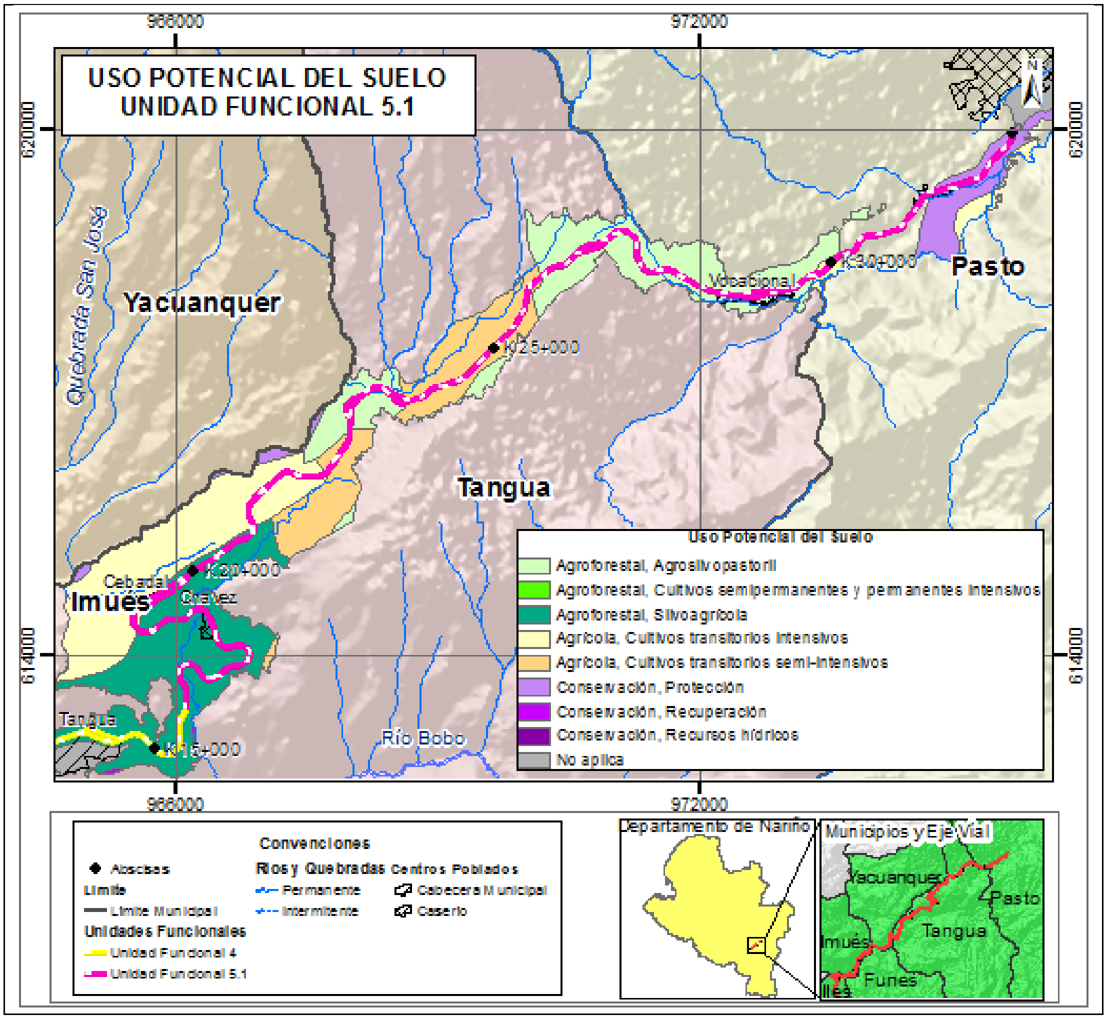


Figure5.1 .24: Cartographic representation of the potential use for the UF 5.1 influence area

(Source: (Gemini consulting S.A.S, 2015)

In the influence area the dominant potential use according to the soils characteristics is of 1933.2 hectares, which is characterized by presence of crops, forestry-farming, agricultural-herding and protection. Table 5.1.16presents the diverse potential uses identified in the project’s influence area.

Table 5.1.16 Potential use of soils in the influence area of the Rumichaca - Pasto double lane road project, Pedregal – Catambuco section

POTENTIAL USE				
USE	**TYPE OF USE**	**NOMENCLATURE**	**AREA (ha)**	**%**
Agricultural	Transient intensive farming	CTI	325,74	16,85
Agricultural	Transient semi-intensive farming	CTS	258,72	13,38
Agricultural	Intensive semi-permanent and permanent crops	CSI	112,15	5,80
Agroforestry	Forestry-Agricultural	SAG	327,09	16,92
Agroforestry	Agro-Forestry-Herding	SAP	269,05	13,91
Conservation	Protection	CFP	539,25	27,89
Conservation	Water resources	CRH	3,71	0,19
Conservation	Recuperation	CRE	21,96	1,14
Not applicable	Not applicable	N/A	75,94	3,93
TOTAL			1933,62	100,00

(Source: (Geminis Environmental Consultants, 2016)

the above information in the Table 5.1.16 and in the Figure 5.1 .23 and Figure5.1 .24 identify the environmental conditions of the soil and its limiting considerations, given that the largest number of hectares are for conservation and agricultural use, is where the projection of the areas subject to study is placed.

Taking into account the natural capacity of the soils a determination was made for the protection areas that are construed as zones where we will take into account the environmental zoning and provide the appropriate management, the areas for agricultural use are for transient crops and it is necessary to identify the alternatives for sustainable use so as to guarantee and maintain the soil's productivity with the minimum risk of deterioration.

Areas for agro-forestry-herding systems

are systems that combine agriculture, grazing and forestry. The continuous removal of the soil is not required, allowing forestry exploitation and pastures simultaneously; i.e. they combine together the forestry-herding and agricultural-forestry systems. The forestry-herding system includes: Lots with legumes trees, fixing live fences with trees or shrubs, legumes settling. The forestry-agricultural systems include: trees to provide shade for crops, family crops, strip crops. These systems provide the soils with a greater support and retention of organic matter, greater product diversification and erosion control.

5.1.4.4. Potential use of soil by agrological class

The soil units for the project's influence area were classified within 4 great agrological groups as follow:

- Class U

These are urban soils, with homogeneous characteristics and shapes, constructions and forms that differ from the landscape. Also, there are patched crops, parks, lots or passages of small proportions and varied uses. In this class is unit MLCc2 is since they sit on a mountainous landscape, with a cold and moist or very moist climate and a moderately steep slope. Erosion is moderate, caused by anthropic sources. This class found in 15 + 700 to 37 + 948 (UF5).

- Class III

Undulated soils with slopes between 7% and 12%. These are appropriate for transitory crops, prairies, forestry plantations, intensive cattle growing. They are limited by a high susceptibility to erosion, frequent floods, low effective depth, low capacity for water retention, moderate acidity and the presence of surface rocks.

This kind of lands is in the cold, medium and warm wet, very wet and dry weathers, in a flat outline strongly inclined, with soils varying from very deep to superficial.

They present moderate limitations in use due to one or more of the following causes: effective depth, presence of rock fragments, compacted material, saturation of aluminum, water mantle level, slopes, rainfall, drainage, floods and frost.

In this class you will find subclasses III sc3, III t3, III c4 and III sc6

- Class IV

These are moderate to strongly sloped floors, with slopes that range from 7 to 25%. Crops that can develop there are very limited. Likewise, the lands of this kind are found in cold, medium and warm wet and dry climates , in flat to strongly sloped outlines. The soils are from very deep to superficial and strong to slightly acidic. They have moderate to severe use limitations due to one or more of the following: moderate erosion, little and poor distribution of rainfall, high saturation of aluminum, strongly inclined slopes, surface effective depth, low fertility, abundant rock fragments and superficial water mantle level.

In this class, we find the subclass IV ts3.

- Class VI

The lands of this kind are present in very cold, cold and warm weathers and humid and very humid, as well as medium dry and warm dry and rainy. The soils vary in effective depth from deep to superficial, well drained, extremely acidic to slightly alkaline. The outline is slightly inclined to slightly sheer.

They have severe use limitations due to one or more of the following causes: high saturation of aluminum, strong winds, frequent frosts, high cloud cover, excessive or insufficient rains, low fertility, presence of abundant fragments of rock, sheer slopes, rocky outcrops and moderate erosion. Soils with slopes moderate to strong from 25% to 50%; Given these steep slopes, forestry-herding, agro-forestry-herding and agro-forestry activities are recommended, with fertilization management and erosion control; crops such as potato, peas, barley, wheat, use of selected seeds and planting using level curves.

In this class, we find the sub class VI tec6.

- Class VII

The lands of this kind are found in cold, medium and warm climates, humid and very humid, and in the dry cold and warm rain, in light and moderately steep outlines. The soils are from very deep to superficial and very strong to moderately acidic.

These soils have severe use limitations due to one or more of the following causes: steep outline, scarce and/or excessive rainfall, very shallow effective depth, very high susceptibility to erosion. In addition, they present less severe limitations due to moderate erosion, low fertility, rocky outcrops, or high saturation of aluminum.

In this class we find the sub classes VII ts5 and VII tsc4.

- Class VIII

The lands of this kind occur in snow, sub-snow, extremely cold, very cold, cold, warm and half humid and very humid climates; as well as in cold, medium and warm dry and very dry and warm rainy weather; in flat outlines and moderately to strongly steep; soils of varied depth, from very shallow to very deep and very strongly acid to moderately alkaline.

These lands have extremely severe use limitations due to one or more of the following reasons: very low effective depth, steep slopes, prolonged flooding, low temperatures, strong winds, little solar exposure, high salts and sodium contents, excessive or insufficient rains, very high saturation of aluminum, or very low fertility.

In this class, we find the sub class VIII tc4.

AGROLOGICAL CLASS	NOMENCLATURE	AREA (ha)
Agrological Class VII	VIItsc4	21,98
Agrological Class VII	VIIts5	327,09
Agrological Class VI	VItec6	33,25
Agrological class VIII	VIIItc6	342,40
Agrological class VIII	VIIItc4	157,64
Agrological class III	IIIt3	61,50
Agrological class III	IIIt3	207,43
Agrological class III	IIIsc6	87,12
Agrological class III	IIIsc3	183,46
Not applicable	N/A	73,91
Agrological class III	IIIc4	423,22
Agrological class IV	IVts3	14,62

5.1.4.5. Land use conflicts

The imbalance that exists between the current use, the land cover and the potential aptitude of the soil causing erosion or degradation of the land, is what is referred to as conflict of use.

When there are discrepancies between different types of utilization of soils with the qualities of the Earth and the basic biotic resources, you may generate a conflicts map.

The conflicts identified in the territory of influence of the functional unit were:

- *Lands in adequate use*

are areas that are used on farms in line with their ability to use, since they do not exceed the capabilities of the soil and therefore is not causing negative impact. In this class type of use handling practices are required that may assure a sustainable exploitation.

- *Earth in inadequate use*

They correspond to the zones in which the present use or demand of resources surpasses the potential use that the lands can support, that is to say, the soils are being subjected to intensive activities which exceed their use capacity and the handling practices are inadequate, bringing as a consequence erosive processes, causing progressive deterioration in the terrains, for example, extensive cattle ranching or in lands with strong slopes subjected to erosive processes, whose vocation is fundamentally agro-forestry.

- *Lands in very inappropriate use*

These are areas in which the current use is well above potential fitness that the soil can withstand, meaning that the soil is subjected to activities or intensive use, which exceed its sustainability capacity. Usually the conflicts that arise are related to agro-herding uses in areas considered strategic ecosystems.

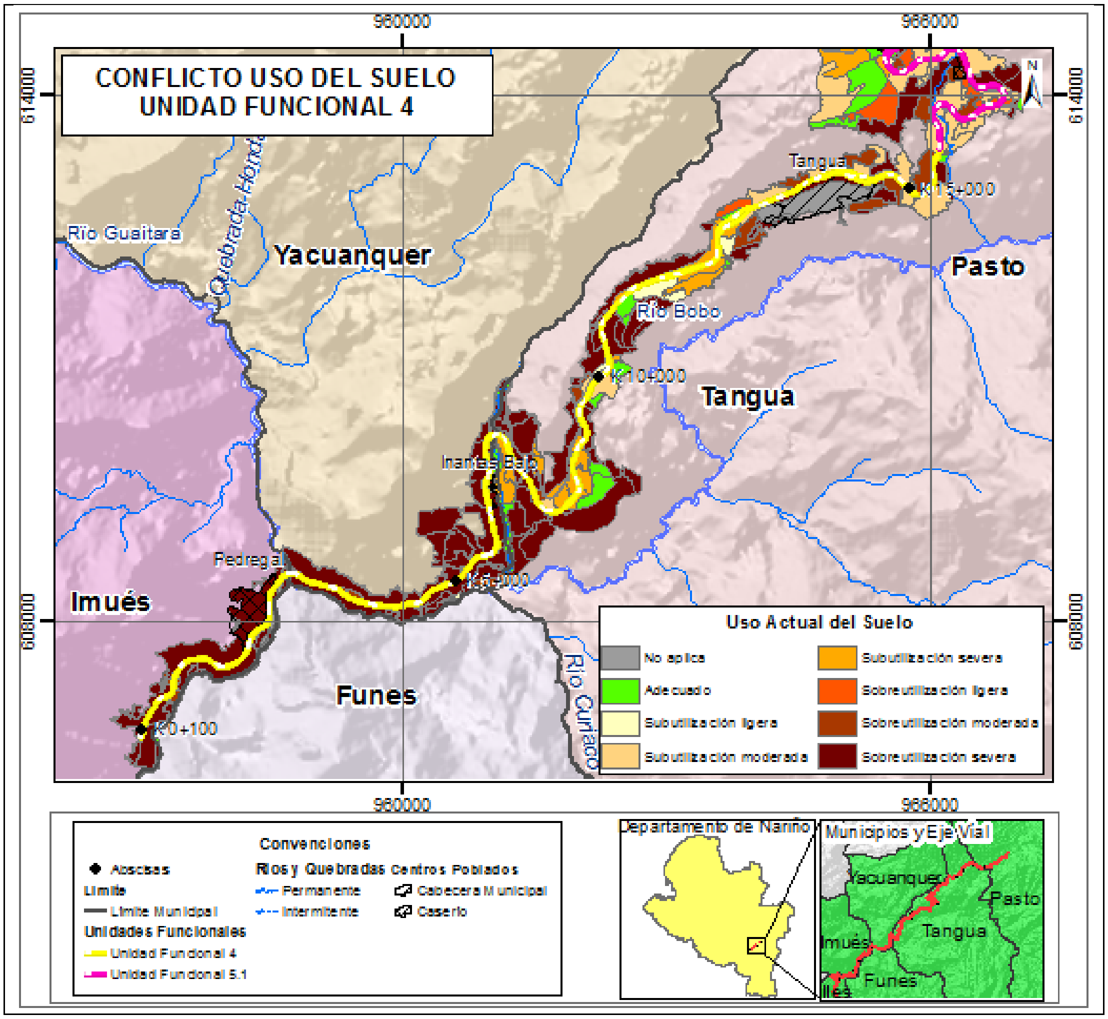


Figure5.1 .25: Cartographic representation of the conflict of use of the soil for the UF 4 influence area

(Source: (Geminis Environmental Consultants, 2016)

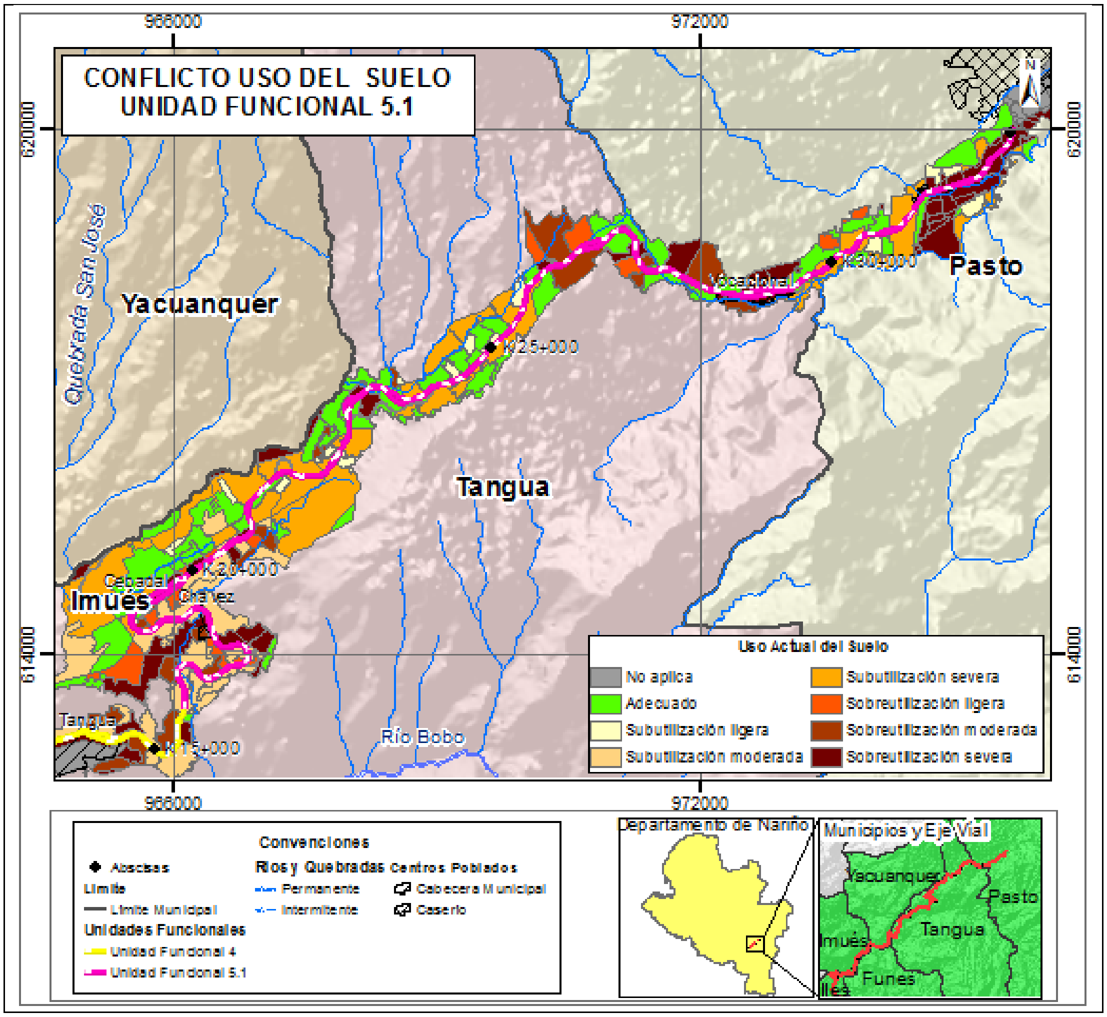


Figure5.1 .26: Cartographic representation of the conflict of use of the soil for the UF 5.1 influence area

(Source: (Geminis Environmental Consultants, 2016)

The Figure5.1 .25 and Figure5.1 .26 represent the conflicts of the soil present in the area of influence of the project, which is characterized by areas of protection, transient crops, agroforestry, for a total of 1582 has. Table Table 5.1.17 presents the diverse potential uses identified in the project's influence area.

Table 5.1.17 Conflict of use of soils in the influence area of the Rumichaca - Pasto double lane road project, Pedregal – Catambuco section

CONFLICT	NAME	CURRENT USAGE	POTENTIAL USE	AREA (ha)	% AREA
Lands without conflict of use or adequate use	Adequate	Agricultural	Agricultural	0,57	0,03
		Agricultural	Agroforestry	0,09	0,00
		Agricultural	Agricultural	4,77	0,25
		Agricultural	Agricultural	68,13	3,52
		Agricultural	Agricultural	15,44	0,80
		Agricultural	Agroforestry	22,30	1,15
		Agroforestry	Agroforestry	4,94	0,26
		Agroforestry	Agroforestry	70,10	3,63
		Agroforestry	Agroforestry	48,38	2,50
		Forestry	Agroforestry	1,66	0,09
		Forestry	Agroforestry	6,33	0,33
		Forestry	Conservation	0,00	0,00
		Forestry	Conservation	0,84	0,04
		Forestry	Conservation	0,22	0,01
		Conservation	Conservation	14,79	0,77
		Conservation	Conservation	13,44	0,69
		Conservation	Conservation	2,51	0,13

CONFLICT	NAME	CURRENT USAGE	POTENTIAL USE	AREA (ha)	% AREA
		Agro-herding	Agricultural	27,25	1,41
		Agro-herding	Agricultural	30,52	1,58
		Agro-herding	Agroforestry	17,27	0,89
Not applicable	Not applicable	Agricultural	Not applicable	3,19	0,16
		Agricultural	Not applicable	16,76	0,87
		Agroforestry	Not applicable	3,75	0,19
		Agroforestry	Not applicable	2,57	0,13
		Cattle ranching	Not applicable	6,90	0,36
		Conservation	Not applicable	0,46	0,02
		Agro-herding	Not applicable	1,89	0,10
		Infrastructure	Not applicable	3,25	0,17
		Infrastructure	Not applicable	37,17	1,92
Conflict due to slight overuse	Slight overuse	Agricultural	Agroforestry	34,63	1,79
		Agricultural	Agroforestry	19,27	1,00
		Agroforestry	Agroforestry	5,27	0,27
Conflict due to moderate overuse	Moderate overuse	Agroforestry	Conservation	15,05	0,78
		Cattle ranching	Agroforestry	54,29	2,81
		Cattle ranching	Agroforestry	64,41	3,33

CONFLICT	NAME	CURRENT USAGE	POTENTIAL USE	AREA (ha)	% AREA
Conflict due to severe overuse	Severe overuse	Agricultural	Agroforestry	2,21	0,11
		Agricultural	Conservation	5,97	0,31
		Agricultural	Agroforestry	4,53	0,23
		Agricultural	Agroforestry	5,81	0,30
		Agricultural	Conservation	33,68	1,74
		Agricultural	Conservation	0,22	0,01
		Agroforestry	Conservation	0,01	0,00
		Agroforestry	Conservation	100,67	5,21
		Agroforestry	Conservation	0,35	0,02
		Agroforestry	Conservation	210,29	10,88
		Agroforestry	Conservation	1,19	0,06
		Agroforestry	Conservation	2,88	0,15
		Cattle ranching	Conservation	51,50	2,66
		Cattle ranching	Conservation	7,52	0,39
		Agro-herding	Agroforestry	59,36	3,07
		Agro-herding	Agroforestry	32,51	1,68
		Agro-herding	Conservation	47,25	2,44

CONFLICT	NAME	CURRENT USAGE	POTENTIAL USE	AREA (ha)	% AREA
		Agro-herding	Conservation	9,82	0,51
		Infrastructure	Agricultural	8,92	0,46
		Infrastructure	Agricultural	5,24	0,27
		Infrastructure	Agroforestry	1,99	0,10
		Infrastructure	Agroforestry	9,62	0,50
		Infrastructure	Agroforestry	5,36	0,28
		Infrastructure	Conservation	14,17	0,73
		Infrastructure	Agricultural	3,02	0,16
		Infrastructure	Agricultural	0,05	0,00
		Infrastructure	Agroforestry	21,33	1,10
		Infrastructure	Agroforestry	9,50	0,49
		Infrastructure	Agroforestry	5,32	0,28
		Infrastructure	Conservation	32,21	1,67
		Infrastructure	Conservation	0,32	0,02
Conflict due to light underutilization	Light underutilization	Cattle ranching	Agricultural	25,49	1,32
		Cattle ranching	Agricultural	18,05	0,93
		Cattle ranching	Agricultural	7,93	0,41
Conflict due to moderate underutilization	Moderate underutilization	Agroforestry	Agricultural	25,43	1,31
		Agroforestry	Agricultural	10,81	0,56
		Agroforestry	Agroforestry	69,27	3,58

CONFLICT	NAME	CURRENT USAGE	POTENTIAL USE	AREA (ha)	% AREA
		Agroforestry	Agroforestry	77,09	3,99
Conflict due to severe underutilization	Severe underutilization	Agroforestry	Agricultural	89,11	4,61
		Agroforestry	Agricultural	114,40	5,92
		Agroforestry	Agroforestry	32,74	1,69
		Agroforestry	Agricultural	63,09	3,26
		Agroforestry	Agricultural	41,03	2,12
		Agroforestry	Agroforestry	8,50	0,44
		Forestry	Agricultural	13,04	0,67
		Forestry	Agricultural	3,43	0,18
		Forestry	Agricultural	3,98	0,21
		Conservation	Agricultural	1,70	0,09
		Conservation	Agricultural	6,52	0,34
		Conservation	Agroforestry	6,30	0,33
		Conservation	Agricultural	4,48	0,23

Source (Geminis Environmental Consultants, 2016)

5.1.5. Hydrology

Water is the element that determines the allocation of uses in the environmental component, therefore, water supply and demand, i.e., the availability and use of resources at different times of the year is the tool to plan constructive activities that require water for the development of the project inherent to the Project. (See detail in GDB/cartografia/PDF/EIADCRP_PC_013)

Bearing in mind that the study of interest focuses on the development of the environmental component, the availability of water resources represents the allocation of uses, therefore, it is important to know the water supply offer to determine the degree of supply that can be achieved.

Hydrology focuses on the analysis, the properties, distribution and circulation of water in the Earth's surface and in the subsoil. In addition to forming part of all the production and extractive processes as a vital resource for the different ecosystems, which is why the hydrological study provides tools to understand the behavior of surface runoff, the real water supply offer and the behavior of the different drainage mechanisms in a given area.

Likewise, hydrology is responsible for studying the dynamics of water, its circulation and distribution in a specific area; as well as its interaction with the environment. This area is comprised of basins, which can be defined as territorial units delimited by the edges of the mountains, where drain waters naturally drain (runoff) and the springs that emerge from the groundwater to naturally drain into streams, creeks, rivers, deliver flows to larger water courses, lakes or to the sea, forming an interconnected system. These territorial units generate environmental goods and services that are in demand primarily for populations located in the study area.

5.1.5.1. Lentic systems

These correspond to all inland waters that do not present continuous currents, without flows, such as wetlands, which correspond to intermediate ecosystems with permanently flooded environments and normally dry environment; lagoons, which represent landforms of special importance from the ecological point of view of the region. There are no representative lentic bodies identified within the area of influence.

5.1.5.1. Lotic Systems that Intercept the Project

The identification of the hydrographic network of the project area, was performed from IGAC mapping at a scale of 1:25000, finding that it is essentially constituted by a network of drains of lotic type. In the Table 5.1.18 is a summary of the lotic water bodies identified in the area of influence of the Rumichaca - Pasto divided highway project, Pedregal - Catambuco segment. We have included within these both the seasonal types as the perennials, and in general we're dealing with medium sloped basins, of elongated oval shape that are less susceptible to floods.

Table 5.1.18 Lotic systems in the influence area of the Rumichaca - Pasto double lane road project, Pedregal – Catambuco section

UF	Geographical Name	Coordinates Magna Sirgas West Origin		Municipality	Municipal Rural Settlement	Photographic record
		x	y			
UF 4	Magdalena Creek	961058,11	610157,55	Yacuanquer	High Inantas	
UF 4	Tributary NN	964060	612763	Tangua	Tangua	
UF 4	Tributary NN	957289	607155	Imués	Pilcuán El Pedregal	

UF	Geographical Name	Coordinates Magna Sirgas West Origin		Municipality	Municipal Rural Settlement	Photographic record
		x	y			
UF 4	Tributary NN	957050	606805	Imues	Pilcuán	
UF 4	Guáitara River	958736,48	608557,67	Imués	Pedregal	
UF 4	Tributary NN	963630	612526	Tangua	San Pedro Obraje Tangua	
UF 4	Tributary NN	963658	612495	Tangua	San Pedro Obraje Tangua	

UF	Geographical Name	Coordinates Magna Sirgas West Origin		Municipality	Municipal Rural Settlement	Photographic record
		x	y			
UF 5	Tributary NN	967741	616108	Tangua	El Tambor	
UF 5	Tributary NN	966629	613875	Tangua	Chavéz	
UF 5	Taminango Creek	976120	620727	San Juan de Pasto	Botanilla	

UF	Geographical Name	Coordinates Magna Sirgas West Origin		Municipality	Municipal Rural Settlement	Photographic record
		x	y			
UF 5	Catambuco Creek	977771	622936	San Juan de Pasto	Municipal Seat	
UF 5	Tributary NN	977565	623497	San Juan de Pasto	Municipal Seat	
UF 5	Santa Monica Creek	976385	621138	San Juan de Pasto	Botanilla Fray Ezequiel	
UF 5	Piquisiqui Creek	971560	618407	San Juan de Pasto	High Gualmatán	

UF	Geographical Name	Coordinates Magna Sirgas West Origin		Municipality	Municipal Rural Settlement	Photographic record
		x	y			
				Tangua	La Palizada	
UF 5	Tributary NN	971287	618541	Tangua	La Palizada	
UF 5	Cubijan Creek (Piedra Pintada Creek)	974594	619280	San Juan de Pasto	Huertecillas	
UF 5	Cubijan Creek (Piedra Pintada Creek)	974594	619280	San Juan de Pasto	La Merced	
UF 5	Los Ajos Creek	968435	617048	Tangua	Los Ajos	

UF	Geographical Name	Coordinates Magna Sirgas West Origin		Municipality	Municipal Rural Settlement	Photographic record
		x	y			
					El Tambor	
UF 5	Los Ajos Creek	968196	617037	Tangua	Los Ajos	
					El Tambor	
UF 5	Los Ajos Creek	968412	617037	Tangua	Los Ajos	
UF 5	Los Ajos Creek	968412	617037	Tangua	El Tambor	
UF 5	El Quelal Creek	966284	614554	Tangua	El Cebadal	
UF 5	El Quelal Creek	966284	614554	Tangua	Chavéz	

UF	Geographical Name	Coordinates Magna Sirgas West Origin		Municipality	Municipal Rural Settlement	Photographic record
		x	y			
UF 5	El Quelal Creek	966073	613874	Tangua	El Cebadal	
UF 5	El Quelal Creek	966073	613874	Tangua	Chavéz	

(Source: (Geminis Environmental Consultants, 2016)

5.1.5.2. Hydrographic river basins

A basin, in a broad sense, is a unit of territory where the waters flow through an interconnected natural system; into which one or several biophysical-socioeconomic and cultural elements can interact (IDEAM, Zoning and Coding of Hydrographic and Hydro-geologic Units of Colombia, 2013).

As a biophysical subsystem, the basin consists of an environmental offer in an area bounded by the watershed waters and with specific characteristics of climate, soil, forests, hydrographic network, uses of soil, geological components, etc. As an economic subsystem, the basin has an availability of resources that are combined with different techniques to produce goods and services; i.e. in all basins there are either one or some possibilities of exploitation or transformation of resources. As a social subsystem, it involves human communities based in its demographic area, access to basic services, organizational structure, activities, among others, that necessarily causes impacts on the natural environment. It also includes the set of traditional cultural values and beliefs of the settled communities (Ministry of Environment, 2013).

Decree 1640 of 2012 (which regulates the instruments for the planning, ordering and management of watersheds and aquifers, and other provisions are issued), consistent with the National Policy for the Integral Management of the Hydrological Resource (PNGIRH), sets the structure for the planning, ordering and management of watersheds and aquifers at four levels:

- **Hydrographic areas or macro-basins**: These correspond to the five macro-watersheds or hydrographic areas of the country (Magdalena-Cauca, Caribbean, Orinoco, Amazonas and Pacífico) that are the subject of Strategic Plans, long-term environmental planning instruments with national vision and constitute the framework for formulation, adjustment and/or implementation of the different policy, planning, management and monitoring instruments in each of them, the Strategic Plans will be formulated at 1:500.000 scale.

- **Hydrographic areas**: These correspond to those defined in the hydrographic zoning map of Colombia (41), which are the space to monitor the condition of the water resource and the impact caused on it by the actions developed within the framework of the National Policy for the Integral Management of the Hydrological Resource. The planning instrument for the hydrographic zones is the National Program for Monitoring the Hydrological Resource.

- **Hydrographic sub-zones or their subsequent level**: It corresponds to the basins that are the object of ordering and management (311), defined in IDEAM's hydrographic zoning map, upon which the Plans of Ordering and Management of Watersheds (POMCA) will be formulated and implemented.

- **Micro-basins and aquifers**: It corresponds to the watersheds of inferior order to the hydrographic sub-zones or their subsequent level that do not form part of a POMCA, as well as, the priority aquifers; These will be subjected to Environmental Management Plans.

The present numeral describes and characterizes the results of the hydrography and hydrology analysis for the area of influence of the project, based on the information obtained from the main entities consulted, such as Institute of Hydrology, Meteorology and Environmental Studies (IDEAM), Agustín Codazzi Geographic Institute (IGAC) and the Regional Autonomous Corporation of Nariño (CORPONARIÑO).

The hydrological characteristics of the water bodies of interest, referring to the hydrological regime and the characteristic flows, are based on the analysis of historical series information from the hydrographic units as instrumented by the IDEAM through representative hydrometric stations for this project.

The Project is located in one of the five hydrographic areas, corresponding to the Hydrographic Area of the Pacific (5), which is comprised of more than 200 rivers. It is fundamentally due to the presence in the eastern end of the Western Cordillera and the Baudó and Pacific mountain ranges, which serve as hydrographic centers where the rivers are born, as well as natural barriers to the oceanic winds, which, by producing permanent rains, feed the flow of them.

On the other hand, of the 41 hydrographic zones established by the IDEAM, the project is located in No 52 - Patía river, and of the 311 sub-sectors in corresponding to the Guáitara river (5205) and Juanambú river (5204), as related in
Table 5.1.19.

Table 5.1.19 Hierarchical structuring of the Hydrographic Network of the basins related to the AI of the Rumichaca - Pasto double lane road project, Pedregal - Catambuco section according to Decree 1640 of 2012

Hydrographic Area	Hydrographic Zone	Hydrographic Sub.zone	Hydrographic Unit Level I (Micro-basin)	Hydrographic Unit Level II (Micro-basin)
Order 0	**Order 1**	**Order 2**	**Order 3**	**Order 4**
Pacific (5)	Patía River (52)	Guáitara River (5205)	Direct Tributaries	Direct Tributaries (mi)
			Bobo River	La Unión Creek
				El Quelal Creek
				Direct Tributaries (md)
		Juanambú River (5204)	Pasto River	Miraflores River (Guachucal Creek)

(Source: (Nariño, 2007)

- *Hydrographic Area of the Pacific (5).*

The Pacific slope has an extension of 77,311 km2 and is formed by more than 200 rivers. Its rivers cross jungle areas and because of the high rainfall they are torrents, their courses are short and of great slopes that favors the drag of a great load of sediments, which when being deposited in the low zones favor the formation of deltas. It is comprised of the following basins (IDEAM, Zoning and codification of hydrographic and hydro-geological units of Colombia., 2013) See Photography5.146.

- Mira river basin (5,865 km²)
- Patía river basin (24,000 km²)
- Tapaje - Dagua - Directos river basin (20,804 km²)
- San Juan River Basin (16,411 km2)
- Baudó - Directos - Pacífico river basin (5,965 km2)
- Pacífico - Directos river basin (4,252 km2)
- Pacific Islands basin (14 km2)

Photography5.146 Pacific Mangroves downstream of the mouth of the Patía river
Source: Google Earth. 2013.

The Pacific Macro-basin (see Figure 5.1.27) spans longitudinally from the North end in Juradó, municipality of the department of Chocó, to the South end in Tumaco, municipality of the department of Nariño, a distance of approximately 740 km, 40% of the maximum length of our country.

The Pacific Macro-basin has jurisdiction in the departments of Chocó, Risaralda, Valle del Cauca, Cauca and Nariño, with the Department of Nariño being the most representative (36.48%), and Risaralda the least (1.42%) (IIAP, February 2013).

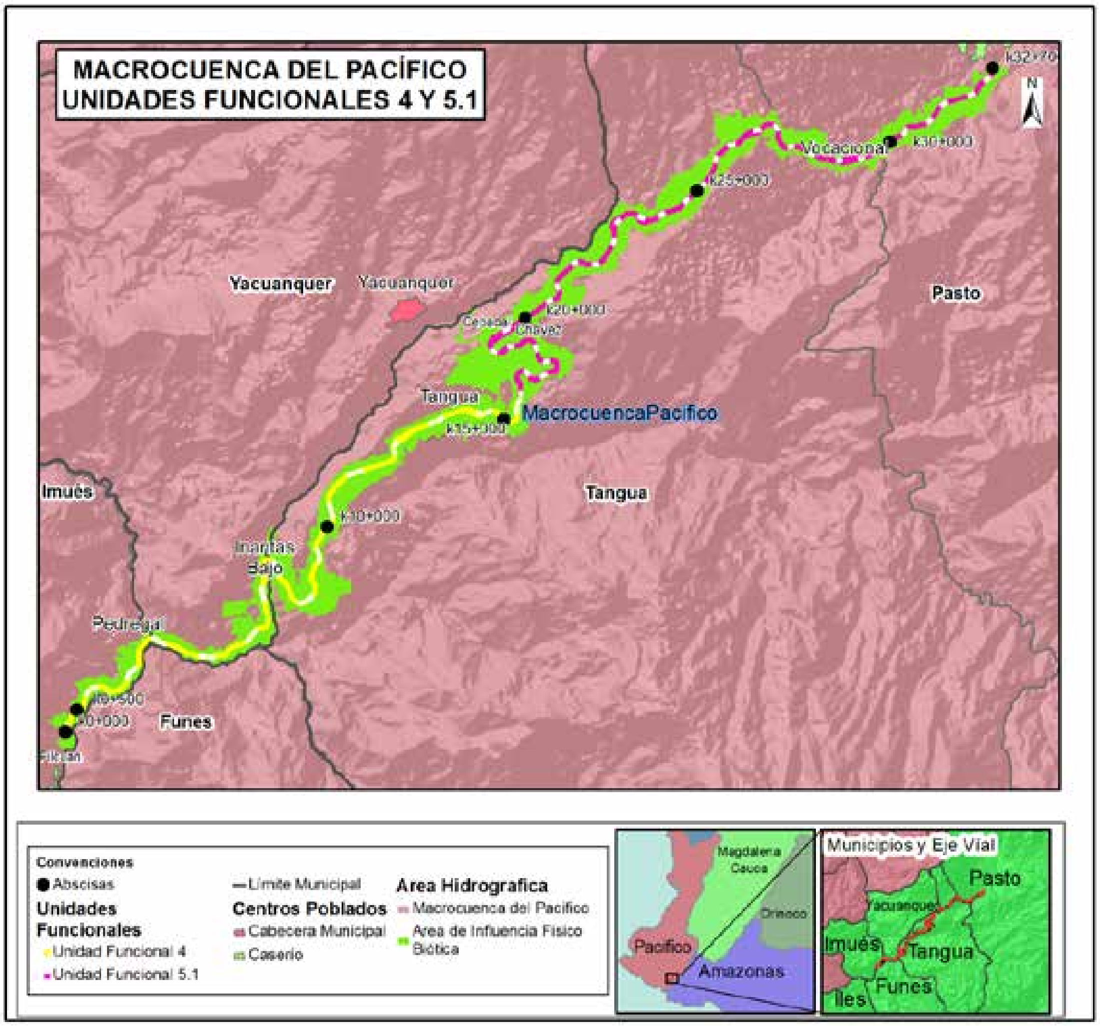


Figure 5.1.27 Pacific Macro-basin , Pedregal-Catambuco Sector.
(Source: (Geminis Environmental Consultants, 2016)

Photography5.1.47 Pacific Mangroves downstream of the mouth of the Patía river
Source: Google Earth. 2013

- *Classification of basins*

o Patía River Hydrographic Zone (52)

The Patía is the most extensive river of the Colombian Pacific slope and of South America, with its 400 km of course, of which only 90 are navigable because it is a mountain and plains river. It travels southwards, between the Central mountain range (where it is born in the Colombian Massif) and Western mountain range, which it breaks at the Hoz de Minamá depression, to enter later in the Pacific plain where it receives its main tributary, The Telembí. The basin of the Patía river is presented In Figure 5.1.28 as a Hydrographic Zone according to the codification established by the IDEAM (2013).

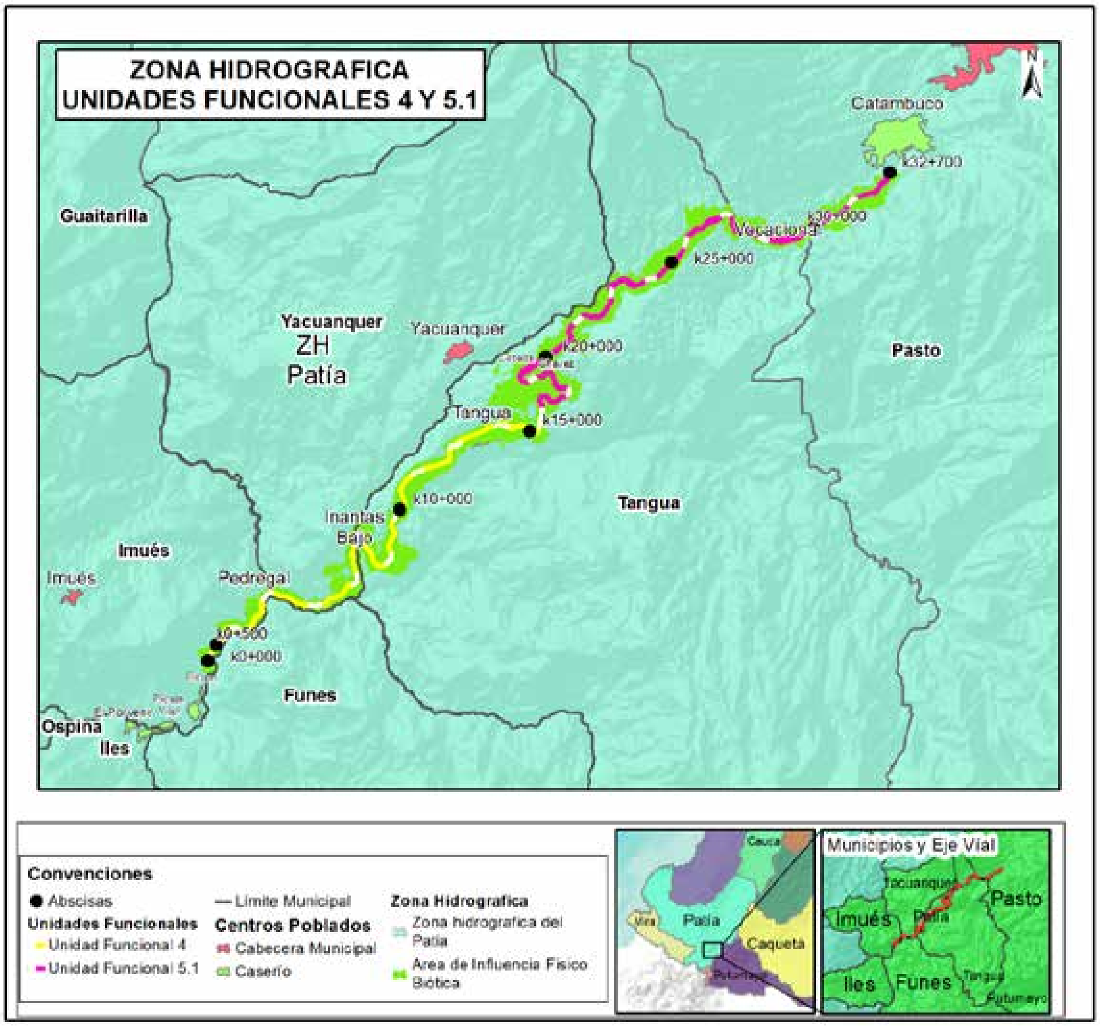


Figure 5.1.28 Patía River Hydrographic Zone
Source: (Geminis Environmental Consultants, 2016)

the Patía basin stands out economically because of its wealth in gold, cocoa and bananas. It is comprised of the following basins (IDEAM, Zoning and codification of hydrographic and hydro-geological units of Colombia., 2013):

- High Patía river basin (3,228 km^2)

- Guachicono River basin (2.626 km²)
- Mayo river basin (874 km ²)
- Juanambú river basin (2,070 km ²) - see Photography5.1.49
- Guáitara river basin (3,650 2 km2) - see Photography5.1.48
- Telembí river basin (4,635 2 km2)
- Medium Patía River basin (2.390 km2)
- Lower Patía River basin (4,527 km2)

Photography5.1.48 River Patía downstream of the mouth of the river Guáitara
Source: Google Earth. 2013.

In its route it encompasses the departments of Cauca and Nariño, and its watershed covers an area close to 24,000 km2, which is why it is considered the second mightiest river in the Colombian Pacific coast and the first in basin extension. It afterwards crosses the Nariño Pacific plain and empties into the Pacific Ocean, forming a large delta of an area of approximately 5,000 km2. Along its course it receives numerous tributaries like the rivers Guachicono, Mayo, Juanambú, Guáitara, Telembí, Magüí, Mamaconde, Piusbí and Nansalví.

Photography5.1.49 Patía river downstream of the mouth of the Juanambú river
Source: Google Earth. 2013.

ü Guáitara River Hydrographic sub-zone (5205)

The hydrographic basin of the Guáitara River or Hydrographic Sub-zone of Order 2 (Code 5205), is a trans-boundary basin, because it is between Colombia and Ecuador. In Colombia, it is located in the department of Nariño, with an extension of 364,045.43 ha. Equivalent to approximately 91% of the total area of the basin. In Ecuador, it is located in the province of Carchi. (See Figure 5.1.29)

The hydrographic basin of the Guáitara river is located within the jurisdiction of 33 municipalities in the Department of Nariño: Ancuya, Aldana, Consacá, Contadero, Córdoba, Cuaspud, Cumbal, El Peñol, El Tambo, Fúnes, Guachucal, Guaitarilla, Gualmatán, Iles, Imués, Ipiales, La Florida, La Llanada, Linares, Los Andes, Ospina, Pasto, Potosí, Providencia, Puerres, Pupiales, Samaniego, Sandoná, Santacruz de Guachavez, Sapuyes, Tangua, Túquerres and Yacuanquer; corresponding to a 51.6% of the total of 64 municipalities of the department(CORPONARIÑO, 2009).

Photography5.1.50 Guáitara River
Magna Sirgas Coordinates West Origin X: 955756,19 Y: 602509,24
(Source: (Geminis Environmental Consultants, 2016)

Given that the Guáitara river is characteristically canyoned, see Photography5.1.50 andPhotography5.1.51 it has been used as collector of all solid wastes and fluids produced by the city of Ipiales and some municipal capitals through where it passes, presenting a high degree of contamination of its waters.

Photography5.1.51 Guáitara River
Magna Sirgas Coordinates West Origin X: 956009,90 Y: 596120,60

(Source: (Geminis Environmental Consultants, 2016)

ü Juanambú River hydrographic sub-zone (5204)

The Juanambú river is born in the area known as Cascabel in the Central mountain range and has an extension of 19.519 has. The Juanambú basin is comprised of the High Juanambú river sub-basin, Buesaquito river sub-basin, Ijagui river sub-basin and Lower Juanambú river sub-basin. The High Juanambú river sub-basin covers an extension of 19.519 Has (see Figure 5.1.29).

The high Juanambú river sub-basin is located in a high degree of intervention due to the use of wood for cooking and is formed by the microbasins of the rivers Negro, Runduyaco, San Pablo, Sara - Concha, Tambillo, Buesaquito, Negro, Chicajo, Panacas and low Buesaquito.

the lower part of this micro-basin is 70% deforested, its terrains have been used intensively mainly to cover agricultural and livestock activities. On the other hand, due to the slope observed in the environment, mild to severe erosion processes are common. It is formed by the micro-basins of the rivers Ijagui, High Ijagui, Sacha, Medium Ijagui and Low Ijagui, among others.

Most of the micro-basins mentioned above displace their flows through sloped zones exceeding 40% of the deep and superficial soils, dedicated to corn and vegetables crops and grasses. The upper part of this sub-basin is a great water reserve, while the middle part exhibits soil limitations for agro-herding use.

Photography5.1.52 Juanambú River
Source: Google Earth. 2013.

Photography5.1.53 Juanambú River
Source: Google Earth. 2013.

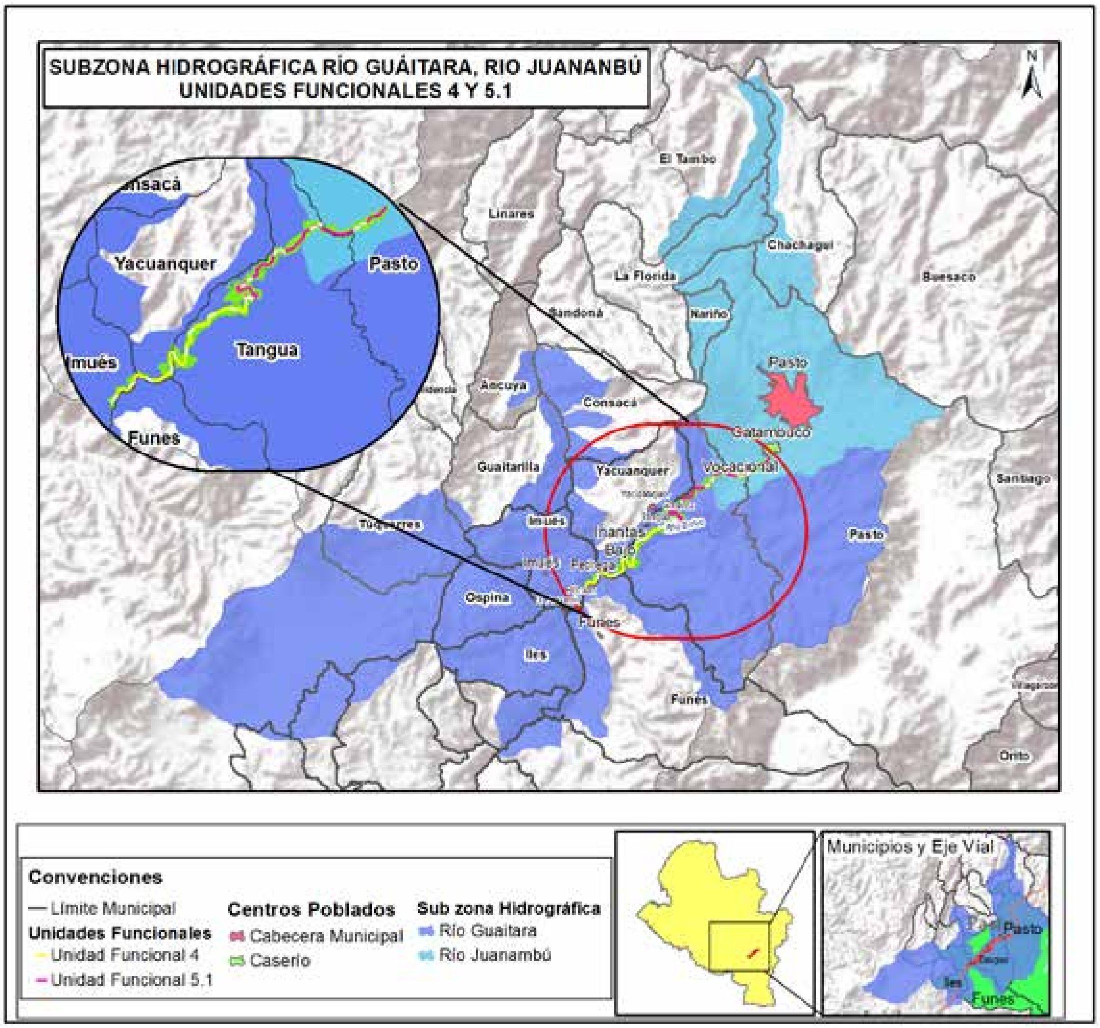


Figure 5.1.29 Guáitara River and Juanambú river hydrographic sub-zone
Source: (Geminis Environmental Consultants, 2016)

- Hydrographic unit Level I - Bobo River

the Bobo River basin is located at a distance of 25 kilometers from Pasto, about half an hour from its origin site found at kilometer 10 South bound, via an unpaved road, is part of the Patía River basin, its waters flow into the Guáitara river (western slope of Nariño).

It borders to the North with the Pasto River, to the northeast with the Guamués River basin, to the South with the Alisales river, to the West with the Totoral Creek and to the South with the Curiaco lagoon.

It is composed of two sub-basins: The Bobo river sub-basin located in the municipality of Pasto (see Photography5.1.54); It is important because on this site the Bobo river Reservoir was built, and the Opongoy river sub-basin which is part of the municipalities of Tangua and Pasto. The Bobo river basin is very essential because it is the birth place of a dam that supplies the aqueduct for the city of Pasto, generates power for regional use, and has touristic and water sports potential that have still not been developed (see Photography5.155).

The following major landscapes are highlighted in the Bobo river basin: Mountainous and volcanic outlines represented in high outlines with steep gradients and well formed and representative slopes.

Photography5.1.54 Bobo River
Source: Google Earth. 2013.

Photography5.155 Embalse Río Bobo
Source: Google Earth. 2013.

- Hydrographic Unit Level I - Pasto River

The hydrographic unit of the Pasto river is basically comprised of the Cubijan micro-basin that is born in the Negra Lagoon, which is in the "Sanctuary of Flora and Fauna of the Galeras" National Park, 3600 m.s.n.m. ; also, it receives a small affluent called El Zanjón on the side of the palisade There are innumerable streams and underground springs in this basin that bring incalculable benefits to human needs.

Photography5.1.56 Pasto River
Source: Google Earth. 2013.

- Drainage patterns

A drainage pattern is defined as the form in which a network is seen in an area. It is determined by the relationship between infiltration and runoff of each material, they depend on the gradient of the slopes, the drainage area, vegetation cover, resistance of the lithology, flow, soil permeability, level and intensity of rains and structural activity.

to understand a current drainage pattern, you must know its erosional development or the parts through which it runs, namely: the upper course, middle course and lower course (see Figure 5.1.30).

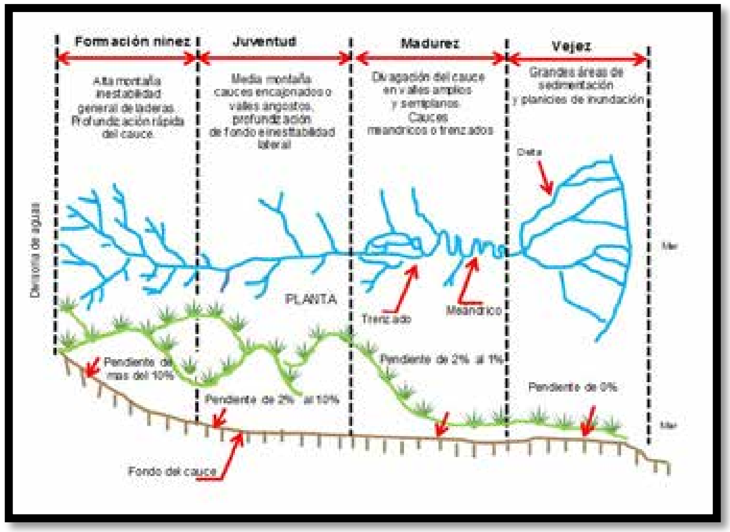


Figure 5.1.30 Erosive stage of a river and its relationship with drainage patterns
Source: IDEAM, 2016

- *Dendritic Drainage pattern*

according to the cartographic base of the IGAC, satellite images and field work in the AI project, it was determined that the drainage system that dominates the main water sources and their micro-basins in the area of influence is the dendritic to subdendritic, which is characterized by an arborescent ramification in which the tributaries join the main stream forming acute angles. The presence of this type of drain is an indication of homogeneous soils and in areas of soft sedimentary rocks and ancient coastal plains; and parallel where runways have a parallel conformation, draining in different places. Particularly, a dendritic drainage pattern can be observed in some of the tributaries that drain towards the Pasto river (municipality of El Tambo, San Juan de Pasto and Chachagüí), Ijagui river and Buesaquito river (municipality of Buesaco), which are characterized by a dendritic drainage pattern with respect to the Juanambú River. (See Figure 5.1.31)

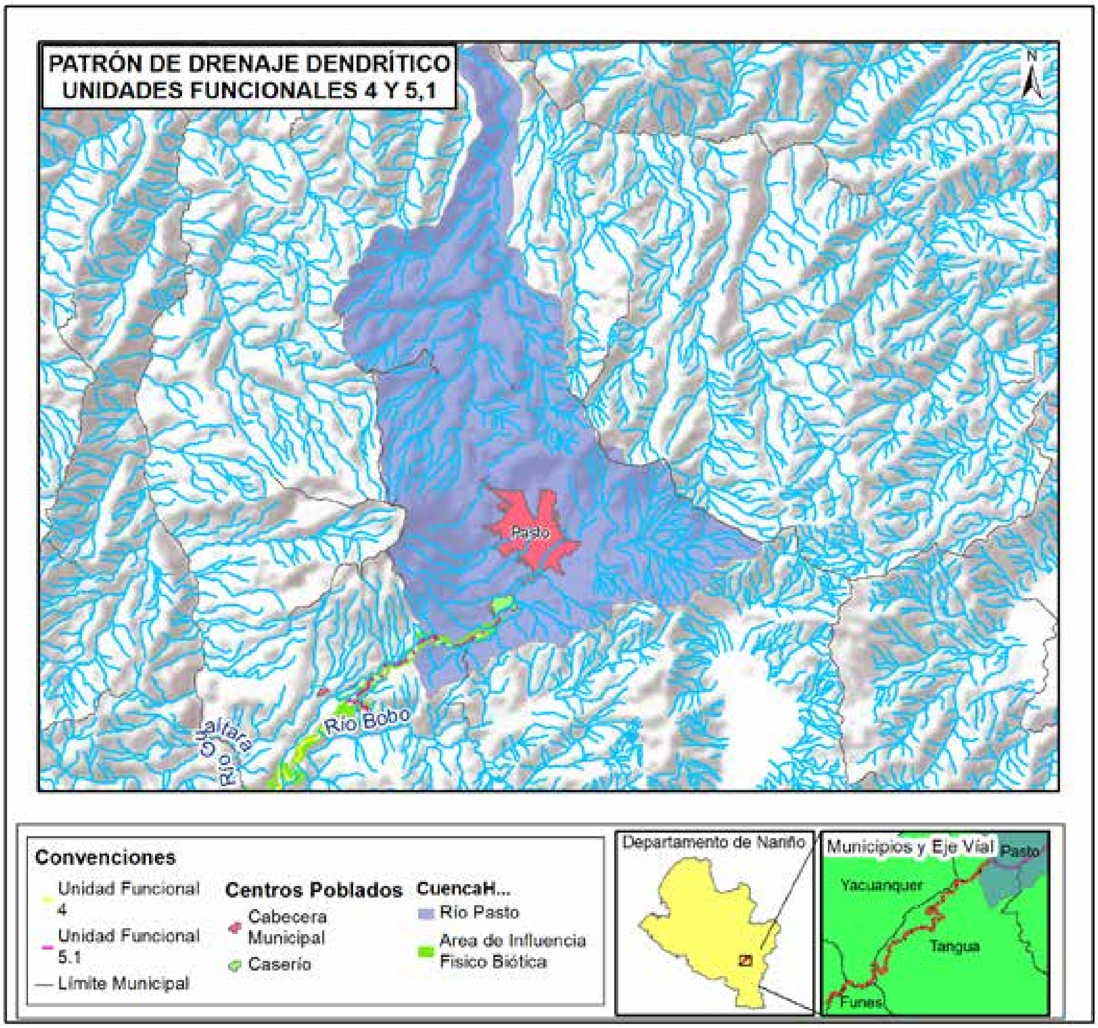


Figure 5.1.31 Dendritic Drainage Pattern - Pedregal - Catambuco section (Pasto river and Bobo river)
(Source: (Geminis Environmental Consultants, 2016)

- *Meanderic Drainage Pattern*

The Guáitaraand Juanambú rivers maintain a predominant type meanderic drainage pattern in the upper, middle and lower sections, due to the continuous curves that occur throughout their channel see Figure 5.1.32 and Figure 5.1.33 . The meanderiform sections are developed when the flow is increased downstream, and there are gentle slopes (see Photography5.1.57).

Photography5.1.57 Meanders in the Juanambú river (from the bridge to the North of the municipality of Buesaco)

Source: Google Earth. 2013.

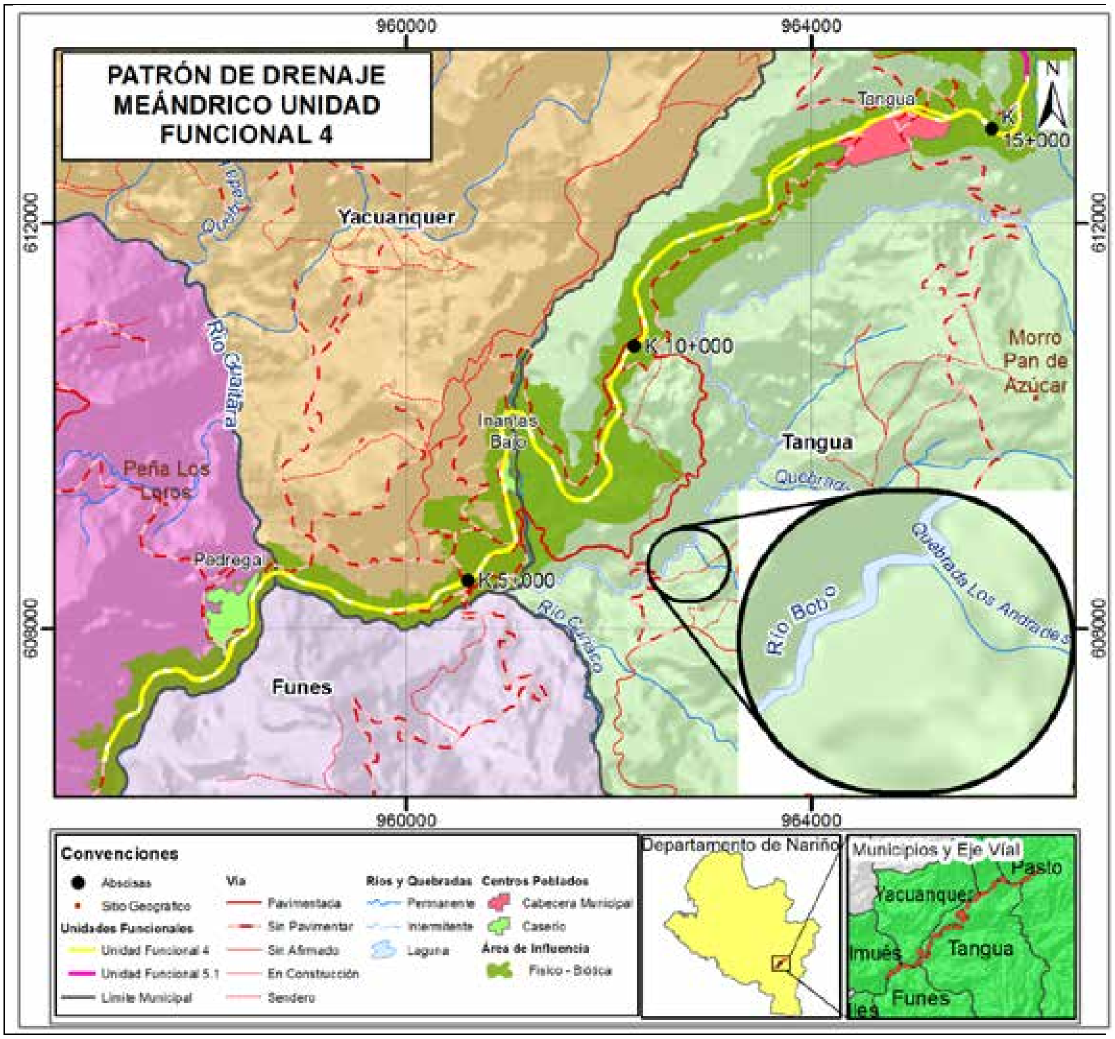


Figure 5.1.32 Meanderic Drainage Pattern - Guáitara and Juanambú rivers, UF5 4
Source (Geminis Environmental Consultants, 2016)

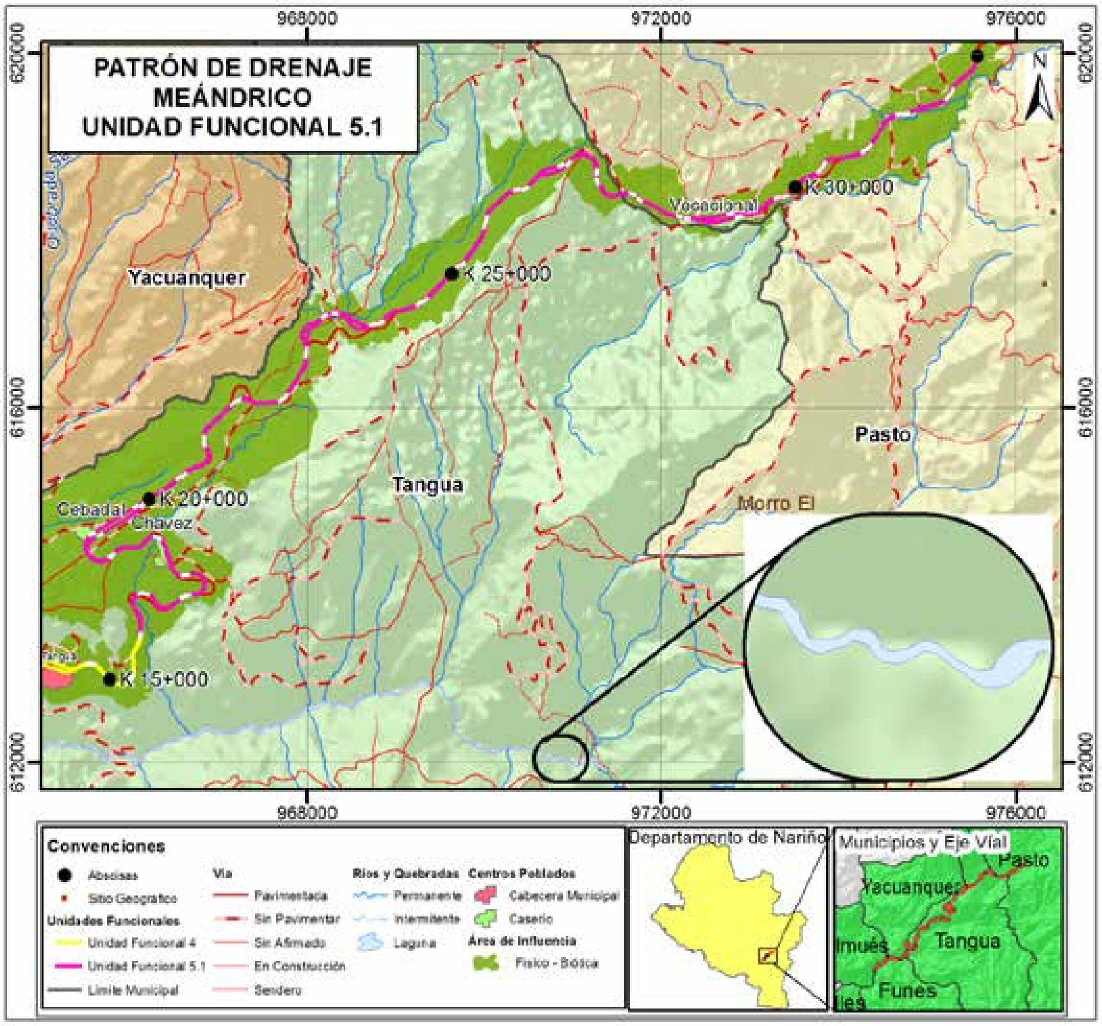


Figure 5.1.33 Meanderic Drainage Pattern - Guáitara and Juanambú rivers, UF5.1
(Source: (Geminis Environmental Consultants, 2016)

- *Parallel Meanderic Drainage Pattern*

Drainage is parallel to sub-parallel in the vicinity of the Guáitara river, with short tributaries with very little water or lacking it, which flow into the main stream at almost right angles. The drainage runs between narrow, V-shaped valleys, surrounded by mountains of pointed peaks, evidence of its little evolution, such is the case of the Cano and La Guasca creeks in the municipality of Chachagüí, creeks such as La Jaguindo, Tamboguaico, Sachamates in the municipality of Buesaco are characterized by a pattern of parallel drainage with regard to the Juanambú river. (See Figure 5.1.34)

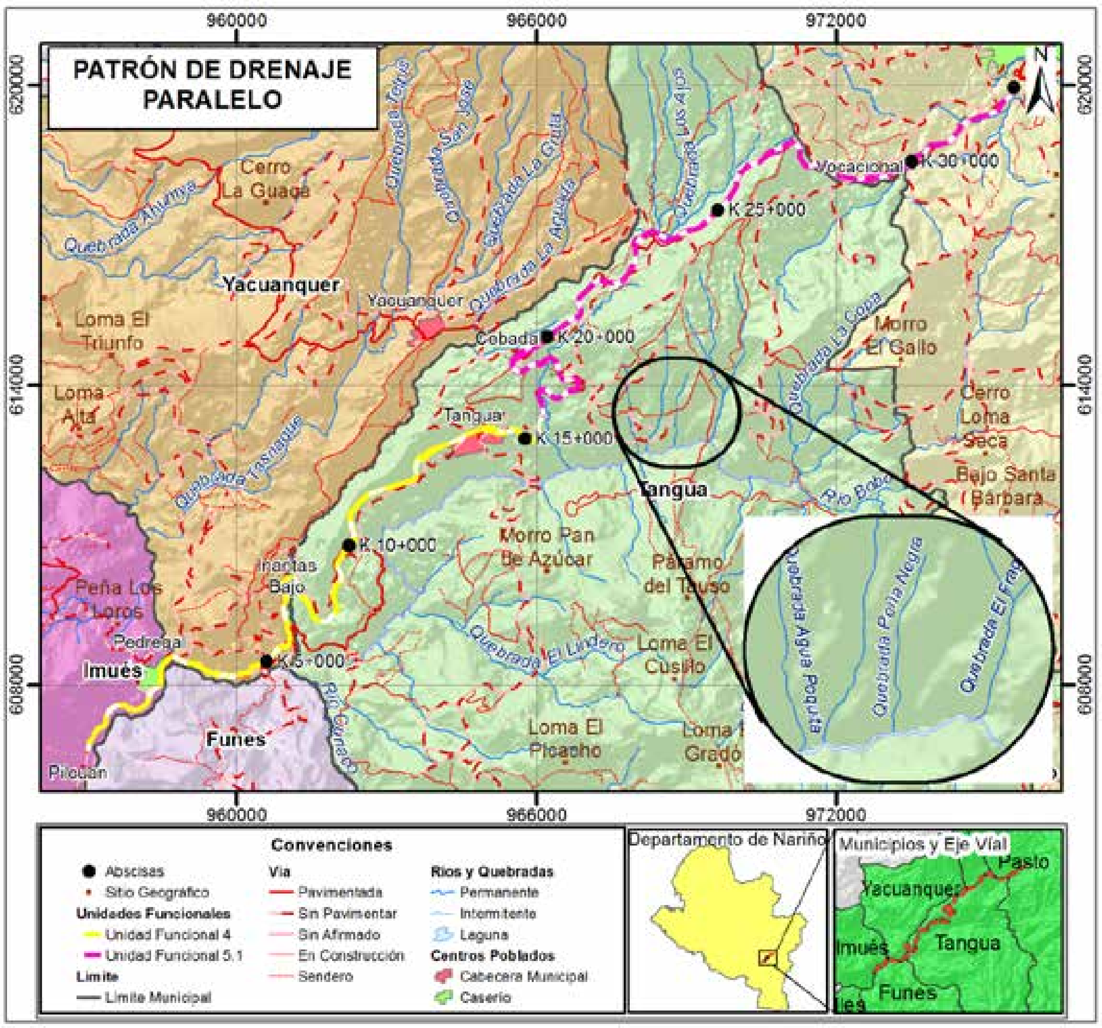


Figure 5.1.34 Parallel Drainage Pattern - Guáitara river Affluents
(Source: (Geminis Environmental Consultants, 2016)

· Hydrological Regime and Characteristic Flow Rates for Instrumented Basins

Under normal conditions, the spatial variation of the flow rate of a source occurs when it increases downstream, as it collects the contributing waters from other sources that flow into the main stream as tributaries. Because of this, the flow of a stream tends to be smaller in the header near its birth, and much greater in the lower areas of the basin near its mouth. This condition may be altered by the impact of the anthropic factor, as it is normal that in some sources or drains there is an inverse spatial relationship due to the over-exploitation of that resource.

the hydrological regime is the behavior of the average liquid flow rate carried by a river, every month, throughout the year. It depends on rainfall, temperature, the outline, the geology, vegetation and human action.

The hydrological characteristics of the water bodies of interest, referring to the hydrological regime and the characteristic flows, are based on the analysis of historical series information from the hydrographic units as instrumented by the IDEAM through representative hydrometric stations for this project.

in Colombia there is a great lack and/or inexistence of hydrological stations, especially in medium-sized and small basins which does not allow to know the real water production. In the Table 5.1.20. There is a listing of the stations that provide information on the characteristic flow rates for the study basins, in order to establish the dynamics of the resource framed within the hydrographic zone and sub-zone. (See Figura 5.1.35)

With the analyzed stations, a sectorization was made for the calculation of the historical average volumes for the Patía river, Guaitará river and Juanambú river, which provide information of the monthly behavior or prvalent during most of the times throughout the analyzed years, where the hydrologic regimes of the currents being studied may be determined at the local level (study area) and regional.

Table 5.1.20 Hydrometric Stations near the Study Area Pedregal Section

Municipality	Station	Code	Flow Rate	Type	Magna Sirgas West Origin Coordinates	
					East	North
Policarpa	Guascas Bridge	5201701	Patía River	LG	960.846,69	668.057,45
Imués	Pilcuán	52057010	Guáitara River	LG	956.002,27	604.752,70
Los Andes	Agrocayo	52057030		LG	959.362,58	665.833,87
El Tambo	San Pedro	5205705		LG	954.953,89	644.695,90
Chachagüí	Juanambú Bridge	52047020	Juanambú River	LG	974.090,95	659.562,71

Municipality	Station	Code	Flow Rate	Type	Magna Sirgas West Origin Coordinates	
					East	North
Policarpa	Guascas Bridge	5201701	Patía River	LG	960.846,69	668.057,45
Pasto	Providencia	5204704	Pasto River	LG	975.178,09	650.105,29
Pasto	Centenario Intake	52047030	Pasto River	LG	981.049,76	624.611,03
Pasto	Casanare Automatic	52057090	Bobo River	LG	980.433,94	614.886,59

LM: Water Stage, LG: Water Stage Graph
Source: IDEAM 2015

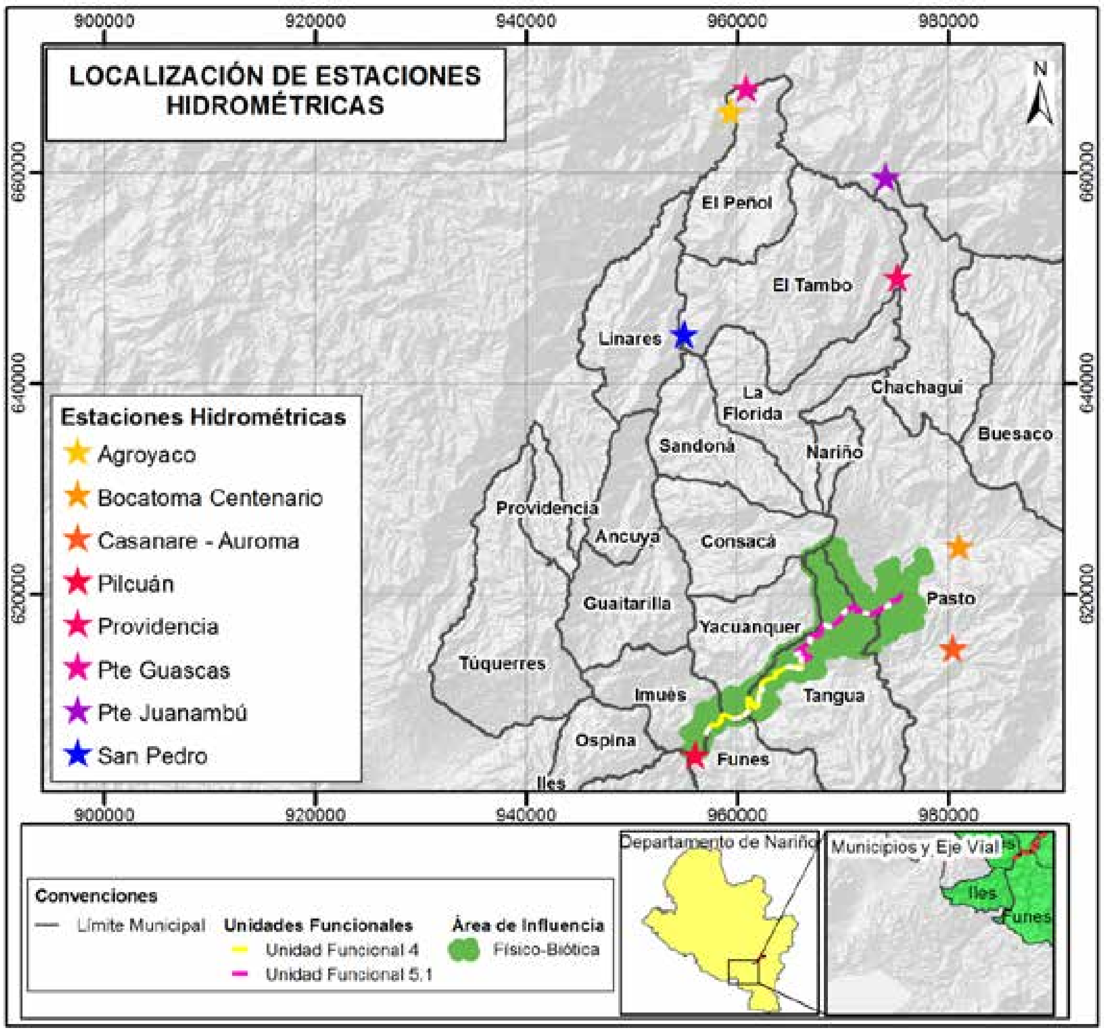


Figure 5.1.35 Location of Hydrometric Stations, Pedregal - Catambuco segment.
Source: (Geminis Environmental Consultants, 2016)

- *Patía River Hydrographic Zone*

o Guascas Bridge Station

The Patía River has the Guascas Bridge hydrometric station operated by IDEAM with a record of 39 years from 1966 to 2004, which allowed to directly characterize the hydrological regime. Figure 5.1.34, Figure 5.1.35 and Figure 5.1.36 show the annual multiannual time distribution of the mean, maximum and minimum flows. In Figure 5.1.34 it is observed that the flow regime is of the monomodal type

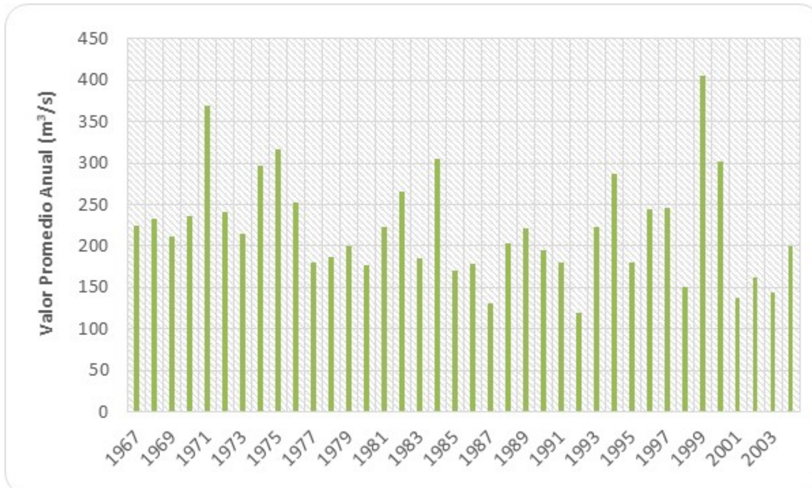


Figure 5.1.36 Distribution of Mean Flows - Guascas Bridge Station (Patía River)
Source: (Geminis Environmental Consultants, 2016)

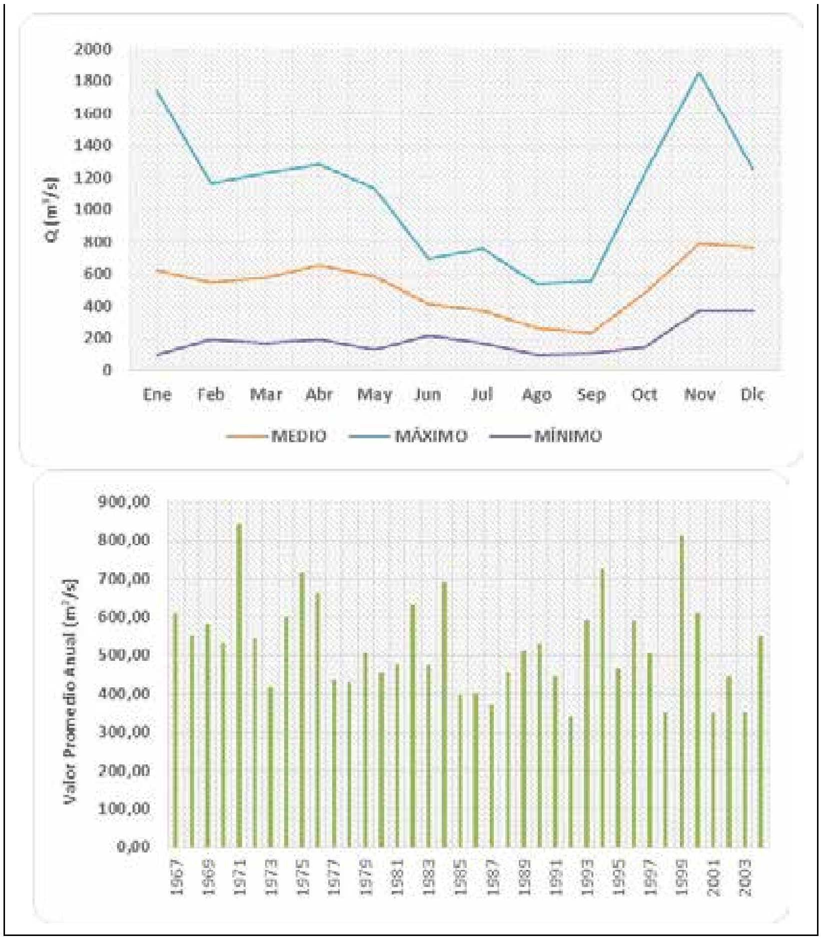


Figure 5.1.37 Distribution of Maximum Flows - Guascas Bridge Station (Patía River)
Source: (Geminis Environmental Consultants, 2016)

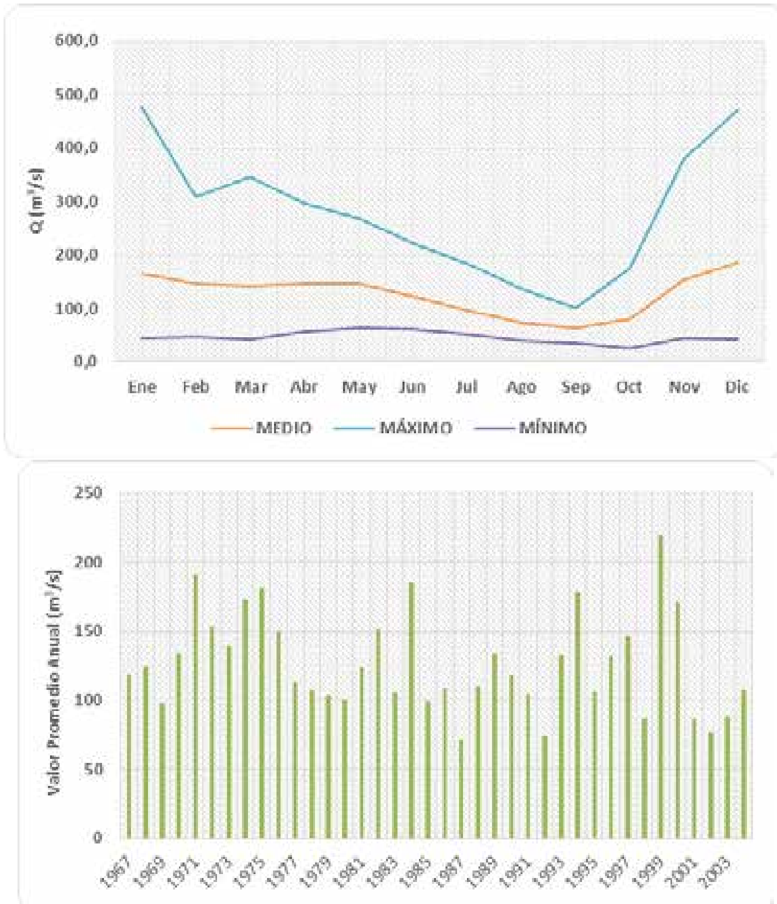


Figure 5.1.38 Distribution of Minimum Flows - Guascas Bridge Station (Patía River)
Source: (Geminis Environmental Consultants, 2016)

The mean average flow of the Patía River at the Puente Guascas station is 220.42 m^3/ s. The average multi-year maximum flow is 472.86 m^3/ s, and the minimum flow is 86.05 m^3/ s. The winter period or high flows occurs during the months of November to May, with average peaks of the order of 335.58 m^3 / s, being November the month where these flows occur. The period of low flows occurs during the months of June to October, with September being the month where the lowest flows are recorded, with a multiannual average of 97.70 m^3/ s.

Taking into account the total annual mean flow values for the Puente Guascas station from 1967 to 2004, it can be concluded that in 1999 the largest flow record (406 m^3/ s) was presented, Followed by 1971 (369 m^3/ s), 1975 (316.09 m^3/ s) and 1984 (305.11 m^3/ s), coinciding with the years in which Winter crisis in Colombia have happened equivalent to the "La Niña" phenomenon, where for 1999-2000, 1970-1971 and 1975-1976 the intensity corresponded to a between moderate to strong phenomenon.

On the other hand, and taking into account the total annual minimum flow values for the Puente Guascas station and for the same years under study, the lowest flow record was recorded in 1987 (71.79 m^3/ s), followed by 1992 (74,3 m^3/ s), corresponding to one of the years in which the socio-economic impact of the "El Niño" phenomenon was received, with an intensity between moderate and strong.

Finally, in the Figure 5.1.37, a graphical summary of the flow series in boxes and whiskers diagram (*boxplots*) is presented using the mean, maximum and minimum values of the multiannual monthly average records of the Guascas Bridge station (Patía River), concluding the following:

- The average monthly multiannual flow records have a symmetric distribution because the mean, median and mode of the distribution coincide and the data are distributed equally on both sides of that measure.
- On the other hand, the record of multiannual monthly mean maximum and minimum flows have a positive or biased asymmetric distribution to the right, since the data tends to be concentrated towards the lower part of the distribution. The mean is to the right of the median.

- *Guáitara River Hydrographic Sub-zone*

o Pilcuan Station

The Guáitara River has the Pilcuan hydrometric station operated by IDEAM with a record of 24 years from 1987 to 2013, which allowed to directly characterize the hydrological regime. Figure 5.1.38, Figure 5.1.39 and Figure 5.1.40 show the annual multiannual time distribution of the mean, maximum and minimum flows. From these figures, it is observed that the flow regime is of the monomodal type.

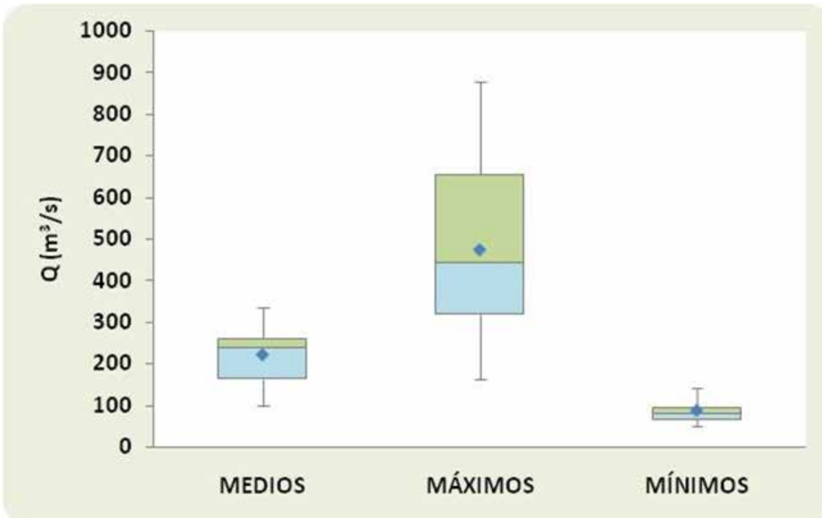


Figure 5.1.39 Diagram of Boxes and Whiskers - Monthly Multiannual Mean Values - Guascas Bridge Station (Patía River)

Source: (Geminis Environmental Consultants, 2016)

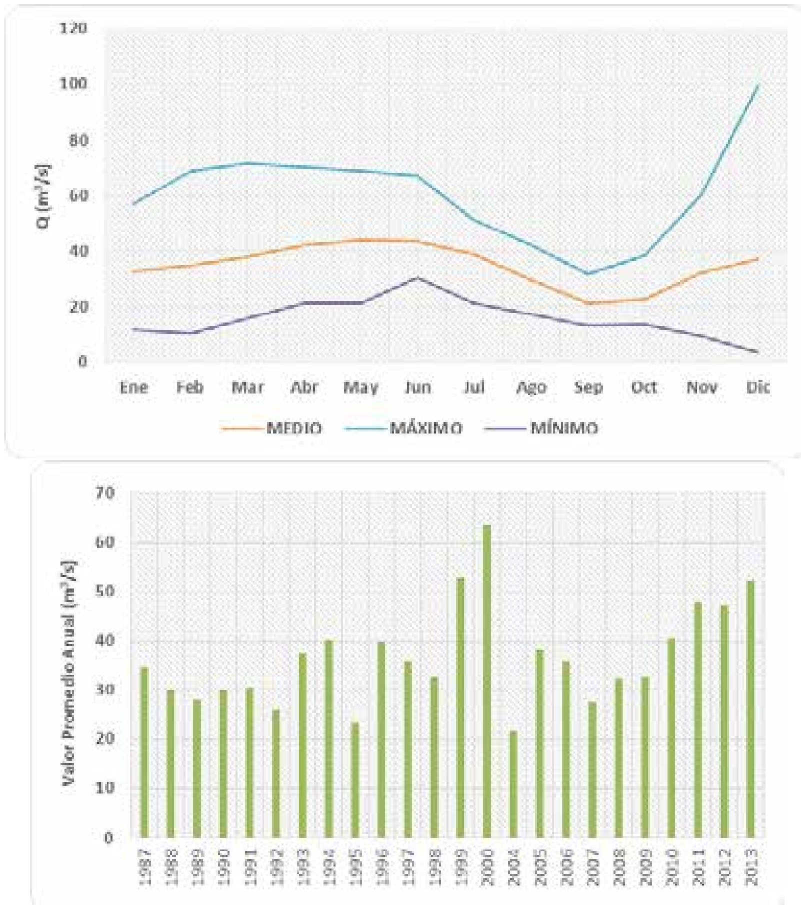


Figure 5.1.40 Distribution of Mean Flows - Pilcuan Station (Guáitara River)

Source: (Geminis Environmental Consultants, 2016)

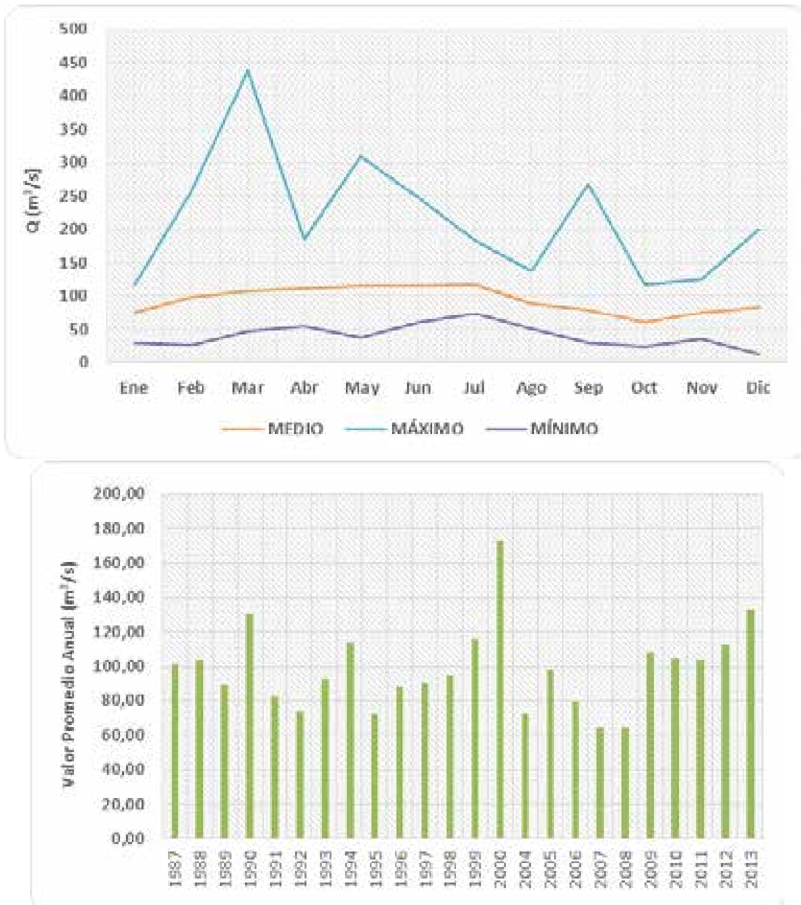


Figure 5.1.41 Distribution of Maximum Flows - Pilcuan Station (Guáitara River)
Source: **(Geminis Environmental Consultants, 2016)**

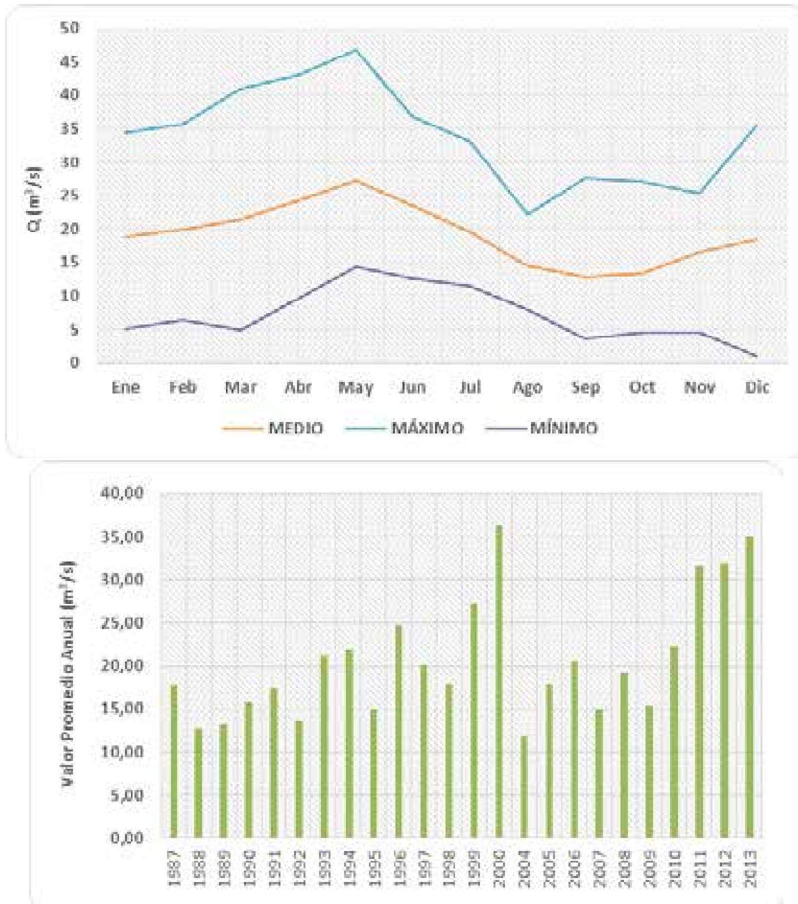


Figure 5.1.42 Distribution of Minimum Flows - Pilcuán Station (Guáitara River)
Source: Geminis Environmental Consultants, 2016

The mean average flow of the Guáitara River at the Pilcuan station is 36.72 m^3/ s. The average multiannual maximum flow is 173.38 m^3/ s, and the minimum flow is 11.82 m^3/ s. The winter period or high flows occurs during the months of November to June, with average peaks of the order of 43.92 m^3/ s, being May the month where these flows occur. The period of low flows occurs during the months of December to May, with September being the month where the lowest flows are recorded, with a multiannual average of 21.53 m^3/ s.

Taking into account the total annual mean flow values for the Pilcuán station from 1987 to 2013, it can be concluded that in 2000 the largest flow record (63.61 m^3/ s) was presented, Followed by 1999 (52.75 m^3/ s), 2013 (52.22 m^3/ s) and 2011 (48 m^3/ s), coinciding with the years in which Winter crisis in Colombia have happened equivalent to the "La Niña" phenomenon, where for 1999-2000, and 2010-2011 the intensity corresponded to a moderate phenomenon.

On the other hand, and taking into account the total annual minimum values of flow for the Piulcan station and for the same years under study, the lowest flow record was recorded in 2004 (11.82 m^3/ s), followed by 1988 (12.69 m^3/s).

Finally, in the Figure 5.1.41, a graphical summary of the flow series in boxes and whiskers diagram (*boxplots*) is presented using the mean, maximum and minimum values of the multiannual monthly average records of the Pilcuán station (Guáitara River), concluding the following:

- Monthly multi-year mean flow records have an asymmetric negative or biased left-handed distribution as data tends to be concentrated towards the top part of the distribution. The mean is to the left of the median.
- The monthly multiannual minimum flow records have a symmetric distribution because the mean, median and mode of the distribution coincide and the data are distributed equally on both sides of that measure.
- FInally, the record of multiannual monthly maximum mean flows have a positive or biased asymmetric distribution to the right, since the data tends to be concentrated towards the lower part of the distribution. The mean is to the right of the median.

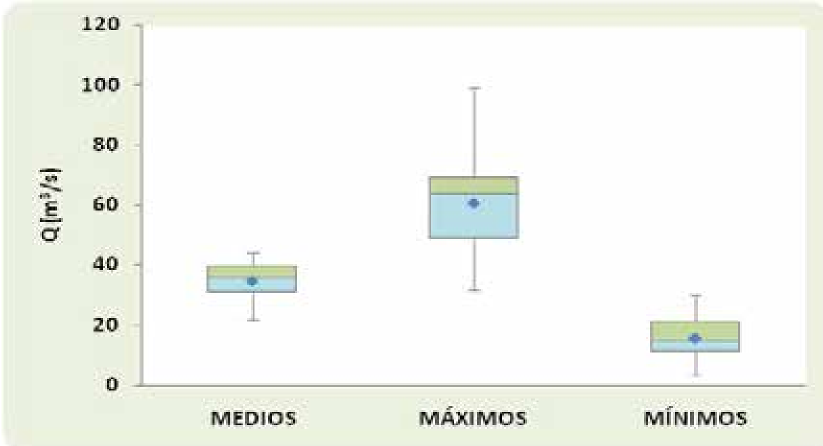


Figure 5.1.43 Diagram of Boxes and Whiskers - Monthly Multiannual Mean Values - Pilcuán Station (Guáitara River)

Source: (Geminis Environmental Consultants, 2016)

- Agroyaco Station

The Guáitara River also has the Agroyaco hydrometric station operated by IDEAM with a record of 41 years from 1969 to 2000, which allowed to directly characterize the hydrological regime. Figure 5.1.42, Figure 5.1.43 and Figure 5.1.44 show the annual multiannual time distribution of the mean, maximum and minimum flows. From these figures, it is observed that the flow regime is of the monomodal type.

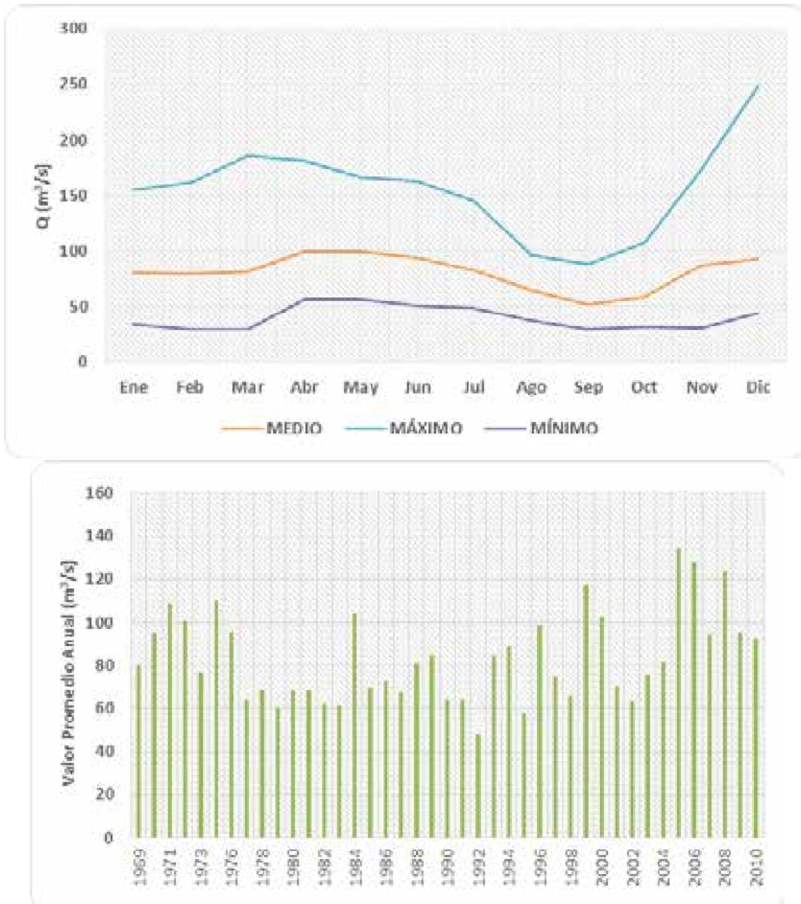


Figure 5.1.44 Distribution of Mean Flows - Agroyaco Station (Guáitara River)
Source: (Geminis Environmental Consultants, 2016)

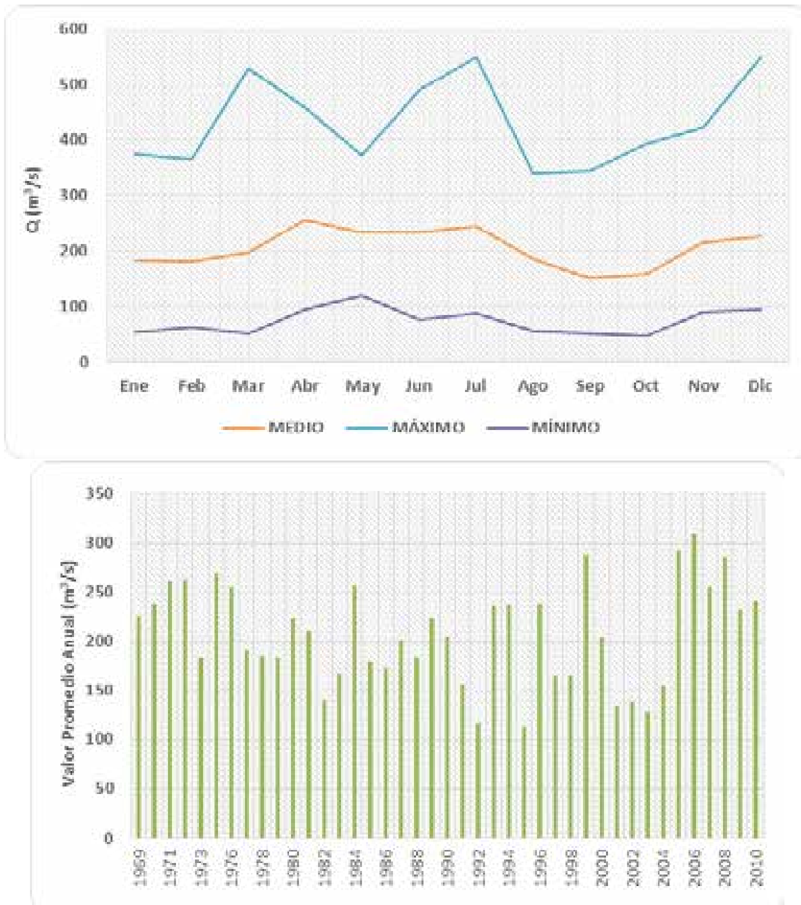


Figure 5.1.45 Distribution of Maximum Flows - Agroyaco Station (Guáitara River)
Source: (Geminis Environmental Consultants, 2016)

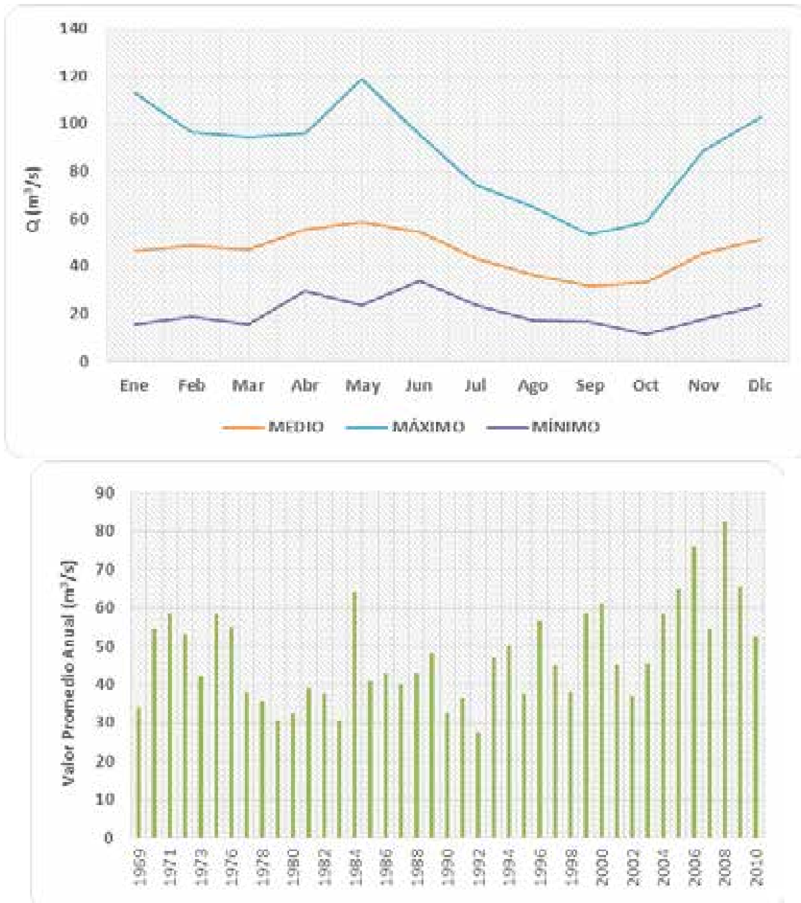


Figure 5.1.46 Distribution of Minimum Flows - Agroyaco Station (Guáitara River)

Source: **(Geminis Environmental Consultants, 2016)**

The mean average flow of the Guáitara River at the Agroyaco station is 34.74 m^3/s. The average multiannual maximum flow is 432-925 m^3/s, and the minimum flow is 20.70 m^3/s. The winter period or high flows occurs during the months of November to June, with average peaks of the order of 99.97 m^3/s, being April the month where these flows occur. The period of low flows occurs during the months of December to May, with September being the month where the lowest flows are recorded, with a multiannual average of 52.52 m^3/s.

Taking into account the total annual mean flow values for the Agroyaco station from 1969 to 2010, it can be concluded that in 2006 the largest flow record (309.02 m^3/ s) was presented, Followed by 2005 (292.5 m^3/ s), 2013 (288.34 m^3/ s) and 2008 (286.05 m^3/ s), coinciding with the years in which Winter crisis in Colombia have happened equivalent to the "La Niña" phenomenon, where for 2007-2008 the intensity corresponded to a very strong phenomenon.

On the other hand, and taking into account the total annual minimum flow values for the Agroyaco station and for the same years under study, the lowest flow record was recorded in 1992 (117.65 m^3/ s), followed by 1995 (113.5 m^3/ s), corresponding to one of the years in which the socio-economic climatic impact of the "El Niño" phenomenon was received, with a strong intensity.

Finally, in the Figure 5.1.45, a graphical summary of the flow series in boxes and whiskers diagram (*boxplots*) is presented using the mean, maximum and minimum values of the multiannual monthly average records of the Agroyaco station (Guáitara River), concluding the following:

- Monthly multi-year mean flow records have an asymmetric negative or biased left-handed distribution as data tends to be concentrated towards the top part of the distribution. The mean is to the left of the median.
- FInally, the record of multiannual monthly minimum and maximum mean flows have a positive or biased asymmetric distribution to the right, since the data tends to be concentrated towards the lower part of the distribution. The mean is to the right of the median.

o San Pedro Station

The Guáitara River also has the San Pedro hydrometric station operated by IDEAM with a record of 35 years from 1980 to 2014, which allowed to directly characterize the hydrological regime. Figure 5.1.46, Figure 5.1.47 and Figure 5.1.48 show the annual multiannual time distribution of the mean, maximum and minimum flows. From these figures, it is observed that the flow regime is of the monomodal type.

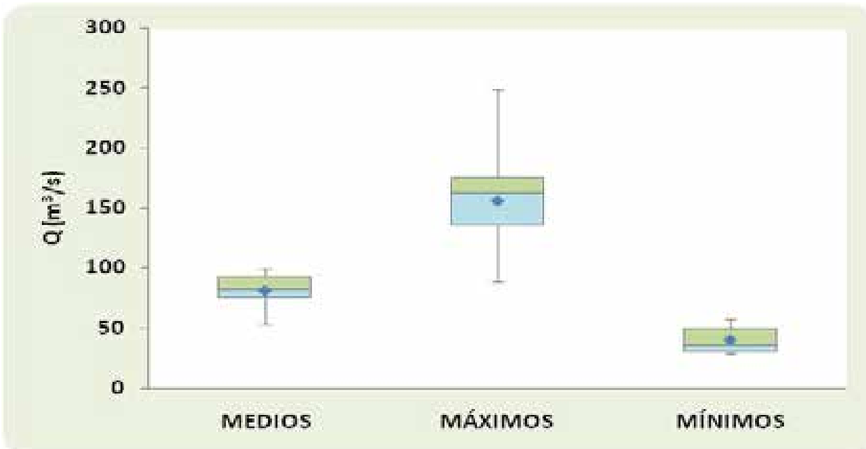


Figura5.1.47 Diagram of Boxes and Whiskers - Monthly Multiannual Mean Values - Agroyaco Station (Guáitara River)

Source: (Geminis Environmental Consultants, 2016)

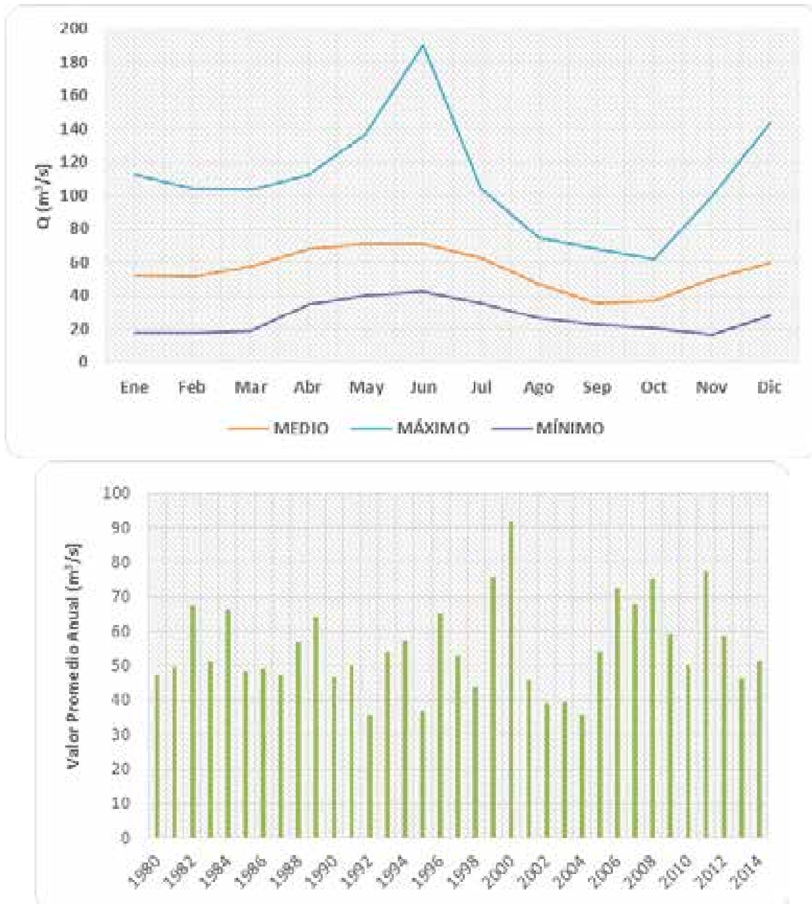


Figure 5.1.48 Distribution of Mean Flows - San Pedro Station (Guáitara River)
Source: (Geminis Environmental Consultants, 2016)

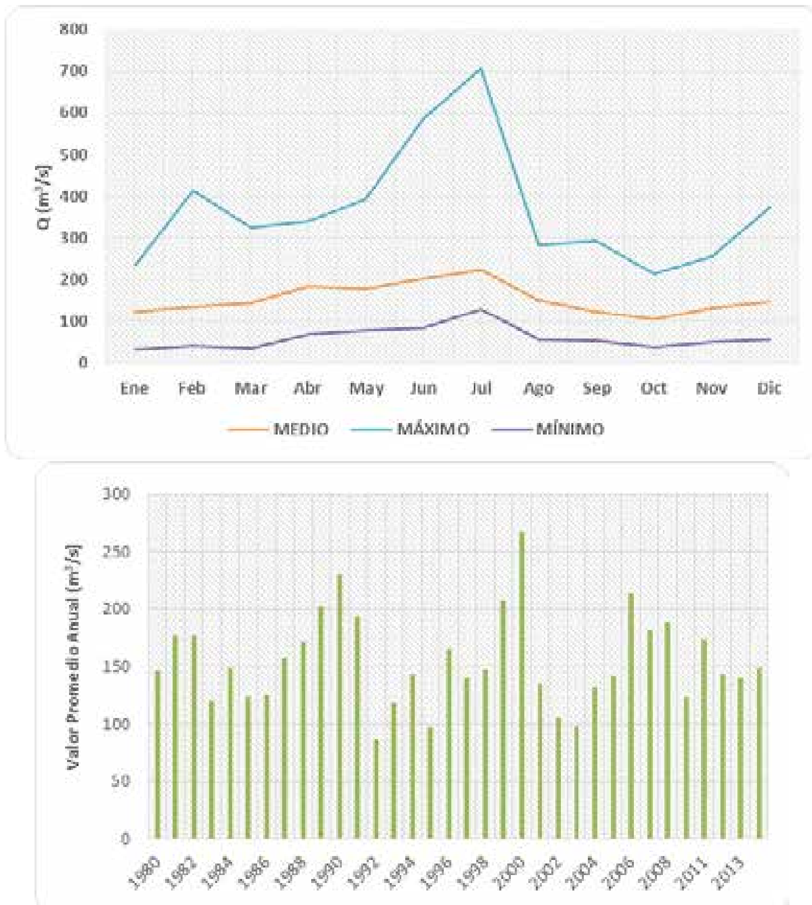


Figure 5.1.49 Distribution of Maximum Flows - San Pedro Station (Guáitara River)

Source: **(Geminis Environmental Consultants, 2016)**

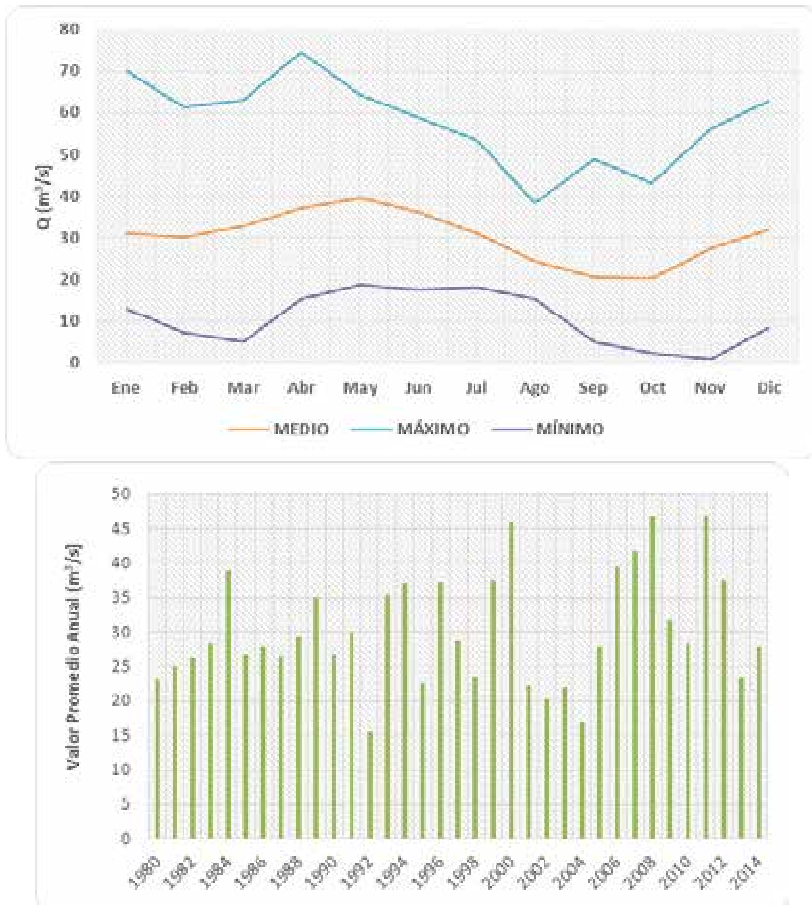


Figure 5.1.50 Distribution of Minimum Flows - San Pedro Station (Guáitara River)
Source: **(Geminis Environmental Consultants, 2016)**

The mean average flow of the Guáitara River at the San Pedro station is 55.13 m^3/s. The average multiannual maximum flow is 708.3 m^3/ s, and the minimum flow is 0.9 m^3/s. The winter period or high flows occurs during the months of November to June, with average peaks of the order of 99.97 m^3 / s, being April the month where these flows occur. The period of low flows occurs during the months of December to May, with September being the month where the lowest flows are recorded, with a multiannual average of 35.76 m^3/s.

Taking into account the total annual mean flow values for the San Pedro station from 1980 to 2014, it can be concluded that in 2000 the largest flow record (92.07 m^3/ s) was presented, Followed by 2010 (77,39 m^3/ s), 1999 (75,45 m^3/ s) and 2 m^3/ s), coinciding with the years in which Winter crisis in Colombia have happened equivalent to the "La Niña" phenomenon, where for 1999-2000, and 2010-2011 the intensity corresponded to a moderate phenomenon.

On the other hand, and taking into account the total annual minimum flow values for the San Pedro station and for the same years under study, the lowest flow record was recorded in 1992 (35.83 m^3/ s), followed by 2004 (35,55 m^3/ s), corresponding to one of the years in which the socio-economic climatic impact of the "El Niño" phenomenon was received, with a strong intensity.

Finally, in the Figure 5.1.49, a graphical summary of the flow series in boxes and whiskers diagram (*boxplots*) is presented using the mean, maximum and minimum values of the multiannual monthly average records of the San Pedro station (Guáitara River), concluding the following:

- Monthly multi-year mean flow records have an asymmetric negative or biased left-handed distribution as data tends to be concentrated towards the top part of the distribution. The mean is to the left of the median.
- FInally, the record of multiannual monthly minimum and maximum mean flows have a positive or biased asymmetric distribution to the right, since the data tends to be concentrated towards the lower part of the distribution. The mean is to the right of the median.

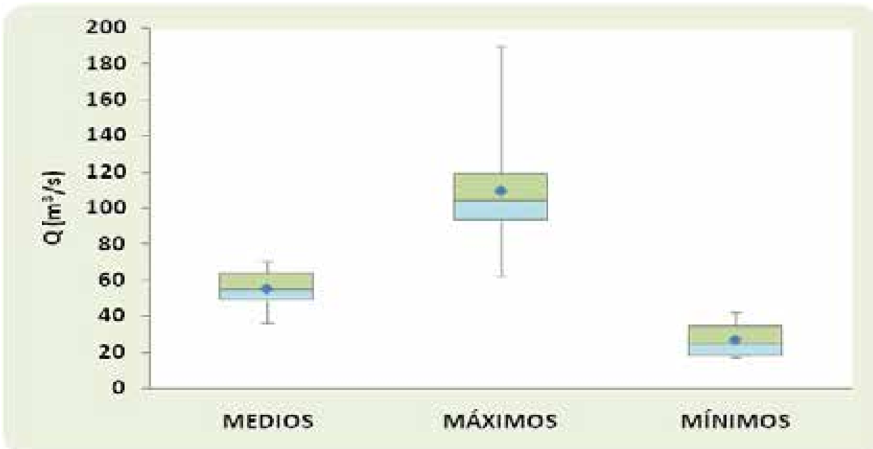


Figure 5.1.51 Figura. Diagram of Boxes and Whiskers - Monthly Multiannual Mean Values - San Pedro Station (Guáitara River)

Source: (Geminis Environmental Consultants, 2016)

- *Hydrographic unit Level I - Bobo River*

o Automatic Casanare station

The Bobo River has the Automatic Casanare hydrometric station operated by IDEAM with a record of 24 years from 1989 to 2012, which allowed to directly characterize the hydrological regime. Figure 5.1.50, Figure 5.1.51 and Figure 5.1.52 show the annual multiannual time distribution of the mean, maximum and minimum flows. From these figures, it is observed that the flow regime is of the monomodal type.

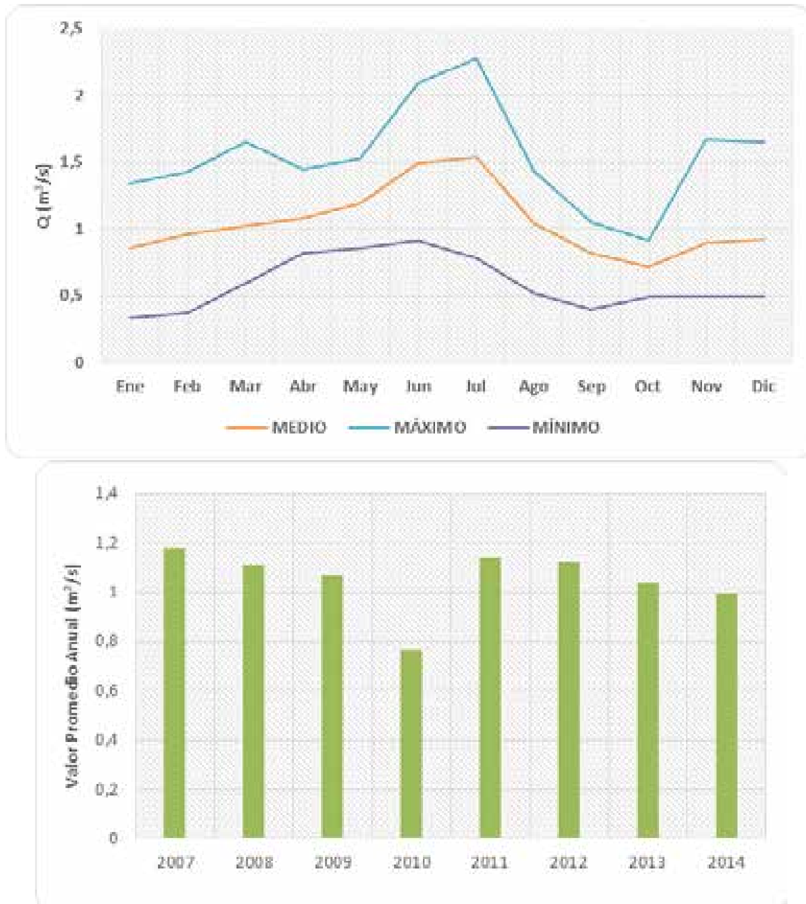


Figure 5.1.52 Distribution of Mean Flows - Automatic Casanare Station (Bobo River)
Source: (Geminis Environmental Consultants, 2016)

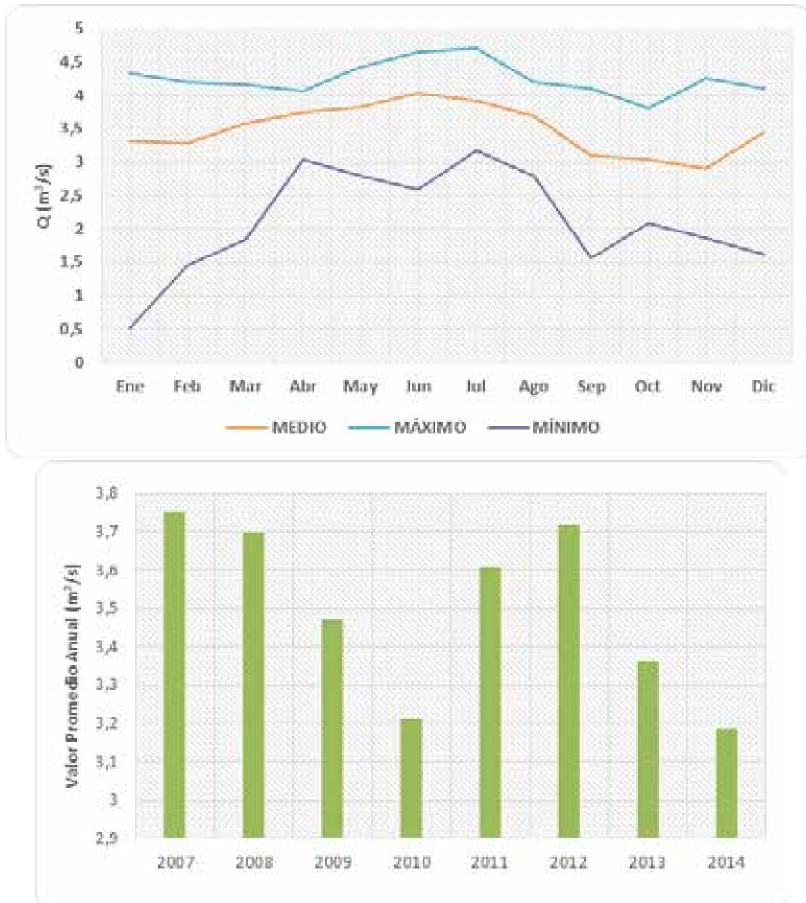


Figure 5.1.53 Distribution of Maximum Flows- Automatic Casanare Station (Bobo River)

Source: **(Geminis Environmental Consultants, 2016)**

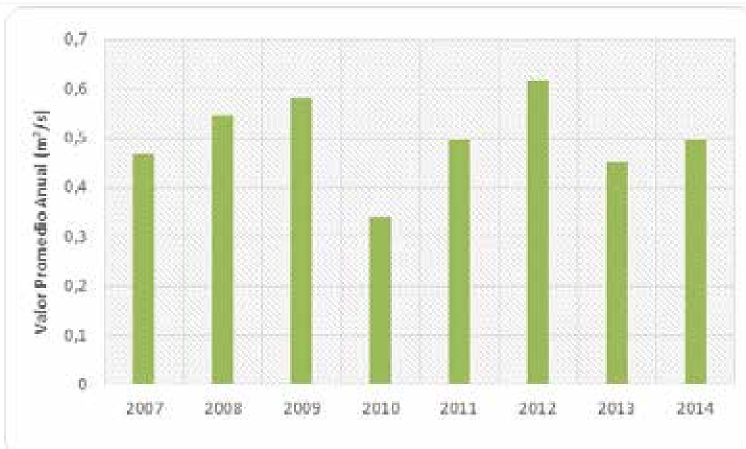


Figure 5.1.54 Distribution of Minimum FLows- Automatic Casanare Station (Bobo River)
Source: **(Geminis Environmental Consultants, 2016)**

The average mean flow of the Bobo river in the Automatic Casanare station is of 1.044 ms^3/s. The maximum multiannual maximum flow is 4.71 $m^3/$ s, and the minimum flow is 0,23 m^3/s. The winter period or high flows occurs during the months of May to August, with average peaks of the order of 1.53 $m^3/$ s, being July the month where these flows occur. The period of low flows occurs during the months of September to March, with October being the month where the lowest flows are recorded, with a multiannual average of 0.71 $m^3/$ s.

Considering the mean annual total flow values for the Casanare Automatic station from year 2007 to year 2014, it is possible to conclude there are not significant differences in the registries of flows for these years, nevertheless, year 2007 showed the greatest flow registry (1.17 ms^3/s), followed by 2014 (1.14 m^3/s), 2012 (1,12m^3/s) and 2008 (1.11 m^3/s).

Finally, in the Figure 5.1.53, a graphical summary of the flow series in boxes and whiskers diagram (*boxplots*) is presented using the mean, maximum and minimum values of the multiannual monthly average records of the Casanare Automatic station (Bobo River), concluding the following:

- The record of multiannual monthly minimum and maximum mean flows have a positive or biased asymmetric distribution to the right, since the data tends to be concentrated towards the lower part of the distribution. The mean is to the right of the median.

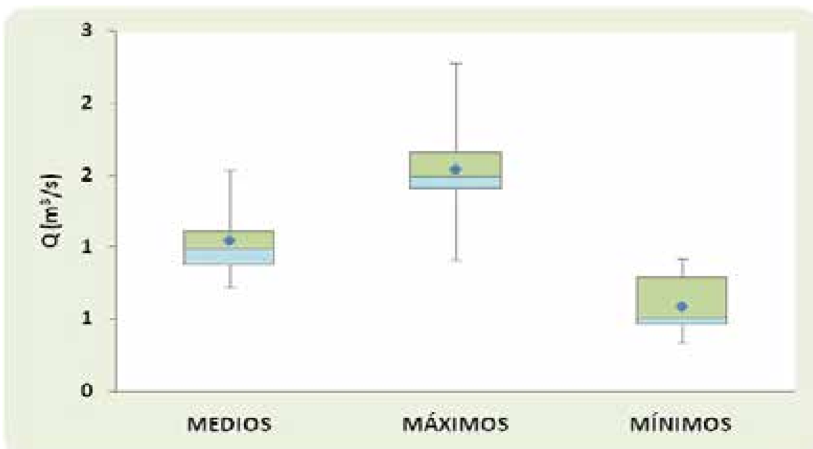


Figure 5.1.55 Diagram of Boxes and Whiskers - Monthly Multiannual Mean Values - Automatic Casanare (Bobo River)

Source: (Geminis Environmental Consultants, 2016)

- *Juanambú River hydrographic sub-zone*

o Puente Juanambú Station

The Juanambú River has the Juanambú Bridge hydrometric station operated by IDEAM with a record of 35years from 1987to 2014, which allowed to directly characterize the hydrological regime. In the Figure 5.1.54

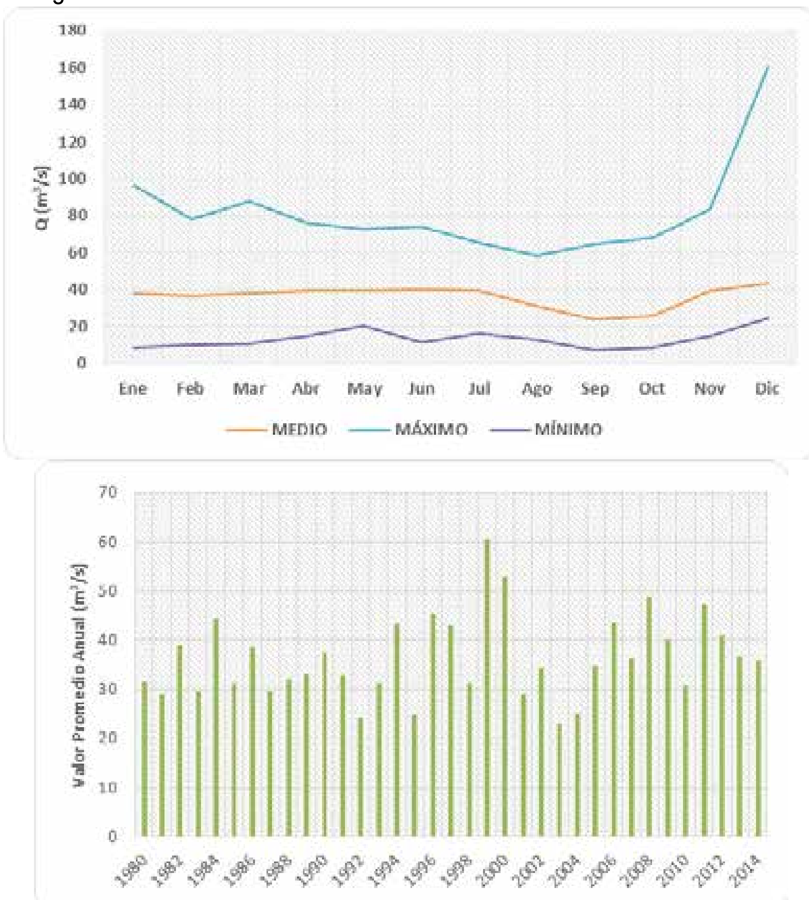
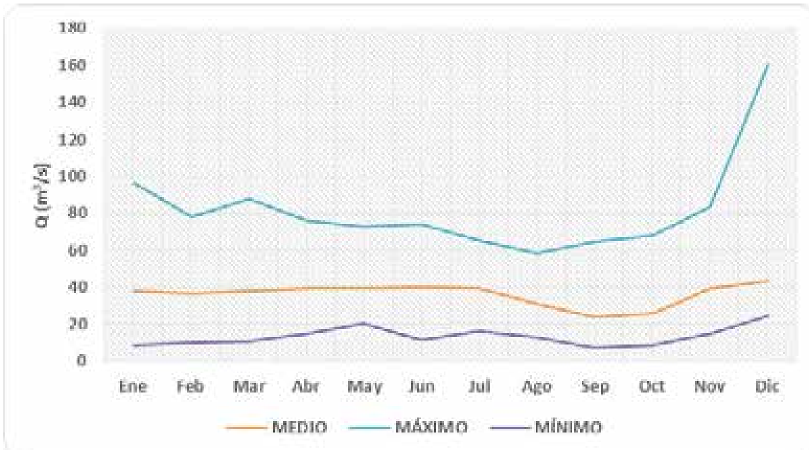


Figure 5.1.56 Distribution of Mean Flows - Juanambú Bridge Station (Juanambú River)
Source: (Geminis Environmental Consultants, 2016)



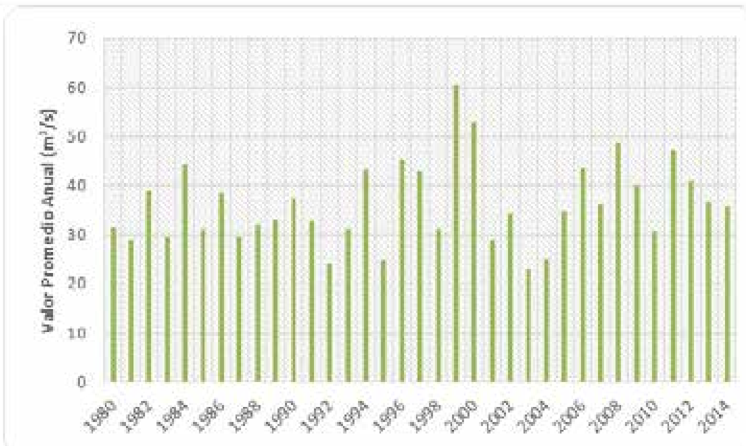


Figure 5.1.54, Figure 5.1.55 and Figure 5.1.56 show the annual multiannual time distribution of the mean, maximum and minimum flows. From these figures, it is observed that the flow regime is of the monomodal type.

Figure 5.1.57 Distribution of Máximum Flows - Juanambú Bridge Station (Juanambú River)
Source: **(Geminis Environmental Consultants, 2016)**

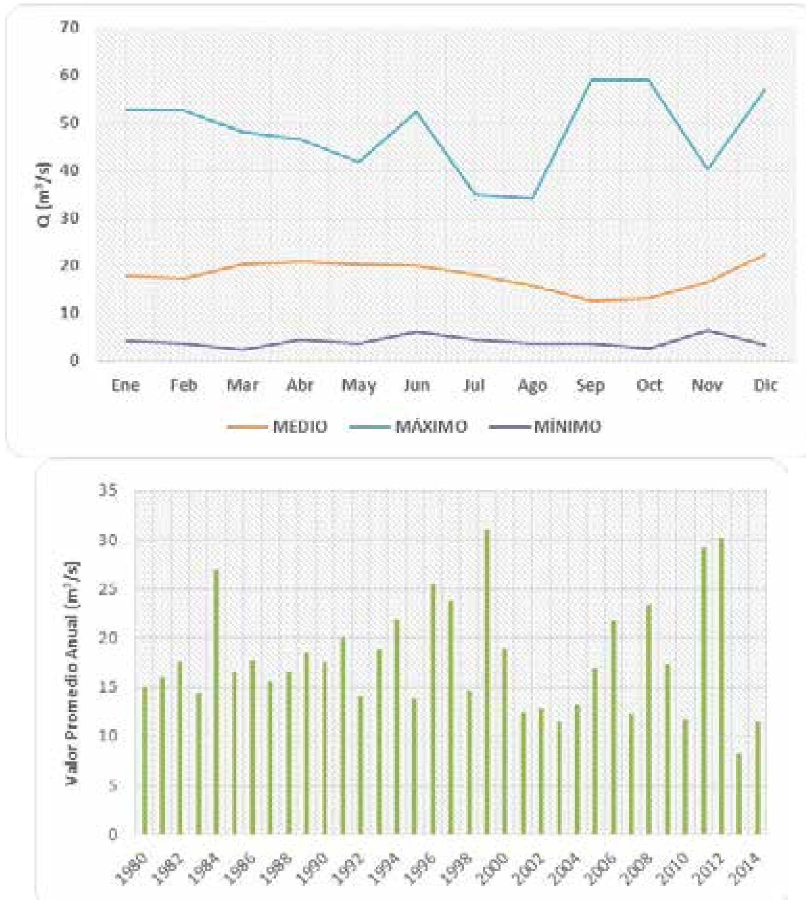


Figure 5.1.58 Distribution of Minimum Flows - Juanambú Bridge Station (Juanambú River)
Source: **(Geminis Environmental Consultants, 2016)**

The mean average flow of the Juanambú River at the Puente Juanambú station is 36,233 m^3/ s. The average multiannual maximum flow is 509,5 m^3/ s, and the minimum flow is 2,325 m^3/s. The winter period or high flows occurs during the months of December to July, with average peaks of the order of 43,31 m^3/ s, being July the month where these flows occur. The period of low flows occurs during the months of August to November, with September being the month where the lowest flows are recorded, with a multiannual average of 23,72 m^3/ s.

Taking into account the total annual mean flow values for the Juanambú Bridge station from 1980 to 2014, it can be concluded that in 1999 the largest flow record (60,74 m^3/ s) was presented, Followed by 2000 (52,95 m^3/ s), 2008 (48,87 m^3/ s) and 2011 (47,39 m^3/ s), coinciding with the years in which Winter crisis in Colombia have happened equivalent to the "La Niña" phenomenon, where for 1999-2000, and 2010-2011 the intensity corresponded to a moderate phenomenon.

On the other hand, and taking into account the total annual minimum flow values for the Juanambú Bridge station and for the same years under study, the lowest flow record was recorded in 2003 (23,18 m^3/ s), followed by 1992 (24,09 m^3/ s), corresponding to one of the years in which the socio-economic climatic impact of the "El Niño" phenomenon was received, with a strong intensity.

Finally, in the Figure 5.1.57, a graphical summary of the flow series in boxes and whiskers diagram (*boxplots*) is presented using the mean, maximum and minimum values of the multiannual monthly average records of the Juanambú Bridge station (<Juanambú River), concluding the following:

- Monthly multi-year mean flow records have an asymmetric negative or biased left-handed distribution as data tends to be concentrated towards the top part of the distribution. The mean is to the left of the median.
- FInally, the record of multiannual monthly minimum and maximum mean flows have a positive or biased asymmetric distribution to the right, since the data tends to be concentrated towards the lower part of the distribution. The mean is to the right of the median.

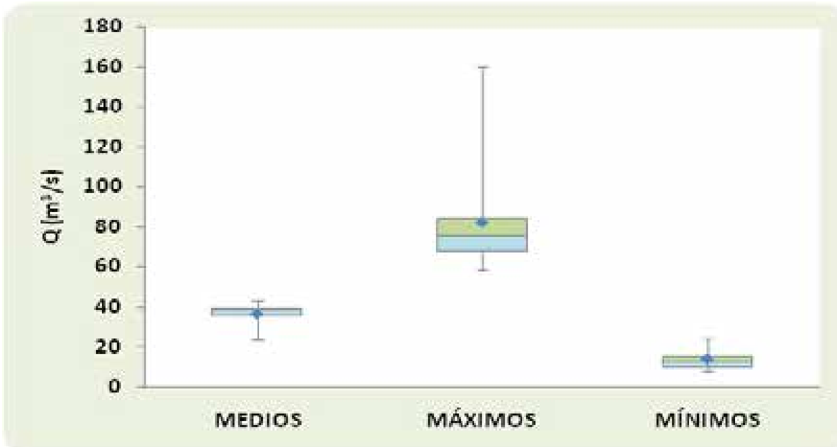


Figure 5.1.59 Diagram of Boxes and Whiskers - Monthly Multiannual Mean Values - Juanambú Bridge Station (Juanambú River)
Source: **(Geminis Environmental Consultants, 2016)**

- *Hydrographic Unit Level I - Pasto River*

o Providencia Station

The Pasto River has the Providencia hydrometric station operated by IDEAM with a record of 24 years from 1989 to 2012, which allowed to directly characterize the hydrological regime. Figure 5.1.58, Figure 5.1.59 and Figure 5.1.60 show the annual multiannual time distribution of the mean, maximum and minimum flows. From these figures, it is observed that the flow regime is of the monomodal type.

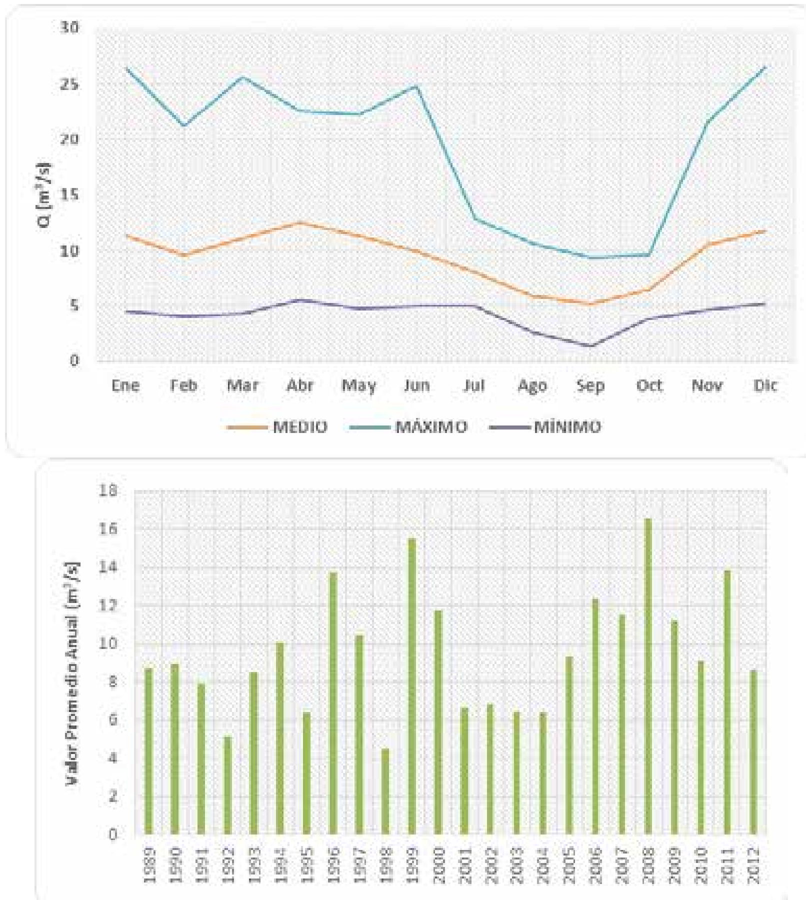


Figure 5.1.60 Distribution of Mean Flows - Providencia Station (Pasto RIver)
Source: (Geminis Environmental Consultants, 2016)

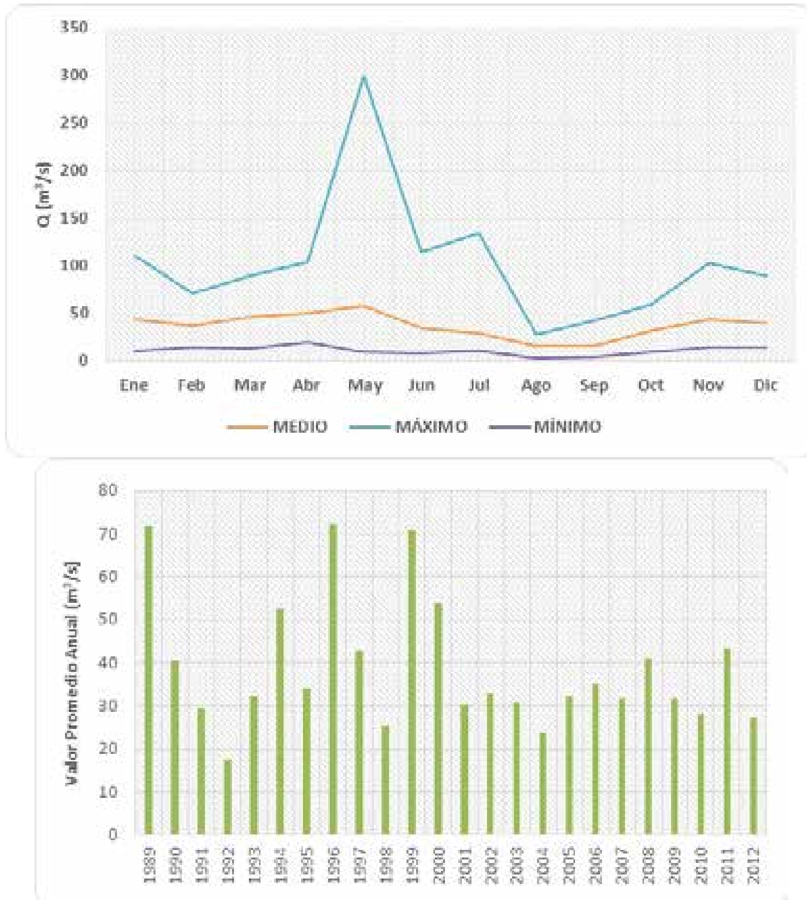


Figure 5.1.61 Distribution of Maximum Flows - Providencia Station (Pasto RIver)
Source: **(Geminis Environmental Consultants, 2016)**

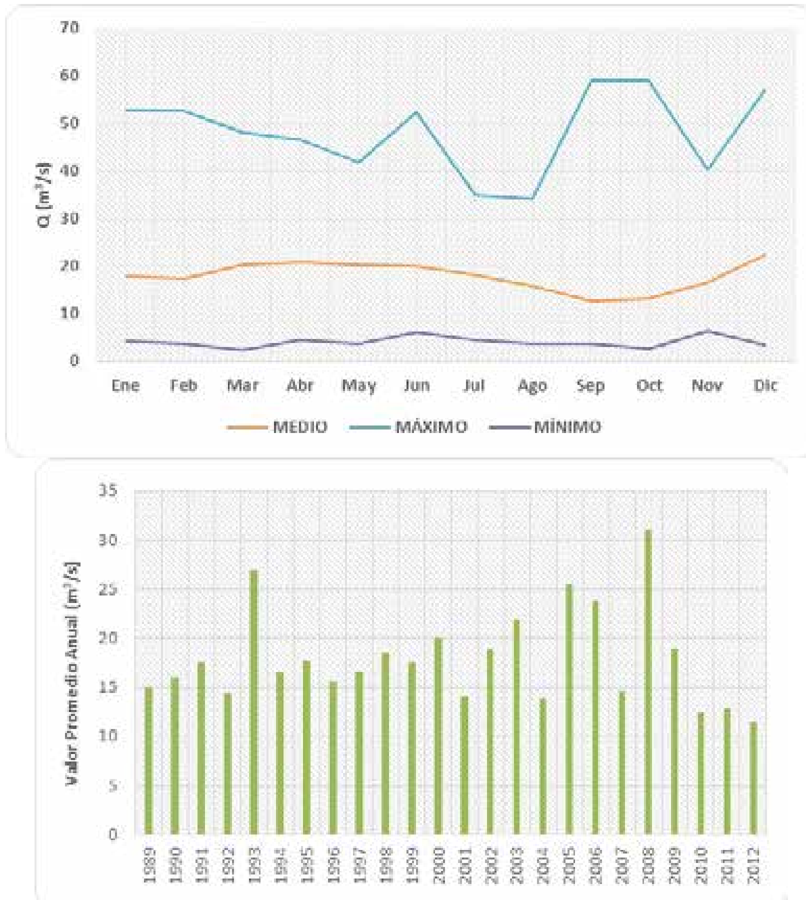


Figure 5.1.62 Distribution of Minimum Flows - Providencia Station (Pasto RIver)
Source: **(Geminis Environmental Consultants, 2016)**

The mean average flow of the Pasto River at the Providencia station is 9,46 m ^{3}/ s. The average multiannual maximum flow is 300,8 m^3/ s, and the minimum flow is 2,32 m^3/s. The winter period or high flows occurs during the months of November to July, with average peaks of the order of 12,53 m³ / s, being April the month where these flows occur. The period of low flows occurs during the months of December to June, with September being the month where the lowest flows are recorded, with a multiannual average of 5,17 m^3/s.

Taking into account the total annual mean flow values for the Providencia station from 1980 to 2014, it can be concluded that in 2014 the largest flow record (16,54 m^3/ s) was presented, Followed by 1999 (15,51 m^3/ s), 2011 (13,89 m^3/ s) and 1996 (13,73 m^3/ s), coinciding with the years in which Winter crisis in Colombia have happened equivalent to the "La Niña" phenomenon, where for 2007-2008, and 2010-2011 the intensity corresponded to a between moderate and very strong phenomenon.

On the other hand, and taking into account the total annual minimum values of flow for the Providencia station and for the same years under study, the lowest flow record was recorded in 1998 (4,52 m^3/ s), followed by 1992 (5,19 m^3/s).

Finally, in the Figure 5.1.61, a graphical summary of the flow series in boxes and whiskers diagram (*boxplots*) is presented using the mean, maximum and minimum values of the multiannual monthly average records of the Providencia station (Pasto River), concluding the following:

- Monthly multi-year mean, maximum and minimum flow records have an asymmetric negative or biased left-handed distribution as data tends to be concentrated towards the top part of the distribution. The mean is to the left of the median.

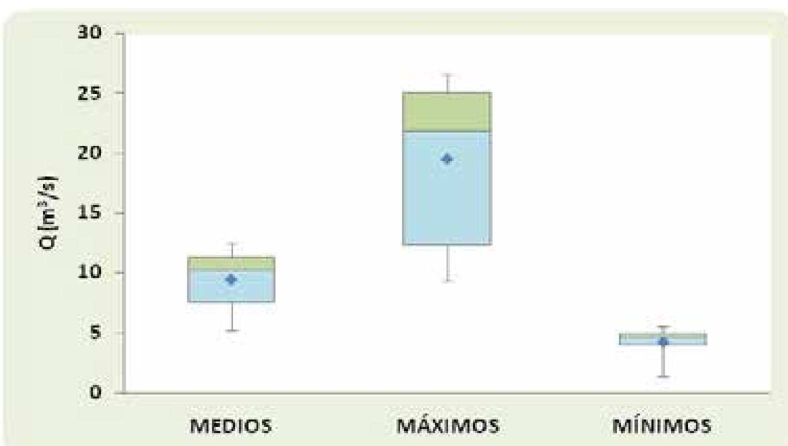
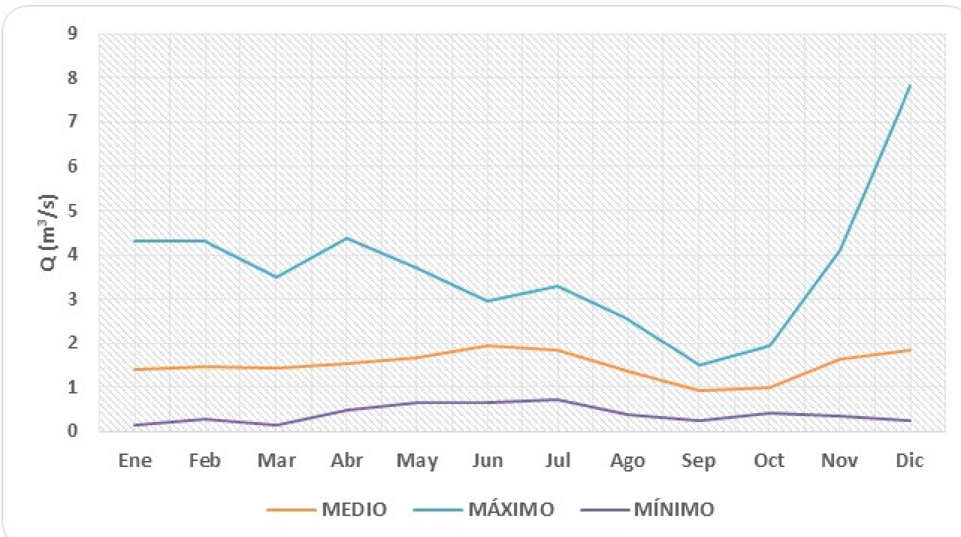


Figure 5.1.63 Diagram of Boxes and Whiskers - Monthly Multiannual Mean Values - Providencia Station (Pasto River)
Source: **(Geminis Environmental Consultants, 2016)**

- Bocatoma Centenario Station

The Pasto River also has the Bocatoma Centenario hydrometric station operated by IDEAM with a record of 24 years from 1988 to 2014, which allowed to directly characterize the hydrological regime. Figure 5.1.62, Figure 5.1.63 and Figure 5.1.64 show the annual multiannual time distribution of the mean, maximum and minimum flows. From these figures, it is observed that the flow regime is of the monomodal type.



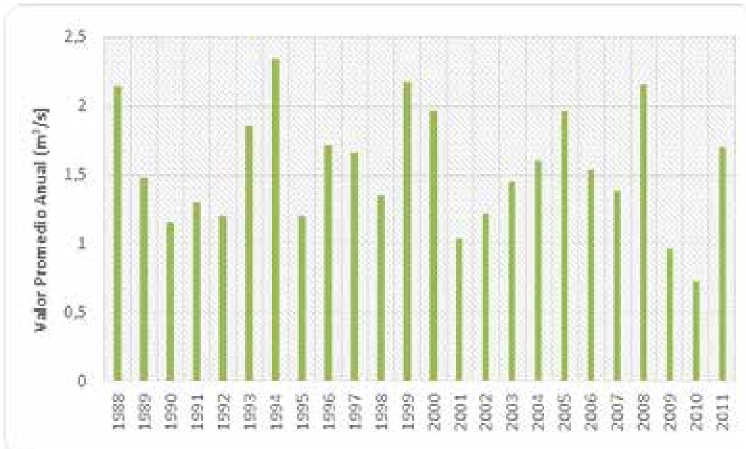
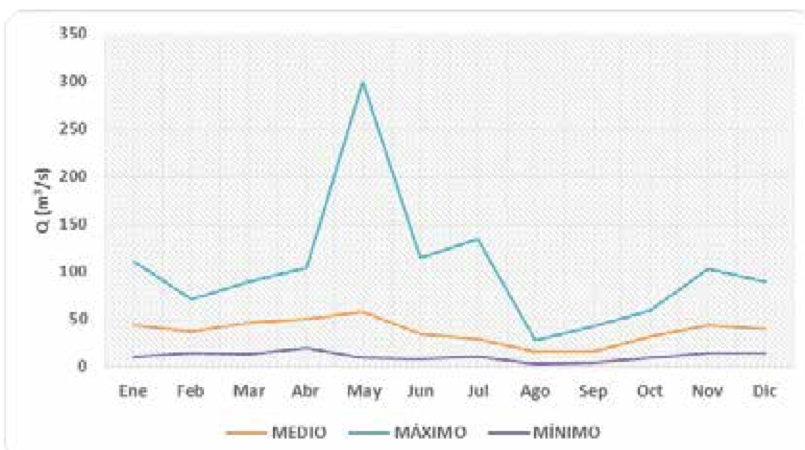


Figure 5.1.64 Distribution of Mean Flows - Bocatoma Centenario Station (Pasto RIver)
Source: (Geminis Environmental Consultants, 2016)



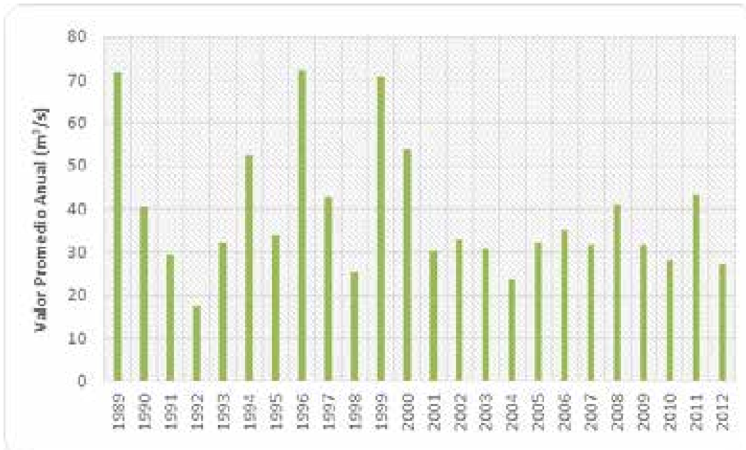


Figure 5.1.65 Distribution of Maximum Flows - Bocatoma Centenario Station (Pasto RIver)
Source: (Geminis Environmental Consultants, 2016)

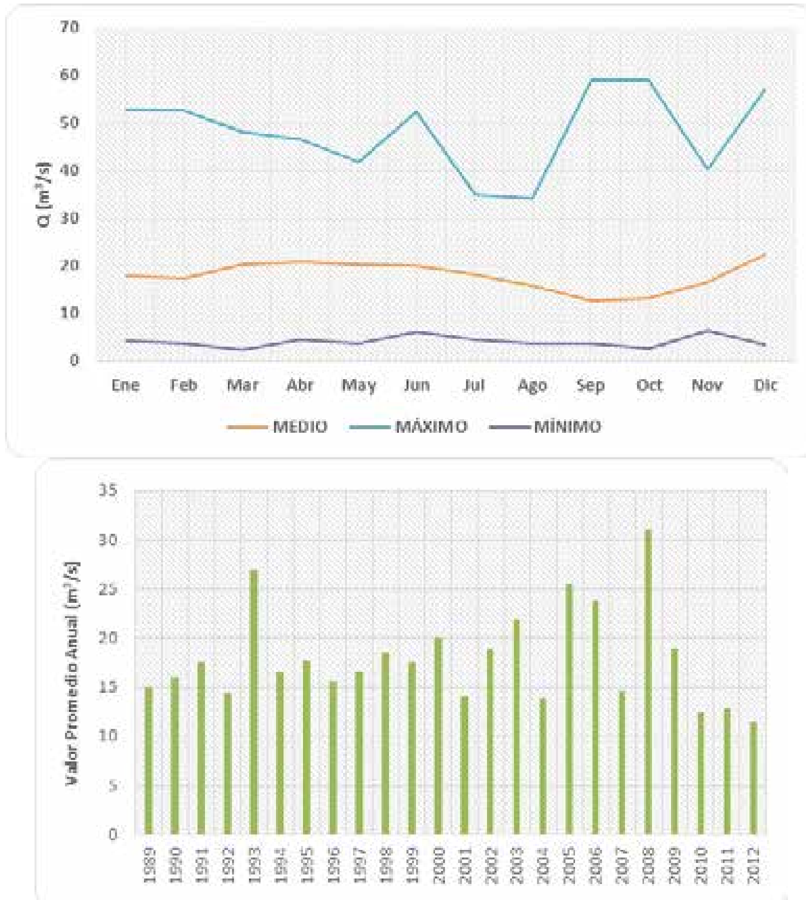


Figure 5.1.66 Distribution of Minimum Flows - Bocatoma Centenario Station (Pasto RIver)
Source: Geminis Environmental Consultants, 2016

The mean average flow of the Pasto River at the Bocatoma Centenario station is 1,50 m ^{3}/ s. The average multiannual maximum flow is 117,1 m^3/ s, and the minimum flow is 0,084 m^3/s. The winter period or high flows occurs during the months of November to July, with average peaks of the order of 1,95 m³ / s, being June the month where these flows occur. The period of low flows occurs during the months of December to June, with September being the month where the lowest flows are recorded, with a multiannual average of 0,93 m^3/s.

Taking into account the total annual mean flow values for the Bocatoma Centenario station from 1988 to 2014, it can be concluded that in 1994 the largest flow record (2,33 m^3/ s) was presented, Followed by 1999 (2,17 m^3/ s), 2008 (2,15 m^3/ s) and 1988 (2,14 m^3/ s), coinciding with the years in which Winter crisis in Colombia have happened equivalent to the "La Niña" phenomenon, where for 2007-2008, 1999–2000 and 1988-1989 the intensity corresponded to a between moderate and very strong phenomenon.

On the other hand, and taking into account the total annual minimum flow values for the Bocatoma Centenario station and for the same years under study, the lowest flow record was recorded in 2010 (0,73 m^3/ s), followed by 2009 (0,96 m^3/ s), corresponding to one of the years in which the socio-economic climatic impact of the "El Niño" phenomenon was received, with a weak intensity.

Finally, in the Figure 5.1.61, a graphical summary of the flow series in boxes and whiskers diagram (*boxplots*) is presented using the mean, maximum and minimum values of the multiannual monthly average records of the Bocatoma Centenario station (Pasto River), concluding the following:

- Monthly multi-year mean flow records have an asymmetric negative or biased left-handed distribution as data tends to be concentrated towards the top part of the distribution. The mean is to the left of the median.
- The monthly multiannual minimum flow records have a symmetric distribution because the mean, median and mode of the distribution coincide and the data are distributed equally on both sides of that measure.
- FInally, the record of multiannual monthly maximum mean flows have a positive or biased asymmetric distribution to the right, since the data tends to be concentrated towards the lower part of the distribution. The mean is to the right of the median.

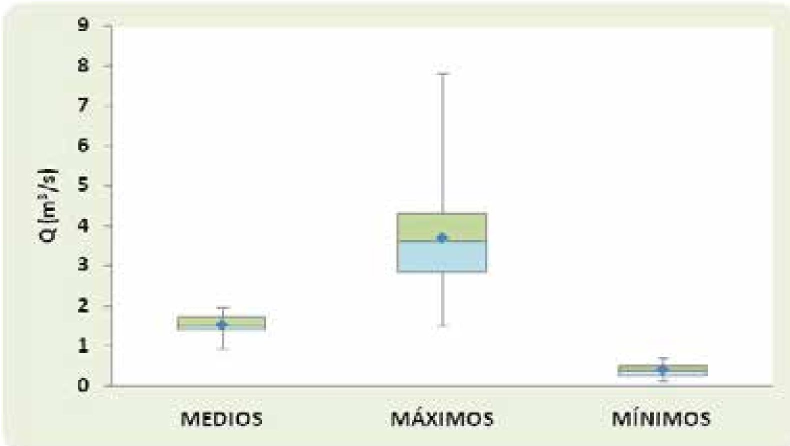


Figure 5.1.67 Diagram of Boxes and Whiskers - Monthly Multiannual Mean Values - Bocatoma Centenario Station (Pasto River)

Source: Geminis Environmental Consultants, 2016

- <u>Fluvial dynamics</u>

- *Analysis of the fluvial dynamics of the Guáitara River*

From the point of view of fluvial hydraulics, all rivers are subject to a greater or lesser degree to processes of erosion or degradation, equilibrium and sedimentation or aggradation. A river is considered in a state of equilibrium when the profile of the bottom and the banks of the channel does not change and therefore, there is compensation between the sediments that are transported towards the site and from the site.

Degradation occurs when the bed level falls or if the margins move outwards, which occurs when the sediment load is lower than the transport capacity of the water flow. This process is accelerated and intensifies during crescents, which also give rise to flooding problems, especially in the flat alluvial areas of the rivers.

Aggradation is the accumulation of sediments, which occurs when the sediments of a river exceed the amount that the river can drag in its channel. This process is accelerated and intensified in the drier conditions of the channel that cause the river flow to decrease at the same time as the sediments occur in greater amounts

Morphological changes in rivers may be due to natural or anthropogenic causes. Human interventions on a hydraulic system can trigger processes at high speeds that would naturally take a long time to occur and, in some cases, may become irreversible.

In order to establish the fluvial dynamics of the streams, especially that of the Guáitara river, a comparison was made through satellite images of Google Earth from 2005 (Weak "El Niño" period) and 2015 (strong "El Niño" period).

Taking into account the behavior of the Guáitara River for the years 2005 and 2015, observed in the Figure 5.1.66 Figure 5.1.67 and Figure 5.1.68 , specifically between the boundary of the municipalities of Contadero and Puerres, It can be concluded that there are changes related to the disappearance of braided type drainage patterns in the year 2015 with respect to 2005 (seeFigure 5.1.66), as a consequence of the intensified flow rate during rainy season, on the other side, there are some changes in the characteristic meanders (Figure 5.1.67 and Figure 5.1.68), also associated to the increase of the flow of the source under study.

Guáitara River - Year 2005

Guáitara River - Year 2015

Figure 5.1.68 Fluvial Dynamics of the Guaitara River - Years 2015 and 2005

Source: Google Earth 2005 and 2015

Guáitara River - Year 2005

Guáitara River - Year 2015

Figure 5.1.69 Fluvial Dynamics of the Guaitara River - Years 2015 and 2005

Source: Google Earth 2005 and 2015

Guáitara River - Year 2005

Guáitara River - Year 2015

Figure 5.1.70 Fluvial Dynamics of the Guaitara River - Years 2015 and 2005 (Limit Between the municipalities of Puerres and Contadero)

Source: Google Earth 2005 and 2015

- *Possible Alterations to the Natural Regime*

In the region of study there are different threats in relation to the seasons of the year in the triggering of the processes. Floods are associated with high precipitation, in short times, as well as flash floods of streamed currrents, generating a flood peak that also passes quickly, which is a phenomenon more strictly linked to exclusive surface conditions. Increases in water levels which provide an important flow into the permanent currents, raising their base level, causing overflow and invasion of topographically higher grounds.

It is worth noting that the treatment of the hazards and risks study, in general, not always contemplate the susceptibility or sensitivity of each geomorphological environment exposed to danger. The response of each geomorphological unit or territorial unit is different when exposed to the same danger or threat, due to the variations in their intrinsic properties (nature and characteristic of the deposit, cementation, soil, other) external to the regional environment where they're located. The susceptibility is the propensity or tendency of a zone to be physically affected by a hazard. It is with regards to their exposure to the natural hazard, the more it is exposed to the analyzed risk, in this case, flooding, the greater the susceptibility.

for this area of study, the water resource is a very important element within the hydrological context of the area. In the lower area the Guáitara River basin, it receives the contributions of creeks between perennial and intermittent, which pour their waters mainly in winter times.

To establish the spatial relationship of floods in the study area, we first consulted the cartography of the environmental information system of Colombia-SIAC, however, for the polygon defined as Area of physical-Biotic influence, there are no specified areas susceptible to flooding or flooded by the "La Niña" extraordinary meteorological event of the 2010-2011.

Furthermore, and taking into account the susceptibility to flooding based on geomorphological characterization, it can be concluded that since the study area presents a mountain (M) landscape where the slopes are pronounced, we feel a degree of threat by flood as almost null..

for the Pedregal - Catambuco section, 38 events of floods for the municipalities of Imues, Yacuanquer, Tangua, and San Juan de Pasto for the same years. Taking into account the records presented in the table 5.1.26 , the flood events at the regional level in the municipalities of the study area are not frequent, however, the most critical is the one that occurred in the municipality of Imues in the month of December 2010 with 1,716 people affected, followed by the one that occurred in the year 2010 in the municipalities of Tangua, Imues and Pasto with 1,400, 1,716 and 1,274 people affected.

Table 5.1.21 Consolidated emergency care for flood events presented during the last ten years in the municipalities associated with the area of study of the Pedregal - Catambuco Segment.

Date	Municipality	Impact								observations
		Deceased persons	Person wound	Affected persons	Affected families	Destroyed homes	Damaged homes	Roads	Schools	
21/12/2014	Pasto	---	---	85	10	---	10	---	---	An overflow of the El Barranco Creek, in the municipal rural settlement of Ramos, sector of the La Cocha Lagoon, destroyed 10 homes, leaving 50 adults and 35 children without their household.
25/12/2014	Pasto	---	---	165	33	---	33	---	---	A flood is reported in La Vuelta Negra affecting 30 families, in the Cementerio neighborhood 3 families, and in the lower Cujacal neighborhood due to heavy rains, earth and mud removal was made. The large amount of water that fell collapsed the drain water system, producing sewers to overflow in several areas of the city.
02/11/2014	Pasto	---	---	125	25	---	25	---	---	Flooding in the neigborhoods of Pinar del Rio (3 families affected with 12 people), El Pilar (1 family affected with 6 people), municipal rural settlement of Pejendino Reyes (7 families with 34 people), Buesaquillo village (14 families with 63 people), for a total of 25 families.
30/06/2014	Pasto	---	---	1.650	330	---	80	2	---	On the municipal rural settlement of Encando, on 30th June a flood affected the

Date	Municipality	Impact								observations
		Deceased persons	Person wound	Affected persons	Affected families	Destroyed homes	Damaged homes	Roads	Schools	
										community in fish farming, due to heavy rains in the area, representing risk for the dwellings of the inhabitants of the municipal rural settlements of Naranjal and Motilón. On the other hand, as consequence of the rise in the level of the La Cocha lagoon there were floods in he municipal rural settlements of Motilón, Santa Lucia, Ramos, Romerillo and Casapampa, flooding 80 homes, most of which derive their livelihoods from commercial and tourist activities; the access road to the municipal rural settlement of El Puerto was also flooded due to the fooding of the terrrains surrounding the houses. There were losses of livestock crops (pigs, chickens, Guinea pigs, hens, rabbits, cows) and self-consumption vegetable gardens. Also in the municipal rural settlements of El Naranjal, Santa Lucia, Ramos, Romerillo, Santa Rosa, Motilon, Santa Teresita, Carrizo and El Puerto there was affectation of trout production, affecting 45 families that derive their livelihood from this production.
08/05 /2014	Pasto	---	---	45	9	---	9	---	---	Flooding in the Mijitayo, El Pilar and Chambú neighborhoods.

Date	Municipality	Impact								observations
		Deceased persons	Person wound	Affected persons	Affected families	Destroyed homes	Damaged homes	Roads	Schools	
22/01 /2014	Pasto	---	---	---	---	---	---	---	---	Pasto River overflow
19/11 /2013	Pasto	---	---	20	4	---	4	---	---	Due to the rains registered, the sewer system collapsed by overflow, affecting 4 houses.
25/07 /2013	Pasto	---	---	120	24	---	24	---	---	Se reportó inundación en el corregimiento: reported flooding in the village: El Encano, 13 affected homes, 5 families, 5 restaurants affected, also flooding was reported due to the increased water level of La Cocha lagoon, in the El Encano village, leaving: 24 affected families. Affected families
27/05 /2013	Pasto	---	---	8	2	---	1	---	---	A flood arose in a dwelling composed of 2 families of 8 people in the La Palma neighborhood.
22/04 /2013	Pasto	---	---	---	---	---	---	---	---	a flood arose in the Santa Clara neighborhood, affecting one dwelling.
20/04 /2013	Pasto	---	---	547	142	---	---	---	---	Flood in the the El Encano village affecting 142 families, 547 persons of which 22 families were affected in their household, 116 by damage to crops and animals.
22/03 /2013	Pasto	---	---	29	8	---	5	---	---	Overflow of the La Pila and Duarte creeks, in the Cabrera village, 4 houses, 5 families, 18 persons affected, as well as affectation of crops and animals. In the Village of Mocondino 1 housing, 3 families 11 persons affected.
21/03 /2013	Pasto	---	---	5	1	1	---	---	---	1 dwelling destroyed at Carrera 22F Nº 11 - 12 Santiago, evacuation of 5 families

Date	Municipality	Impact								observations
		Deceased persons	Person wound	Affected persons	Affected families	Destroyed homes	Damaged homes	Roads	Schools	
29/11/2012	Pasto	---	---	224	58	---	45	---	---	Inundación en 18 barrios de la ciudad ellos son: Flood in 18 neighborhoods of the city they are: Capusigra, El Pilar, Morasurco, Avenida Chile, Pandiaco, Club del Comercio, Villas de San Rafael, Santa Clara, La Paz, Potrerillo, Chapal, Las Lunas, Progreso, Mercedario, Sendoya, Mitigallo, Obrero, Avenida Idema, affecting 45 homes, 224 people, 58 families, 2 parking lots.
16/11/2012	Pasto	---	---	90	18	---	15	---	---	Flood in the village of Cabrera, municipality of Pasto, causing affectation to 18 families, 90 people, 15 houses besides self-consumption crops.
24/04/2012	Pasto	---	---	98	22	---	12	---	---	---
21/04/2012	Pasto	---	---	98	16	---	15	---	---	In the village of Abonuco 22 families were affected in the sector of the Divino Niño.
19/04/2012	Yacuanquer	---	---	40	11	1	10	2	---	Overflow of the Telpies creek in the village of Tasnaque, affectation to the La Guada, La Pradera roads; affectation to potato and pea crops.
27/03/2012	Pasto	---	---	204	48	---	48	---	---	...
12/03/2012	Yacuanquer	---	---	---	---	---	---	---	---	---
29/07/2011	Pasto	---	---	241	107	---	---	---	---	Due to heavy rains the Guachucal Creek was dammed, affecting the Potrerillo market and several houses in the Venice, Chapal, Chambu and Minga neighborhoods.
23/07/2011	Pasto	---	---	855	171	---	171	---	---	Due to heavy rains in the sector there have been floodings in the village of El

Date	Municipality	Impact								observations
		Deceased persons	Person wound	Affected persons	Affected families	Destroyed homes	Damaged homes	Roads	Schools	
										Encano, municipal rural settlement of El Puerto.
21/05/2011	Pasto	---	---	500	100	---	100	---	---	---
18/05/2011	Yacuanquer	---	---	264	66	---	66	---	---	---
11/05/2011	Tangua	---	---	---	---	---	---	---	---	San Antonio - La Cocha road
16/02/2011	Pasto	---	---	15	3	---	3	---	---	Mijitayo Creek Flood
15/12/2010	Tangua	---	---	1400	1400	---	---	---	---	---
15/12/2010	Imués	---	---	1716	1716	---	---	---	---	---
17/11/2010	Pasto	---	---	1274	317	2	35	---	---	
04/04/2010	Pasto	---	---	115	23	---	23	---	---	Bernal, El Pilar and Chapal neighborhoods. Mijitayo Sector
01/04/2010	Pasto	---	---	280	56	---	56	---	---	San Martín, Santa Clara and El Pilar Neighborhoods
15/10/2009	Pasto	---	---	7	1	---	1	---	---	---
29/03/2009	Pasto	---	---	310	62	---	62	---	---	Pasto river overflow
25/12/2008	Yacuanquer	1	---	---	---	---	---	---	---	---
01/11/2008	Imués	---	---	---	---	---	---	---	---	---
01/11/2008	Tangua	---	---	---	---	---	---	---	---	---
27/01/2007	Pasto	---	---	---	---	---	---	---	---	Guamuez River overflow. El Encanto village affected.
07/03/2005	Pasto	---	---	30	12	---	---	---	---	overflow of the Malagato creek and increase of the flow of the rivers Pasto and Chapal. The most affected sectors were Figueroa, Quintas de San Pedro, Lorenzo de Aldana, Pandiaco, Juan 23, Santa Bárbara, Santa Mónica, Santiago, Río Blanco, La Colina, Villa de San Rafael, El Pilar, El Chapal and Las Lunas.

Source: (Geminis Environmental Consultants, 2016)

· Morphometric Features of the Studied Hydrographic Units

The water system analysis of the study area includes rates determined on the basis of geomorphological factors and characteristics of the flow in the currents that determine the features of the basins, which at the end are the basis for the estimation of surface runoff maximum flows. Aftewards, the indexes for the analysis of the basin of the rivers Guáitara and Juanambú are defined.

- **Area (A):** The basin area is established with support of the geographical information system and according to the delimitation of the study area; the minimum and maximum flow averages will vary depending on the area of the basin.

- **Perimeter (P):** The perimeter is the length of the edge of the basin. While the perimeter is a measure or parameter that does not indicate anything per se, it becomes a fundamental factor for the calculation of the shape parameters of the basin.

- **Average Slope of the River Beds (Pm)**: It sets the average inclination that the drains have from birth to mouth, and lets you determine important aspects such as the differently sized sediments drag capabilities, possible flood areas during overflows and time of concentration, among others. It is defined as the ratio between the total height of the main channel (maximum level less minimum level) and the length of the river bed.

$$Pm = \frac{Hmáx - Hmín}{L} * 100$$

Where:

p_m: Mean Slope
H_{max}: Maximum Level
H_{min}: Minimum Level
L: Length of the River bed

- **Concentration Time (Tc):** Time it takes for the water falling at the furthest point to reach the base level or the mouth of the basin. It can be defined by mathematical models which take into account variables such as the length of the river bed, slope, among others. It is useful to determine the torrent potential of a basin on the basis of its physical characteristics.

there are a series of formulas developed by different authors that allow for the calculation of this time. Some of the formulas that are used for the calculation of this time are the following:

ventura - Heras: $Tc = a * \left(\frac{S^{0.52}}{i}\right)$

Passini: $Tc = a * \frac{(S*L)^{1/3}}{i^{0,5}}$

Where:

Tc: Time of concentration (hours)
L: Length of the main river bed in (km)
i: Slope of the main river bed (%)
S: Area of the river basin (km^2)
a: Mean Distance ($a = \frac{L}{\sqrt{S}}$))

- **Length (L):** the length (L) of the hydrographic area may be defined as the horizontal distance of the downstream point of the hydrographic area of departure and a point upstream, where the general trend of the river bed cuts the contour line of such hydrographic area.

- **Form Factor:** Given the importance of the configuration of the basins, its purpose is to quantify the characteristics of shape by means of indices or coefficients, which relate the water movement and the basin's responses to such a movement (hydrographical). A basin tends to be elongated if the form factor tends to zero, while its form is perfectly square when the form Factor is equal to the unit. This factor, like the others that are used in this analysis, are a reference to establish the expected dynamics of surface runoff of the basin, taking into account that those basins with elongated forms, tend to present a faster water flow, compared to rounded basin, achieving a faster basin water evacuation, further development of kinetic energy in the sediments drag toward the base level, mainly.

the shape of the basin affects the hydrographs of maximum flows, so numerous efforts have been made to try to quantify this effect by means of a numerical value. Horton suggested a dimensionless form factor Rf, as an index in the form of a basin as well:

$$Rf = \frac{A}{{L^2}_b}$$

- **Coefficient of Compactness or Gravelius Index:** The coefficient of compactness is defined as the ratio between the perimeter P and the perimeter of a circle containing the same area A of the hydrographic basin:

$$K = 0.282 * \frac{P}{\sqrt{A}}$$

where K is the radius of the circle equivalent in area to the basin. By how it was defined: K>=1. Obviously for the case K = 1, you get a circular basin. The reason to use the ratio of the area occupied by a circle is that a circular basin has greater possibilities of producing extreme avenues given its symmetry.

The degree of approximation of this index to the unit will indicate the tendency to concentrate strong volumes of runoff water, being more pronounced as it gets closer to the unit, which means that the lower K is, the greater the concentration of water

- **Coefficient of Massivity:** The coefficient of massivity defines the type of mountain outline, relates the mean elevation of the basin with its surface.

$$Km = \frac{Altura\ Media\ de\ la\ Cuenca}{A}$$

For ranges of coefficient of massivity between 0 and 35, the kind of massivity is very mountainous, between 35 and 70 is mountainous and between 70 and 105 is moderately mountainous.

- **Drainage Density:** It is defined as the Dd ratio between total length along all the water canals of the microbasin in a horizontal projection and the total surface of the river basin:

$$Dd = \frac{\sum l_i}{A}$$

Where:

Σl_i : total length of all water channels in km
A: area in km ^{2}
l_i : length of each river bed (km)

The typical values for drainage density are 7 for the minimum, average values in the range of 20 to 40 and peak values in the order of 400 . Low Dd values are usually associated with regions with a high erosion resistance, very permeable and low outline. High values are mainly found in regions of impermeable soils, sparse vegetation and mountainous outline. It is mainly used to determine the water availability in the basin in each of its sectors, assuming a direct proportionality between the density and the water availability in a given area. Expressed in other words, the higher the drainage density, the more dominant the flow in the River is versus the flow on the slope, which translates into a slower response time of the basin and, therefore, less time to reach the peak of the hydrograph.

The drainage density varies inversely to the extension of the basin. In order to categorize a basin as well or poorly drained, analyzing its drainage density, you can consider that Dd values close to 0.5 km/km^2 or greater indicate the efficiency of the drainage network. The drainage network takes its characteristics, influenced by rainfall and topography. Therefore, it holds that for a high value of Dd correspond large runoff volumes, as well as higher speeds of waters displacement.

Table 5.1.27 and Table 5.1.28 show the morphometric data corresponding to general aspects, shape, topography and drainage, as support to the analysis of the hydrological units that are part of the study area, for the Pedregal - Catambuco segment, respectively.

Table 5.1.22 Morphometric Data of the the Lotic Systems belonging to the Area of study, Pedregal - Catambuco segment.

Basin	Area (ha)	Área (km²)	Perimeter (km)	Length of the River bed Main (km)	Maximum Level	Minimum Level	Slope River bed	Average Height	Total Length of Drains (km)	Length Axial (km)	Width Average (km)	Horton Form Factor (Kf)	Gravelius Compaction Coefficient (Kc)		
DIRECT TRIBUTARIES	28163,98	281,64	160,51	44,97	3261,19	1057,00	45,08	2284,66	318,46	49,49	6,26	0,115	Very little flattened	2,678	Rectangular Oblong
PASTO RIVER	48102,75	481,03	130,73	33,22	4201,78	762,25	36,86	2592,90	556,52	40,01	14,48	0,300	Slightly Flat	1,669	Oval Oblong to Rectangular Oblong Shape
BOBO RIVER	43840,83	438,41	112,73	23,98	3987,69	1683,61	34,43	3109,52	645,59	35,32	18,28	0,352	Slightly Flat	1,507	Oval Oblong to Rectangular Oblong Shape

Source: Geminis Environmental Consultants, 2016

Table 5.1.23 Morphometric Data of the Plot Systems belonging to the Study Area

Basin	Elongation Index (Ia)		Drainage Density (Dd)		Coefficient of Massivity (Dd)		Concentration Times (h)			Concentration Times	
							Ec. Kirpich	Ec. Culverts	Ec. US Bureau	Hours	minutes
DIRECT TRIBUTARIES	3,96	Very Stretched	1,131	Low	8,11	Moderately Mountainous	3,964	3,969	3,949	3,961	237,6
PASTO RIVER	1,71	Moderately Stretched	1,157	Low	5,390	Moderately Mountainous	2,354	2,357	2,345	2,352	141,1
BOBO RIVER	1,44	Moderately Stretched	1,473	Low	7,093	Moderately Mountainous	1,886	1,888	1,878	1,884	113,0

Source: Geminis Environmental Consultants, 2016

5.1.6. *Water quality*

The evaluation of water quality is carried out using analytical techniques to determine the physicochemical and microbiological characteristics, in order for the results of these determinations to be representative it is necessary to give great importance to the sampling processes, the units and terminology used. (See detail in GDB/cartografia/PDF/EIADCRP_PC_013)

5.1.6.1. Inland water bodies

The project presents continental-type water bodies, which are part of the Guáitara and Juanambú river basin system.

- *Physicochemical characterization*

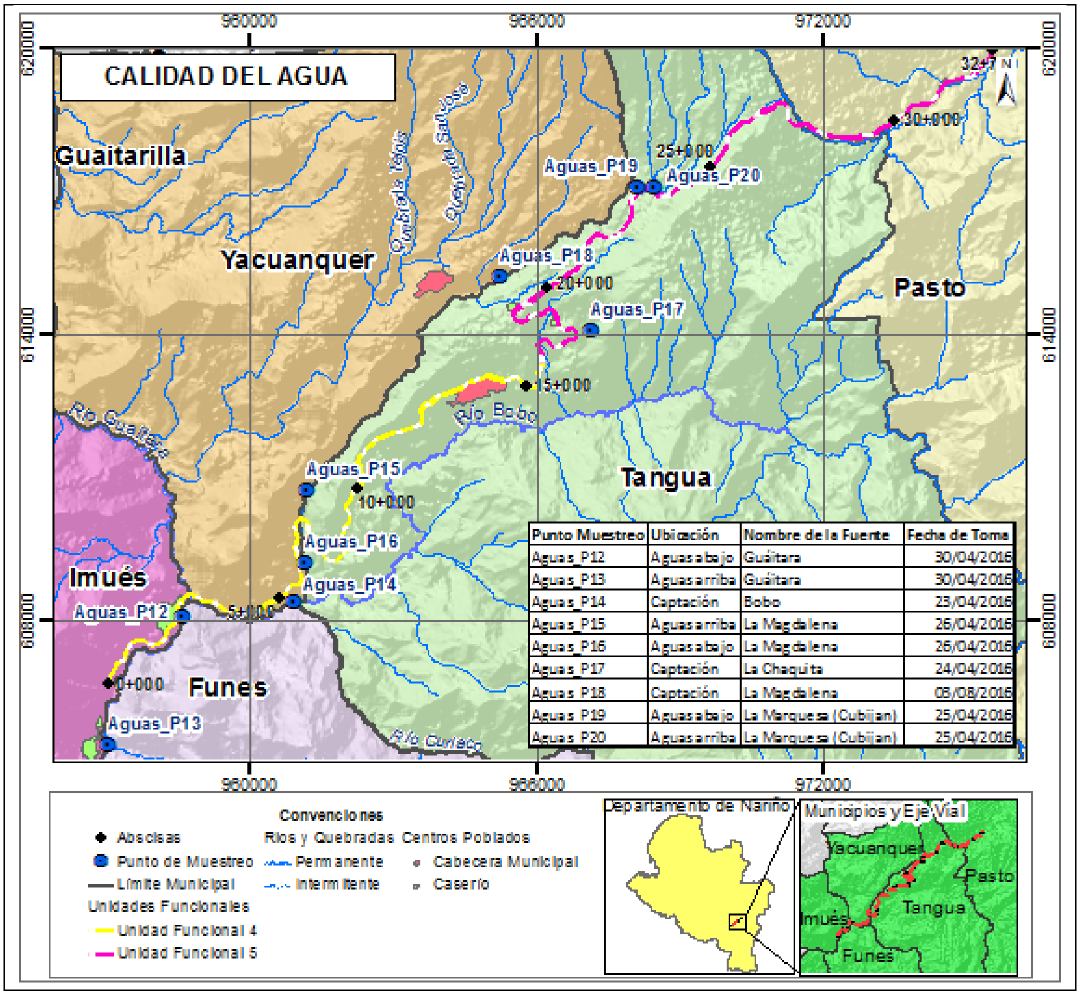
The characterization of water quality for the main water sources located in functional units 4 and 5.1 of the project, were made considering the two (2) climatic periods (dry season and rainy season), complying with the provisions of Resolution 0751 of March 26, 2015.

The location of the monitoring stations established for the project can be observed in the Table 5.1.29, where the name of the source, coordinates, municipality and point monitored (upstream and downstream) is specified.

Table 5.1.24 Points of monitoring of surface water bodies, Pedregal - Catambuco segment

N°	MUNICIPALITY	SOURCE NAME	Magna Sirgas West origin Coordinates		LOCATION
			EAST	NORTH	
1	Imués	Guáitara	958574,41	608089,36	Upstream
2	Imués	Guáitara	957030,886	605405,693	Downstream
3	Tangua	Bobo	960904,88	608425,82	Punctual
4	Tangua	Magdalena	961200,086	610748,832	Upstream
5	Tangua	Magdalena	961152,905	609232,409	Downstream
6	Tangua	La Chaquita	967144,451	614093,653	Punctual
7	Yacuanquer	Magdalena	965250,584	615213,667	Punctual
8	Tangua	La Marquesa	968133,676	617098,577	Upstream
9	Tangua	La Marquesa	968462,979	617078,496	Downstream

Source: (Geminis Environmental Consultants, 2016)



Punto Muestreo	Ubicación	Nombre de la Fuente	Fecha de Toma
Aguas_P12	Aguas abajo	Guáitara	30/04/2016
Aguas_P13	Aguas arriba	Guáitara	30/04/2016
Aguas_P14	Captación	Bobo	23/04/2016
Aguas_P15	Aguas arriba	La Magdalena	26/04/2016
Aguas_P16	Aguas abajo	La Magdalena	26/04/2016
Aguas_P17	Captación	La Chaquita	24/04/2016
Aguas_P18	Captación	La Magdalena	08/08/2016
Aguas_P19	Aguas abajo	La Marquesa (Cubijan)	25/04/2016
Aguas_P20	Aguas arriba	La Marquesa (Cubijan)	25/04/2016

Figure5.1 .71: Water quality points, Pedregal - Catambuco segment

The laboratory analysis was performed following the methodologies established in AWWA's Standard Methods for the Examination of Water and Wastewater, APHA and WEF, Edition 21 of 2005.

- *Dry season*

The monitoring for the dry season was carried out between April 21 and May 1, 2016, a period of low precipitation due to the "El NIño" phenomenon. The quality of the monitored points fluid was evaluated, based on the analysis and relation of the physicochemical, microbiological and hydrobiological variables of the water. The characterization was carried out by the company AGROSOLUCIONES AMBIENTALES (ASOAM), which has the accreditation of IDEAM (See Annex 5.1.6.1).

The methodology used for the characterization of water bodies is presented in detail in chapter 2 of the present study, complying with the specifications established in the protocols for surface water monitoring, regarding sampling, preservation protocol , storage, packaging and transportation to the laboratory.

- *Physicochemical and bacteriological characterization*

The definition of water quality was carried out with the measurement of physicochemical and bacteriological parameters that allow to determine the water quality of the monitored sources. This procedure is done in order to know if the values of these parameters are within the range of current legislation. Physicochemical analysis was performed taking into account the PO-PSM-45 guidelines for water sampling and techniques of *Standard Methods* 1060 edition 22. In the Photograph 5.1.46 and Photograph 5.1.47 shows the record of the process of collecting water samples in the field.

Photography5.158 Water sampling for analysis of physicochemical and microbiological parameters downstream La Marquesa creek

Magna Sirgas Coordinates West Origin Y 617098,5774 X 968133,6764

Source: (Geminis Environmental Consultants, 2016)

Photography5.159 Collection of water quality analysis samples, downstream La Marquesa creek

Magna Sirgas Coordinates West Origin Y 617098,5774 X 968133,6764

Source: (Geminis Environmental Consultants, 2016)

The results of the measured parameters for the characterization of the water sources intervened directly by the project are shown below, see Table 5.1.30

Table 5.1.25 Laboratory analysis results of points sampled in the Rumichaca-Pasto divided highway project, Pedregal-Catambuco segment

PARAMETERS		SAMPLING POINTS EIA UF 4 and 5, PEDREGAL - CATAMBUCO SEGMENT							
	Upstream Guáitara River	Downstream Guáitara River	Bobo River	Upstream La Magdalena Creek	Downsteam La Magdalena Creek	La Chaquita Creek	La Magdalena Creek	Upstream La Marquesa Creek	Downsteam La Marquesa Creek
pH (Units)	6,82	7,92	7,21	7,23	7,12	7,05	7,04	7,42	7,11
Temperature ° C	15,3	15,8	19	19,4	19,9	20,8	10,7	20,0	19,8
Dissolved Oxygen (mg / L)	4,01	3,98	4,32	4,12	4,25	4,28	7,9	3,98	4,06
Conductivity (uS / cm)	382	427	451	415	401	414	116,7	398	372
BOD mg / L	16,2	6,7	13,1	14,9	10,7	11,8	5	5,2	9,8
COD mg / L	32,5	17,1	24,8	27,5	21	21,8	20	10,4	19,1
Total Suspended Solids mg / L	61	<20	<20	28	<20	25,6	<10	<20	<20
Greases and Oils mg/L	<9,0	<9,0	<9,0	<9,0	<9,0	<9,0	<10	<9,0	<9,0
Alkalinity mg/L	47,6	24,9	20,7	31,1	55,9	72,5	42,82	47,6	58
Total Hardness mg/L	48	24	68	36	40	48	52,16	40	24
Total Coliforms NMP/mL	4900	1100	11000	230	5400	3500	3500	790	22000

PARAMETERS			SAMPLING POINTS EIA UF 4 and 5, PEDREGAL - CATAMBUCO SEGMENT						
	Upstream Guáitara River	Downstream Guáitara River	Bobo River	Upstream La Magdalena Creek	Downstream La Magdalena Creek	La Chaquita Creek	La Magdalena Creek	Upstream La Marquesa Creek	Downstea m La Marquesa Creek
Thermotolerant coliforms NPM/ml	240	260	4900	45	490	340	330	100	9200
E. coli	Presence	Presence	Presence	Presence	Presence	Presence	Presence	Presence	Presence
Turbidity NTU	*36,1*	*7,6*	2,22	21,5	19,2	13,1	2,5	6,88	4,37
True Color UPC	*117*	*26,5*	<5,00	46,2	35,1	<5,00	38	22,4	17,4
Total Nitrogen mg/L	<3,00	<3,00	<3,00	<3,00	<3,00	<3,00	0,68	<3,00	<3,00
Total Phosphorus mg/L	*<0,062*	*<0,062*	<0,062	0,096	0,102	<0,062	<0,06	0,086	0,080
Total Phenols mg/L	<0,002	<0,002	<0,002	<0,002	<0,002	<0,002	-	<0,002	<0,002
Zinc mg/L	*<0,014*	*<0,014*	<0,014	<0,146	<0,146	<0,014	<0,05	<0,146	<0,146
Total Barium mg/L	<0,141	<0,141	<0,141	<0,141	<0,141	<0,141	< 0,50	<0,141	<0,141
Total Cadmium mg/L	<0,0048	<0,0048	<0,0048	<0,0048	<0,0048	<0,0048	<0,003	<0,0048	<0,0048
Total Copper mg/L	<0,0088	<0,0088	<0,0088	<0,0088	<0,0088	0,0153	<0,10	<0,0088	<0,0088
Total Chromium mg/L	<0,0046	<0,0046	<0,0046	<0,0046	<0,0046	<0,0046	-	<0,0046	<0,0046
Total Mercury mg/L	<0,0006	<0,0006	0,0007	<0,0006	<0,0006	0,0008	<1,00	<0,0006	<0,0006

PARAMETERS	SAMPLING POINTS EIA UF 4 and 5, PEDREGAL - CATAMBUCO SEGMENT								
	Upstream Guáitara River	Downstream Guáitara River	Bobo River	Upstream La Magdalena Creek	Downsteam La Magdalena Creek	La Chaquita Creek	La Magdalena Creek	Upstream La Marquesa Creek	Downsteam La Marquesa Creek
Total Nickel mg/L	<0,0045	<0,0045	<0,0045	<0,0045	<0,0045	0,0058	<0,02	<0,0045	<0,0045
Total Silver mg/L	<0,007	<0,007	<0,007	<0,007	<0,007	<0,007	<0,04	<0,007	<0,007
Total Lead mg/L	<0,0054	<0,0054	<0,0054	<0,0054	<0,0054	<0,0054	<0,01	<0,0054	<0,0054
Total Selenium mg/L	<0,0055	0,0062	<0,0055	<0,0055	<0,0055	<0,0055	<0,01	<0,0055	<0,0055
Arsenic mg/L	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 10	< 0,010	< 0,010

Source: (ASOAMSAS, 2016)

- Temperature

The temperature registers in the nine (9) monitoring points are presented in the Figure 5.1.73, for this parameter values are between 10.7 and 20.8 ° C, these values are totally consistent with the climatic conditions and the geographical location of the monitoring sites.

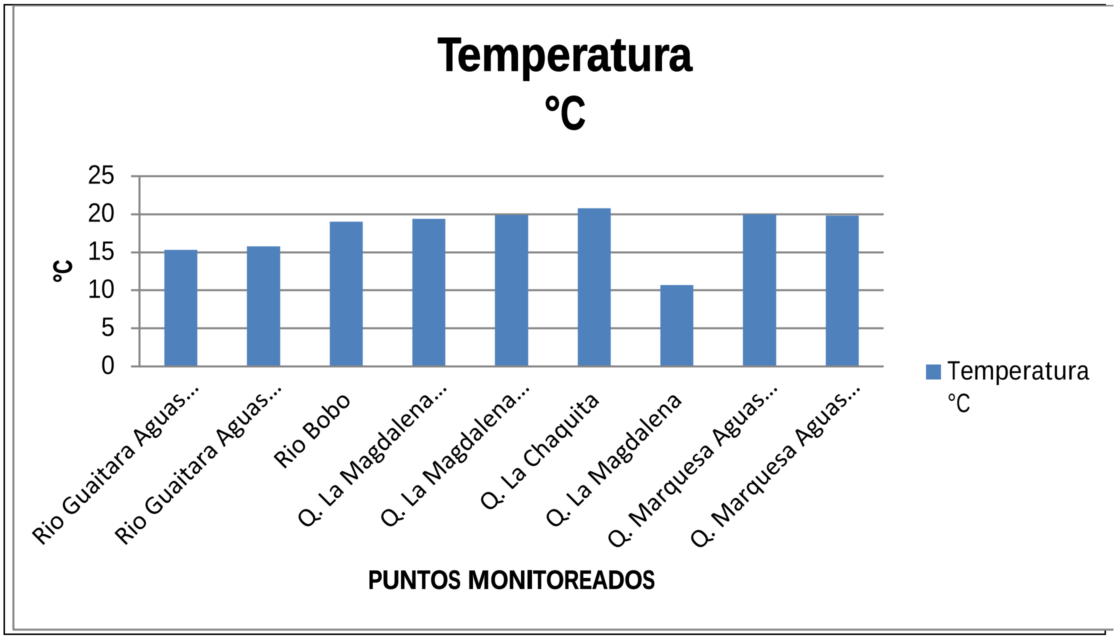


Figure 5.1.72 Temperature Results for monitored sources Pedregal - Catambuco segment
Source: (Geminis Environmental Consultants, 2016)

- Total suspended solids

The presence of suspended solids produces the apparent color in the water and reduces the passage of solar radiation, which leads to a decrease in photosynthesis and death of plants that do not reach this radiation (EPHA, 1998). the Total Suspended Solids registered a maximum value at the Upstream Guáitara River point of 61 mg/L and a minimum value at the La Chaquita Creek point of 25.6 mg/L.

However, the points Downstrean Guáitara River, Bobo River, Downstream La Magdalena Creek, Upstream Cubiján Creek and Downsteam Cubiján Creek reported values below the limit of quantification of the analytical technique used by the laboratory with respect to Suspended Solids Totals, being these <20 mg/L.

- Conductivity

This parameter is intimately related to the total dissolved solids representing the concentration of substances or minerals dissolved in natural waters. Conductivity measures the ability of water to transfer electrical current, which increases mainly with the dissolved ion content and temperature, and is expressed as microSiemens per centimeter (µS/cm). The conductivity values are between 116.7 and 451 µS/cm. The maximum value was reported at the Bobo River point with a value of 451 µS/cm. (See Figure 5.1.74)

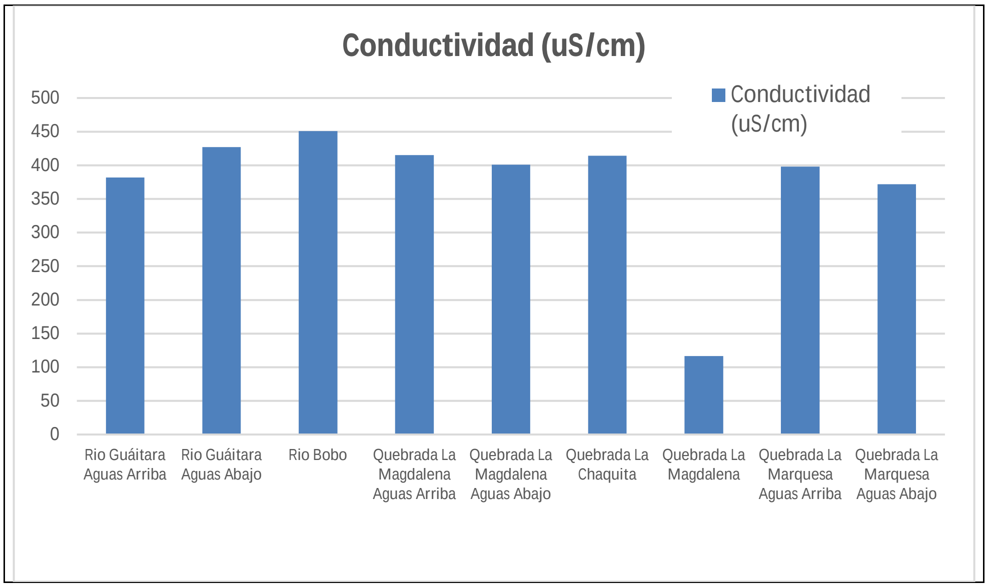


Figure 5.1.73 Conductivity Results for monitored sources Pedregal - Catambuco segment
Source: (Geminis Environmental Consultants, 2016)

Accordingly, the salt content in all sampled water bodies is normal, knowing that these are inland waters and have a conductivity of between 250 µS/cm and 750 µS/cm.

o pH

According to Roldán Pérez (1992), the hydrogen - pH potential is a measure of the concentration of hydrogen [H+] in the water bodies used to determine the acidity or basicity in them; At lower pH the waters are more acidic while at higher pH the waters are more basic.

The pH in natural waters varies by the contribution of CO2 that forms carbonic acid, which acidifies the water, by the degree of eutrophication or massive enrichment of inorganic nutrients in the water, soil properties, decomposition of plant species that gives rise to the formation of humic acids and other compounds, among others.

The pH at the 9 monitoring points was reported within the ranges defined by the standard for agricultural use, livestock and flora and fauna preservation, where values between 6.82 and 7.92 were recorded, as shown in Figure 5.1.75.

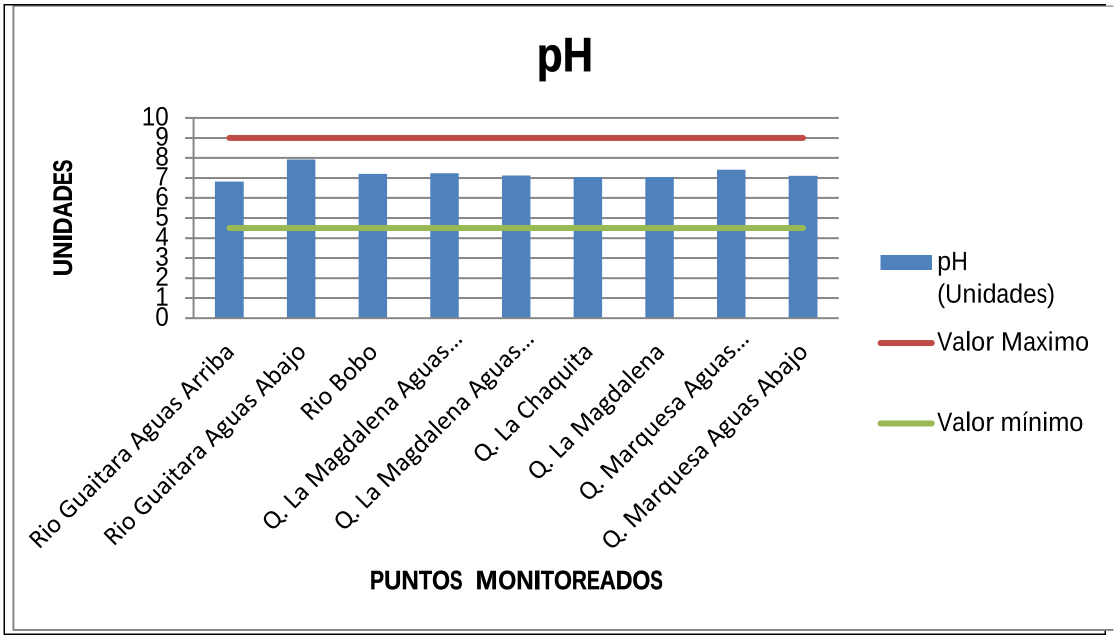


Figure 5.1.74 pH Results for monitored sources Pedregal - Catambuco segment
Source: (Geminis Environmental Consultants, 2016)

o Turbidity

Turbidity is an expression of the optical effect caused by the dispersion and interference of light rays passing through a sample of water, it can be caused by a large variety of suspended materials, ranging in size from colloidal dispersions to thick particles, among other clays, silt, finely divided organic and inorganic matter, planktonic organisms, microorganisms, among others. In the sampled points, the turbidity presents values between 2.22 and 36.1 NTU for the points monitored.

According to the above, it can be concluded that at the sampling points for the Bobo river and for the upstream La Marquesa creek , the turbidity value is quite good, from the human consumption perspective, since they have values lower than 5 NTU, indicating a low presence of suspended material and microorganisms.

As for the Guáitara river, there is a drastic change in turbidity values, going from 7.6 NTU to 36.1 NTU, possibly due to the polluting contributions made to the river in the Pilcuan area; The other water bodies have normal characteristics, taking into account their proximity to established human settlements.

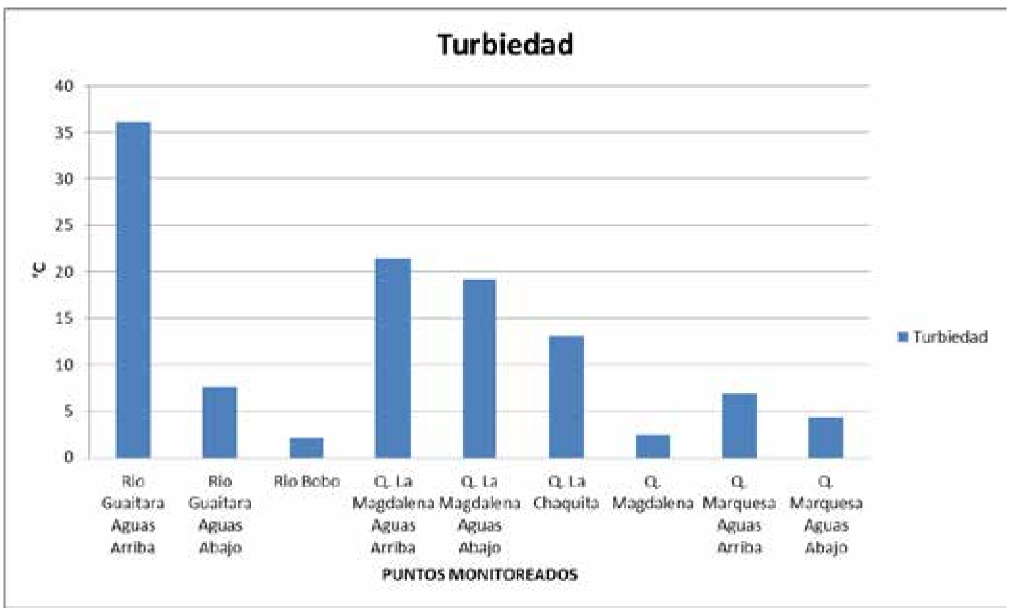


Figure 5.1.5.1.75 Turbidity Results for monitored sources Pedregal - Catambuco segment
Source: (Geminis Environmental Consultants, 2016)

o Dissolved oxygen

This parameter constitutes one of the most important elements in aquatic ecosystems, since its presence and concentration determines the existence of species, according to their tolerance and range of adaptation, establishing the structure and biotic functioning of these systems (Ramírez and Viña, 1998). The *in situ* results for concentrations of dissolved oxygen in water are presented in Figure 5.1.77; The results obtained for all water bodies vary between 3.98 and 4.32 mg / L, these are acceptable, since this concentration of oxygen allows the life of the great majority of species of the aquatic environment.

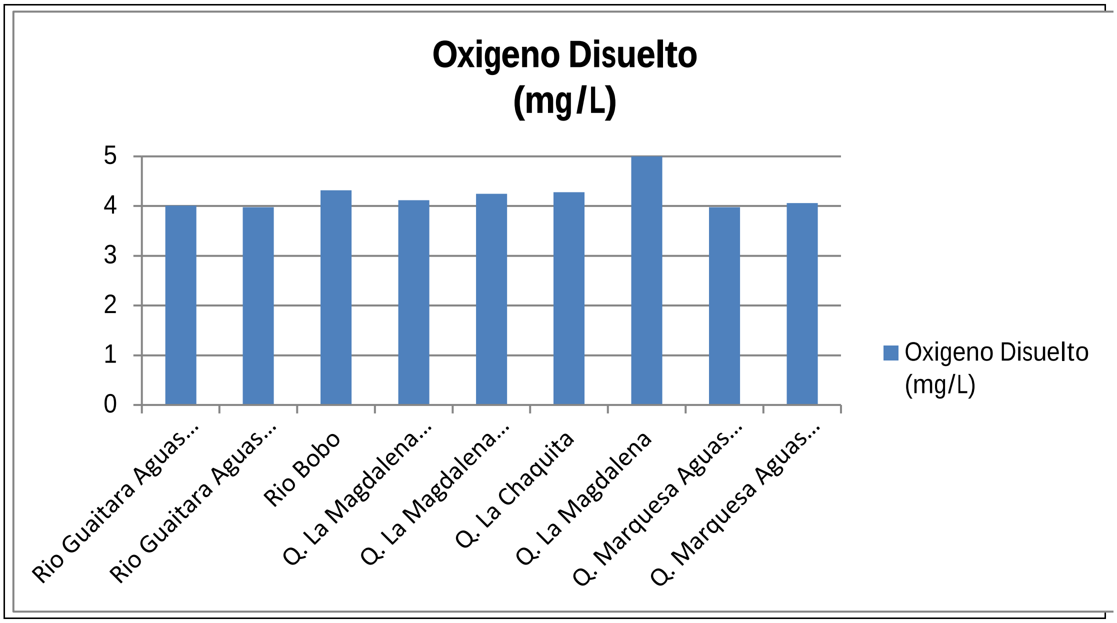
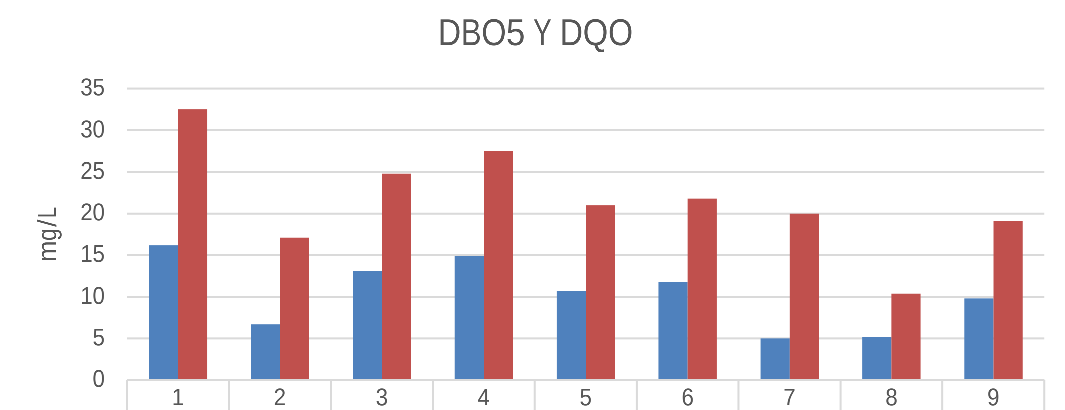


Figure 5.1.76 Dissolved Oxygen Results for monitored sources Pedregal - Catambuco segment
Source: (Geminis Environmental Consultants, 2016)

- Biochemical oxygen demand (BOD_5) - Chemical Oxygen Demand (COD)

The Biochemical Oxygen Demand (BOD5) is the oxygen measurement required by microorganisms to degrade the organic matter present; While the Chemical Oxygen Demand (COD), is an estimate of the total amount of oxidizable matter, biodegradable or not, present in a body of water. Both variables are closely related and used as indicators of water quality.

The BOD has concentrations with values between 5 and 16.2 mg/L in the sampled points. On the other hand, COD was found to be proportional and in accordance with the concentrations of biodegradable organic matter, reporting a value between 17.1 and 32.5 mg/L, indicating an acceptable water quality for the development of aquatic life, see Figure 5.1.78.



	1	2	3	4	5	6	7	8	9
DBO mg/L	16.2	6.7	13.1	14.9	10.7	11.8	5	5.2	9.8
DQO mg/L	32.5	17.1	24.8	27.5	21	21.8	20	10.4	19.1

Figure 5.1.77 BOD5 and COD Results for monitored sources Pedregal - Catambuco segment
Source (ASOAM, 2016)

- Total Nitrogen

The values reported fare below the quantification limit for the analytical technique used by the laboratory, this being <3,00 mg/L.

- Total Phosphorus

This is an essential nutrient for living organisms; In fresh waters and marine systems it is subjected to continuous transformation processes that include consumption or detachment of the element in its different forms or species (Sánchez, 2001), Phosphorus is quickly oxidized in terrestrial rocks as orthophosphate, which is very soluble and is the useful fraction absorbed by autotrophic plants. The values obtained to date for total phosphorus are below the quantification limit for the analytical technique used by the laboratory, this being <0.062 mg/L for all points.

- Greases and Oils

Greasess and oils are organic compounds immiscible in water, consisting mainly of fatty acids of animal and plant origin, and also of anthropogenic origin. They mostly reach bodies of water from food waste or industrial processes (automobiles, lubricants, etc.), float forming films on the surface that prevent the passage of light necessary to carry out photosynthesis processes and are metabolized by bacteria, Decreasing normal amounts of oxygen (Kirchman, 2000).

The Colombian legislation does not have an allowable value of Greases and Oils in terms of quality criteria for the use of superficial waters; However, according to Decree 1594 of 1984, the water bodies destined for the preservation of fauna and flora or for recreation, should not contain fats and oils that form a visible film that interferes with the photosynthetic activity or the aesthetic quality of the ecosystem. There is no evidence of oils or greases for any of the points.

- Alkalinity

Alkalinity is defined as the measure to neutralize acids, which confers buffer properties, that is, it hinders their changes in pH, it is directly related to the amount of carbonate and bicarbonates ions present in the water; it is generally determined by the content of carbonates, bicarbonates and hydroxides; however, some salts of weak acids such as borates, silicates, nitrates and phosphates may also contribute to alkalinity. These negative ions in solution are commonly associated with positive ions of calcium, magnesium, potassium, sodium and other cations. The maximum value of 72.5 mg / L is recorded at La Chaquita point, while the Bobo River point reports the minimum concentration of 20.7 mg / L, i.e. all monitored water bodies have a low alkalinity, which implies that these bodies are susceptible to acidification. (See Figure 5.1.79)

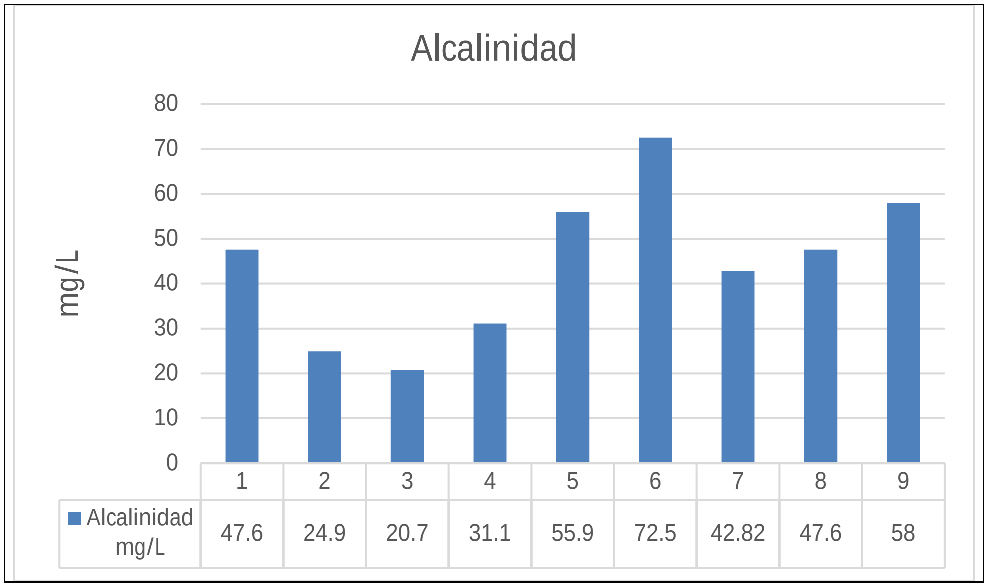


Figure 5.1.78 Alcalinity Results for monitored sources Pedregal - Catambuco segment
Source (ASOAM, 2016)

- Total phenols

From the analytical point of view, the term phenol encompasses this product and its immediate higher homologues, such as chlorophenols, phenols and nitrophenols. At low rates of degradation of organic matter, the concentration of phenols is minimal and does not incide upon the structure and dynamics of the aquatic ecosystem. When the concentration is high, since phenol is heavier than water, it sinks dissolving slowly and forming toxic solutions (Marín, 2009). The values obtained for total phenols are below the quantification limit for the analytical technique used by the laboratory, this being <0.002 mg / L for all points.

- Metals

Metals are generally found in concentrations considered to be trace in natural systems and some of them are essential for the normal development of life, and the absence of sufficient quantities of them could limit the growth of aquatic plants. However, several of these metals, such as those having a very high molecular weight, when found at very high concentrations may be harmful to organisms.

The values obtained to date for Zinc are below the quantification limit for the analytical technique used by the laboratory, this being <0.014 mg / L for the Bobo River and La Chaquita Creek points..

The values of Barium, Cadmium, Chromium, Silver and Lead, are below the limit of quantification of the analytical technique used by the laboratory for the points monitored.

The values obtained for Total Mercury for the Bobo River point were 0.0007 mg / L. However, in the points Upstream Guáitara River, Downstream Guáitara River, Upstream La Magdalena Creek, Downstream La Magdalena Creek, La Chaquita Creek, Upstream Cubiján Creek and Downstream Cubiján Creek are below the limit of quantification of the Analytical technique used by the laboratory, this being <0.0006 mg / L.

The results for Total Nickel for the La Chaquita Creek point were 0.0008 mg / L. For the points Upstream Guáitara River, Downstream Guáitara River, Bobo River, Upstream La Magdalena Creek, Downstream La Magdalena Creek, Upstream Cubiján Creek and Downstream Cubiján Creek the results obtained are below the limit of quantification of the Analytical technique used by the laboratory, this being <0.0045mg / L.

The values for Total Selenium are below the limit of quantification of the analytical technique used by the laboratory, being this <0.0055mg / L, for the points Upstream Guáitara River, Bobo River, Upstream La Magdalena Creek, Downstream La Magdalena Creek, La Chaquita Creek, Upstream Cubiján Creek and Downstream Cubiján Creek. However, for the Downstream Guáitara River point the value obtained was 0.0062 mg / L.

The concentations obtained for Arsenic for all points are below the quantification limit for the analytical technique used by the laboratory, this being <0,010mg/L for all points.

- Total coliforms and Escherichia coli

Total coliforms are lactose-positive Enterobacteriaceae and constitute a group of bacteria that are defined more by the tests used for their isolation than by taxonomic criteria. They belong to the family Enterobacteriaceae and are characterized by their ability to ferment lactose with acid and gas production, more or less rapidly, in a period of 48 hours and with an incubation temperature between 30-37 ° C, whereas fermentation of lactose by fecal Coliforms is made at 44.5 °C, within this last group E. coli is the most representative bacteria of the group.

Table 5.1.26. Comparison of Coliform values obtained with the maximum limits of Decree 1076 of 2015

Monitoring Point	Value	Art 2.2.3.3.9.3	Art 2.2.3.3.9.4	Art 2.2.3.3.9.5	Art 2.2.3.3.9.7
Upstream Guáitara River	4900	Does not comply	Does not comply	Complies	Does not comply
Downstream Guáitara River	1100	Complies	Does not comply	Complies	Does not comply
Bobo River	11000	Does not comply	Does not comply	Does not comply	Does not comply
Upstream La Magdalena creek	230	Complies	Complies	Complies	Complies
Downstream La Magdalena creek	5400	Does not comply	Does not comply	Does not comply	Does not comply
La Chaquita creek	3500	Does not comply	Does not comply	Complies	Does not comply
La Magdalena creek	3500	Does not comply	Does not comply	Complies	Does not comply
Upstream La Marquesa creek	790	Complies	Complies	Complies	Complies
Downstream La Marquesa creek	22000	Does not comply	Does not comply	Does not comply	Does not comply

All surface water bodies sampled have total coliform values, of which there is a percentage associated with faeces. These values can be directly related to the liquid waste discharges from the nearby settlements and the livestock activities of the area. When comparing with the standard, you get what is shown in the Table 5.1.31.

- Langelier index

The Langelier index method is used to determine the water balance, if the index is 0 the water is perfectly balanced, if it represents a negative index it indicates that the water is corrosive therefore its tendency will be to dissolve calcium carbonate; In general it is interpreted as the possibility that the water is aggressive, if the index is positive it indicates that the water is scaling therefore the water will have tendency to form calcium carbonate scales. The further the water pH is from the saturation pH, the more pronounced the instability will be. (See annex 5.1.6.1)

- Buffer Capacity

Buffer capacity is determined by calculating the alkalinity and bicarbonate in a body of water, according to the guidelines and techniques recommended in the guide for the monitoring of discharges, surface water and groundwater of the institute of Hydrology, Meteorology and Environmental Studies - IDEAM, the US Environmental Protection Agency-US EPA in its Handbook for Analytical Quality Control in Water and Wastewater Laboratories, and by the American Water Works Association - AWWA- in the American Standard Methods for Examination of Water and Wastewater under the code of *APHA-AWWA-WEF-SM-2320 B: Alkalinity, Titration Method. 22 Edition 2012 and APHA-AWWA-WEF-SM-3500-Ca B: Calcium, EDTA titulometric Method. 22 Edition 2012.*

This procedure is carried out by the company SERAMBIENTE SAS's laboratory

Then, according to the results obtained, the buffer capacity is determined according to the general recommendations for the upper and lower limits of buffer capacity provided by secondary information. The buffer capacity categories are related in the Table 5.1.31 .

Table 5.1.27 Buffer Capacity Category

Capacity	To	Bicarbonated ppm
LOW	Mild	<80 ppm (mg/L)
MODERATE		100-200 ppm (mg/L)

HIGH	High	>200 ppm (mg/L) >60 ppm (mg/L) Ca >25 ppm (mg/L) Mg

SOURCE (ASOAM, 2016)

It is important to remember that the alkalinity of water is not a constant value. This can change seasonally or over time. Producers must perform water tests at least once a year to know the pH and alkalinity of the same. Table 5.1.32 presents the buffer capacity of the monitored water sources.

Table 5.1.28 Relation of the presence of bicarbonates with the buffer capacity of the monitored sources

Sample	Type of water	Point	Bicarbonate (mg/l)	Buffer Capacity
38883	Superficial	Bobo River	20,7	B
38884	Superficial	La Chaquita creek	72,5	B
38915	Superficial	Upstream La Marquesa creek	47,6	B
38916	Superficial	Downstream La Marquesa creek	58,0	B
38926	Superficial	Upstream La Magdalena creek	31,1	B
38927	Superficial	Downstream La Magdalena creek	55,9	B
39204	Superficial	Upstream Guáitara River	47,9	B
39205	Superficial	Downstream Guáitara River	24,9	B
38926	Superficial	La Magdalena creek	43,5	B

SOURCE (ASOAM, 2016)

- *Water Quality Index*

As a methodological tool for the determination of water quality of monitored points, the following water pollution indexes (ICO) were estimated in the present study: Organic Matter Pollution Indexes (ICOMO) and Suspended Solids Pollution Index (ICOSUS), which relate different variables, such as: BOD5, total coliforms and percentage of oxygen saturation for

ICOMO and suspended solids for ICOSUS , Whose involved variables are specified in Table 5.1.33. Also, each index is defined by equations in which the physicochemical variables are integrated, as described below:

ICOMO = 1/3 (IDBO + Total Coliforms + Oxygen%)
ICOSUS = -0.02 + 0.003 Suspended solids (mg/L)

Table 5.1.29 Variables taken into account for the determination of the water pollution indexes

ÍNDICES	VARIABLE	INTERPRETACIÓN	
		Valor del ICO	Grado de Contaminación
ICOMO	DBO_5 Coliformes totales % de Saturación Oxígeno Disuelto	0,000 – 0,200	Ninguna
		0,200 - 0,400	Bajo
ICOSUS	Sólidos suspendidos	0,400 – 0,600	Medio
		0,600 – 0,800	Alto
		0,800 – 1,000	Muy alto

Source: (Ramirez and Viña, 2016)

Table 5.1.30 Water Pollution Index (ICO)

DATE	MONITORING POINT	POLLUTION INDEX	
		ICOSUS	ICOMO
30/04/2016	Upstream Guáitara River	0,163	0,273
30/04/2016	Downstream Guáitara River	0,040	0,062
23/04/2016	Bobo River	0,040	0,338
30/04/2016	Upstream La Magdalena Creek	0,064	0,031
26/04/2016	Downsteam La Magdalena Creek	0,040	0,260
24/04/2016	La Chaquita Creek	0,057	0,238

DATE	MONITORING POINT	POLLUTION INDEX	
		ICOSUS	ICOMO
03/0/2016	Magdalena Creek	0,01	0,1170
25/04/2016	Upstream La Marquesa Creek	0,040	0,021
25/04/2016	Upstream La Marquesa Creek	0,040	0,358

Source: (ASOAM, 2016)

For the ICOMO Pollution Index in four (4) of the nine (9) points, it is determined as a LOW degree of contamination by organic matter when reporting values of 0.273, 0.338, 0.260 and 0.358, Upstream Guáitara River, Bobo River, Downstream La Magdalena Creek and Downstream La Marqueza Creek, respectively. For the calculation of the ICOSUS pollution, for points Downstream Guáitara River, Bobo River, Downstream La Magdalena Creek, Upstream La Marqueza Creek and Downstream La Marqueza Creek, such was carried out in an indicative way, since the reported values were below the limit of quantification of the analytical technique used by the laboratory with respect to Total Suspended Solids, these being <20 mg/L. Consequently, the ICOSUS indexes of the nine (9) points sampled showed values between 0.040 and 0.163, therefore NO degree of contamination with respect to total suspended solids was determined.

- Index of potential alteration of water quality (IACAL)

The index of potential alteration of water quality is the numerical value that qualifies in one of five categories, the existing ratio between the pollutant load estimated to be received by a hydrographic subzone j over a time period t and the surface water offer, for an average year and a dry year, of this same hydrographic subzone estimated from a time series.

The indicator reflects the potential alteration of the quality of surface water systems in a given hydrographic sub-area. It allows to recognize areas susceptible to the types of pollution estimated to the extent that the threat category is rated as high and very high in a specific time interval.

The indicator calculation formulas are the following (one for an average year and one for dry year):

For an average year:

$$IACAL_{jt-a\tilde{n}omed} = \frac{\sum_{i=1}^{n} catiacal_{ijt-a\tilde{n}omed}}{n}$$

Where:

IACALjt-añomed: Is the index of potential alteration of the water quality of a hydrographic subzone j during the period of time t, evaluated for a water supply typical of an average year.

Catiacalijt-añomed: Is the classification category of the vulnerability due to the potential alteration of the water quality that represents the value of the pressure of the estimated load of the quality variable i that can be discharged to the hydrographic subzone j during the period of time t Divided by the water supply typical of an average year.

N: Is the number of quality variables involved in the calculation of the indicator; n is equal to 5.

For a dry year:

$$IACAL_{jt-a\tilde{n}osec} = \frac{\sum_{i=1}^{n} catiacal_{ijt-a\tilde{n}osec}}{n}$$

IACALjt-añosec: Is the index of potential alteration of the water quality of a hydrographic subzone j during the period of time t, evaluated for a water supply typical of a dry year.

Catiacalijt-añosec: Is the classification category of the vulnerability due to the potential alteration of the water quality that represents the value of the pressure of the estimated load of the quality variable i that can be discharged to the hydrographic subzone j during the period of time t Divided by the water supply typical of a dry year.

Is the number of quality variables involved in the calculation of the indicator; n is equal to 5.

Figure 5.1.80, prepared for the National Water Study 2010 (ENA) and modified for the ERA, presents the scheme that synthesizes the process to obtain the estimates of pollutant load and generation of IACAL.

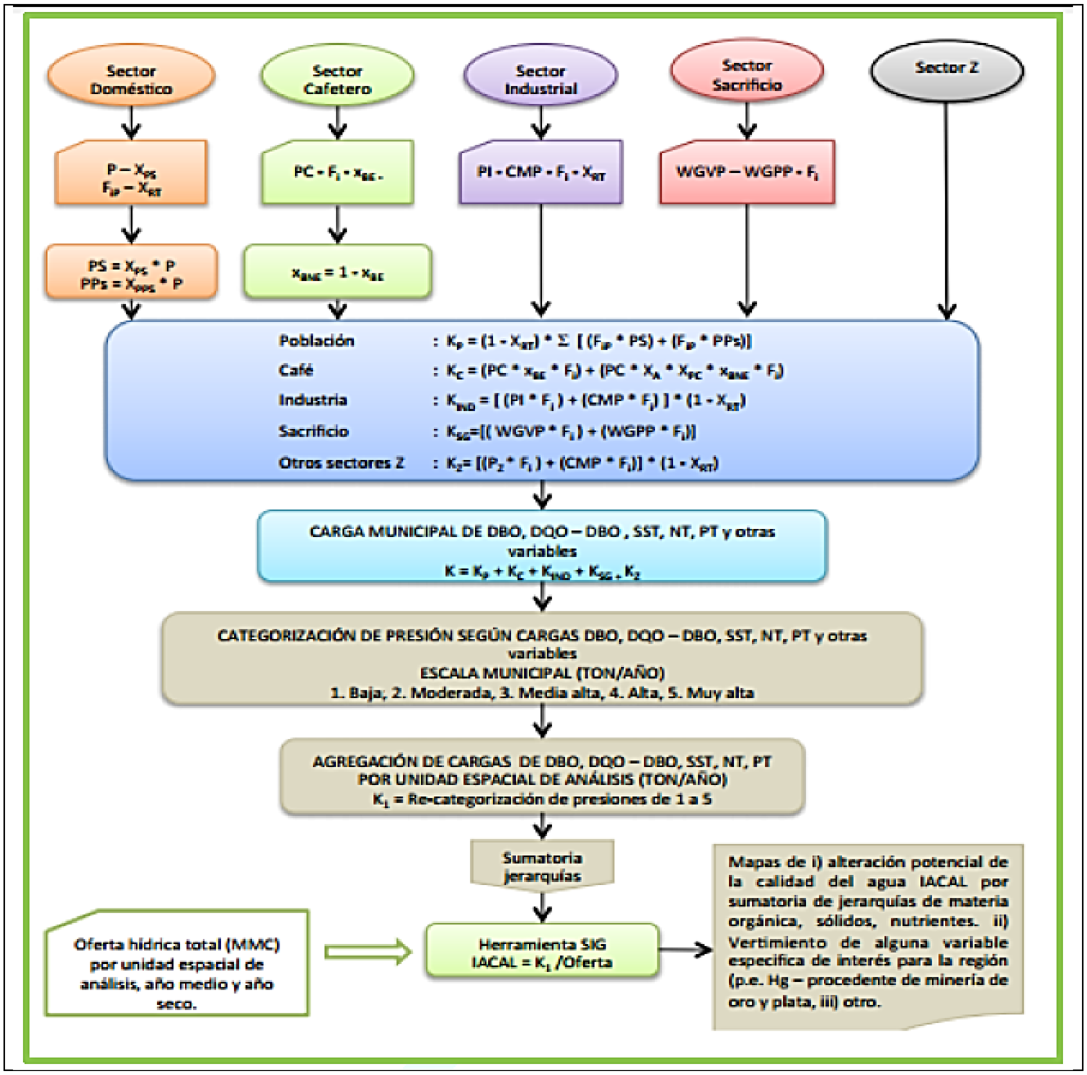


Figure 5.1.79 Diagram methodology for IACAL information processing

SOURCE (ASOAM, 2016)

The methodology for estimating discharged loads, including the loads removed by wastewater treatment systems and the categorization of pressures can be found in the National Water Study 2014 (ENA), Chapter 6. (IDEAM).

Table 5.1.31 Category and IACAL descriptor

IACAL	
Average Category (NT+PT+SST+BOD+(COD-BOD))/5	
Category	**Value**
Low	1
Moderate	2
Medium High	3
High	4
Very High	5

Source (ASOAM, 2016)

- *Rainy season*

The day of sampling for the rainy season was held on December 10 and 12, 2016 by INCO AMBIENTAL SAS, during which simple samples were collected at nine (9) sampling points for the physicochemical, microbiological and hydrobiological characterization of water. The flat coordinates associated with the sampling points can be seen in Table 5.1.36. (See annex 5.1.6.1)

Table 5.1.326 Water quality monitoring points

WATER MONITORING POINTS UF4 AND 5.1				
No.	MUNICIPALITY	SOURCE NAME	COORDINATES	
			NORTH	EAST
1	Imués	Guáitara	958574,41	608089,36
2	Imués	Guáitara	957030,886	605405,693
3	Tangua	Bobo	960904,88	608425,82
4	Tangua	Magdalena	961200,086	610748,832
5	Tangua	Magdalena	961152,905	609232,409

6	Tangua	La Chaquita	967144,451	614093,653
7	Tangua	Magdalena	965250,584	615213,667
8	Tangua	Marquesa	968133,676	617098,577
9	Tangua	Marquesa	968462,979	617078,496

Source: INCOAMBIENTAL, 2017

The entire collection and sampling process was carried out following the protocols established by IDEAM. pH, Dissolved Oxygen, Conductivity and Temperature values were recorded in situ. In Table 5.1.337 the measured physicochemical parameters are regsitered.

Table 5.1.347 pH, Temperature, DO and Conductivity Logs

No.	MUNICIPALITY	SOURCE NAME	pH	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)
1	Imués	Guáitara	8,10	20,1	6,2	0,179
2	Imués	Guáitara	8,13	17,4	6,1	0,191
3	Tangua	Bobo	8,13	18,0	5,8	0,099
4	Tangua	Magdalena	7,76	18,2	4,9	0,119
5	Tangua	Magdalena	7,00	18,9	5,3	0,082
6	Tangua	LA CHAQUITA	7,51	15,6	3,9	0,093
7	Tangua	Magdalena	7,81	15,0	6,1	0,088
8	Tangua	Marquesa	6,73	12,8	4,9	0,092
9	Tangua	Marquesa	6,79	12,9	5,1	0,092

Source: INCOAMBIENTAL, 2017

o Temperature

The temperature registers in the nine (9) monitoring points are presented in Figure 5.1.81, for this parameter values are between 12,8 and 20.1°C, these values are totally consistent with the climatic conditions and the geographical location of the monitoring sites.

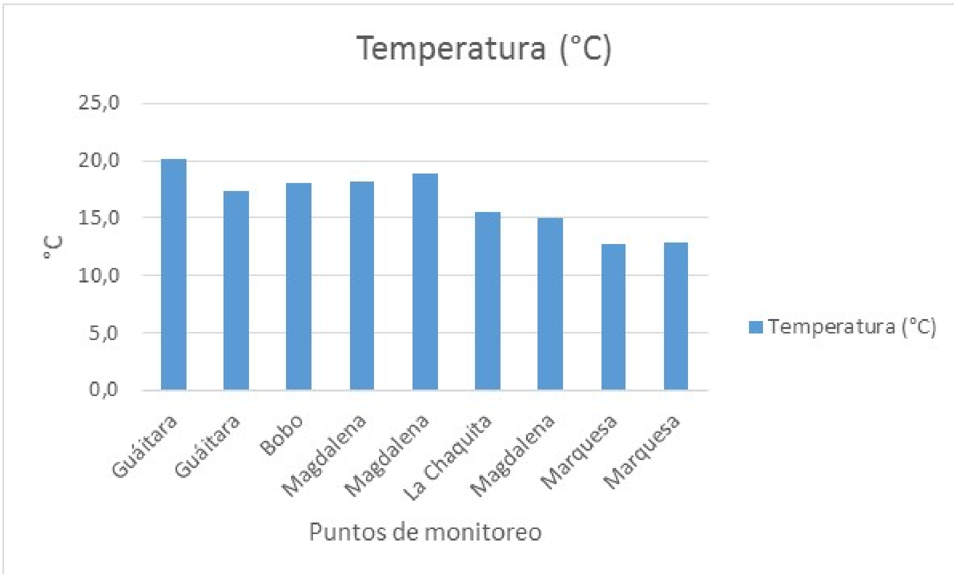


Figure 5.1.81 Temperature monitoring values

- pH

It is a measure of the acid, neutral or alkaline nature of water. The rules suggest that it should be close to 7 units, ie neutral. Most surface waters have a pH that is between 7 and 8 units. The pH value of the simple sample collected in each body of water was used to calculate the index. The Figure 5.1.82 shows the graph of the pH values recorded for each of the monitored sites.

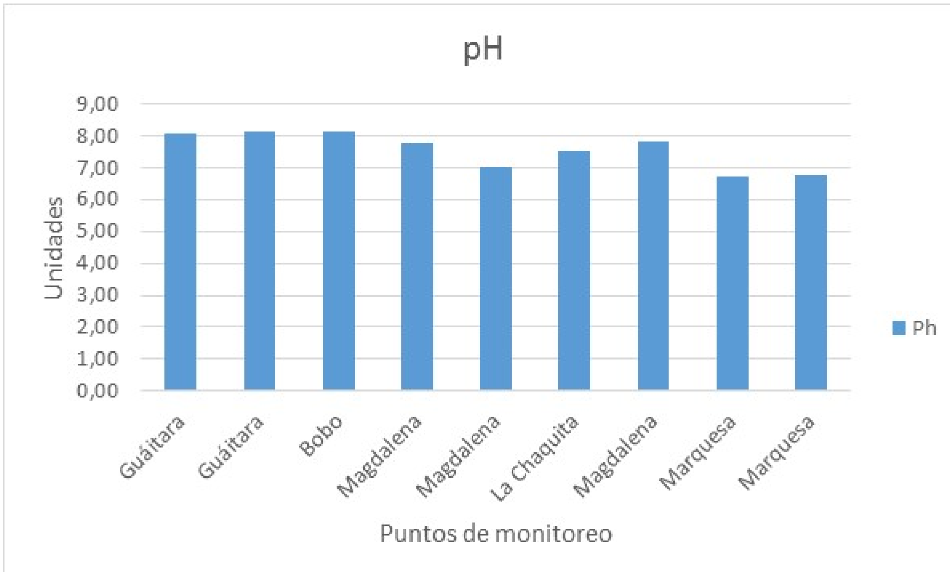


Figure 5.1.82 pH Values at monitoring points

- o Conductivity

It is closely related to the sum of cations and anions determined chemically, it reflects mineralization. Calculated as follows:

$= 1 – 10^{(-3,26+1,34_{10})}$

When I_{CE} <0, then I_{CE} = 0

The conductivity values are between 0,082 and 0,191 µS/cm. The maximum value was reported at the downstream Guáitara River point with a value of 0.191 µS / cm. (See Figure 5.1.83)

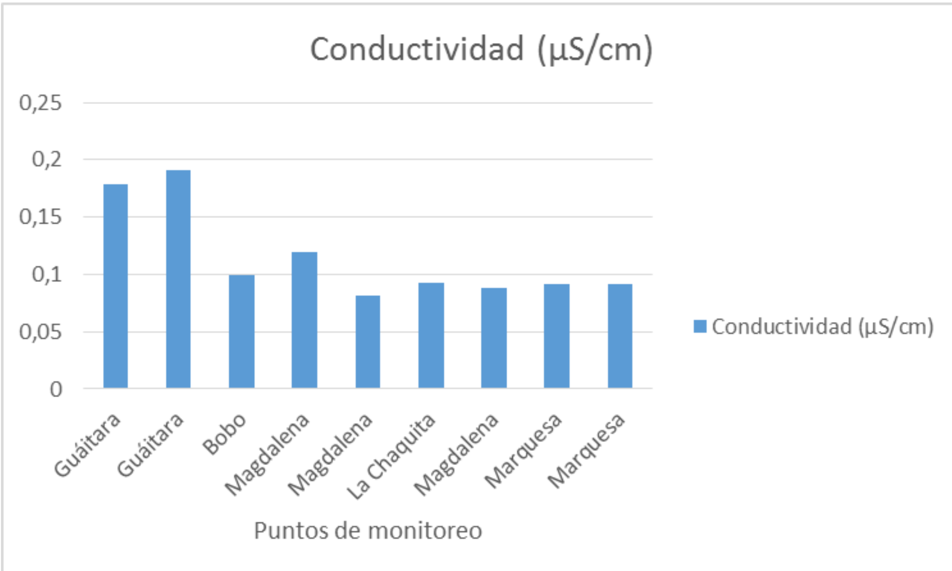


Figure 5.1.83 Conductivity Registers Monitor

- Dissolved oxygen

This variable has the fundamental biological role of defining the potential presence or absence of aquatic species.

Oxygen is both produced and consumed in a body of water. Oxygen production is related to photosynthesis, while the consumption will depend on respiration, decomposition of organic substances and other chemical reactions. Oxygen can also be exchanged with the atmosphere by diffusion or turbulent mixing. The total dissolved oxygen concentration ([DO]) will depend on the balance between all these phenomena. Figure 5.1.84 presents the DO registers for the monitored points.

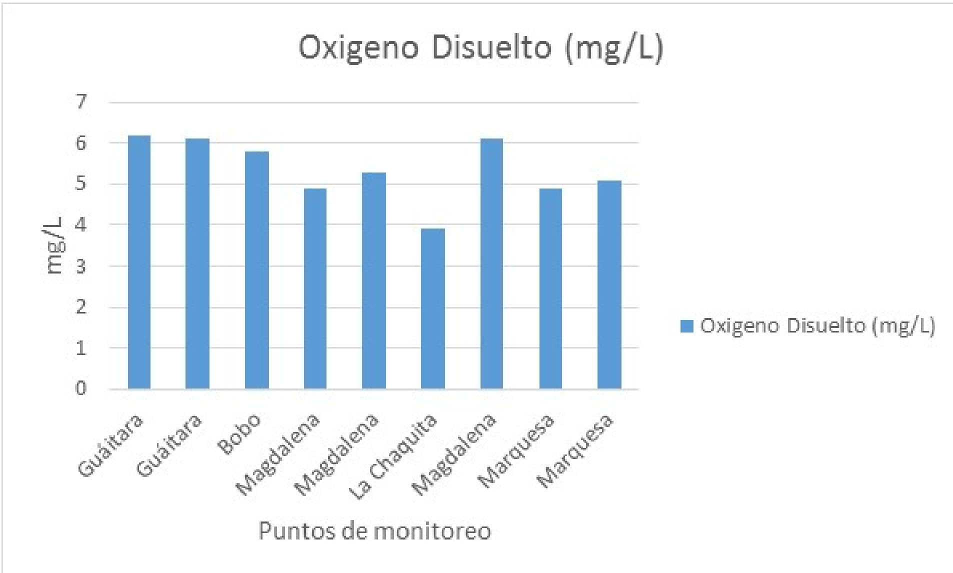


Figure 5.1.84 Dissolved Oxygen Registers Monitor

- Total suspended solids (SST)

The presence of suspended solids in water bodies indicates a change in the state of the hydrological current conditions. Such presence may be related to erosive processes, industrial dumping, material extraction and debris disposal. It has a direct relationship with turbidity.

The quality subindex for suspended solids is calculated as follows:

= 1 - (-0,02 + 0,003 *)

If SST = 4.5, then I_{SST} = 1
If SST = 320, then I_{SST} = 0

The results of SST obtained for the monitored points are presented in Figure 5.1.85, where we can observe that the highest value is recorded in the La Chaquita creek point with 110 mg CaCO3/L.

Figure 5.1.85 Total Suspended Solids Registry

- BOD

A parameter that measures the amount of oxygen consumed by degrading the organic matter of a liquid sample. It is the matter contained dissolved or suspended in a liquid sample susceptible of being consumed or oxidized by biological means. It is used to measure the degree of pollution; It ils usually measured after five days of reaction and is expressed in milligrams of diatomic oxygen per liter (mg O_2/L). Figure 5.1.86 reports the BOD records of the monitored points.

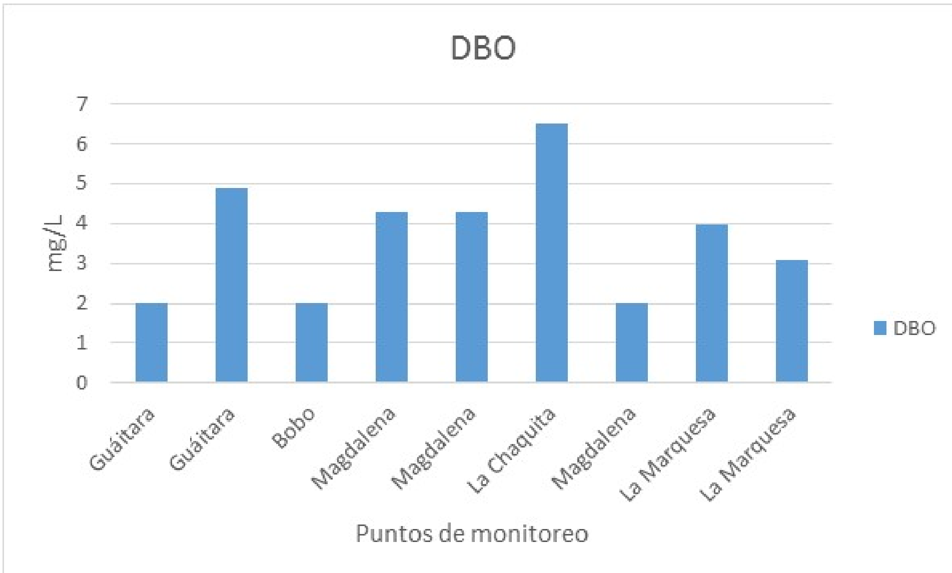


Figure 5.1.86 BOD Registers monitoring points

The physicochemical and microbiological analyzes (See Table 5.1.358)of the point samples were developed by the accredited laboratory ANALISIS AMBIENTAL SAS (Cali), in accordance with Resolution No. 503 of April, 2015 (See Annex 5.1.6.1).

Table 5.1.368 Laboratory results

Parameters	Units	NUMBER OF SAMPLING POINTS								
		Guáitara	Guáitara	Bobo	Magdalena	Magdalena	LA CHAQUITA	Magdalena	La Marquesa	La Marquesa
BOD	mg/L	<2.0	4.9	<2.0	4.3	4.3	6.5	<2.0	3.99	3.1
COD	mg CaCO3/L	<2.0	12.42	2.7	10.62	9.9	15.3	<2.0	11.34	10.53
Total suspended solids	mg CaCO3/L	110	28	36	38	38	250	26	24	18
Total dissolved solids	mg CaCO3/L	103.5	108.5	61	78	56	62.5	59	59	61
Oils and Greases	UNT	10.59	8.57	4.83	4.18	3.14	3.64	6.93	5.65	3.52

Parameters	Units	NUMBER OF SAMPLING POINTS								
		Guáitara	Guáitara	Bobo	Magdalena	Magdalena	LA CHAQUITA	Magdalena	La Marquesa	La Marquesa
Alkalinity	UPC	69.18	68.87	54.42	58.84	45.22	62.62	50.5	38.32	40.13
Total hardness	mg NO2/L	68.86	69.59	49.28	53.81	46.51	51.22	51.55	46.13	47.96
Calcium hardness	mg NO3/L	35.07	31.75	21.23	27.98	23.19	28.36	25.04	21.67	23.72
Turbidity	mg N/L	46.40	10.80	9.51	21.40	20.30	47.70	4.90	6.12	7.56
True color	mg/L	53.30	103.00	92.00	120.00	73.70	288.00	39.00	54.00	63.40
Nitrites	mg/L	0.201	0.368	0.0315	0.607	0.0251	0.105	<0.018	0.0295	0.0234
Nitrates	mg/L	1.72	1.36	0.326	1.07	0.525	0.195	1.51	1.29	0.834
Total Nitrogen	mg/L	<5.00	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Phosphorus	mg/L	<0.08	0.10	0.28	0.15	0.45	<0.08	0.45	0.11	<0.08
Phenolic compounds	mg/L	0.02	0.02	<0.002	0.01	0.01	<0.002	0.03	<0.002	<0.002
Zinc	mg/L	0.01	0.02	0.01	0.04	0.03	0.03	0.02	0.01	0.02
Barium	mg/L	<0.80	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8
Cadmium	mg/L	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Copper	mg/L	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01
Chrome	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Mercury	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01
Nickel	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.001
Silver	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lead	mg/L	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Selenium	mg/L	<0.0152	<0.0152	<0.0152	<0.0152	<0.0152	<0.0152	<0.0152	<0.0152	<0.0152
Arsenic	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Total Nitrogen *	mg N/L	<6.92	<6.73	<5.36	<6.68	<5.55	<5.3	<6.51	<6.3195	<6.8574

Parameters	Units	NUMBER OF SAMPLING POINTS								
		Guáitara	Guáitara	Bobo	Magdalena	Magdalena	LA CHAQUITA	Magdalena	La Marquesa	La Marquesa
Total Coliforms	MPN / 100ml	33000	49000	3300	46000	920000	380	11000	94000	46000
Fecal Coliforms	MPN / 100ml	17000	33000	1700	16000	9200	33	Absence	240	24000
E. coli	MPN / 100ml	17000	33000	1700	16000	9200	33	Absence	240	24000

Source: INCOAMBIENTAL, 2017

- *(ICA - NSF) water quality index*

the parameters that are required to measure for calculating the ICA index, according to the methodology formulated by IDEAM, are as follows: Dissolved oxygen of the water body in units of mg/L, the Water temperature in °C, Ambient temperature in °C, TSS in mg/L, COD in mg/l of O2, Total Nitrogen in units of mg/L, Total phosphorus in units of mg/L, Cconductivity in units of ɰs/cm, pH in pH units and Height of the sampling in units of masl.

ü ICA Calculation

the indicator is calculated as the sum of the indices calculated above (IOD, ISST, IDQO, ICE, INT/PT, IpH) weighted by their respective relative weights, which are listed below (see table 5.1.379).

table 5.1.389 relative weight to each subscript

Variable	Unit of measure	Weighting
OD	mg/L	0,17
COD	mg/L	0,17
SST	mg/L	0,17
NT/PT	Dimensionless	0,17
C.E.	µS/cm	0,17
pH	pH units	0,15

Source: INCOAMBIENTAL, 2017

The formula for the ICA calculation is as follows:

$$ICA_{njt} = \sum_{i=1}^{6} W_i I_{ikjt}$$

below is the classification of the quality index of water according to the ICA - NSF for the four (4) evaluated surface water bodies. (See Table 5.1.40)

table 5.1.40 ICA calculation, for each monitoring station

STATION	OD	Temperature of the water body	Ambient temperature	SST	COD	NT	PT	CE	pH	Height	ICA index	
	mg/L	°C	°C	mg/L	mg/L	mg/L	mg/L	µs/cm	Unit	masl		
Guáitara	6,2	20,1	22,1	110	1,87°	<5*	<0,08*	0,179	8,1	1728	**0,719**	Good
Guáitara	6,1	17,4	19,4	28	12,42	<5*	0,1	0,191	8,13	1711	**0,744**	Good
Bobo	5,8	18	20	36	2,7	<5*	0,28	0,099	8,13	1760	**0,846**	Good
Magdalena	4,9	18,2	20,2	38	10,62	<5*	0,15	0,119	7,76	2051	**0,767**	Good
Magdalena	5,3	18,9	20,9	38	9,9	<5*	0,45	0,082	7	1850	**0,852**	Good
LA CHAQUITA	3,9	18,2	20,2	250	15,3	<5*	0,08*	0,093	7,51	2689	**0,64**	Medium
Magdalena	6,1	15	17	59	°1,67	<5*	0,45	0,088	7,81	2658	**0,86**	Good
La Marquesa	4,9	12,8	14,8	24	11,34	<5*	0,11	0,092	6,73	3006	**0,75**	Good
La Marquesa	5,1	12,9	14,9	18	10,53	<5*	<0,08*	0,092	6,79	2995	**0,77**	Good

* The reported results correspond to the minimum value of detection of the analysis technique.
° The results are outside the certainty value of the analysis technique
Source: INCOAMBIENTAL, 2017

As in any model, the present index simplifies and organizes the huge amount of quality data in a homogeneous framework that allows to communicate and assess the state of the water body in an understandable way and without significant distortion in information.

You can see that all checkpoints monitored in the UF4 and UF5.1, indicate a similar behavior, resulting in a Good ICA valuation, which is uniform for the entire study area.

ü Langelier index

Also called stability index or cosmetic index, it is used as an approximation method, for determining the corrosive or scaling condition of a water body in a pond or pool. It is usually a value associated to the characteristics: pH, Total Alkalinity, Total Hardness, and Temperature. (Ministry of social protection, 2010).

The parameters used for the determination of the Langelier index are pH measured in pH units, Total Alkalinity pH measured in mg/L $CaCO_3$, Total Hardness measured in units of ppm $CaCO_3$ and Temperature measured in units of °C. The Temperature Factor (CT), the Hardness Factor (CD) and the Alkalinity Factor (CA) are calculated based on these parameters. Table 5.1.41 presents the results of the Langelier index for each monitored point.

table 5.1.41 Langelier index for each station

STATION	pH	CT	CD	CA	INDEX	
Guáitara	8,1	0,489	1,439	1,835	-0,237	Corrosive
Guáitara	8,13	0,431	1,444	1,828	-0,267	Corrosive
Bobo	8,13	0,444	1,297	1,742	-0,487	Corrosive
Magdalena	7,76	0,448	1,333	1,776	-0,783	Corrosive
Magdalena	7	0,464	1,264	1,662	-1,71	Corrosive
LA CHAQUITA	7,51	0,45	1,32	1,8	-1,02	Corrosive
Magdalena	7,81	0,38	1,32	1,71	-0,89	Corrosive
La Marquesa	6,73	0,32	1,26	1,59	-2,19	Corrosive
La Marquesa	6,79	0,33	1,28	1,61	-2,09	Corrosive

Source: INCOAMBIENTAL, 2017

According to the Langelier index, for all the UF 4 and UF5.1 sampling points, the water presents corrosivity features.

ü Index of potential alteration of water quality (IACAL)

the parameters used for the calculation of the potential alteration of the water quality index are: Flow rate measured in L/sec, BOD5 measured in mg/L, COD measured in mg/L, SST measured in mg/L Total Nitrogen measured in mg/L Total Phosphorus measured in mg/L, as well as the water offer for an average and dry year values measured by municipality in units of MMC (million cubic meters) Table 5.1.42 presents the results of the IACAL monitored points.

table 5.1.42 results of the IACAL for the UF4 and UF5.1

Potential water alteration IACAL - IDEAM index										
STATION	Flow	BOD5	COD	SST	NT	PT	CATEGORY OF CLASSIFICATION AND THREAT AVERAGE YEAR		CATEGORY OF CLASSIFICATION AND THREAT DRY YEAR	
	L/sec	mg/L	mg/L	mg/L	mg/L	mg/L				
Guáitara	8962	1,79*	1,87*	110	5*	0,08*	5	VERY HIGH	5	VERY HIGH
Guáitara	8962	4,9	12,42	28	5*	0,1	5	VERY HIGH	5	VERY HIGH
Bobo		1,47*	2,7	36	5*	0,28				
Magdalena	306	4,3	10,62	38	5*	0,15	3	MEDIUM HIGH	4	HIGH
Magdalena	306	4,3	9,9	38	5*	0,45	4	HIGH	4	HIGH
LA CHAQUITA	2,21	6,5	15,3	250	5*	0,08*	1	LOW	1	LOW
Magdalena		1,58*	1,67*	59	5*	0,45	†	†	†	†
La Marquesa	56	3,99	11,34	24	5*	0,11	2	MODERATE	2	MODERATE
La Marquesa	56	3,1	10,53	18	5*	0,08*	1	LOW	2	MODERATE

† no calculation could be done as there is no flow data for this station.
* The reported results correspond to the minimum value of detection of the analysis technique.
° The results are outside the certainty value of the analysis technique
Source: INCOAMBIENTAL, 2017

Due to the characteristics of the sampling area, the flows for the Bobo water body could not be determined, therefore it was not possible to determine the IACAL for it. Regarding the Guáitara water body, the ICA category classification was determined as Very High both for the average years as for the dry years. As for the Magdalena water body, except the station upstream during the average years; the potential alteration of the water quality was determined as High, both for the average years as for the dry years, upstream and downstream of the intervention.

- Analysis of results

As for the physicochemical parameters, the pH of the La Chaquita and Magdalena creeks present optimal conditions; for the water bodies Guáitara and Bobo, Ph was slightly Basic, while La Marquesa creek has slightly acidic conditions. With regard to the dissolved oxygen, La Marquesa and Magdalena creeks have adequate conditions, while the Magdalena creek and La Chaquita stations present hypoxia conditions.

for the UF4, the ICA results are due to the fact that these water bodies have high dissolved oxygen levels and low Nitrogen levels which are even below the measuring range of the method. It is important to note that this index was calculated via the IDEAM methodology, which does not consider parameters such as Fecal Coliform and Water Turbidity.

in the UF5.1, the ICA results for the Magdalena and La Marquesa water bodies stations present Good results, however the station La Chaquita, presents a Medium category, due to its high concentrations of COD and SST. It is important to note that this index was calculated via the IDEAM methodology, which does not consider parameters such as Fecal Coliform and Water Turbidity.

On the other hand, according to the Langelier index, the water of all sampled stations of this functional unit, present trends to corrosivity, so it is advisable for any downstream activities, to make adjustments to the pH as necessary for activities such as recreation and intakes by pumping, etc.

As for the bioindicators, all evaluated points present characteristics of pollution with classification according to the COL/BMWP and ASPT indexes between "DOUBTFUL and VERY CRITICAL", due to the presence of macroinverterbrates highly tolerant to low quality of aquatic environment conditions, agreeing with the results of potential pollution measured by the IACAL index for water bodies of the fourth functional unit.

5.1.6.2. Coastal - marine water bodies

There are no coastal -marine water bodies within the Rumichaca - Pasto divided highway project, Pedregal - Catambuco segment.

5.1.7. Uses of water

The water uses are the different kinds of utilization of the resource, as well as any other activity that may have significant impact on the condition of the waters. These applications include domestic, agricultural, livestock and industrial, among others.

- Current uses

The water uses are the different kinds of utilization of the resource, as well as any other activity that may have significant impact on the condition of the waters. These uses include the population supply, irrigation and agricultural applications, industrial applications, aquaculture, recreation, among others.

- Current and projected uses

Taking into account the secondary data obtained from the POMCAS and collected in the field, it was determined that the existing uses of water sources are basically for household, agricultural, livestock, recreational and industrial activities.

Ancillary industrial projected uses are being contemplated, such as compaction, unpaved roads wetting, concrete plants, crushing, construction and improvement of hydraulic works as required in the project, also referred to greater water demand for greater coverage of use in agricultural and livestock, recreational, tourism and services, this since this area is going to have higher recurrence of population

- Inventory of uses and users

With primary and secondary information herein are mentioned some uses and users who have been identified in the POMCA of the area to be operated, in addition it took into account information requested to the competent environmental authority (CORPONARIÑO) where information was obtained from concessions authorized legally to different uses with their respective users, then there is evidence of the sources that are going to be affected by project activities such as :

Water intakes to be used for industrial character for the construction of the project. (See Table 5.1.43)

table 5.1.43 Uses and users collection points

UF	SOURCE	USES	Users	FLOW RATE (l/s) UNDER CONCESSION
4	LA MAGDALENA	Irrigation, livestock, cattle and pig keeping	782	1.5
4	LA CHAQUITA	-	-	-
4	BOBO RIVER	Domestic	24257	47
		Agricultural		40
		Livestock		5
5	MARQUEZA (CUBIJAN)	Human consumption	80	1.5

for the occupations of the river flows, the following uses and users were defined where the demand for each of the drainages were identified (see Table 5.1.44 and annex GDB/cartografia/PDF/EIADCRP_PC_015).

table 5.1.44 uses and users of water sources, Pedregal-Catambuco Segment

SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
1	Low Inantas	Yacuanquer	608362	960297
SOURCE TYPE AND NAME	Superficial			
USES	Domestic and agro-herding			
Users	15 subscribers, 90 users			

OBSERVATIONS	on the left side of the road there is a hoses channeling for clean water as residual waters, which are elevated and others cross the road culvert. The water is supplied from the Yacuanquer aqueduct which is used for drinking, washing pork pits and in summer for irrigation of coffee, guava and banana crops, among others. Presence of abundant vegetation.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
2	Low Inantas	Yacuanquer	608439	960500
SOURCE TYPE AND NAME	Yacuanquer aqueduct.			
USES	Domestic.			
Users	12 subscribers, 60 users			
OBSERVATIONS	on the left side of the road there is a channeling of hoses of clean water for human consumption, from the Yacuanquer aqueduct, these cross through the culvert to the right margin. Presence of abundant vegetation.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
3	Low Inantas	Yacuanquer	608439	960500
SOURCE TYPE AND NAME	Superficial			
USES	Domestic.			
Users	10 subscribers, 60 users			
OBSERVATIONS	Left margin hoses crossing, residual waters water and aqueduct drainages, passing to the right margin through the road culvert, where plantations of banana, coffee, guava are observed, and vegetation.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
4	Low Inantas	Yacuanquer	608709	960800
SOURCE TYPE AND NAME	Without Name			
USES	Agricultural			
Users	8 persons			

OBSERVATIONS	Waterless river bed, secondary vegetation, presence of crops of coffee and bananas, located to the left margin.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
5	Low Inantas	Yacuanquer	608736	960866
SOURCE TYPE AND NAME	Superficial			
USES	Agricultural			
Users	5 persons			
OBSERVATIONS	A waterless river bed is observed, around it there is evidenced of aboundant vegetation.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
6	Low Inantas	Yacuanquer	609353	960950
SOURCE TYPE AND NAME	Superficial			
USES	Agricultural			
Users	7 persons			
OBSERVATIONS	There is evidence of vegetation presence (eucalyptus) in addition to clean water broken pipelines crossing, overflow tank storage (aqueduct) left belonging to the service station El Placer, which runs down the road culvert to the right margin.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
7	Low Inantas	Yacuanquer	609432	960929
SOURCE TYPE AND NAME	Water lenticular spring			
USES	Domestic and Agro-herding			
	7 subscribers 30 users			
OBSERVATIONS	A clean water hoses crossing can be observed comming from the Yacuanquer private aqueduct. There is abundant vegetation around it.			

SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
8	Low Inantas	Yacuanquer	609422	960916
SOURCE TYPE AND NAME	La Magdalena creek, Surface			
USES	Domestic, agricultural and industrial.			
Users	approximately 35 people			
OBSERVATIONS	A construction of untreated water storage tanks is observed, which supply the El Placer service station, which has a hotel, restaurant, vehicles washing and tire repair service. The source water has a concession "resolution 209 on August 21, 2014, awarded flow of 1.5 l/s to use for irrigation to fruit trees and coffee, livestock, cattle and pig-keeping."			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
9	High Inantas	Yacuanquer	610652	961069
SOURCE TYPE AND NAME	Outcrop			
Users	13 subscribers			
USES	N/A			
OBSERVATIONS	It is located at the left side of the road, and around it has secondary vegetation.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
10	High Inantas	Yacuanquer	610061	960939
SOURCE TYPE AND NAME	Without Name			
USES	Domestic			
Users	60 persons approx. 12 subscribers.			
OBSERVATIONS	Source with abundant flow, which remains constant, there is abundant vegetation around it.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W

11	Tablón Obraje	Tangua	610754	961237
SOURCE TYPE AND NAME	Outcrop			
USES	Domestic			
Users	10 people.			
OBSERVATIONS	It is located to the left margin of the route, the water is caught by means of hoses and taken to a collection box from where it is later transported for consumption. It has no waters concession. The flow is constant, does not vary with the weather.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
12	Tablón Obraje	Tangua	610776	961215
SOURCE TYPE AND NAME	Magdalena			
USES	Industrial			
Users	15 persons			
OBSERVATIONS	It has abundant flow, its surroundings are covered with diverse shrubby vegetation, as well as plantain and bean crops, discharges of wastewater from the dwelling and car washes are done here.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
13*	Tablón Obraje	Tangua	610217	961234
SOURCE TYPE AND NAME	Magdalena creek Branch			
USES	Agricultural			
Users	5 persons			
OBSERVATIONS	Its surroundings are covered with aboundant shrubby vegetation, the water is captured for irrigation, it has an average flow.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
14	San Pedro	Tangua	609775	961515

SOURCE TYPE AND NAME	Magdalena creek Branch			
USES	Agricultural and poultry			
Users	7 Users			
OBSERVATIONS	water source with low flow, upstream there is an intake into a tank to be carried through hoses as shown in the attached photographic registry. There is abundant shrub vegetation in the surroundings. It has a concession rate of 1.50 lps on behalf of Pollos al Dia S.A.S., with a period of 5 years. It is in force, expires in 2020.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
15	San Pedro	Tangua	610229	962035
SOURCE TYPE AND NAME	La Magdalena Creek			
USES	Agricultural			
Users	10 persons			
OBSERVATIONS	The source is located to the right margin of the road, runs through a canal, which crosses the dwellings around it, this is used exclusively for irrigation; crops of plantains, coffee, corn, fruit trees, among others.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
16 *	San Pedro	Tangua	610282	961987
SOURCE TYPE AND NAME	La Magdalena Creek			
USES	Agricultural			
Users	23 users			
OBSERVATIONS	Falling water from the Magdalena Creek, the water is captured for irrigation. Concessioned flow of 0.50 lps to the name of Mr Carlos Omar Benavides Basante. It is in force until 2019. Resolution Number 501.			
SOURCE		MUNICIPALITY	COORDINATE	

	MUNICIPAL RURAL SETTLEMENT		N	W
17	Tangua	Tangua	610476	961957
SOURCE TYPE AND NAME	Superficial			
USES	Agricultural			
Users	5 persons			
OBSERVATIONS	Fall of water from the ravine Magdalena, possesses abundant shrub vegetation, there is channeling of hoses that are used to irrigate crops of peas, corn, coffee and compost.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
18	Tangua	Tangua	612936	964199
SOURCE TYPE AND NAME	Water spring			
USES	Domestic and Agro-herding			
USERS	4 houses, approximately 20 people.			
OBSERVATIONS	the water spring is located at the left side of the road, it is used for domestic use, irrigation of crops such as corn, tomato and passion fruit, it is also used for trout hatcheries. There are abundant low and shrub vegetation. There is no wáter concession.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
19	Tangua	Tangua	612939	964214
SOURCE TYPE AND NAME	Outcrop			
USES	Domestic and Agro-herding			
Users	17 users			
OBSERVATIONS	This water spring will be used for possible urbanizing construction, it has aboundant shrubby vegetation. It is surrounded by willows.			

	Human settlements, located parallel to the intake of the water spring, make water abstractions through hoses transferred to tanks for domestic use, irrigation and crop.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
20	Tangua	Tangua	613116	964899
SOURCE TYPE AND NAME	Superficial			
USES	Agricultural			
Users	8 persons			
OBSERVATIONS	intermittent waterfall, crossing hoses, abundant shrub and herbaceous vegetation with presence of peas and bean crops. It receives discharges of wastewater from agricultural use.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
21	El Vergel	Tangua	613293	965216
SOURCE TYPE AND NAME	Without Name			
USES	Domestic and agro-herding			
USERS	29 houses, approximately 174 inhabitants			
OBSERVATIONS	There are abundant low and shrub vegetation. There is no presence of human settlements in its boundaries, present facilities in the photographic are in a state of abandonment.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
22	El Vergel	Tangua	613097,08 74	965569,064
SOURCE TYPE AND NAME	Source from the Santa Isabel Creek			
USES	Domestic and Agro-herding			
USERS	2 subscribers, approx. 12 people.			

OBSERVATIONS	There are two intakes, one for human consumption and another for irrigation, these intakes are of the crossed type with small diameter pipes (hoses).			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
23	San Antonio	Tangua	613069,4363	965637,078
SOURCE TYPE AND NAME	Source for the San Antonio gorge			
USES	Domestic and Agro-herding			
	12 subscribers, 72 users approx			
OBSERVATIONS	There are two intakes, one for human consumption and another for irrigation, these intakes are of the crossed type with small diameter pipes (hoses).			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
24	El Cebadal	Tangua	614119,8785	965952,538
SOURCE TYPE AND NAME	Source of the San Antonio gorge 1			
USES	Domestic, agro-herding			
Users	7 subscribers, 42 persons			
OBSERVATIONS	There are two intakes, one for human consumption and another for irrigation, these intakes are of the crossed type with small diameter pipes (hoses).			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
25	El Cebadal	Tangua	614328	966206
SOURCE TYPE AND NAME	Arrayan Creek (intermittent)			
USES	Agricultural			
Users	4 persons			

OBSERVATIONS	This source is intermittent, due to the climate factor, is surrounded by flush and shrubby vegetation.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
26	Chávez	Tangua	614635	966326
SOURCE TYPE AND NAME	Outcrops			
USES	Domestic and agro-herding			
USERS	5 Subscribers, approximately 25 users.			
OBSERVATIONS	Water extraction is made by means of one motorized pump, in all the zone there are water mantles and flush vegetation predominate.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
27	Chávez	Tangua	614654	966264
SOURCE TYPE AND NAME	EL Quelal creek (intermittent)			
USES	Livestock			
USERS	3 persons			
OBSERVATIONS	this source is intermittent, due to the climate factor. It is surrounded by vegetation with very dense shrub stratification.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
28	El Cebadal	Tangua	614356	965510
SOURCE TYPE AND NAME	Without Name			
USES	Domestic			
USERS	18 subscribers, 82 people approx.			
OBSERVATIONS	This source has a low flow and is used for the sanitary supply of afferent households.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W

29	Cebadal	Tangua	614663	965624
SOURCE TYPE AND NAME	Tangua Aqueduct			
USES	Domestic			
USERS	12 persons			
OBSERVATIONS	They feature a storage tank which is stocked by the Tangua aqueduct and is used for human consumption.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
30	Cebadal	Tangua	614986	966271
SOURCE TYPE AND NAME	Tangua Aqueduct			
USES	Domestic			
USERS	154 users			
OBSERVATIONS	The service station is supplied by the Tangua aqueduct, where itis given a domestic and sanitary use. There is a concessioned rate of 1.5 lps, for a total of 80 users.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
31*	El Tambor	Tangua	616082	967297
SOURCE TYPE AND NAME	La Marquesa creek (Cubiján)			
USES	Domestic, agro-herding			
USERS	23 Users			
OBSERVATIONS	Parallel to the tributary there are human settlements and extensions of moderately large crops, with a predominance of pea, manioc, potato, barley and wheat; as well as livestock use. There is a concessioned rate of 7 lps, for a total of 170 users.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
32	El Tambor	Tangua	616248	967708
SOURCE TYPE AND NAME	Water spring - El Horno Hole			

USES	Domestic			
Users	10 subscribers, 45 people approx.			
OBSERVATIONS	The water spring comes from a rocky outcrop, which make it impossible to determine the exact location of the spring.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
33*	El Tambor	Tangua	616269	967708
SOURCE TYPE AND NAME	La Marquesa creek (Cubiján)			
USES	Livestock			
USERS	7 persons			
OBSERVATIONS	It is surrounded by flush and shrubby vegetation, used for livestock.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
34	El Tambor	Tangua	616506	968070
SOURCE TYPE AND NAME	Direct current of the La Marquesa creek (intermittent)			
USES	Livestock			
USERS	6 persons			
OBSERVATIONS	This source has a very low flow, which is used for activities of livestock, surrounded with flush and shrubby vegetation.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
35	El Páramo	Tangua	617141	969316
SOURCE TYPE AND NAME	Outcrop No.1 (Llano Grande farm)			
USES	Domestic and livestock			
USERS	3 subscribers, approx. 20 people. 3 persons			
OBSERVATIONS	It is a water spring surrounded by flush vegetation, used for human consumption; when the spring overflows, it is used for livestock.			
SOURCE		MUNICIPALITY	COORDINATE	

	MUNICIPAL RURAL SETTLEMENT		N	W
36	El Páramo	Tangua	617274	969452
SOURCE TYPE AND NAME	Outcrop No. 2 (Llano Grande farm)			
USES	Agro-herding			
USERS	5 subscribers			
OBSERVATIONS	is a water spring where there is a continuous flow of resources; It is used for livestock and spraying crops as potatoes, manioc and lima bean. It should be noted that approximately 5 years ago there are eucalyptus planting.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
37*	La Palizada	Tangua	617934	969959
SOURCE TYPE AND NAME	El Ajo Aqueduct			
USES	Domestic			
USERS	15 Users			
OBSERVATIONS	The service station is located in the municipal rural settlement of La Marquesa bajo, it intakes from the El Ajo aqueduct and its use is purely domestic. The aqueduct has conections for 74 houses of 6 people, for a total of 444 users that take their supply from it.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
38*	La Merced	Pasto	618535	974382
SOURCE TYPE AND NAME	Miraflores Creek			
USES	Human and Domestic consumption			
OBSERVATIONS	· In the municipal rural settlement of la Merced, sector Miraflores is the Miraflores creek, where it drains its waters to the Pasto river, the water captured at the Bobo river reservoir for human consumption of the inhabitants of the city of Pasto, crosses the Miraflores creek via a flyover in the sector of the bridge which connects the Miraflores hamlet			

	wih the Southern Panamerican Highway , bound for the Centenario Drinking Water Treatment Plant. · Since the main flow is a topographically low conduction point, the utilities company EMPOPASTO SA ESP has installed a purge valve, for the emptying of the piping, drain or whose output is directed towards the water current. It has authorized the intake of 120 lps. · The flow contribution of this deviation toward the main channel of the Miraflores creek is very sporadic since it occurs only when the company EMPOPASTO carries out a service suspension and emptying of the pipeline for repairs or replacement of any accessory · It should be noted that according to information provided by the inhabitants of the sector, during the summer when the mainstem flow decreases considerably, the purge is open for short periods by EMPOPASTO operators in order to bring water to the Creek so that they can ensure a flow downstream at the point where an intake is located, intended also for human consumption of the inhabitants of the city of Pasto belonging to the area influence of the treatment plant of the Mijitayo neighborhood.			
SOURCE	MUNICIPAL RURAL SETTLEMENT	MUNICIPALITY	COORDINATE	
			N	W
39	La Merced	Pasto	619414	974686
SOURCE TYPE AND NAME	Underground well			
USES	Domestic			
USERS	7 Users			
OBSERVATIONS	the Bavaria S.A. Enterprise conducted a drilling for water for human and domestic consumption (baths and cafetería operation), located at a depth of 127m, with a diameter of 4m, 6 " pipe and 5.35 l/s flow. It has a total of 48 employees distributed in two shifts per day. It has waters concession.			

Source: (Geminis Environmental Consultants, 2016)

Below is a description of the most significant uses that were collected and analyzed (livestock, agricultural, domestic and industrial). The uses considered the most relevant according to the table above are:

-Livestock use

Livestock use of water is refered to its use for livestock consumption, within the area of influence of livestock activities in greater magnitude than the existing road network, due to its rural location; its source of hydration are water bodies close to the grazing lands. In the points requested as intake points direct users were identified on the water bodies, who whether directly or indirectly by the use of hosestransport water to dams or troughs, that as the word says are for cattle drinking.

-Agricultural use

Agricultural use of water, is for irrigation of crops and other related or complementary activities. (MAVDT, 2010)

For the area of influence of the project, much of the lotic bodies (rivers, streams and water springs) are used for crops irrigation of each municipality, since most of the interest area of the project is rural.

-Domestic use

Water use for human and domestic consumption involves activities such as:

1. Direct drinking and food preparation for human consumption.
2. Satisfaction of domestic, individual or collective needs, such as personal hygiene and cleaning items, materials or utensils.
3. Food preparation in general and especially for marketing or distribution, that do not require elaboration. (MAVDT, 2010)

In the area of influence the supply of water for human consumption is given by afferent water bodies alongside the existing and projected road, such as creeks and water springs.

-Industrial use

It means industrial use, for employment in activities such as transformation or exploitation manufacturing processes, as well as those related and complementary, use for power generation and mining. (MAVDT, 2010).

within the area of influence we find a wide variety of commercial establishments such as shops, restaurants, process, distribution and sale of dairy products, sand mines, brick factories, among others. Their source of supply are water springs, owned by the establishments.

- Water balance

taking into account that the different climatic factors foster specific conditions for the transport of water and at the same time determines the hydric supply in a given area, it is necessary to perform a hydric balance in which the scarcity and availabilty of the resource for the area of influence are established. This can be established from an integrated analysis of phenomena associated to the dynamics of water in the atmosphere and their exchange with the soil, such as: the process of evapotranspiration, precipitation, infiltration or storage processes and runoff processes due to excess of the resource. This assessment correlated these latest parameters under the principle of mass conservation resulting in final availability or deficit of the resource.

the stations used to make the hydric balance were those that better represent the conditions of the area of influence by their space location. (See Table 5.1.45)

table 5.1.45 Stations Used for the Calculation of the Hydric Balance

Type	Cod	Station	Municipality	Department	Latitude
SP	52055010	Apto San Luis	Ipiales	Nariño	0,51
AM	52055040	Botana	Pasto	Nariño	1,09
AM	52045010	Obonuco	Pasto	Nariño	1,11
CP	52055090	Sindagua	Tangua	Nariño	1,62

Source: IDEAM 2015.

the balance starts as of the precipitation records and potential evaporation, starting with the month that gives start to the dryest period of the year. Starting with a theoretical floor water storage value of a column of 100 mm, which when overflowed at the end of the month, generates an excess which becomes surface runoff.

The potential evapotranspiration, in principle was calculated using Thornthwaite formula (see table 5.1.46)

Table 5.1.46 Evapotranspiration Potential Calculation - Thornthwaite Method

Variable	Equation
(*i*) monthly heat index - from the monthly average temperature	*i* = (t / 5) 1.514
Annual Heat Index (I) adding the 12 values of I	i = S *i*
Monthly Uncorrected ETP	$ETP_{uncorrected} = 16 (10 t / I)^a$ I: Caloric index t:Monthly average temperature a: Empiricall exponent, I function. a: $(675*10^{-9} I^3) – (771*10^{-7} I^2) + (1792*10^{-5} I) + 0.49239$
Corrected monthly ETP	$ETP_{corrected} = ETP_{uncorrected} * N/12 * d/30$ d: Number of days of the month N: Maximum number of sunlight hours, depending on the month and latitude

Source: University of La Laguna. Spain. http://fjferrer.webs.ull.es/Bibliog/Biblio/Evapotranspiracion.pdf.

The temperature records for the studied stations do not have values greater than the 26.5°C at a monthly level, according to the formulation given by Thornthwaite, the convergence point arises in this value, therefore it is not necessary to make the adjustment to these values.

Hereafter in Table 5.1.47 the uncorrected potential evapotranspirations are presented for each of the stations to analyze in the hydric balance, starting as of the average monthly mean multiannual temperatures recorded in each.

Table 5.1.397 Projection of Uncorrected Potential Evapotranspiration

Station	ETP (mm)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Apto San Luis	51,405	52,116	52,419	52,508	51,992	48,872	46,037	45,582	47,831	51,281	52,704	52,276
Botana	53,08	53,95	54,10	55,21	52,66	49,88	49,92	52,26	54,11	53,79	53,10	47,81

Station	ETP (mm)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Obonuco	55,39	51,13	56,49	56,34	56,54	55,83	53,26	53,60	54,21	56,28	53,74	55,72
Sindagua	53,65	54,02	54,02	54,82	54,78	53,80	52,65	53,30	54,89	54,52	53,06	53,45

Based on the previous estimates of potential evapotranspiration and the precipitation historic values, a hydric balance was made for each one of the previousy selected stations, which represent the climatic conditions of the area of study.

Hydric balance - Botana Station

As can be observed, the deficit in the area adjacent to this station recorded a value of zero throughout the annual cycle, so for the analyzed period, there was no lack lack of quantity of water to meet the potential needs.

between the months of October to April, there are excesses, being November the one that recorded a higher rate of excess (54,35 mm), perhaps associated to the fact the largest multiyear monthly average precipitation occurs in this month (107,98 mm). These excesses will be lost by superficial or deep runoff.

Table 5.1.408: Hydric balance - Botana Station

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Prec (mm)	80,35	75,31	92,67	96,62	85,72	64,87	54,01	38,32	42,44	90,07	107,98	93,40
ETP (mm)	53,08	53,95	54,10	55,21	52,66	49,88	49,92	52,26	54,11	53,79	53,10	47,81
Prec-ETP (mm)	25,15	24,60	36,41	40,86	32,54	12,99	2,09	-16,03	-12,21	34,13	54,35	43,68
RFU (mm)	100,00	100,00	100,00	100,00	32,54	78,07	100,00	83,97	71,75	100,00	100,00	100,00
AET (mm)	55,20	50,71	56,26	55,76	53,19	51,88	51,91	54,35	54,66	55,94	53,63	49,72
Deficit (mm)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Excess (mm)	25,15	24,60	36,41	40,86	0,00	0,00	0,00	0,00	0,00	5,88	54,35	43,68
Runoff (mm)	30,66	27,63	32,02	36,44	0,40	0,20	0,10	0,05	0,03	2,95	28,65	36,17

ETP: Potential evapotranspiration of the month (mm)
Prec: Monthly rainfall (mm)
RFU: Amount of water accumulated on the floor and available for crops (mm)
AET: Current evapotranspiration (mm)

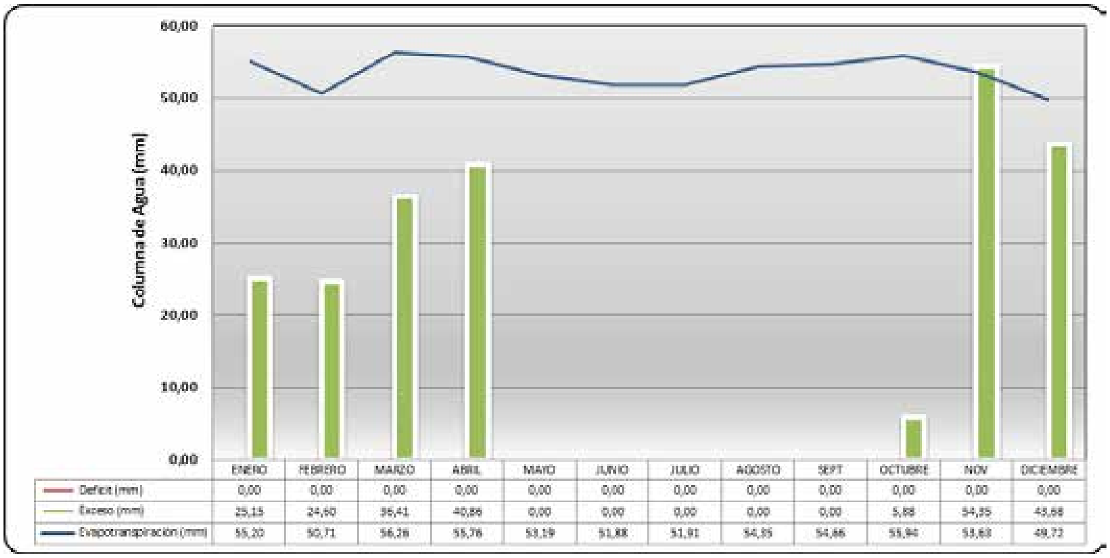


figure 5.1.807: Hydric balance Botana Station

Source: (Geminis Environmental Consultants, 2016)

Water balance - Obonuco station

as can be observed the deficit in the adjacent area to this station recorded a value of zero throughout the annual cycle, with the exception of the months of July, August and September. The deficit volume for these months equals the volume of water that is lacking to meet the potential needs (evaporation and transpiration).

on the other hand, there are water excesses in the months from December to April, being April which recorded a higher rate of excess (31,13 mm), associated perhaps to one of the greatest rainfalls that occur in this month (87,47 mm) This period is characterized because there is exceedance of water of the maximum reserve, and excesses will be lost by superficial or deep runoff.

table 5.1.419: Obonuco station hydric balance

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Prec (mm)	72,80	68,82	82,92	87,47	80,90	46,30	35,61	23,73	31,56	96,98	100,31	85,38
ETP (mm)	55,39	51,13	56,49	56,34	56,54	55,83	53,26	53,60	54,21	56,28	53,74	55,72
Prec-ETP (mm)	17,41	17,69	26,43	31,13	24,36	-9,54	-17,65	-29,87	-22,65	40,70	46,57	29,66

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
RFU (mm)	100,00	100,00	100,00	100,00	24,36	14,82	0,00	0,00	0,00	40,70	100,00	100,00
AET (mm)	55,39	51,13	56,49	56,34	56,54	55,83	50,43	23,73	31,56	56,28	53,74	55,72
Deficit (mm)	0,00	0,00	0,00	0,00	0,00	0,00	2,82	29,87	22,65	0,00	0,00	0,00
Excess (mm)	17,41	17,69	26,43	31,13	0,00	0,00	0,00	0,00	0,00	0,00	0,00	29,66
Runoff (m)	16,12	16,91	21,67	26,40	0,40	0,20	0,10	0,05	0,03	0,01	0,01	14,83

ETP: Potential evapotranspiration of the month (mm)
Prec: Monthly rainfall (mm)
RFU: Amount of water accumulated on the floor and available for crops (mm)
AET: Current evapotranspiration (mm)

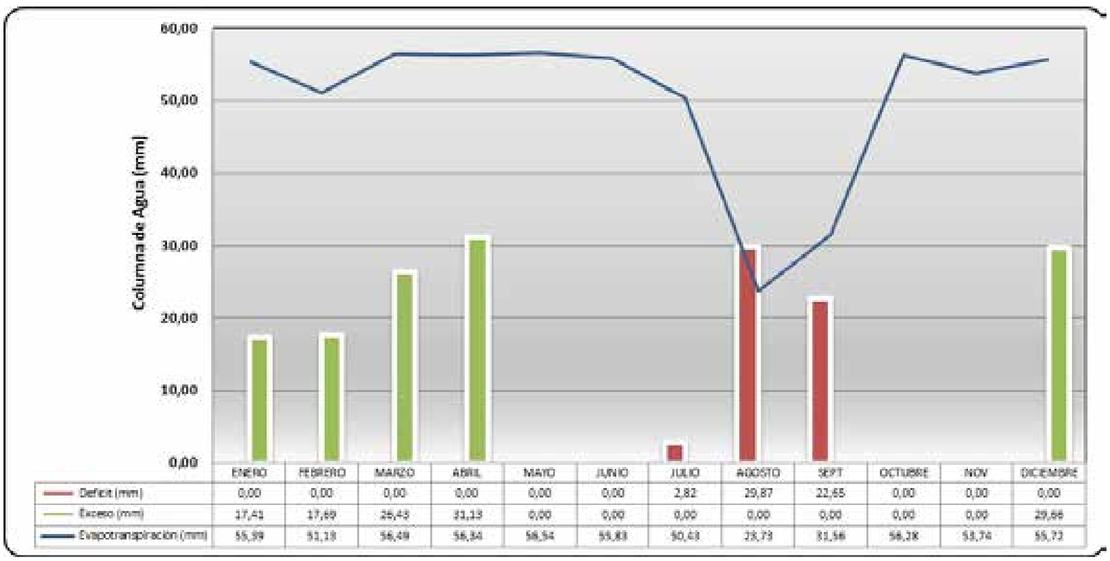


Figure5.1 .81: Obonuco station hydric balance
Source: (Geminis Environmental Consultants, 2016)

Hydric balance - Sindagua Station

As can be observed the deficit in the adjacent area to this station recorded a value of zero throughout the annual cycle, with the exception of the months of July and August. The deficit volume for these months equals the volume of water that is lacking to meet the potential needs (evaporation and transpiration).

on the other hand, there are water excesses in the months from November to April, being April which recorded a higher rate of excess (56,82 mm), associated perhaps to one of the greatest rainfalls that occur in this month (112.187 mm) This period is characterized because there is exceedance of water of the maximum reserve, and excesses will be lost by superficial or deep runoff.

table 5.1. 50: Hydric balance - Sindagua Station

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Prec (mm)	94,47	81,97	94,22	112,18	94,91	53,53	33,66	21,27	45,71	107,80	132,92	108,23
ETP (mm)	55,80	50,78	56,18	55,36	55,33	55,95	54,76	55,43	55,44	56,70	53,59	55,58
Prec-ETP (mm)	38,67	31,19	38,04	56,82	39,58	-2,42	-21,10	-34,16	-9,73	51,10	79,33	52,65
RFU (mm)	100,00	100,00	100,00	100,00	39,58	37,16	16,06	0,00	0,00	51,10	100,00	100,00
AET (mm)	55,80	50,78	56,18	55,36	55,33	55,95	54,76	37,33	45,71	56,70	53,59	55,58
Deficit (mm)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	18,10	9,73	0,00	0,00	0,00
Excess (mm)	38,67	31,19	38,04	56,82	0,00	0,00	0,00	0,00	0,00	0,00	30,43	52,65
Runoff (mm)	36,30	33,75	35,89	46,35	0,40	0,20	0,10	0,05	0,03	0,01	15,22	33,94

ETP: Potential evapotranspiration of the month (mm)
Prec: Monthly rainfall (mm)
RFU: Amount of water accumulated on the floor and available for crops (mm)
AET: Current evapotranspiration (mm)

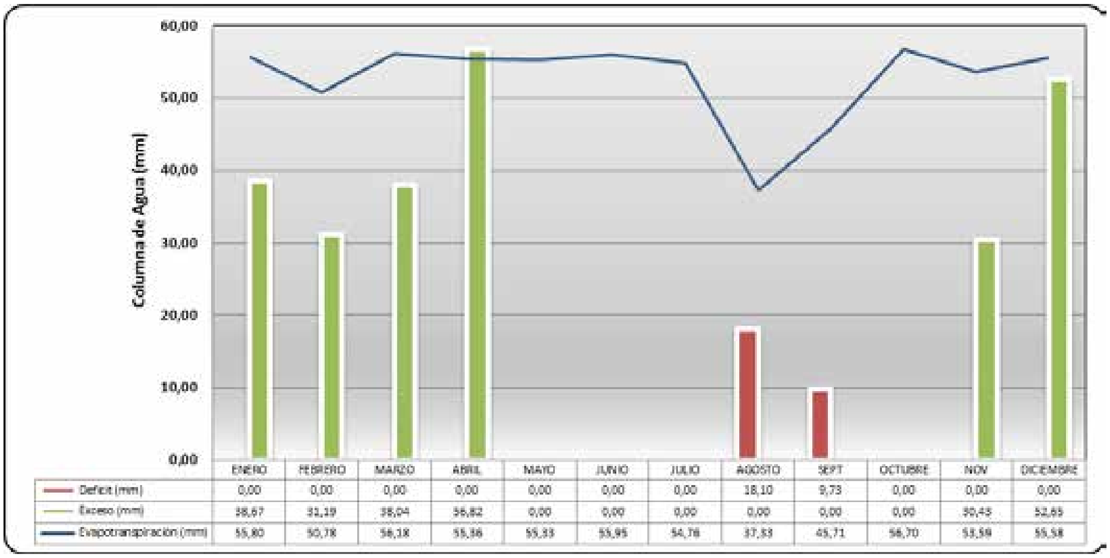


Figure5.1 .82: Hydric balance - Sindagua Station

Source: (Geminis Environmental Consultants, 2016)

- Real water demand

It is the sum of the sectoral demands, herein describes human social and economic activities.

-Domestic use water demand

the demanding population is characterized as mostly rural, as evidenced by the data obtained in the field. Domestic consumption is generally for the preparation of foods, personal hygiene and clothes washing; This comes directly from the creeks through artisan water connections.

-Water demand for livestock use

the peasant family economy is centered around agriculture followed by the livestock being one of the sources of food and income. To deal with everyday and eventual expenditures, some minor species breeding such as birds and Guinea pigs are found. These variations are due to the conditions that each community has in the area of the microbasin, as to a greater availability of pastures and water resource, a greater livestock production is favored which which enables the development of livestock dairy with improved animals. The increased water requirementthe for livestock is for drinking water for the animals that are raised and the development of productive activities; since normally the animals are grazing, they alone move to water sources such as small rivers and irrigation systems, etc. The consumption depends on the characteristics of the food ingested, of environmental characteristics such as temperature and humidity, feeding distances to sources of water, as well as the category, age, and type of animal production.

-Water demand for agricultural use

They are characterized because their productive main activity is the agricultural, with crops such as corn, potato, blackberry, pea, bean, barley, wheat and vegetables, the technological level used by the family production units is the traditional type. characterized by the poor management of soil and water resources, causing erosion processes due to drag of the surface layer; as well as defficient water management

-Demand of water by use of services

Amount of water consumed by the service sector includes trade, transport and storage, housing rentals, personal services

- Current conflicts on the availability and uses of water

these conflicts arise when the resource does not satisfy quantitatively and qualitatively in time the demand that is generated by the different destinations of the water from a water source. This category includes conflicts between each other existing uses such as irrigation, water supply for households, livestock, etc. Between them and new uses which may be novel extractive methods, uses that involve a more intensive use in the sense of higher consumptive use or greater environmental impact; the possibility of reserving a portion of the resource for future exploitations, water transfers between basins, maintenance of echological streams (CEPAL).

water supply is an essential need for all people. The determination of the required amount is one of the first steps to provide the supply. The provision of enough water to satisfy everybody's needs can be difficult to achieve in the short term.

The use of too much water from a finite resource can deprive people located downstream of water and have a negative impact on the environment and health.
The water supply is given mainly by water supplied by the streams and water springs, which are the main source of supply for livestock, agricultural, human consumption and industrial use, presenting conflicts by the use of water among which uses is highlighted the continuity of service, amount of water to satisfy the uses, decrease in the flow of the water sources and the deterioration of the quality of the resource by domestic, industrial and services dumping.

However, the high temporary variability of the supplying sources affects the real water availability, since a current with a very inconstant hydrological regime is unreliable as a source of water supply.

one of the main pressure factors on water resources is population growth, thus generating adverse consequences that are imposed upon the community demanding such water. When the water demand increases, so do the discharges of waste waters that impact the quality of water resources, in some cases inducing water scarcity, not by availability of the same but by inadequate quality for human consumption or for use in productive activities.

- *Frequency Analysis of Minimum Flows for Different Return Periods*

frequency analysis is a procedure for estimating the frequency or probability of occurrence of extreme events, past or future. In this way, the graphic probabilitistic representation is a method of frequency analysis.

The minimum values in drainage hydrology (rainfall or flow), must be treated through probabilistic distributions. Although there are numerous probability distributions for maximum values, it is very common in hydrology to use for these values the Gumbel probability distributions (European school) and log-Pearson type III (American school).

Annual minimum flows from each station information was processed and adjusted through software to probabilistic functions, then, the analysis of each one is presented, the minimum flow rates in different frequency periods is used since an emphasis on summer drought periods resulting in that the more you increase the return period of 1.33, 2 and 5 years the flow has a significant decrease which implies a lower flow availability for the downstream users beneath the intake that will be used for the purposes of the project.

- Casanare Automática Station

The analysis of frequency for the maximum and minimum annual flow records reported during the entire registration period for the Casanare Automática Station in the Bobo River, is reported in table 5.1. 51and Figure 5.1.90.

Table 5.1.51 Minimum Flow Analysis of Frequencies - Casanare Automática Station

RETURN PERIOD	EXPECTED Tr VALUE FOR EACH DISTRIBUTION				
	GUMBEL	NORMAL	PEARSON III	PEARSON LOG III	NORMAL LOG
(years)	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s
1,33	0,54692	0,56006	0,55434	0,54701	0,55497
2	0,48705	0,50125	0,49246	0,47817	0,49396
5	0,43026	0,42851	0,42716	0,42231	0,42769
CHI SQUARE TEST	1,00000	3,00000	---	---	1,00000

Source: (Geminis Environmental Consultants, 2016)

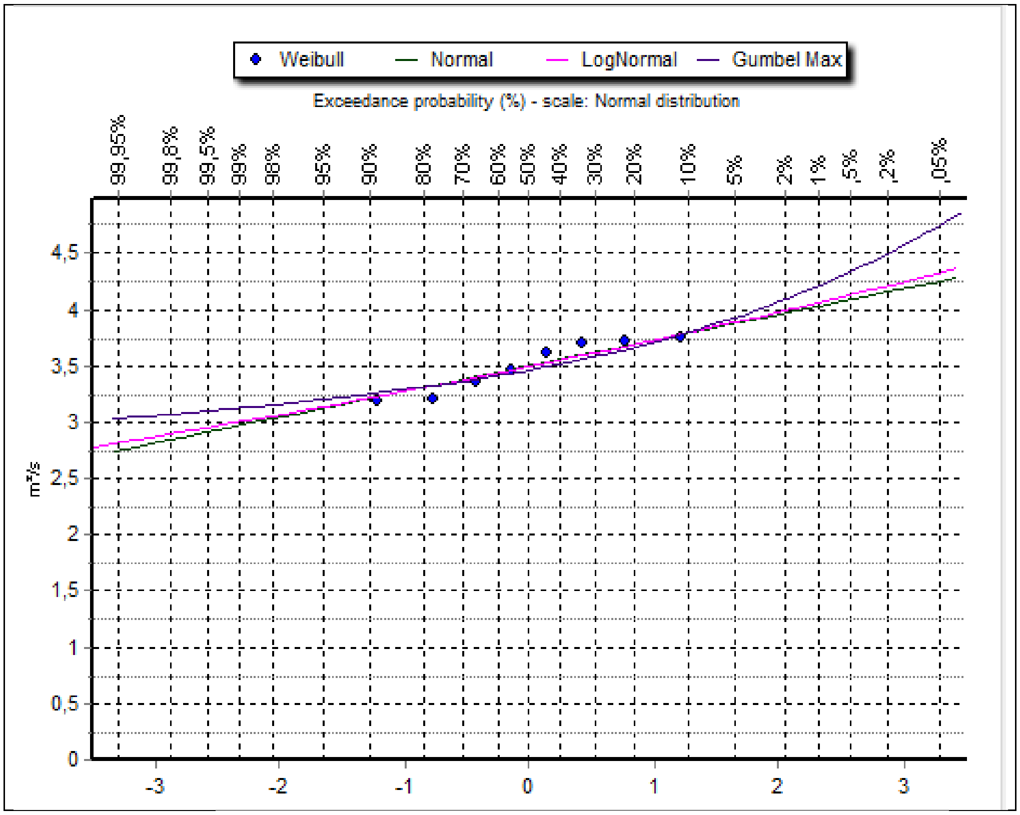


figure 5.1.90 Minimum Flow Analysis fo Frequencies - Casanare Automática Station
Source: (Geminis Environmental Consultants, 2016)

- Puente Juanambú Station

The analysis of frequency for the maximum and minimum annual flow records reported during the entire registration period for the Puente Juanambú Station in the Juanambú river, is reported in table 5.1. 52and Figure 5.1.91.

Table 5.1.52 Minimum Flow Analysis of Frequencies - Puente Juanambú Station

RETURN PERIOD	EXPECTED Tr VALUE FOR EACH DISTRIBUTION				
	GUMBEL	NORMAL	PEARSON III	PEARSON LOG III	NORMAL LOG
(years)	m³/s	m³/s	m³/s	m³/s	m³/s
1,33	21,3119	22,1405	21,5605	21,1710	21,5239
2	17,5357	18,4315	17,6116	17,3680	17,6747

RETURN PERIOD	EXPECTED Tr VALUE FOR EACH DISTRIBUTION				
	GUMBEL	NORMAL	PEARSON III	PEARSON LOG III	NORMAL LOG
5	13,9540	13,8438	13,7767	13,9522	13,8520
CHI SQUARE TEST	0,33333	2,75758	---	---	1,78788

Source Geminis Environmental Consultants, 2016

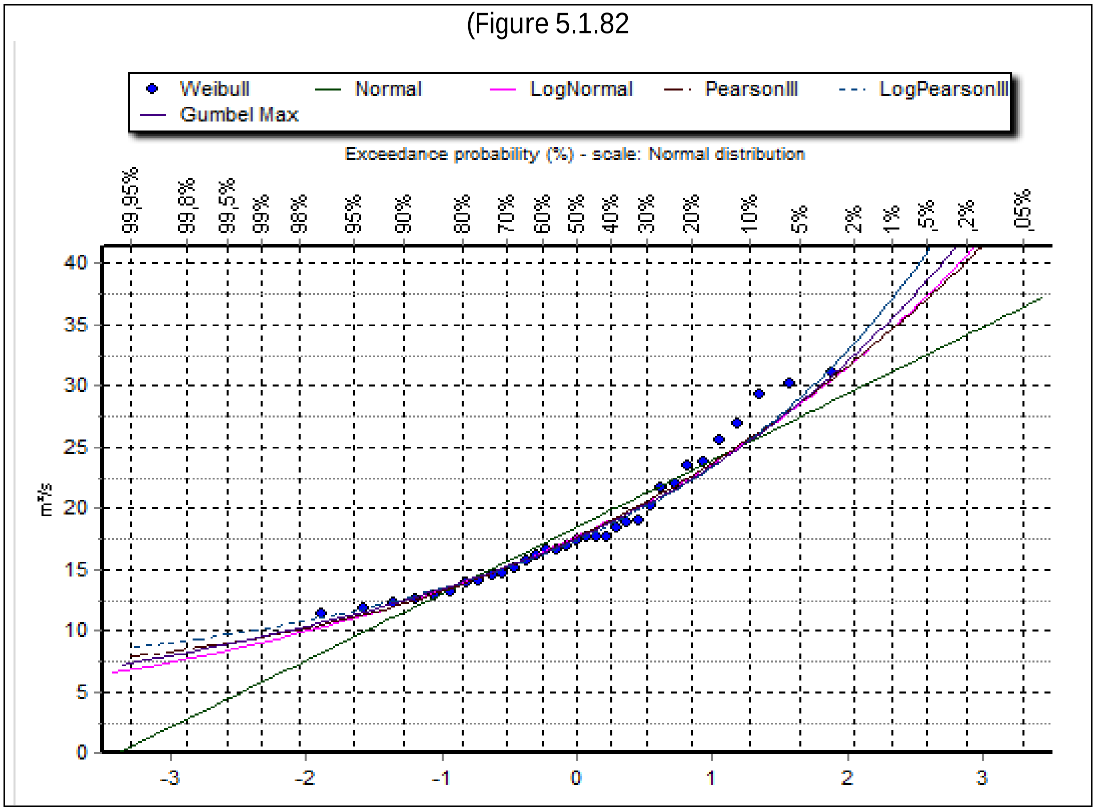


Figure 5.1.91 Minimum Flow Frequencies - Puente Juanambú Station

Source Geminis Environmental Consultants, 2016

o Bocatoma Centenario Station

The analysis of frequency for the maximum and minimum annual flow records reported during the entire registration period for the Bocatoma Centenario Station in the Pasto river, is reported in table 5.1. 53and Figure 5.1.92.

Table 5.1.53 Minimum Flow Analysis of Frequencies - Bocatoma Centenario Station

RETURN PERIOD	EXPECTED Tr VALUE FOR EACH DISTRIBUTION				
	GUMBEL	NORMAL	PEARSON III	PEARSON LOG III	NORMAL LOG
(years)	m³/s	m³/s	m³/s	m³/s	m³/s
1,33	0,86855	0,89856	0,89856	0,86590	0,87964
2	0,73179	0,76423	0,76423	0,70480	0,73994
5	0,60206	0,59807	0,59807	0,57890	0,59744
CHI SQUARE TEST	1,30769	1,30769	1,30769	4,38462	0,92308

Source Geminis Environmental Consultants, 2016

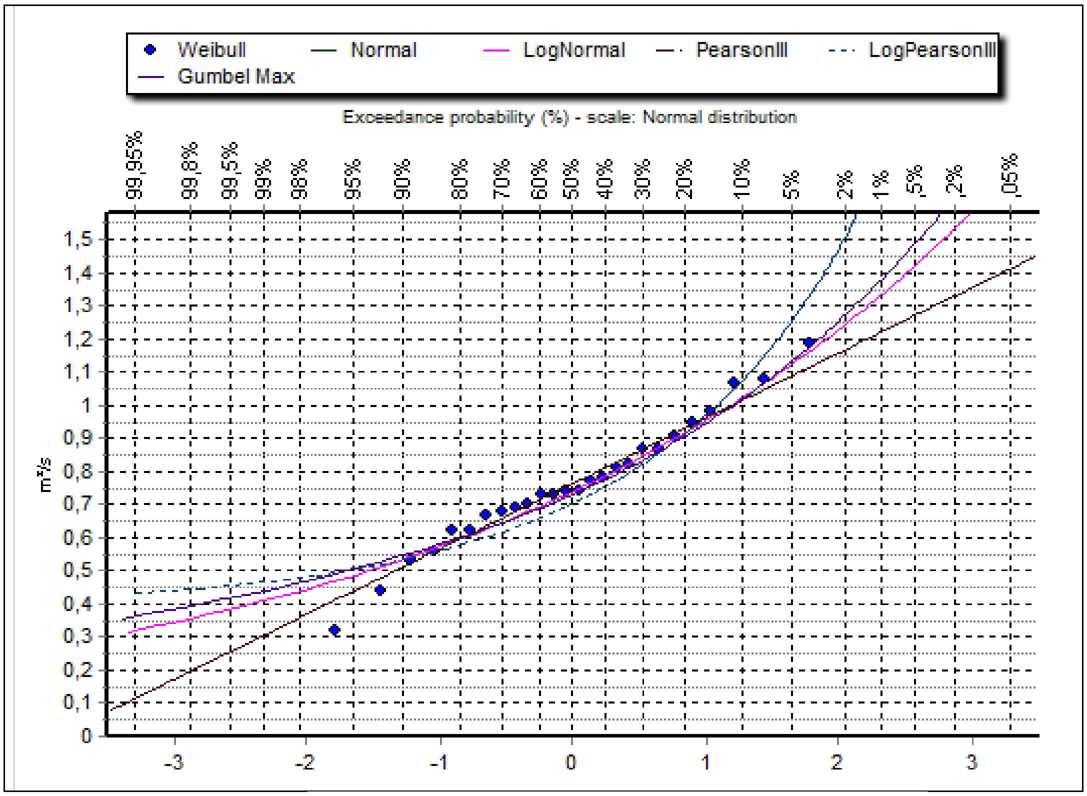


Figure 5.1.92 Minimum Flow Frequencies - Bocatoma Centenario Station

Source Geminis Environmental Consultants, 2016

5.1.8. Hydrogeology

The study aims to propose a conceptual hydrogeological model that allows to identify hydrogeological units and hydrodynamic processes that may be currently appearing in

the area of influence of the road project.
the methodologic plan to develop the hydrogeological model of the influence area of the project, consisted of collecting the available base cartography from the Colombian Geological Service geological plate 429 (Pasto) to 1:100000 scale and the information obtained from volume III of the UF4, UF5 design phase executed by INGETEC, which includes the geological mapping of the Pedregal - Catambuco road alignment, taking as a basis the Geology Units for Engineering (which corresponds to the units upon which the project will take place) and levels of groundwater obtained from surveys carried out in the design phase. We also took into account the inventory of water points and the geophysical study of the vertical electrical surveys points.

Herein is presented the conceptual hydrogeological model, based on the reference information of the hydrogeological units and their main characteristics such as porosity and permeability derived from the textural aspects of the rock units and soil that outcrop in the area. Also, the hydrodynamic conditions of the area of influence of the Pedregal - Catambuco road project were contextualized. (See annex 5.1.8)

- Piezometric Levels

in the design phase of the Pedregal - Catambuco road corridor, drillings were executed to determine the geological properties in depth. In some survey points, piezometers type Casagrande were installed; where groundwater levels were recorded on different dates. In the table 5.1.54 and table 5.1.55 are the averages of the water mantle levels measured on different dates. The surveys with their water mantle levels are located in the Annex 5.1.8, Annex 3. Geological map, 4. Analysis Sections and 5. Hydrogeological Map.

in general, in the UF4 water mantle levels are found at depths greater than 10 m, although in some particular areas these may be found at slightly lower depths. In the UF5, it is also common to find groundwater levels at depths greater than 10 m, but it is more common to find areas where the water mantle level is located at depths below this value.

table 5.1.54 Piezometric levels of UF4 c

SONDEOS UF4				
Sondeo	N	E	Profundidad (m)	Nivel Freático (m)
PEPA-PT-ZOD-1	606514	957154	13	3,3
PEPA-PT-TAL-1	607007	957145	15,1	no presenta
PEPA-PT-MUR-1	607742	958260	15	15
PEPA-PT-PTE-2-3	607931	958385	20	19
PEPA-PT-PTE-3-1	608115	958492	46	44
PEPA-PT-PTE-3-3	608234	958490	30	28
PEPA-PT-PTE-3-4	608293	958493	31,4	30
PEPA-PT-TAL-3	608442	958533	20	19,45
PEPA-PT-PTE-6-1	608475	958586	20,1	19
PEPA-PT-PTE-5-2	608519	958643	23,4	23
PEPA-PT-PTE-5-3	608550	958779	27,9	24
PEPA-PT-PTE-6-5	608504	958614	20,3	19
PEPA-PT-PTE-6-4	608542	958829	35,2	33,6
PEPA-PT-PTE-5-4	608518	958847	20,15	18
PEPA-PT-MUR-2A	608493	958874	20	17
PEPA-PT-ZOD-23	608853	960666	10,15	8,5
PEPA-PT-TAL-6	608832	961042	28	27
PEPA-PT-EST-1	609391	960999	13	13
PEPA-PT-TAL-8	610148	961042	20	5,9
PEPA-PT-TAL-9	610150	961062	20	14,9
PEPA-PT-ZOD-22	609433	962247	10	9,9
PEPA-PT-PTE-7-2	609529	962028	30	29,5
PEPA-PT-TAL-32	610137	962099	28	26
PEPA-PT-TAL-33	610751	962225	10	9,3
PEPA-PT-MUR-6	611000	962364	10	9,5
PEPA-PT-MUR-7	611965	963110	10	9,5
PEPA-PT-ZOD-18	611941	962657	10	8,7
PEPA-PT-TAL-34	612195	963593	18,1	17
PEPA-PT-TAL-13	612541	963672	35	33
PEPA-PT-TAL-15	613157	965003	23	17,2
PEPA-PT-ZOD-20	612906	965562	10	6,1
PEPA-PT-TAL-35	612903	965872	22,5	20,78

Source: (INGETEC, 2016)

Table 5.1. 55 Piezometric levels of UF5

SONDEOS UF5				
Sondeo	N	E	Profundidad (m)	Nivel Freático (m)
PEPA-PT-TAL-16	613817	966057	15	8,9
PEPA-PT-TAL-17	613907	966202	25,5	23,5
PEPA-PT-TAL-18	613885	966676	13	10,4
PEPA-PT-TAL-37	614097	966816	23	21,28
PEPA-PT-ZOD-11	614164	965421	16	14,35
PEPA-PT-TAL-19	614571	966297	16	12
PEPA-PT-TAL-20	615437	966906	18	9,9
PEPA-PT-TAL-21	616106	967723	15	13,5
PEPA-PT-TAL-23	616688	967994	15	6,85
PEPA-PT-BOX-1	617033	968213	13,3	5,3
PEPA-PT-TAL-24	616931	968669	17,5	0,85
PEPA-PT-TAL-25	617044	968903	16	14,4
PEPA-PT-TAL-26	618025	969987	10	7,3
PEPA-PT-TAL-27	618373	971516	10	1,2
PEPA-PT-TAL-28	618140	972651	20	18,87
PEPA-PT-TAL-29	618776	973877	16	15,29
PEPA-PT-TAL-30	619010	974404	16	no presenta
PEPA-PT-PP-1-1	619231	974504	13,35	12,5
PEPA-PT-PP-1-2	619209	974533	13,05	13
PEPA-PT-PP-2-1	621112	976409	14,09	9,5

Source: (INGETEC, 2016)

- Water points

in order to identify the water points existing in the project area, a field visit was made between August 23 and September 11, 2016. The total length of the field survey was 39 km in a width of 100 m on each side of the axis. Field information was collected in FUNIAS formats which are presented in the Annex 5.1.8, annex 2. (FUNIAS formats).

As a result of the field survey, 14 water points along the entire path of the road were identified and classified as springs, wells or tanks according to the following definitions:

- spring: is a natural flow of water that comes from the interior of the Earth from a single point or a small area. They can appear on the Mainland or go to streams, ponds or lakes. The springs can be permanent or intermittent, and have their origin in the rainwater that filters or have an igneous origin.
- Well: Deep hole made in the land, especially to remove water from underground springs.
- Tank: Large deposit and generally underground which serves to collect and conserve water, especially rainfall.

in each one of the water points, where possible, the diameter and the depth of the tanks were measured. In addition, in those points identified as wells or tanks the construction material and the method of operation for the use of the resource was identified.

Also determined was the type of use of each of the water points where the following main uses were found:

- Domestic: It refers to the water used for preparing food, cleaning homes, washing clothes and for hygiene or grooming.
- Stockbreeding: Water used for the feeding of the animals and the cleaning of the stables and other facilities dedicated to cattle breeding.
- Irrigation: Water used for the dampening of the fields.

The water points found along the road alignment, were classified according to the functional unit to which they belong. Figure 5.1.93 shows the road alignment and identified water points.

It must be mentioned that some registered points became apparent as intermittent, given more by shape and vegetation, but without the presence of water flow, in other cases the water point was found outside the Area of influence of the project, although its protection buffer (100 meters) overlapped it. Finally, it should be noted that most water points were already affected by the construction of the existing road, yet still it is necessary to consider the proper and timely management for their preservation.

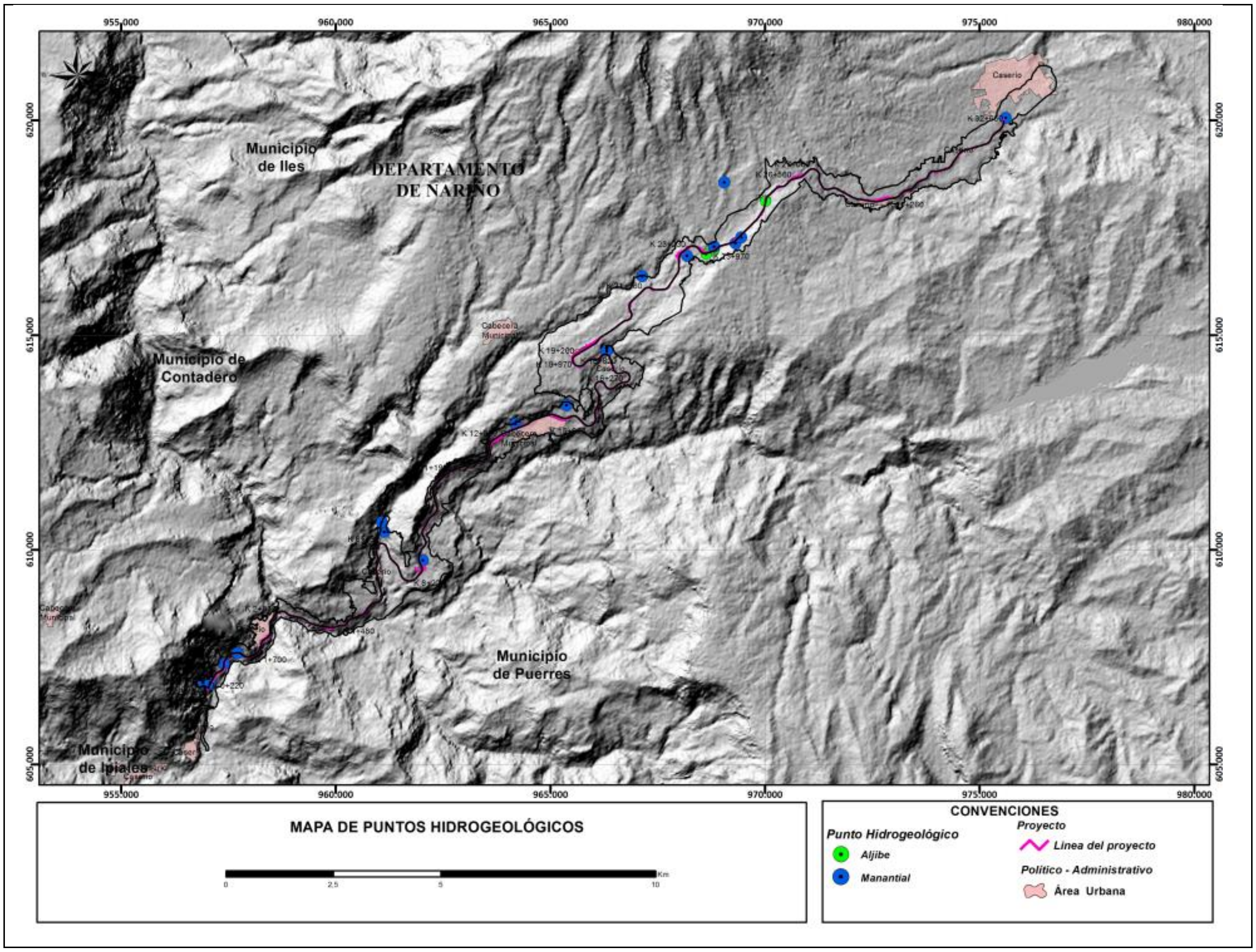


figure 5.1.93 Water points identified in the Pedregal - Catambuco road corridor

Source: M & M Team

The functional units with the corresponding water points and their respective characteristics are shown below:

- *Functional unit 4*

in the functional unit 4 6 water points, all springs, were identified. These points can be seen in Figure 5.1.94 water points identified in the Pedregal - Catambuco road corridor with their respective location, also in the table 5.1.56 the water points mentioned with their main characteristics can be observed.

Table 5.1.42 UF4 Water points

PUNTO	ESTE	NORTE	COTA (msnm)	NOMBRE DEL PREDIO	NOMBRE DEL PROPIETARIO	TIPO DE PUNTO	TIPO DE MATERIAL / ESTRUCTURA DE CAPTACIÓN	DIAMETRO (m)	PROFUNDIDAD (m)	METODO DE EXPLOTACIÒN	USO
PA-M-31	956919	606904	1887	La Lima	Israel Nandar	Manantial	Piedra	0,6		Manguera Gravedad	Doméstico e Irrigación
PA-M-32	957408	607351	1809	La Lima	Luis	Manantial	Cemento	Tanque 2.5x2		Manguera Gravedad	Doméstico
PA-M-33	957720	607590	1817	La Lima	Sobre la via	Manantial	Cemento	1.50		Gravedad	Doméstico
PA-M-34	961137	610415	2037	El tablan	Jose F Torres	Manantial	Cemento			Manguera Gravedad	Doméstico
PA-M-35	965384	613363	2545	B. Bolivar	Reynaldo	Manantial	Terreno	0.60	0.10	Manguera Gravedad	Doméstico
PA-M-36	961072	610643	2024	El placer	sin definir	Manantial	Hueco	0.50		Gravedad	Público

Source: (INGETEC, 2016)

Hereafter are some photographic registries of the identified water points in this functional unit (UF4). (SeePhotography 5.1.56, Photography 5.1.57 and Photography 5.1.58)

Photography5.160 Water point PA-M-31 and Water point PA-M-32

Source: (INGETEC, 2016)

Photography5.161 Water point PA-M-33 and Water point PA-M-34
Source: (INGETEC, 2016)

Photography5.162 Water point PA-M-35 and Water point PA-M-36
Source: (INGETEC, 2016)

- *Functional unit 5*

8 water points were identified in functional unit 5, of which 4 are springs and 4 tanks. Table 5.1.57 depicts the mentioned water points with their main characteristics.

Table 5.1.437 UF5 Water points

PUNTO	ESTE	NORTE	COTA (msnm)	NOMBRE DEL PREDIO	NOMBRE DEL PROPIETARIO	TIPO DE PUNTO	TIPO DE MATERIAL / ESTRUCTURA DE CAPTACIÓN	DIAMETRO (m)	PROFUNDIDAD (m)	METODO DE EXPLOTACIÓN	USO
PA-M-37	967146	616370	2842	sin dedinir	Comunidad	Manantial	Tanque Distribuidor 2.2x5.0	Lote		Acueducto Veredal	Irrigación
PA-M-38	968632	616880	3030	La Ladera	sin defninir	Aljibe	Brota del terreno			sin definir	Irrigación y ganadería
PA-M-39	968821	616988	3035	La victoria	Libardo Muñoz	Aljibe	Quebrado			Bocatoma	Irrigación y ganadería
PA-M-40	968818	617058	3032	Manguesa Baja	Flia Timona	Manantial	Pozo	1.70	0.20	Manguera Gravedad	Irrigación y ganadería
PA-M-41	970020	618129	3153	Manguesa Baja	Lievano Timona	Aljibe	Ninguno	1.0	0.20	Manguera Gravedad	Doméstico Irrigación y Ganadería
PA-M-42	969059	618554	3115	Manguesa Baja	Lievano Timona	Manantial	Pozo	0.80	0.15	Manguera Gravedad	Doméstico Irrigación y Ganadería
PA-M-43	966323	614624	2716	La Joya	Doris Santacruz	Manantial	Hueco Abierto	1.00	0.40	Baldeo	Doméstico
PA-A-09	970017	618118	3155	La Joya	Doris Santacruz	Aljibe	Piedra	1.0	2.0	Baldeo	Doméstico y gnadería

Source: (INGETEC, 2016)

Hereafter are some photographic registries of the identified water points in this functional unit (UF5). (See Photography 5.1.59, Photography 5.1.60, Photography 5.1.61 and Photography 5.1.62)

Photography5.163 Water point PA-M-37 and Water point PA-M-38

Source: (INGETEC, 2016)


Photography5.164 Water point PA-M-39 and Water point PA-M-40
Source: (INGETEC, 2016)


Photography5.165 Water point PA-M-41 and Water point PA-M-42
Source: (INGETEC, 2016)

Photography5.166 Water point PA-M-43 and Water point PA-A-09
Source: (INGETEC, 2016)

Now, within the framework of the process of continuous evaluation of information, field trips and talks with the inhabitants of the region, new sites which may correspond to groundwater outcrops were identified. Such points are presented below with their general characteristics and interaction with the project, and just like above, shall be subjected to control, management and protection in accordance with their affectation by the project.

- Possible water spring PK 0+200

This water spring is located on the project's designed road layout, in the coordinate X 957067,88 - and Y 606866,83, the water is used for agricultural purposes by the owner of the lot. Photography5.167

Photography5.168 Water spring PK 0+200
COORDINATE: X 957067.88 - Y 606866.83
Source (Geminis Consultants S.A.S, 2016)

In the Figure 5.1,95 the location of the water spring in relation to the project can be observed, as well as the 100 meters protection round (red color circle).

Figure 5.1.835 Water spring 100 m buffer
Source (Geminis Consultants S.A.S, 2016)

- Possible water spring PK 0+260

This water spring is located on the project's designed road layout, in the coordinate X 957081.68 - and Y 606901.33, the water is used for agricultural purposes by the owner of the lot. Photography5.169

Photography5.170 Water spring PK 0+260

COORDINATE: X 957081,68 - Y 606901,33

Source (Geminis Consultants S.A.S, 2016)

In the Figure 5.1.96 the location of the water spring in relation to the project can be observed, as well as the 100 meters protection round (red color circle).

Figure 5.1.84 6 Water spring 100 m buffer
Source (Geminis Consultants S.A.S, 2016)

- Possible water spring PK 8+860

This water spring is located 86 m from the edge of the designed road layout, over the right bank, in the coordinate X 962032 - and Y 609756, the water is used for agricultural purposes by the owner of the lot. Photography 5.1.71.

Photography5.1.72 Water spring PK 8+860
COORDINATE: X 962032 - Y 609756

Source (Geminis Consultants S.A.S, 2016)

In the Figure 5.1 .97 the location of the water spring in relation to the project can be observed, as well as the 100 meters protection round (red color circle).

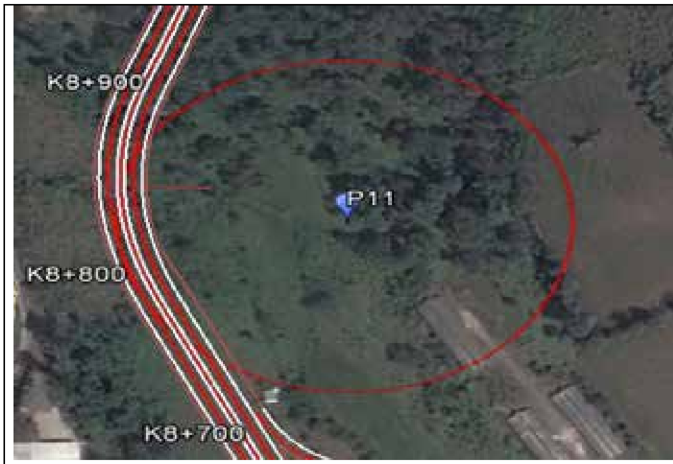


Figure 5.1.85 Water spring 100 m buffer
Source (Geminis Consultants S.A.S, 2016)

- Possible water spring PK 13+300

This water spring is located 100 m from the edge of the designed road layout, over the left bank, in the coordinate X 964199- and Y 612936, the water is used for agricultural and domestic purposes by the owner of the lot.

In Figure 5.1.98 is the 100 meters protection buffer of the water spring in relation to the design of the project, where it is observed that the design of the road layout is outside the protection buffer, nevertheless the intervention area is within the 100 meters.

Figure 5.1.86 Water spring 100 m buffer

Source (Geminis Consultants S.A.S, 2016)

- Possible water spring PK 23+200

This water spring is located 130 m from the edge of the designed road layout, over the right bank, in the coordinate X 968189.01- and Y 616846.68, the water is used for agricultural and domestic purposes by the owner of the lot. Photography5.173

Photography5.174 Water spring PK 23+200

COORDINATE: X 968189,01 - Y 616846,68

Source (Geminis Consultants S.A.S, 2016)

Figure 5.1.99 is the 100 meters protection buffer of the water spring in relation to the design of the project, where it is observed that the design of the road layout is outside the protection buffer, nevertheless the intervention area is within the 100 meters.

Figure 5.1.87 Water spring 100 m buffer

Source (Geminis Consultants S.A.S, 2016)

- Possible water spring PK 24+520

This water spring is located 38 m from the edge of the designed road layout, over the right bank, in the coordinate X 969316- and Y 617141, the water is used for agricultural and livestock purposes by the owner of the lot. It should be noted that this spring is of intermittent type, reason for which the presence of water on the site is not constant.

In Figure 5.1 .100 the location of the water spring in relation to the project can be observed, as well as the 100 meters protection round (red color circle).

Figure 5.1. 100 Water spring 100 m buffer
Source (Geminis Consultants S.A.S, 2016)

- Possible water spring PK 24+700

This water spring is located 35 m from the edge of the designed road layout, over the right bank, in the coordinate X 969452- and Y 617274, the water is used for agricultural and livestockpurposes by the owner of the lot. It should be noted that this spring is of intermittent type, reason for which the presence of water is not constant.

In Figure 5.1 .101 the location of the water spring in relation to the project can be observed, as well as the 100 meters protection round (red color circle).

Figure 5.1. 100 Water spring 100 m buffer
Source (Geminis Consultants S.A.S, 2016)

- Possible water spring PK 32+800

This water spring is located 125 metres from the final section of the projected path, as shown in the Figure 5.1.102, in the coordinate X 975608 - and 620056, the water is used for domestic purposes.

Figure 5.1.102 is the 100 meters protection buffer of the water spring in relation to the design of the project, where it is observed that the design of the road layout is outside the protection buffer, nevertheless the intervention area is within the 100 meters.

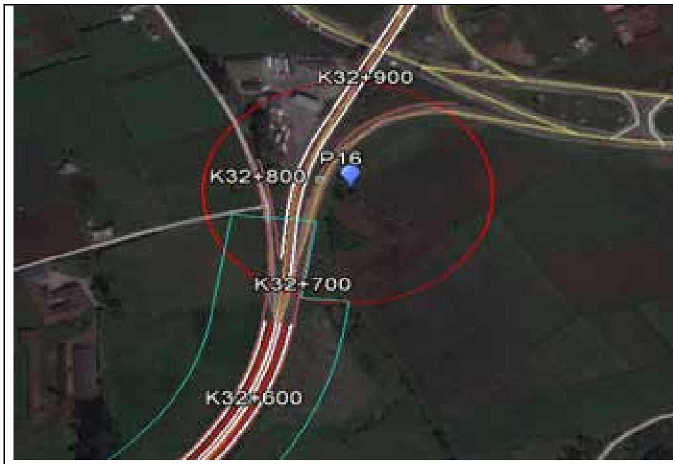


Figure 5.1. 100 Water spring 100 m buffer
Source (Geminis Consultants S.A.S, 2016)

· Geoelectrical Survey

Within the geophysical methods, the geoelectrical is the mostly applied subsoil study in the exploration and evaluation of aquifer areas due to its low cost, its relative ease of application, and the possibility of correlating its results (resistivity values) with the degree of rocks saturation, lithologic changes and water quality (from brackish to freshwater) which allows permeable and impermeable geological layers, and saturated and unsaturated discriminations.

For the conceptual hydrogeological study of the Pedregal - Pasto road project, a total of 8 vertical electrical surveys (SEV) of 50 meters depth were executed, four SEV's per functional unit.

- *Methodology vertical electrical surveys (SEV)*

The methodology applied in the SEV basically comprises the field data acquisition, information processing and interpretation of the data.

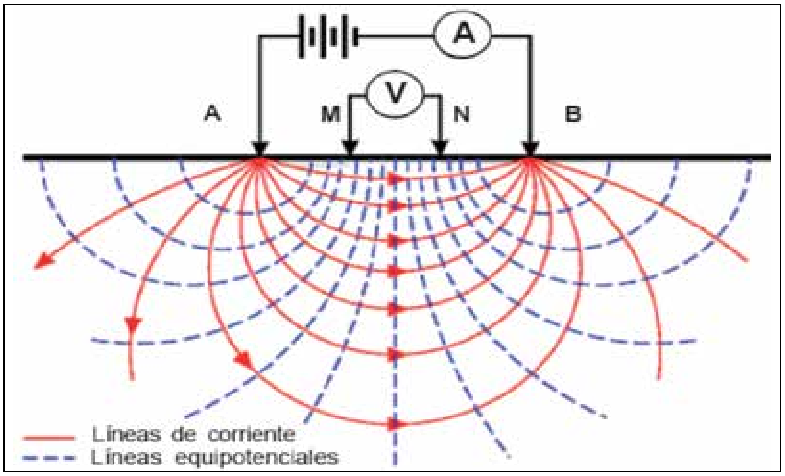
The data acquisition in the executed SEV for this project, was carried out with an Allied Associates resistivity meter with their respective electrodes and wires for current and potential. See Photo 5.1.69.

Photography 5.1.69 Allied Associates resistivity meter
Source: (INGETEC, 2016)

- *Technical specifications of the vertical electrical surveys (SEV)*

An SEV is made via the positioning of four electrodes (points A, B, M, and N in Figure 5.1.103), placed on a surface in a straight line, symmetrically with respect to a central point.

An electric current is then passed through the outer electrodes (A and B) into the subsoil, and this causes a potential drop between the 2 internal electrodes. To start the survey, the current bearing electrodes are placed at a mid-point distance (AB/2) of 1.5 meters and the potential measuring electrodes at a mean distance of 0.5 meters (MN/2). Under the Schlumberger distribution, implemented in this survey, for each survey a series of readings are made, increasing the AB distance each time. The distance between the potential reading electrodes (M and N) expands when the potential fall decreases in such a way that its reading is difficult.



5.1figure.103 diagram of a vertical electrical survey SEV or geoelectrical survey

Source: Modified by INGETEC, 2016

- *Interpretation of the vertical electrical surveys*

for the conceptual hydrogeological model of the Rumichaca - Pasto road project, 8 vertical electrical surveys (SEV) with layouts of between 2 and 250 m and distributed in the functional units 4 and 5, which allows information of the resistivities up to 50 m deep. (See Annex 5.1.8, Annex 3. Geological map).

The applied procedure is to compare the resistivities determined for each layer against the theoretical curves established for different types of material. This procedure is done manually when there are 3 or 4 layers in the analysis. (See Table 5.1.58, Figure 5.1.104).

Table 5.1.58 Coordinates of the vertical electrical surveys

UF	SEV	COORDINATES	
		NORTH	EAST
4	UF4-SEV1	607161,0	957309,0
	UF4-SEV2	610090,0	961069,0
	UF4-SEV3	611919,2	962928,8
	UF4-SEV4	613126,0	965610,0
5	UF5-SEV1	613734,0	966067,0
	UF5-SEV2	616923,5	969043,0

UF	SEV	COORDINATES	
		NORTH	EAST
	UF5-SEV3	618385,0	971496,0
	UF5-SEV4	619242,0	974410,0

Source: (INGETEC, 2016)

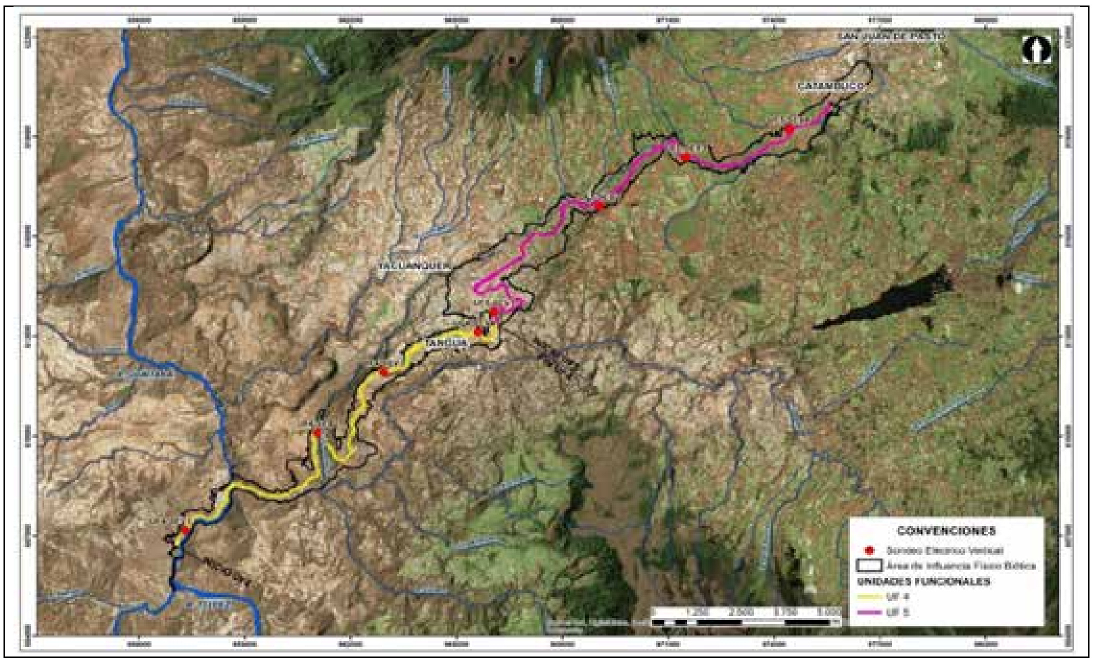


figure 5.1.104 Location of SEV's executed in UF4 and UF5

Source: (INGETEC, 2016)

Below are the results for each of the SEV's executed for this project.

- Functional Unit 4

In the SEV2-UF4, SEV3-UF4 and -SEV4-UF4 low resistivities are observed between 5.0 m and 10.0 m with values between 40 and 60 Ohm. In the UF4-SEV1 the resistivity drop occurs from 25 m depth with values of 10 Ohm (blue color) (Figure 5.1105 and Figure 5.1.106).

The lithology related to the SEV1-UF4 is formed by poorly selected andesites angular fragments, trachites, embedded in glassy matrix, there are some fine ash levels of the Ash Flows and Pumice (TQvf) unit; The SEV2-UF4 and SEV3-UF4 are volcanic agglomerates, embedded in a silty sand matrix composed of plagioclase and volcanic rock lithics from the La Magdalena Volcanic Sedimentary Unit (TQsv); The -SEV5-UF4 was executed in the Lahars and Pyroclasts Unit (TQvlp).

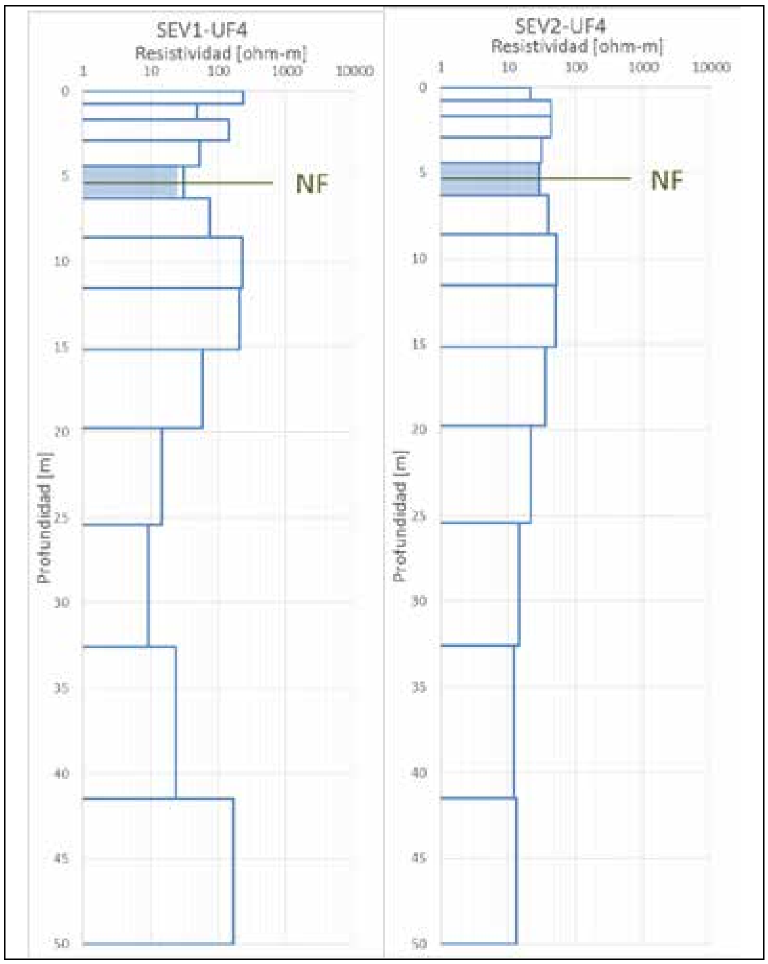


Figure 5.1.88 SEV 1 and 2 Results, functional Unit 4

Source: (INGETEC, 2016)

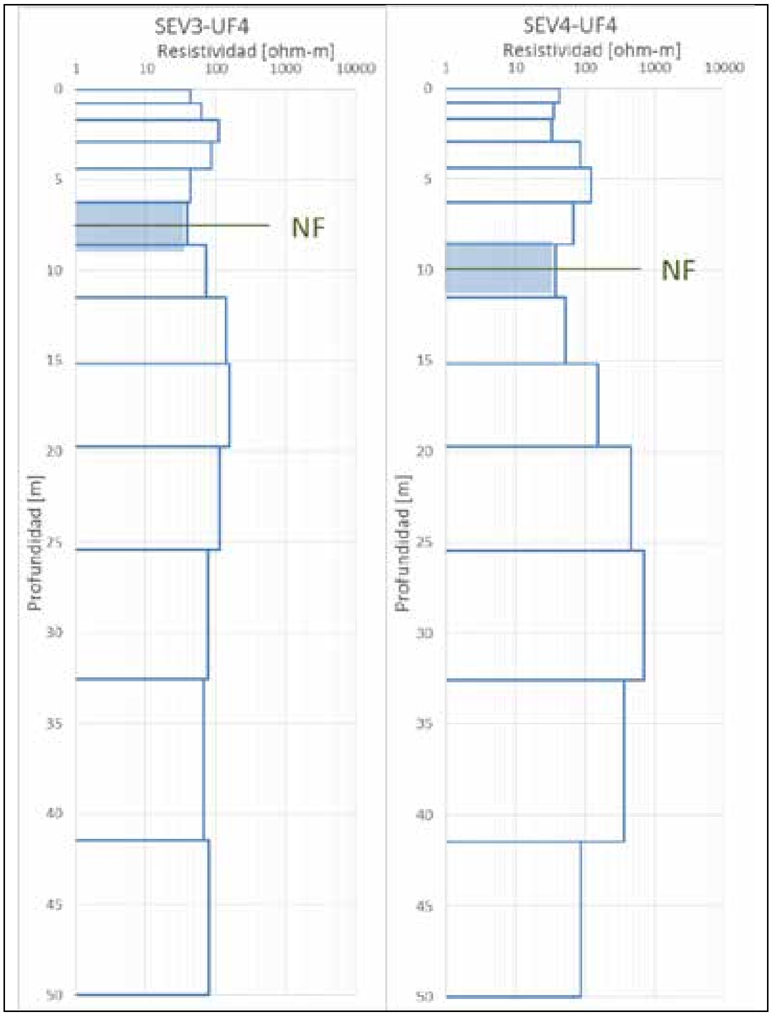


Figure 5.1.89 SEV 3 and 4 Results, Functional Unit 4

Source: (INGETEC, 2016)

- Functional unit 5

In the SEV1-UF5, SEV3-UF5 the resistivity fall occurs between 5.0m and 8.0m with values between 50 and 80 Ohm; In SEV2-UF5, the lowest resistivities occur as of 25 m and 33 m depth with values of 80 Ohm indicating the presence of a saturated permeable zone (blue color) (See Figure 5.1.106 and Figure 5.1.107). SEV2-UF5 does not report saturated areas.

The lythology that is recognized for the SEV1-UF5 is of laharic flows and pyroclastic flows of the Unit (TQvlp); in the SEV2-UF5 the lythology is conformed by ashes of andesitic composition that cover lowly jointed porphyritic andesites, of gray color with plagioclase phenocrysts in a microcrystalline matrix of the Unit of Lavas and Ashes (TQvlc); the UF5-SEV3 presents/displays ashes of lapilli of 4m thickness, weathered andesites with minerals of plagioclase and ferromagnesians in smaller proportion of the Ash Rain Unit (Qvc). The UF5-SEV4 presents fine ashes of andesitic affinity of the Ashes and Pumice Flows (TQvf) unit.

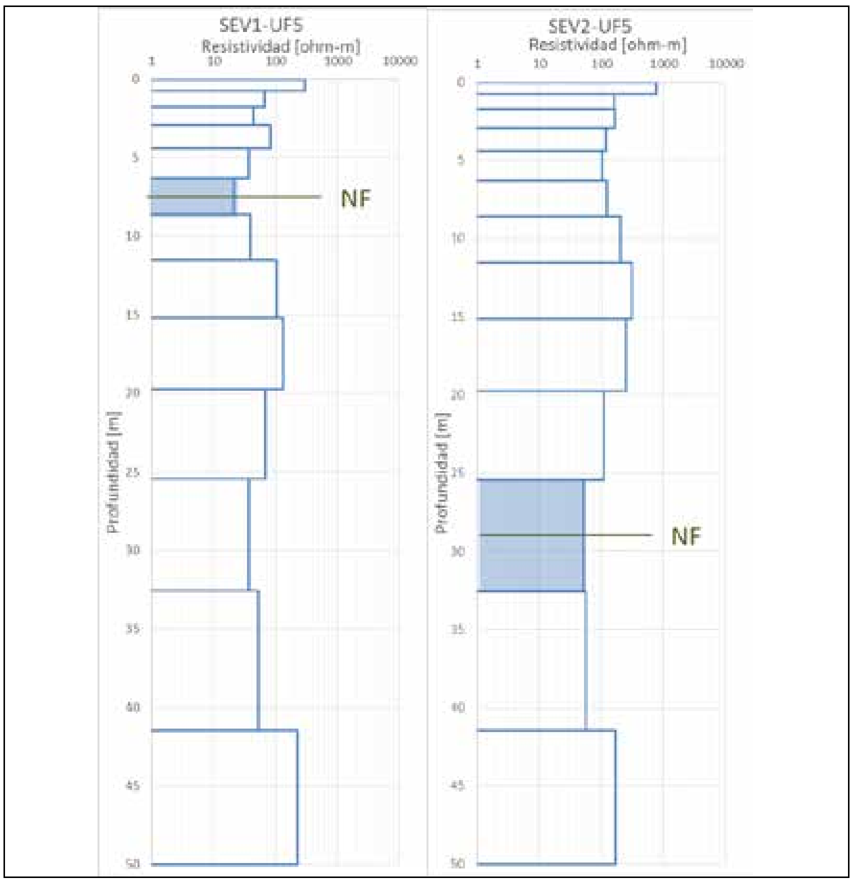


Figure 5.1.90 SEV 1 and 2 Results, functional Unit 5

Source: (INGETEC, 2016)

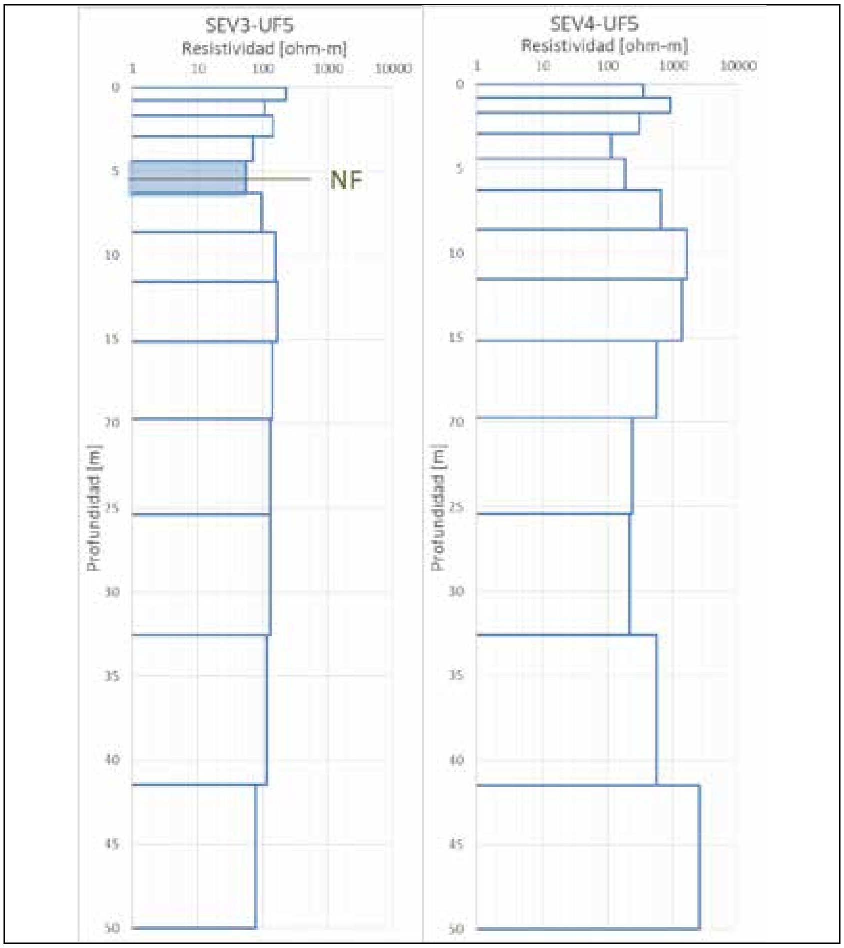


Figure 5.1.91 SEV 3 and 4 Results, Functional Unit 5
Source: (INGETEC, 2016)

- <u>hydrogeochemistry</u>

Based on the inventory of groundwater points described in 5.1.8.2, the groundwater sampling campaign was defined.

The criteria established for the definition of sampling sites correspond to representativeness in functional units, geological units, proximity to works sites, identified uses and users number, thus the sites selected for the UF4 and UF5 are presented in Table 5.1.59.

Table 5.1.44 Sites selected for underground water sampling of UF4 and UF5

UF	POINT	EAST	NORTH	LEVEL	PROPERTY NAME	TYPE OF POINT	TYPE OF MATERIAL	USE
UF4	PA-M-32	957408	607351	1809	La Lima	Spring	Cement	Domestic
UF5	PA-M-38	968632	616880	3030	La Ladera	Well	Outbreak	Irrigation and livestock
	PA-A-09	970017	618118	3155	La Joya	Well	Stone	Domestic and livestock

Source: (INGETEC, 2016)

- *Water quality*

The sampling campaign was carried out on September 28, 2016. Samples acquisition for laboratory analysis, in situ analysis, preservation and transport was performed by technical personnel of the accredited water quality laboratory for simple, composite and integrated sampling (Ambienciq Ingenieros SAS). In Annex 5.1.8, Annex 1. Water quality, laboratory accreditation resolution, calibration certificates of the equipment, field formats and results are presented. A groundwater characterization was made in three points for the functional units UF 4 and UF 5. See Photo 5.1.64.

Photography5.175 Sample acquisition PA-A-09 Functional Unit 5
Source: (INGETEC, 2016)

Figure 5.1.108 shows the location of the sampling sites.

Figure 5.1.92 Location of UF4 and UF5 underground water quality sampling sites

Source: (INGETEC, 2016)

- Results

The parameters sampled correspond to those established in Table 5 of Resolution 0751 of March 26, 2015, under the titles "Water component" and those specific for the interpretation of hydrochemical analyzes. The results obtained are presented in Table 5.1.60

Table 5.1.60 Quality results for underground waters in UF4 and UF5

Parameter	Unit	Quantification limit	UF4	UF5	
			PA-M-32	PA-M-38	PA-A-09
Conductivity at 25°C	µS/cm	0,1	208	149	144,5
pH at 25°C	Units	0,01	6,99	6,04	7,26
Temperature	°C	0,1	21,1	13,7	10,5
Dissolved Oxygen	mg/L	0,01	6,86	5,14	5,58
Color	UPC	5	<5	9	<5
Turbidity	UNT	0,01	1,6	55	1,7
Acidity at pH 8.3	mg/L	9,99	15	20	15
Alkalinity at pH 4.5	mg/L	3,77	92	52	29
Bicarbonates	mg/L	NE	87	51	27
Chlorides	mg/L	5	<5	<5	14
Calcium hardness	mg/L	12	31	36	30
Total hardness	mg/L	5	163	64	89
COD	mg/L	15	<15	<15	<15
BOD	mg/L	3	3	5	7
Oils and Greases	mg/L	0,9	<0,9	<0,9	<0,9
Total Phenols	mg/L	0,01	<0,010	<0,010	<0,010
Total Nitrogen	mg/L	0,5	2,3	2,3	2,3
Total phosphorus	mg/L	0,05	0,27	0,3	0,25
Sulphates	mg/L	3	12	11	11
Total suspended solids	mg/L	6	8	122	<6
Total dissolved solids	mg/L	10	151	140	88

Parameter	Unit	Quantification limit	UF4	UF5	
			PA-M-32	PA-M-38	PA-A-09
Sedimentable solids	mL/L-h	0,1	0,1	1,5	0,3
Arsenic	mg/L	0,005	<0,005	<0,005	<0,005
Barium	mg/L	0,4	<0,4	0,4	<0,4
Cadmium	mg/L	0,0005	<0,0005	<0,0005	<0,0005
Calcium	mg/L	0,1	1,99	1,51	3,5
Copper	mg/L	0,1	<0,10	<0,10	<0,10
Chrome	mg/L	0,1	<0,10	<0,10	<0,10
Magnesium	mg/L	0,01	10,1	5,15	2,85
Mercury	mg/L	0,002	<0,002	<0,002	<0,002
Nickel	mg/L	0,1	<0,10	<0,10	<0,10
Silver	mg/L	0,05	<0,05	<0,05	<0,05
Lead	mg/L	0,001	<0,001	<0,001	<0,001
Potassium	mg/L	0,05	3,7	3,08	4,88
Selenium	mg/L	0,005	<0,005	<0,005	<0,005
Sodium	mg/L	0,05	14,33	11,65	16,85
Zinc	mg/L	0,03	<0,03	<0,03	<0,03
Fecal Coliforms	NMP/100 mL	1	<1,0	200	100

Source: (INGETEC, 2016)

- Analysis of results

The temperature is highlighted within the in situ parameters, with oscillating values between 10 and 21°C, consistent with the climatic conditions of the area. The lowest temperature is present in the PA-A-09 well which is located in the moorland zone (3155 masl). The PA-M-38 recorded a temperature of 13.7 ° C spring located at 3030 masl and the spring identified as PA-M-32 located at the altitude 1809 masl, reported a temperature of 21 ° C.

The term pH is a way of expressing the concentration of the hydrogen ion or, more accurately, the activity of the hydrogen ion. According to the values obtained in the sampling in the study area, pH values between 6.04 and 6.99 were recorded for the springs, and 7.26 units in the well, with a trend towards basicity. (See Figure 5.1.109)

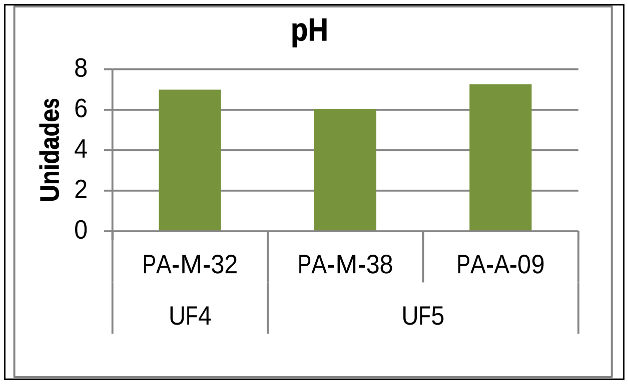


Figure 5.1.93 pH Data for UF4 and UF5
Source: (INGETEC, 2016)

The degree of alkalinity of the waters is determined as follows:

Low Alkalinity: < 50 mg $CaCO_3$/l
Average alkalinity: 50 – 150 mg $CaCO_3$/l
High Alkalinity: > 150 mg $CaCO_3$/l

The alkalinity in water bodies is due to the presence of bicarbonates, carbonates and hydroxides, however, it does not in itself present harmful effects to the consumer. From the results obtained it is concluded that the well sampled in the UF5, identified as PA-A-09, presents low alkalinity and the two PA-M-32 (UF4) and PA-M-38 (UF5) springs report average alkalinity. With regard to acidity, the three groundwater bodies have similar values (between 15 and 20 mg/l) (See Figure 5.1.110).

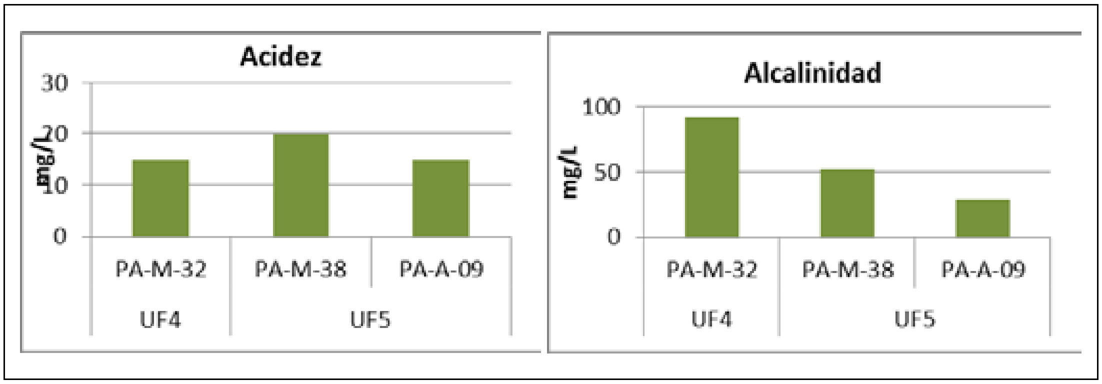


Figure 5.1.94 Acidity and alkalinity UF4 and UF5
Source: (INGETEC, 2016)

The dissolved oxygen at the three sites sampled has concentrations between 5.1 and 6.8 mg/L, considering that there is contact with air in the atmosphere (See Figure 5.1.111).

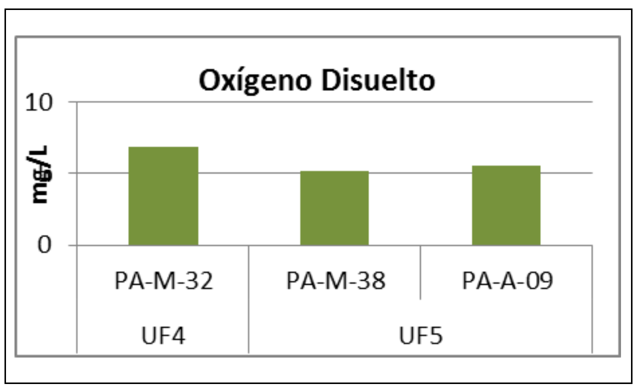


Figure 5.1.95 Dissolved Oxygen UF4 and UF5
Source: (INGETEC, 2016)

The COD in groundwater varies from 1 to 15 mg/L, a range within which the values reported in the three bodies of water sampled for UF 4 and UF5 are found. The biochemical oxygen demand reported higher concentrations in the well identified as PA-A-09 at 1 mg/L, associated with the amount of oxygen needed to eliminate the organic matter contained in water by aerobic biological processes (See Figure 5.1. 112).

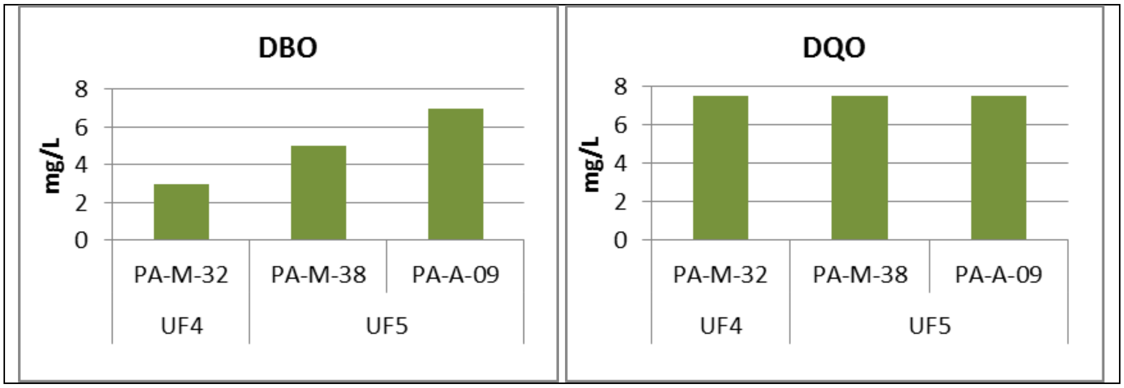


Figure 5.1.96 BOD - COD results for UF4 and UF5
Source: (INGETEC, 2016)

Water conductivity is a numerical expression of its ability to carry an electric current, which depends on the total concentration of dissolved ionized substances in the water. As shown in Figure 5.1.113, the behavior of the conductivity is similar to the behavior of the dissolved solids, obtaining higher values in the spring located in the UF4 identified as PA-M-32 and lower values in the UF5 well identified as PA-A-09.

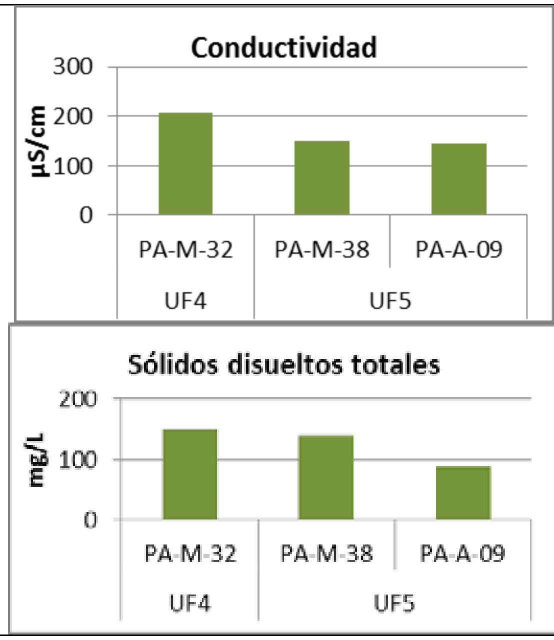


Figure 5.1.97 Conductivity and Total Dissolved Solids findings for UF4 and UF5

Source: (INGETEC, 2016)

The majority of the ions dissolved in the groundwaters correspond to chlorides, bicarbonates, sulphates, calcium, magnesium, sodium and potassium. As shown in Figure 5.1.114, the chlorides in the sampled groundwaters of UF4 and UF5, report low concentrations (14 mg/l in well PA-A-09) and concentrations below the detection limit (<5 mg/l) in the two springs.

The sulfate ion comes from the washing of terrains formed in the marine environment, from the oxidation of sulfides that are widely distributed in igneous and sedimentary rocks and from the decomposition of organic substances. Etc. However, the dissolution of gypsum (CaS0, 2H20) and anhydrite (CaSO) and other types of sulfates dispersed in the ground frequently represent the most significant contribution of this ion to groundwater. The two springs and the sampled well report low sulphate concentrations (11 and 12 mg/L)

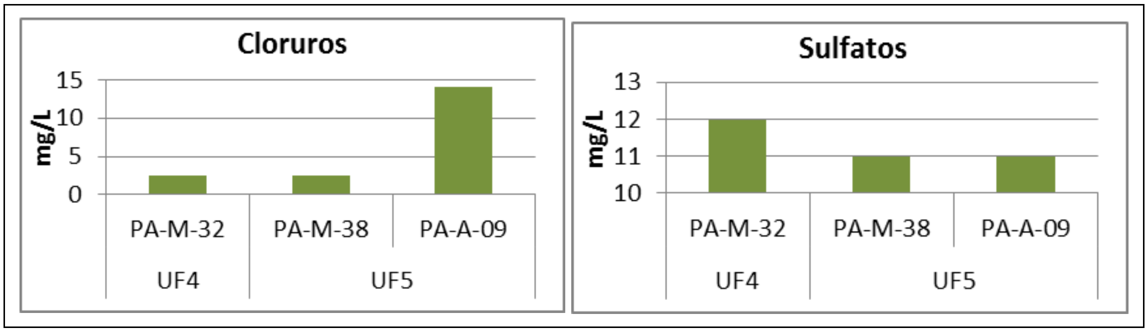


Figure 5.1. 4 98Chlorides and Sulphates results for UF4 and UF5

Source: (INGETEC, 2016)

The calcium ion is usually the main cation in most natural waters due to its widespread diffusion in igneous, sedimentary and metamorphic rocks. The magnesium ion comes from the dissolution of carbonate rocks (dolomites and magnesium limestones), evaporites and the alteration of ferromagnesian silicates. For the three bodies of water sampled, there is evidence of higher concentrations of magnesium compared to calcium (See Figure 5.1.115).

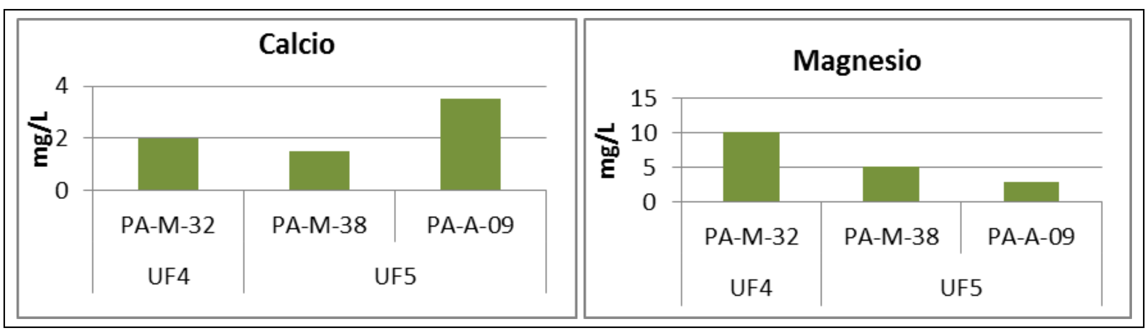


Figure 5.1.99 Calcium and Magnesium Results for UF4 and UF5

Source: (INGETEC, 2016)

Sodium is a very active metal, which does not exist free in nature. All sodium salts are very soluble in water, so it is very common to find waters with sodium. Concentrations ranging from 11.6 mg/L to 16.8 mg/l were reported in the three bodies of water sampled.

Potassium ion comes from the weathering of feldspars and occasionally from the solubilization of evaporite deposits, particularly silvine (KCl) or carnalite (KCl MgCl2) salts. Potassium tends to be irreversibly fixed in clay formation and adsorption processes on the surface of minerals with high ion exchange capacity. In groundwater it usually does not exceed 10 mg/l, which is consistent with the results obtained in the monitoring campaign carried out in the three water bodies of UF4 and UF5 (See Figure 5.1.116).

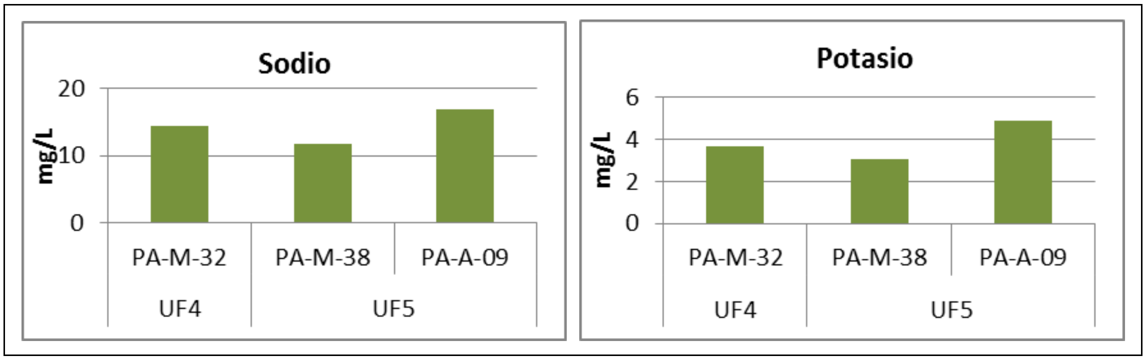


Figure 5.1.1006 Sodium and Potassium results for UF4 and UF5

Source: (INGETEC, 2016)

Phosphorus forms part of a minor constituent of groundwater, is found in lower concentrations considering its tendency to form complex ions and compounds of low solubility with an extensive number of metals and to be adsorbed by hydrolyzed sediments, especially clay minerals, on the ground. The concentrations are between 0.25 and 0.3 mg/L for the three sites sampled.

Total nitrogen is the measure of all the various forms of nitrogen found in a sample. The two springs and the well reported a low concentration corresponding to 2.3 mg/L (See Figure 5.1.117).

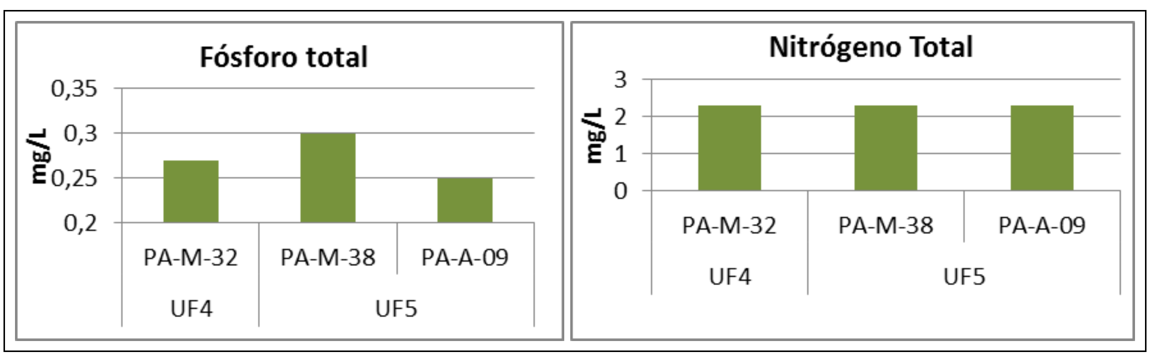


Figure 5.1.101 Phosphorus and Total Nitrogen Results for UF4 and UF5

Source: (INGETEC, 2016)

In terms of hardness, the waters can be classified as:

0 - 75 mg/L	Soft
75 – 150 mg/L	Moderately Soft
150 – 300 mg/L	Hard
>300 mg/L	Very Hard

In view of the foregoing, the spring identified as PA-M-38 is classified as soft water with a concentration of 64 mg/L $CaCO_3$, the well identified as PA-A-09 is classified as moderately soft water with a concentration of 89 mg/L $CaCO_3$ and the spring identified as PA-M-32 is classified as hard water with a concentration of 163 mg/L $CaCO_3$ (See Figure 5.1.118).

The obtained hardness values are considered concordant with the concentrations of calcium and magnesium obtained in the three bodies of water monitored.

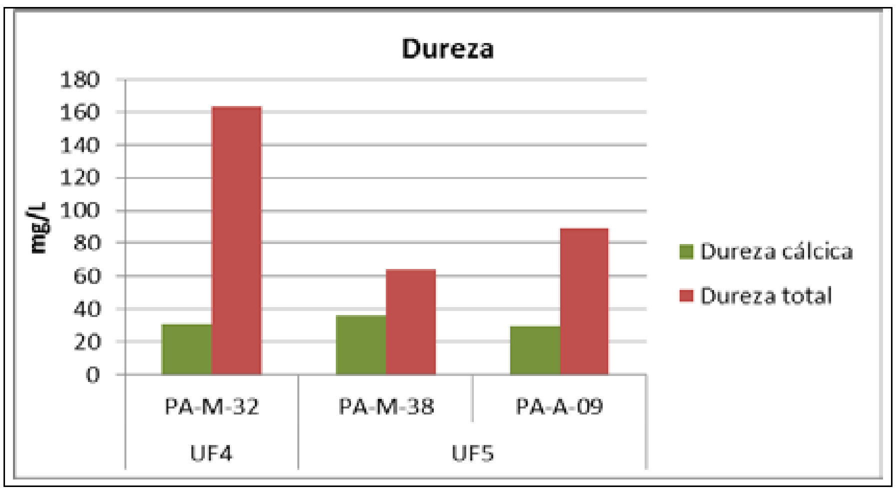


Figure 5.1.102 Calcium and Total Hardness Results for UF4 and UF5
Source: (INGETEC, 2016)

The coliform group includes bacillary, aerobic and facultative anaerobic, Gram-negative, non-spore forming bacteria. Coliforms not only come from human excrement, but can also originate in warm-blooded and cold-blooded animals, and in the soil; Therefore, the presence of coliforms in surface water indicates contamination from human, animal or soil erosion separately, or from a combination of the three sources.

As shown in Figure 5.1.119, the amount of fecal coliforms accounts for less than 1% of the total coliforms, so it is inferred that the contribution of coliforms at the three sampling sites has a predominant soil origin.

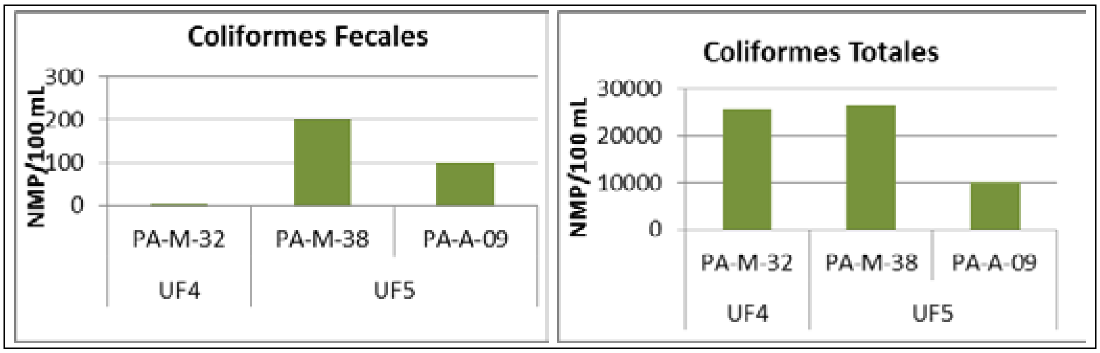


Figure 5.1.103 Fecal coliforms and Total coliforms results for UF4 and UF5
Source: (INGETEC, 2016)

As regards to the heavy metals arsenic, barium, cadmium, copper, chromium, mercury, nickel, silver, lead, selenium and zinc, the sampled groundwater exhibits low values, reporting values below the level of detection according to the technique used.

Table 5.1.61 shows the limit values established in Decree 1594 of 1984 for different uses.

Table 5.1.6 Quality criteria of resource destination for various uses (Decree 1594 of 1984)

Parameter	Human and domestic Treatment. Conventiona l	Human and domestic Treatment. Disinfectio n	Agricultura l	Livestoc k	Recreationa l primary contact	Recreationa l secondary contact
pH	5 - 9 units	6.5 to 8.5 units	4.5 -9.0 units	------	5 - 9 units	5 - 9 units
Color	75	20 Units	------	------	------	------
Turbidity	------	10 UJT	------	------	------	------
Chlorides	250	250	------	------	------	------
Phenolic compounds	0,002	0,002	------	------	0,002	------
Sulphates	400	400	------	------	------	------

Parameter	Human and domestic Treatment. Conventional	Human and domestic Treatment. Disinfection	Agricultural	Livestock	Recreational primary contact	Recreational secondary contact
Arsenic	0,05	0,05	0,1	0,2	------	------
Barium	1	1	0,1	------	------	------
Cadmium	0,01	0,01	0,01	0,05	------	------
Copper	1	1	0,2	0,5	------	------
Chrome	0,05	0,05	0,1	1	------	------
Mercury	0,002	0,002	------	0,01	------	------
Nickel	------	------	0,2	------	------	------
Silver	0,05	0,05	------	------	------	------
Lead	0,05	0,05	5	0,1	------	------
Selenium	0,01	0,01	0,02	------	------	------
Zinc	15	15	0,05	25	------	------
Total Coliforms	20000	1000	5000	------	1000	5000
Fecal Coliforms	2000	------	1000	------	200	------

Source: Modified by INGETEC, 2016

Based on the results obtained, it is evident that the three bodies of water monitored registered concentrations and values within the ranges established in Decree 1594 of 1984 except for total coliforms, which exceed all the limits established in the regulations, These waters are not suitable for human consumption from the microbiological point of view.

In addition, the pH of the PA-M-38 spring is outside the established range to destine the resource for human and domestic consumption where only disinfection is required for its treatment

- *Hydrogeochemical characterization of water*

The source of groundwater and primary chemical composition is in rainwater, once it is infiltrated it will depend directly on the minerals it comes into contact with in the aquifer, and on the interaction time it has with them, which can be thousands of years. Thus, the longer the retention time in the aquifer, the greater will the amount of salts present in the water, due to the greater dissolution of these. A sequence is then determined, which says that the waters with less time of permanence in the subsoil will be generally bicarbonated, and with the passage of time they become sulfated and finally chloruriated.

Analogously for cations, the waters that are initially calcium loaded become magnesium loaded and then sodium loaded:

$$HCO_3^- \rightarrow SO_4^{2-} \rightarrow Cl^-$$
$$Ca^{2+} \rightarrow Mg^{2+} \rightarrow Na^+$$

The aim of the Hydrogeochemical analysis of groundwater is to determine the main and predominant chemical composition of the water captured in the springs and well of the monitoring campaign for functional units 4 and 5; In addition, to have a vision about the chemical evolution, which occurs once the water enters the process of recharge, transit and later discharge into water points.

This analysis is based on the relation of the cations and major anions of groundwater with the mineralogical composition of the rocks through which it circulates, including also the residence time and transport. The cations analyzed are Calcium (Ca++), Magnesium (Mg++), Sodium (Na+) and Potassium (K+), and the anions analyzed are Bicarbonate (HCO3-), Sulphates (SO4=) and Chlorides (Cl-).

- Classification by Dominant Ions

The classification of groundwaters by dominant ions corresponds to the anion or cation which exceeds 50% of the respective sum. In case of not exceeding 50%, the most abundant ions will be named. For this classification, the Piper and Stiff diagrams are used, as illustrated in Figure 5.1.120.

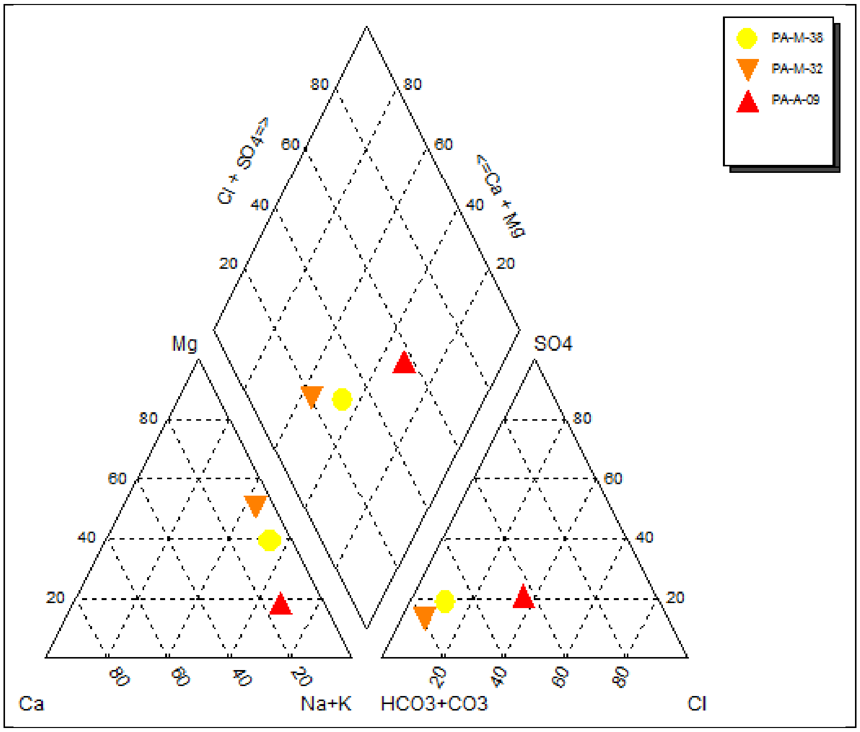


Figure 5.1.104 Piper Diagram for UF4 and UF5
Source: (INGETEC, 2016)

Figure 5.1.104 is representing a water with the following composition for each of the sampled sites of UF4 and UF5 (See Table 5.1.62).

Table 5.1.62 Water composition, Piper diagram

Parameter		Cations			Anions		
		Calcium	**Magnesium**	**Sodium + Potassium**	**Bicarbonates**	**Chlorides**	**Sulphates**
Unit		**%**	**%**	**%**	**%**	**%**	**%**
UF4	**PA-M-32**	5	50	43	80	7	15
UF5	**PA-M-38**	8	40	58	70	10	19
	PA-A-09	18	18	70	45	38	20

Source: (INGETEC, 2016)

Piper's triangular diagram indicates that the water composition of the spring identified as PA-M-32 of UF 4, presents a water chemistry with predominance in calcium and magnesium cations, poor in chlorides and sulfates and predominance in bicarbonates.

The water composition of the spring identified as PA-M-38 of the UF 5, presents similarity to the composition of the spring of the UF4, represented mainly by bicarbonates.

The waters of the PA-A-09 well have chlorinated sodium water and low values of calcium and magnesium cations. (See Figure 5.1.121, Figure 5.1.122 and Figure 5.1.123)

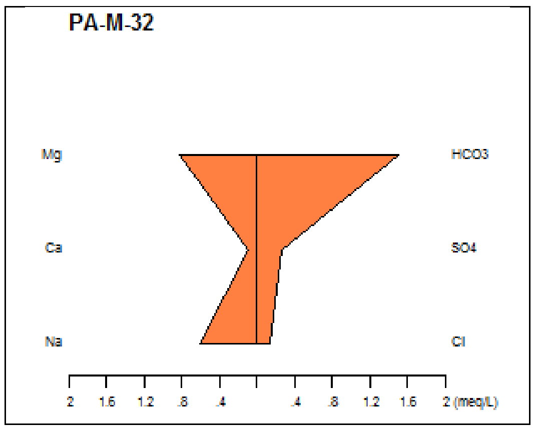


Figure 5.1.105 Stiff Diagram PA-M-32
Source: (INGETEC, 2016)

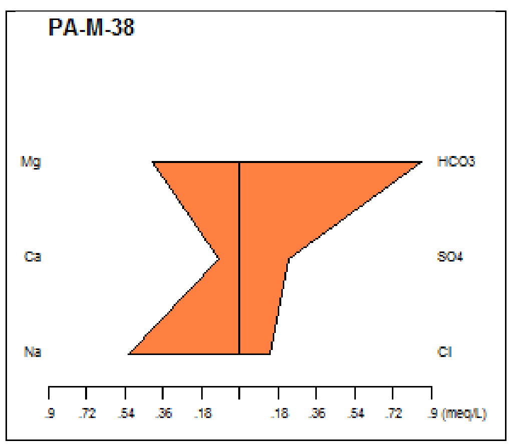


Figure 5.1.106 Stiff Diagram PA-M-38

Source: (INGETEC, 2016)

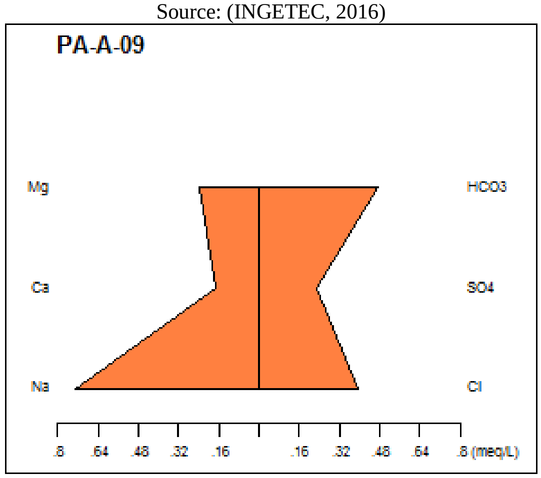


Figure 5.1.107 Stiff Diagram PA-A-09
Source: (INGETEC, 2016)

The Table 5.1.63 shows the classification presented in the Stiff diagrams. In general, it is observed that the waters of the three bodies of water present a sequence with bicarbonate predominance, so it is inferred that it corresponds to waters with less time of permanence in the subsoil.

Table 5.1.63 Water composition, Stiff diagram

UF	POINT	CLASSIFICATION
UF4	PA-M-32	Magnesic bicarbonated
UF5	PA-M-38	Sodic bicarbonated
	PA-A-09	Chlorinated bicarbonated sodic

Source: (INGETEC, 2016)

- Conceptual Hydrogeological Model

To understand the groundwater circulation, it is necessary to define what is known as a conceptual hydrogeological model, which involves the permeability characteristics of the rock, the conditions of recharge and discharge of water, the stratigraphic units and the respective local hydrogeological conditions: directions water flow, hydraulic gradients, transmissivity and storage capacity, etc.

To construct the conceptual hydrogeological model, three stages are followed: 1) define the hydrostratigraphic units present in the project area according to the geological and hydrogeological characteristics of each functional unit within the area of influence, 2) prepare a water balance, 3) define the flow system (Anderson, 1991).

Hydrostratigraphic units include the identification and characterization of geological units with lithological and textural features that are related to similar hydrogeological properties and behaviors. These units are the backbone of the conceptual model. Hydrological information associated with precipitation, evaporation, piezometric data, as well as geochemical data are used to analyze the movement of groundwater throughout the system. The piezometric heads define recharge and discharge zones, connections between aquifers and surface water systems.

- *Hydrogeological units*

A hydrogeological unit is defined as a formation or group of geological formations that exhibit uniformity in their hydrogeological characteristics such as porosity, permeability, infiltration capacity, among others. The units were interpreted from lithology, geological structures and their influence on groundwater flow, the identification of water points, the position of the piezometric levels obtained from the geotechnical explorations of the water phase design and the results of vertical electrical surveys (SEV). Since groundwater flow potential is dependent on lithology (depending on which rocks have primary, secondary, or both types of permeability), hydrogeological units tend to coincide with lithological units in which similar hydraulic properties were observed or assumed.

The types of aquifers identified for the Pedregal - Catambuco road project have certain characteristics or parameters that allow to define and estimate of the hydrodynamic functioning; According to the parameters related in terms of porosity, permeability and storage coefficient for this type of materials, which have been adapted from the literature for the classification of hydrogeological units in the area (See Table 5.1.52) according With IDEAM, 2001, the area does not present hydrogeological interest at the regional level (See Figure 5.1.124).

The permeability varies between one material and another in a significant way, being the granular soils the ones that present greater permeability; While the clayey ones are those that present less permeability. Low-permeability pyroclastic products (mainly lithic tuffs and ash deposits), which are interstratified with lava (rocks with no effective porosity but with secondary permeability), which act as almost horizontal barriers to groundwater flow.

Figure 5.1.125 Relationship between texture and porosity[1]. A) Well classified sediment with high porosity; B) Poorly classified sediment with low porosity; C) Well classified sediment with porous grains; D) Well classified sediment with porosity diminished by cementation; E) Porosity developed by rock dissolution; F) Porosity developed by fracture of the rock.

Due to the lithological diversity and the genesis of the volcanic formations in the area, they present hydrogeological characteristics within the group of semiconsolidated and consolidated rocks and sediments. The factors that determined the storage properties in this type of rocks and deposits are related to the anisotropy and heterogeneity of the formation media, which influences the hydrogeological behavior (permeability - transmissivity) of groundwater in this type of material (See Table 5.1.64).

In addition, the spatial arrangement and geometry of the aquifers is mainly controlled by the geological contrast of the permeable, semipermeable and impermeable formations between the different volcanic and sedimentary materials.

1 Domenico, FA and Schwartz, FW (1998) Physical and Chemical Hydrogeology; John Wiley & Sons, 506 pp.

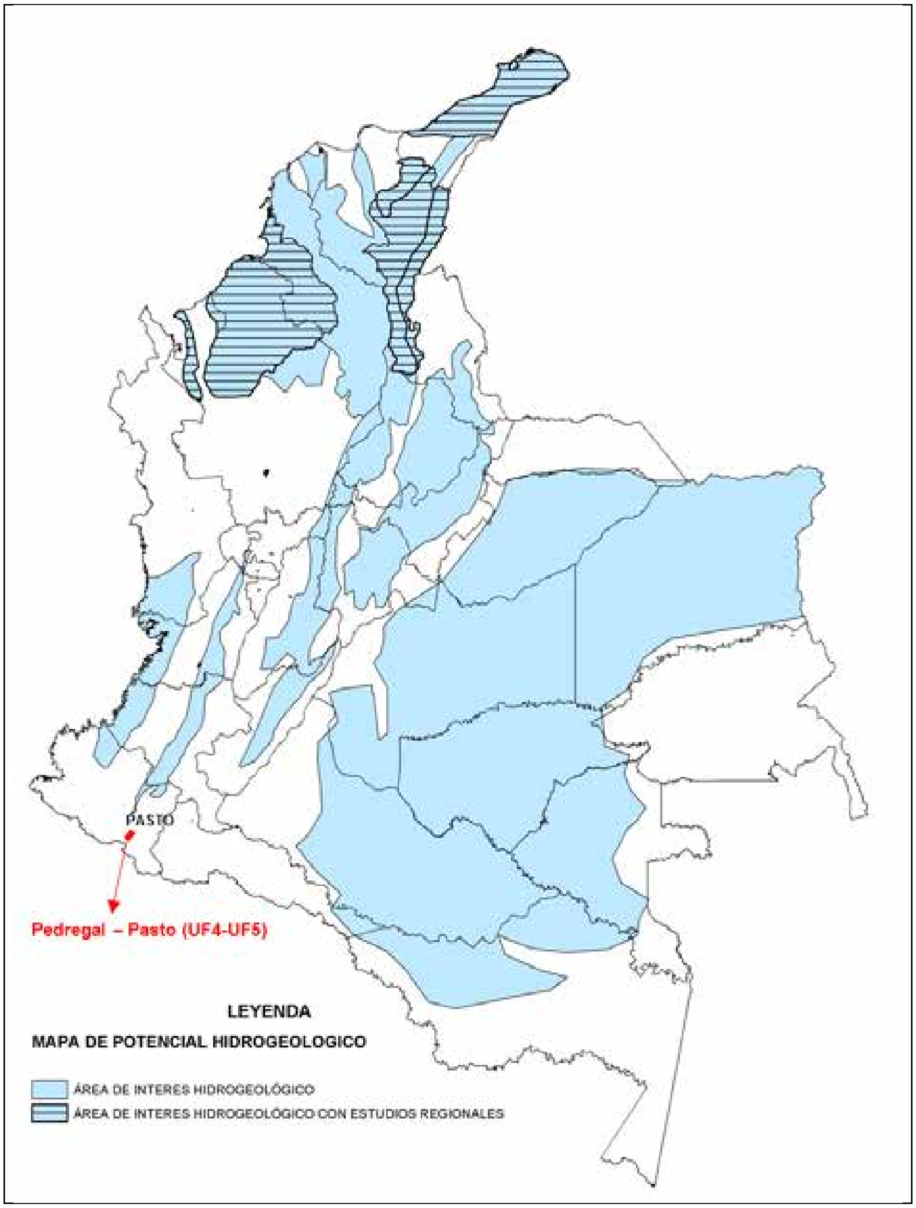


Figure 5.1.108 Hydrogeological potential map of Colombia.

Source: (IDEAM, 2001)

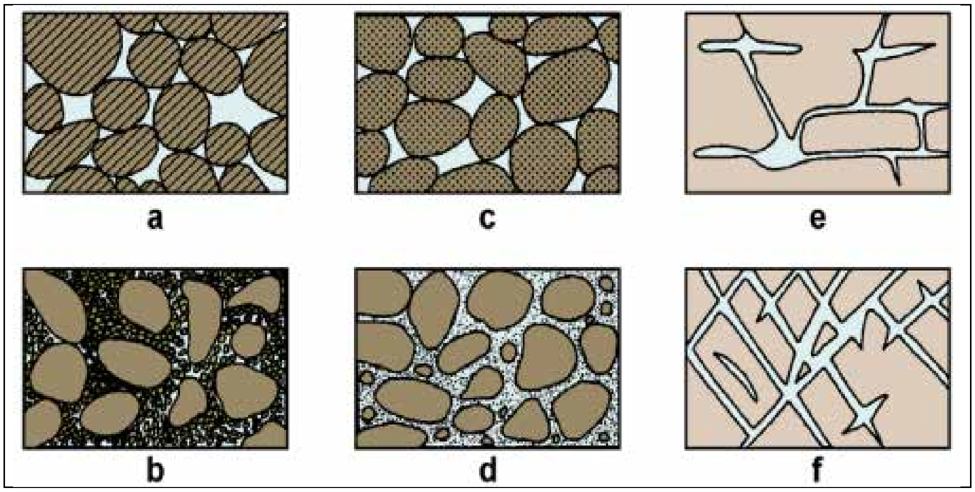


Figure 5.1.109 Relationship between texture and porosity
Source: (INGETEC, 2016)

The definition of hydrogeological units took into account the type of textural packing of the particles that make up each of the units with the greatest storage potential (See Figure 5.1.125); These characteristics determine the pore type and also the porosity as such. The interpretation of the porosity in each of the volcanic deposits takes into account the following classification:

- Deposits of homogeneous granulometry that attribute greater effective porosity.
- Deposits with heterogeneous granulometry and intermediate porosity.
- Deposits with homogeneous granulometry whose porosity has decreased by cementing of their interstices.

The differences in porosity between deposits lie in the following aspects of the hydrogeological analysis:

- Form of the grains that determine the shape and dimensions of the pores.
- Arrangement of the grains.
- Size of the grain, its influence on porosity.

The porosity of the volcanic rocks is very variable depending on the formation process, varying between 10 and 50% in pyroclastic rocks and less than 5% in massive lavas and without vesicles (Custodio, 1978).

Table 5.1,64 Total and effective porosities of diverse geological materials.[2]

Material		Porosidad, n (%)					Porosidad eficaz n_e (%)		
		Valores normales			Valores extraordinarios				
Tipo	Descripción	Media	Máx.	Mín.	Máx.	Mín.	Media	Máx.	Mín.
Rocas masivas	Granito	0.3	4	0.2	9	0.05	< 0.2	0.5	0.0
	Caliza masiva	8	15	0.5	20		< 0.5	1	0.0
	Dolomía	5	10	2			< 0.5	1	0.0
Rocas metamórficas		0.5	5	0.2			< 0.5	2	0.0
Rocas volcánicas	Piroclastos y tobas	30	50	10	60	5	< 5	20	0.0
	Escorias	25	80	10			20	50	1
	Pumitas	85	90	50			< 5	20	0.0
	Basaltos densos, fonolitas	2	5	0.1			< 1	2	0.1
	Basaltos vacuolares	12	30	5			5	10	1
Rocas sedimentarias compactadas	Pizarras	5	15	2	30	0.5	< 2	5	0.0
	Areniscas	15	25	3	30	0.5	10	20	0.0
	Creta blanda	20	50	10			2	5	0.2
	Calizas detríticas	10	30	1.5			3	20	0.5
Sedimentos	Aluviones	25	40	20	45	15	15	35	5
	Dunas	35	40	30			20	30	10
	Gravas	30	40	25	40	20	25	35	15
	Loess	45	55	40			< 5	10	0.1
	Arenas	35	45	20			25	35	10
	Depósitos glaciares	25	35	15			15	30	5
	Limos	40	50	35			10	20	2
	Arcillas sin compactar	45	60	40	85	30	2	10	0.0
	Suelos superiores	50	60	30			10	20	1

Source: (INGETEC, 2016)

- *Geological model for the area of intervention*

2 ITGE (1987) Taluses Engineering Manual; 1st Edition. Technological and Geomining Institute of Spain. pp. 456

There are outcrops of rocks and deposits of Pliocene - Holocene age, as well as colluvial and alluvial deposits of Holocene age in the Pedregal - Catambuco road corridor (Annex 5.1.8, Annex 3. Geological map). The basement is formed by precambrian rocks that correspond to igneous rocks of granodioritic composition affected by blastesis phenomena, and metamorphic mainly gneiss, paragneiss and amphibolites of the Migmatitic Complex of La Cocha unit

the structural style of the region is complex, due to the convergence of large fault systems that define northward the boundaries between the three Colombian mountain ranges. The geological structures demonstrate the tectonic activity that has given the current Northern Los Andes mountainous system their profile, predominantly n-ne high-angle faults, as well as some branching in direction NW - SE.

- *Analysis Sections*

Eight analysis sections were defined for the area of influence of the Pedregal - Catambuco road corridor to complement the hydrogeological analysis, distributing four per functional unit, in order to determine in depth the thickness of the Geology Units for Engineering - UGI (annex 5.1.8, annex 4. Analysis Sections). The information obtained from the geoelectric of Vertical Electric Surveys (SEV) sections, is correlated with information from the geological sections, in order to estimate the depths that are saturated permeable areas according to the contrast of resistivity of different materials. Also included is the information from the phreatic levels obtained from the piezometers in the design stage, and the relationship with the presence of water areas to determine the type of aquifer to which they belong, complemented with porosity and permeability.

In general the water table defined for the different sections of analysis is below 9.0 m in depth and could be linked to the base level of the drainages of major river basins as the rivers Guáitara and Bobo, the La Magdalenacreek and the Hato Viejo Creek near the city of Pasto; it will not be affected by the construction of the divided highway project between Pedregal and Catambuco.

o Functional Unit 4

ü Section A-A

Location: It is located between the coordinates N607302; E957092 and N607067; E957452, direction NW - SE, the section is 450 m long. Scale 1:2500 (see annex 5.1.8, annex 4. Analysis sections) (see Figure 5.1.126).

Geology units for Engineering : The section crosses a 3 m thick colluvial (Qc) deposit, matrix supported with angular fragments of andesites, that lie on top of a stream of debris consisting of poorly selected sharp fragments of andesites, trachytes, embedded in a sandy silty matrix, with some levels of fine ash from the Ash flows and Pumice(TQvf) unit, as can be seen in the survey PEPA-PT-TAL-1. The Ash Flows and Pumice (TQvf) unit lies on top of joined porphyritic andesites (N65 ° W / 77 ° NE), grey colored formed of plagioclase phenocrysts andfeldspar in a microcrystalline matrix of the Lavas (TQvl) unit .

the colluvial deposit (Qc) belongs to the hydrogeological Free Sediment with essentially intergranular flows (Albp) unit. The geological Ash Flows and Pumice (TQvf) unit corresponds to the hydrogeological Rocks and Semipermeables Sediments of low productivity (Aspbp) unit. The geologic Lava (TQvl) unit corresponds to the hydrogeological Impermeable Rocks with Limited underground Water resources (Ri) unit.

The Romeral fault located 200 metres west of the SEV, would be responsible for deepening the phreatic level to 17 meters.

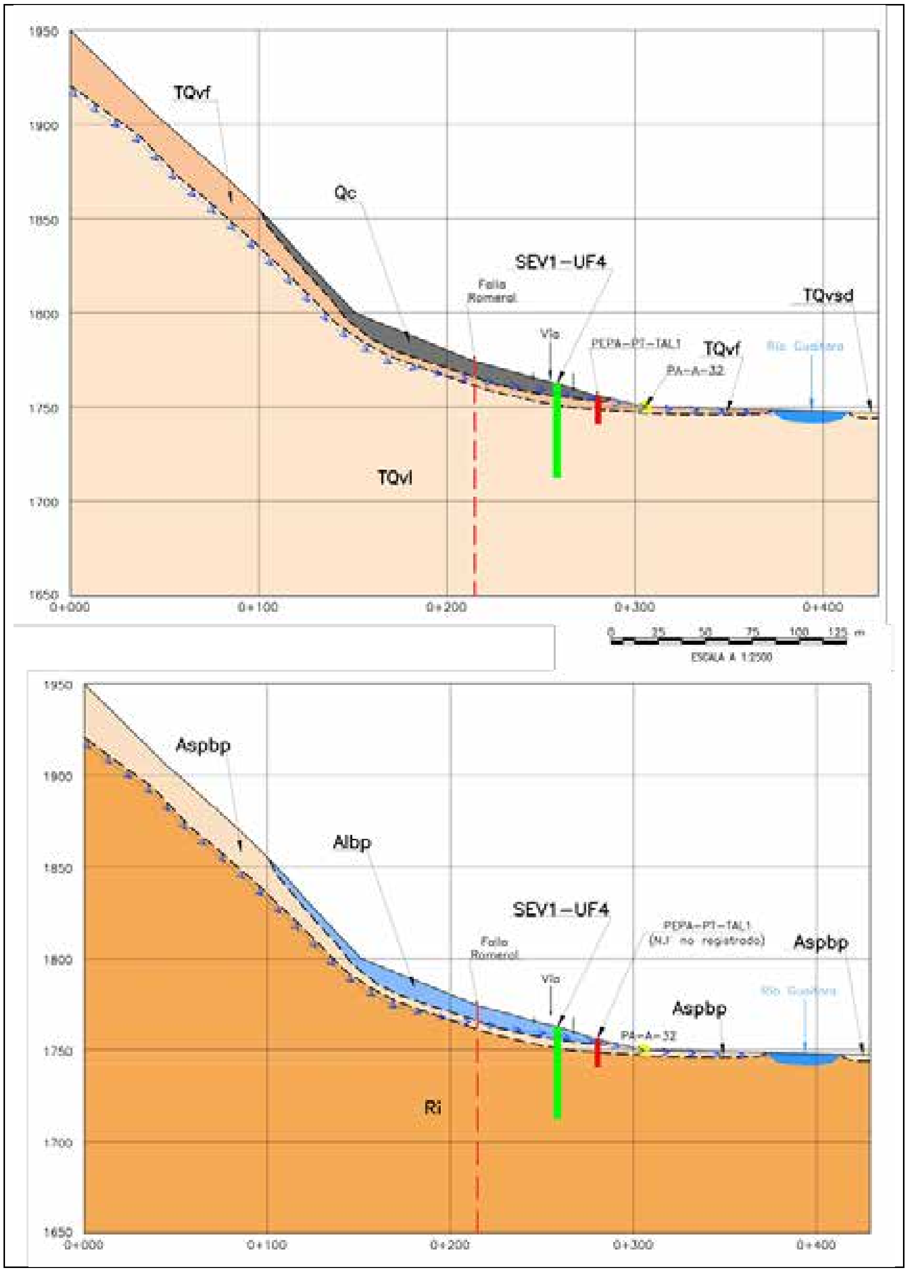


Figure 5.1.110 Analysis section A - A Geological and Hydrogeological

Source: (INGETEC, 2016)

ü Sección B – B

Location: The section is between coordinates N610025; E960657 and N610293; E962457, with SW – NE direction, with a length of 1820 m. Scale 1:5000 (see annex 5.1.8, annex 4. Analysis sections) (see Figure 5.1.127).

Geology Units for Engineering: the lithology spanning the section is lowly lythified volcanic agglomerates lithified and very weathered, the fragments are angular and andesitic and trachytic from the La Magdalena Sedimentary Volcanic unit (TQsv). On both banks of the la Magdalena creek there are two colluvial deposits (Qc) of up to 2m thick, these deposits are composed of angular fragments of volcanic agglomerate, embedded in a Sandy silty matrix composed of plagioclase and volcanic rock rocks.

The colluvial deposits (Qc) belong to the hydrogeological Free Sediment with essentially intergranular flows (Albp) unit. The La Magdalena Sedimentary Volcanic unit (TQsv) geological unit corresponds to the hydrogeological Rocks and Semipermeables Sediments of low productivity (Aspbp) unit..

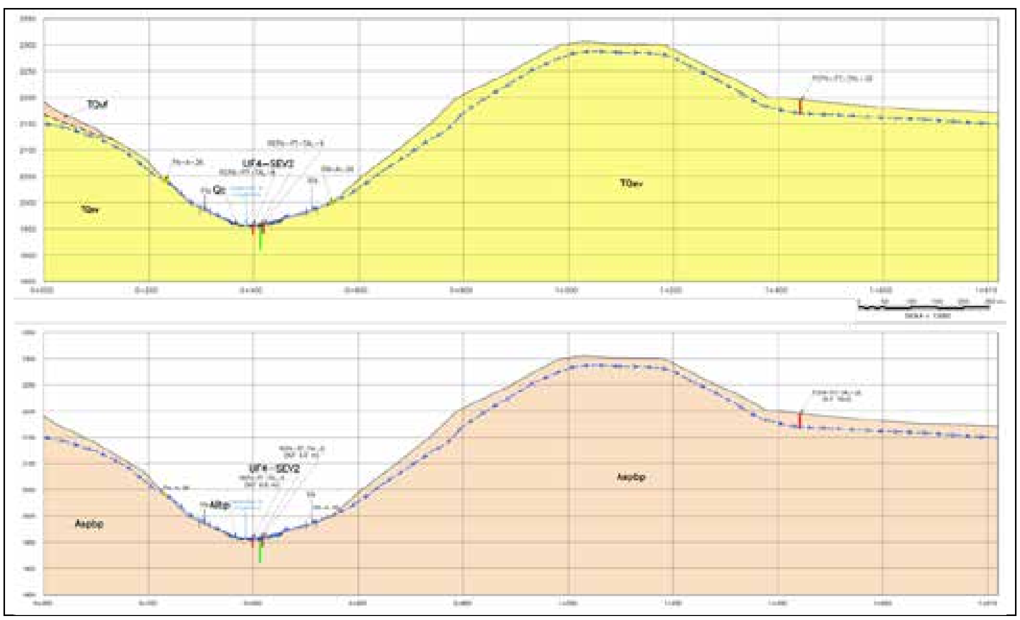


Figure 5.1.111 Analysis Section B - B Geological and Hydrogeological

Source: (INGETEC, 2016)

ü Section C - C

Location: The section is located in coordinates N612195; E962493 and N611673; 963314, with direction NW - SE, with a length of 937 m. Scale 1:5000 (see annex 5.1.8, annex 4. Analysis sections) (see Figure 5.1.128).

Geology units for Engineering : The section in the present route exposes a coluvial deposit (Qc) of 5m of thickness, matrix supported in a silt-sandy factory with some grava sized subangular fragments of volcanic agglomerates and andesites that lies discordantly on top of weathered volcanica gglomerate with andesites and trachytes of the La Magdalena Sedimentary Volcanic unit (TQsv), as can be appreciated in survey PEPA-PT-MUR-7.

The colluvial deposits (Qc) belong to the hydrogeological Free Sediment with essentially intergranular flows (Albp) unit. The La Magdalena Sedimentary Volcanic unit (TQsv) geological unit corresponds to the hydrogeological Rocks and Semipermeables Sediments of low productivity (Aspbp) unit..

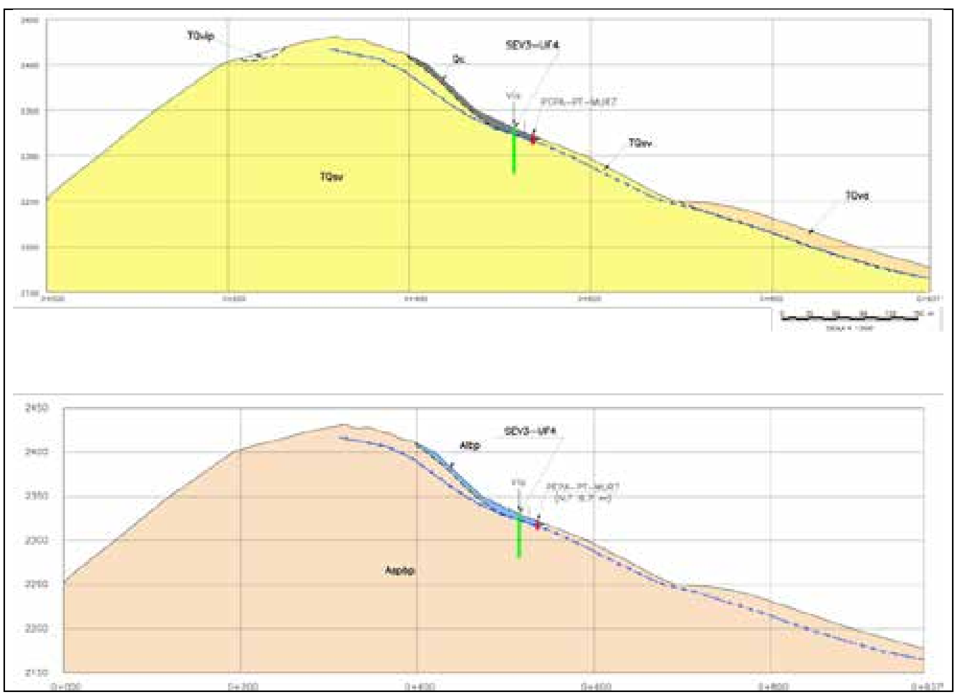


Figure 5.1.112 Analysis Section C - C Geological and Hydrogeological

Source: (INGETEC, 2016)

ü Section D - D

Location: The section is located between the coordinates N613546; E965022 and N612552; E966365, with direction NW – SE, with a length of 450 m. Scale 1:5000 (see annex 5.1.8, annex 4. Analysis sections) (see Figure 5.1.129).

Geology units for Engineering : The outcrops of the present route, present pyroclastic flows of the Lahars and Pyroclasts (TQvlp) unit to the SE of the section, that consist of subrounded bombs of up to 10 cm in diameter in an ash and lapilli matrix as described in survey PEPA-PT-TAL-35; the pyroclastic deposit is on top of the La Magdalena Sedimentary Volcanic unit (TQsv).

The Lahars and Pyroclasts (TQvlp) geological unit and La Magdalena Sedimentary Volcanic (TQsv) geological unit correspond to the hydrogeological Rocks and Semipermeables Sediments of low productivity (Aspbp) unit.

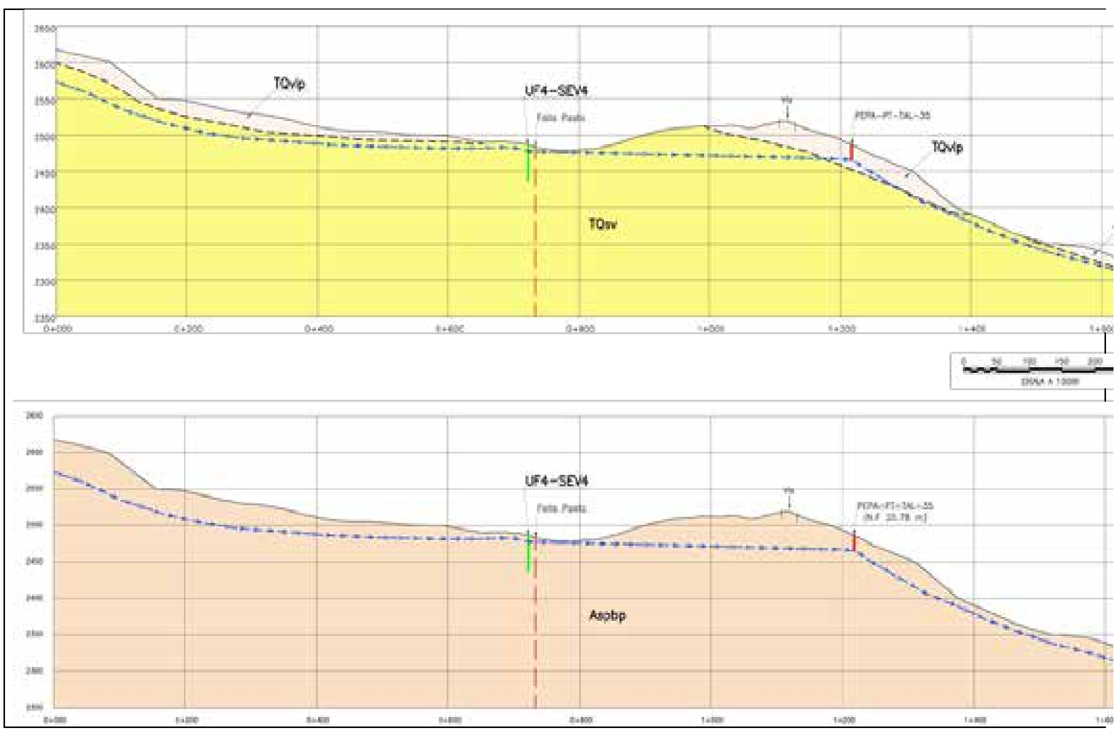


Figure 5.1.113 Analysis Section D - D Geological and Hydrogeological

Source: (INGETEC, 2016)

- Functional Unit 5

ü Section E - E'

Location: Is located between the coordinates N613623; E965815 and N614406; E967587, with direction SW - NE, with a length of 1936 m. Scale 1:4000 (see annex 5.1.8, annex 4. Analysis sections) (see Figure 5.1.130).

Geology units for Engineering : On the slopes of cutting the current via emerges unit lahars and pyroclastic rocks (TQvlp), the laharicos flows are composed of angular fragments of up to 40 cm diameter, embedded in silt matrix andesite Sandy to Sandy. The pyroclastic flows are comprised of subrounded bombs of up to 8cm in diameter in an ash and lapilli matrix as described in survey PEPA-PT-TAL16 AND PEPA-PT-TAL-17, these flows are supralying volcanic sedimentary rocks of the La Magdalena Sedimentary Volcanic unit (TQsv).

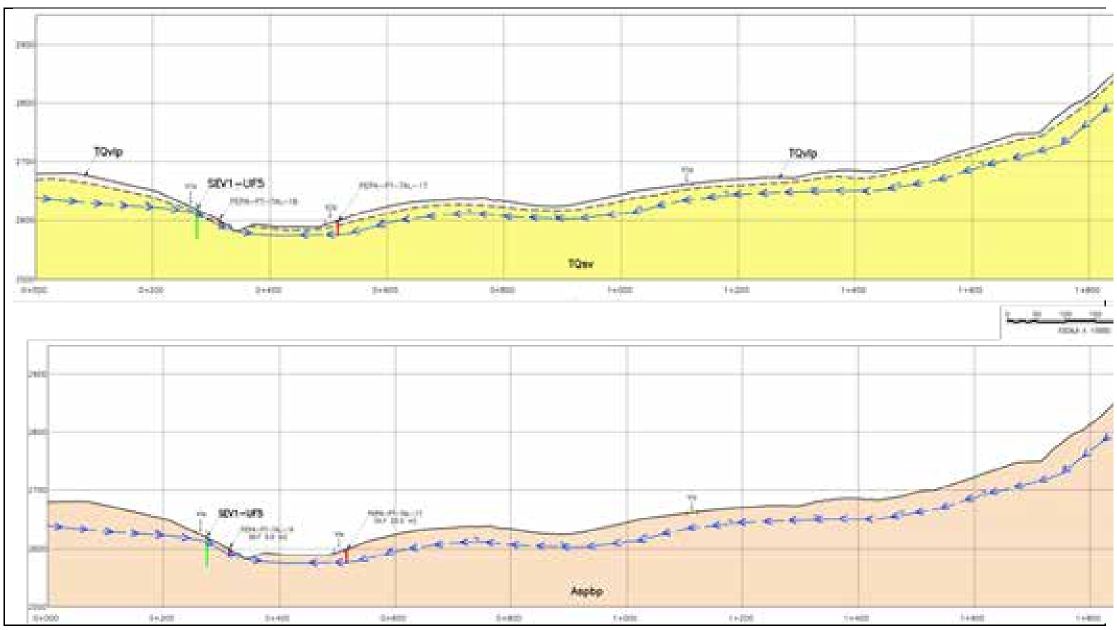


Figure 5.1.114 Analysis Section E - E' Geological and Hydrogeological
Source: (INGETEC, 2016)

The Lahars and Pyroclasts (TQvlp) geological unit and La Magdalena Sedimentary Volcanic (TQsv) geological unit correspond to the hydrogeological Rocks and Semipermeables Sediments of low productivity (Aspbp) unit.

ü Section F-F'

Location: Is located between the coordinates N617129; E968793 and N616893; E969079, with direction NW - SE, with a length of 400 m. Scale 1:1500 (see annex 5.1.8, annex 4. Analysis sections) (see Figure 5.1.130).

Geology units for Engineering : In the outcrops ner the section there are ash deposits of andesitic composition and 16 m thick, formed by felsic minerals and ferromagnesiums to a lesser degree, these have been weatehered and generate 2m thick organic soils as per survey PEPA-PT-TAL-25; these are covering poorly joined porphyritic andesites of a grey color with plagioclase phenocyrsts in a microcrystalline of the Lavas and Ashes (TQvlc) unit.

The SEV2-UF5 reported lower resistivity between 25 m and 33 m with a value of 45 Ohm. Between the surface and 25 m, and from 33 m, resistivity values occur within a range of 60 and 900 Ohm, considering this interval asthe one with less saturation and permeability of the SEV.

The colluvial deposits (Qc) belong to the hydrogeological Free Sediment with essentially intergranular flows (Albp) unit. The geological Lavas and Ashes (TQvlc) unit corresponds to the hydrogeological Rocks and Semipermeables Sediments of low productivity (Aspbp) unit.

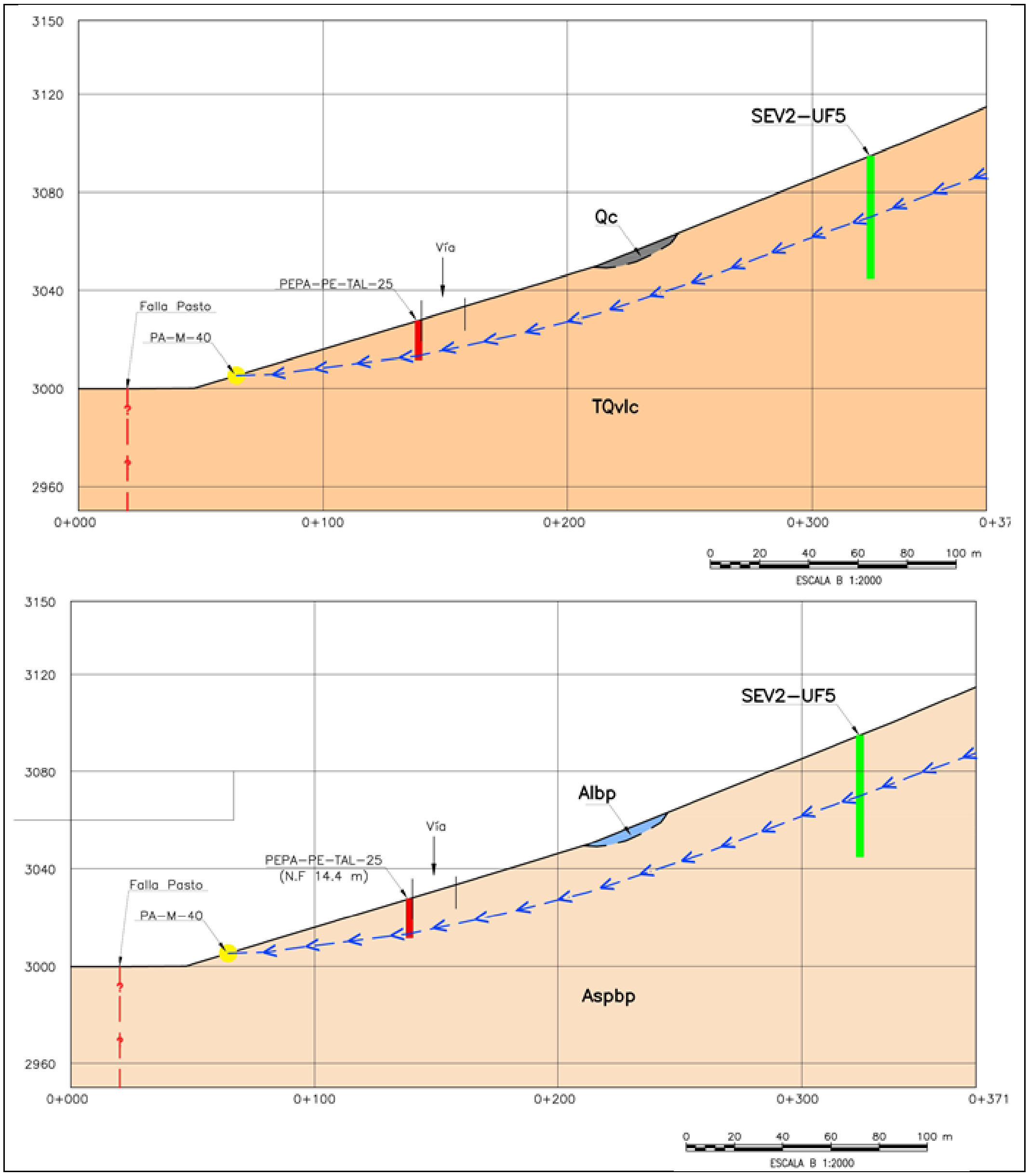


Figure 5.1.115 Analysis Section F - F' Geological and Hydrogeological

Source: (INGETEC, 2016)

ü Section G - G'

Location: Is located between the coordinates N618255; E971241 and N618667; E972170, with direction SW - NE, witha length of 415 m. Scale 1:1500 (see annex 5.1.8, annex 4. Analysis sections) (see Figure 5.1.132).

Geology Units for Engineering: in the sector where the section was drawn there is an outcrop of the Ash Rain (Qvc) unit, comprised of a 4m thick lapilli ash, weathered, of an andesitic with plagioclase and ferromangesium minerals composition, presents iron oxides, as registered by survey PEPA-PT-TAL-27; These ashes are suprayacent to the Lavas and Ashes (TQvlc) unit comprised of porphyritic andesites.

The Ash Rain (Qvc) geological unit and the Lavas and Ashes (TQvlc) geological unit corresponds to the hydrogeological Rocks and Semipermeables Sediments of low productivity (Aspbp) unit.

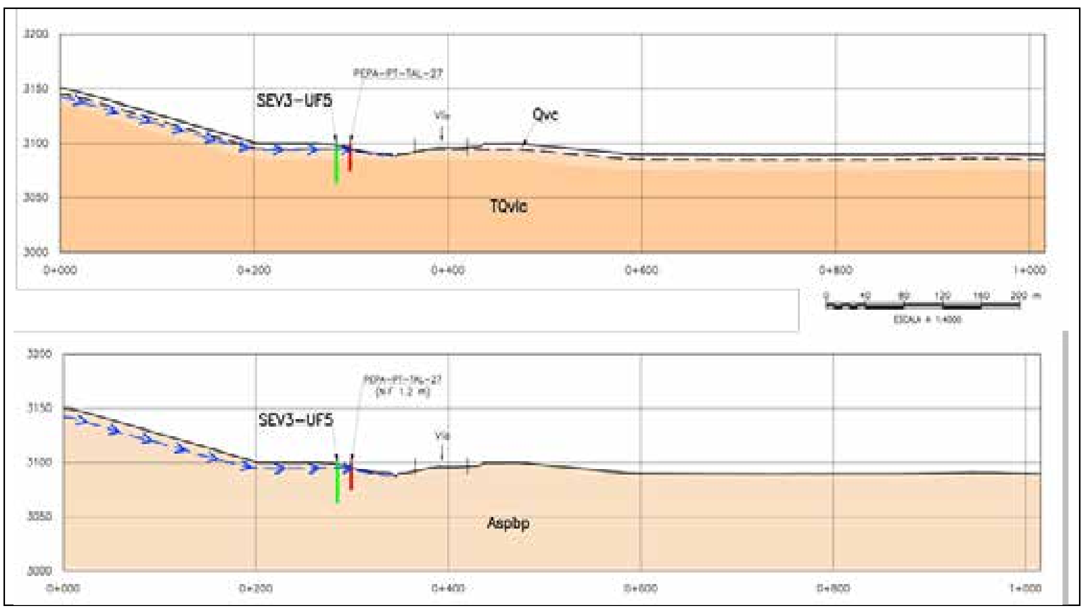


Figure 5.1.116 Analysis Section G - G' Geological and Hydrogeological
Source: (INGETEC, 2016)

ü Section H - H'

Location: The section is located between the coordinates N618405; E974071and N619369; E974520, with direction SW - NE, with a length of 610 m. Scale 1:1500 (see annex 5.1.8, annex 4. Analysis sections) (seeFigure 5.1.133).

Geology units for Engineering : SW of the section the Ashes and Pumice (TQvf) unit outcrops and deposits of fine grained to lapilli ashes of dacitic composition with plagioclase and a few ferromagnesium minerals can be observed; the ashes are weathered with iron oxides producing organic soils of up to 2 m thick which are suprayacent to non-lithified deposits made of subangular fragments of volcanic agglomerate and andesite embedded in a vitreous matrixwith some ash levels, as was recorded in survey PEPA-PT-TAL-30. The Ash Rain (Qvc) unit outcrops to the NW; comprised of lapilli ash with iron oxides and organic matter 3 m thick, as registered in survey PEPA-PT-PP1-1.

The SEV4-UF5 presents resistivities between 110 and 3000 Ohm, considering that they do not have saturated or permeability zones. The Ash Rain (Qvc) geological unit and the Lavas and Ashes (TQvlc) geological unit corresponds to the hydrogeological Rocks and Semipermeables Sediments of low productivity (Aspbp) unit.

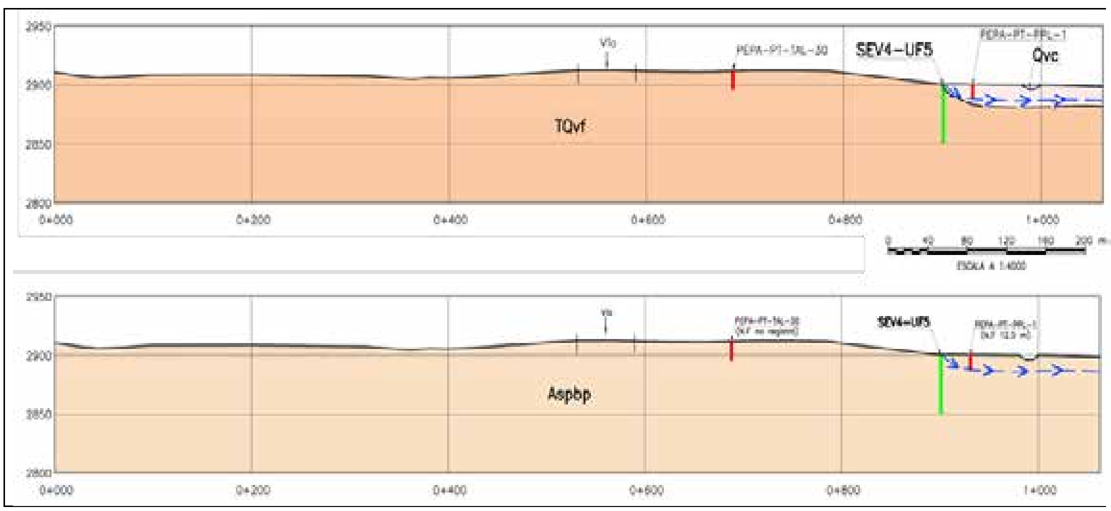


Figure 5.1.117 Analysis Section H - H' Geological and Hydrogeological
Source: (INGETEC, 2016)

Table 5.1.65 Relationship of hydrogeological units with lithostratigraphic units

UNIDAD HIDROGEOLÓGICA	UNIDAD LITOESTRATIGRÁFICA	LITOLOGÍA	ABSCISADO
Albp: SEDIMENTOS LIBRES CON FLUJO ESENCIALMENTE INTERGRANULAR: Acuíferos libres con flujo inetrgranular, doscontinuos de baja productividad y de carácter local.	Depósito Aluvial **(Qal)**	Localizado en las márgenes de la Quebrada La Magdalena. Está conformado por bloques de hasta 2m de espesor de aglomerado volcánico y andesítas en matriz arenolimosa.	K7+000 - k7+060
	Depósito Coluvial **(Qc)**	Depósito no consolidado. Los fragmentos del depósito son generalmente angulares a subangulares de hasta 60cm de diámetro que corresponden a rocas volcánicas extrusivas de composición básica e intermedia. La fábrica tiene una variación de matriz soportada a clasto soportada y es areno limosa. El espesor del depósito coluvial es de hasta 6m y forma suelos orgánicos de hasta 50cm de espesor.	0+450 - 0+910, K6+950 - K7+090, K11+295 - K11+575
Aspbp: ROCAS Y SEDIMENTOS SEMIPERMEABLES DE BAJA PRODUCTIIDAD:Acuitardos semiconfinados a confnados de carácter regional y local, discontinuos de baja productividad.	Conjunto Sedimentario Volcánico La Magdalena **(TQsv)**	En la base Intercalación de areniscas finas, arcillolitas y diatomitas finamente laminadas de color habano, parcialmente meteorizada; hacia el techo aglomerado volcánico poco litificado y muy meteorizado, los fragmentos son angulosos y de composición andesítica y traquitica.	K3+200 – K3+950, K5+150 – K5+700, K5+930 - K6+950, K7+090 - K11+295, K11+575 - K12+620, K14+700 - K15+120, K15+665 - K15+720, K15+722 - K16+050
	Flujo de Cenizas y Pumitas **(TQvf)**	Flujos de detritos con fragmentos de diversos tamaños (hasta 2m de diámetro), intercalados con cenizas volcánicas de color habano de hasta 1.5m de espesor. Los fragmentos son de dacitas y andesitas. La fábrica variable de matriz soportada a clasto soportada, es rica en líticos y pómez de tamaño arena a limo con algunos finos y presenta cambios de color como gris, ocre, rojo, siendo el más común el primer color. Forman suelos orgánicos de hasta 50cm de espesor.	K0+000 – K0+450, K0+910 - K1+265, K1+365 – K1+590, K2+280 – K2+550, K3+110 - K3+200, K4+160 – K5+150, K5+700 – K5+930, K30+030 – K31+300, K33+960 – K34+360, K36+828 – K37+076, K37+224 – K37+947
	Lavas y cenizas **(TQvlc)**	Andesitas porfiriticas cubiertas o intercaladas por cenizas tipo "ash fall" (cenizas y lapilli) y cenizas tipo "ash flow" (bombas piroclásticas de hasta 10cm de diámetro).	K22+250 - K22+540, K24+018 – K26+130, K29+000 – K30+030
	Lahares y Piroclastos **(TQvlp)**	Intercalaciones de flujos lahàricos, flujos piroclásticos y capas de ceniza. Los eventos laháricos presetan fragmentos angulosos de rocas ígneas extrusivas de composición básica a intermedia de hasta 0.6m de diámetro, embebidos en fábrica matriz soportada compuestas de líticos y pómez varía de tamaño arena a limo con algunos finos. Los flujos piroclásticos contienen bombas subredondeadas de hasta 15cm de diámetro compuestas por lavas soldadas muy duras y la matriz es de composición volcánica generalmente feldespato y plagioclasa. Las cenizas volcánicas de tamaños de finos y lapilli con algunas bombas piroclásticas de hasta 3cm; la ceniza contiene vidrio volcánico, plagioclasa y cuarzo.	K12+620 – K14+700, K15+120 - K15+665, k16+050 - K18+876, K21+2900 - K24+018
	Luvia de Cenizas **(Qvc)**	Estos depósitos representan la actividad explosiva de los diferentes focos volcánicos, se observan suavizando la morfología preexistente y modelan, en gran parte, la actual.Generan suelos orgánicos de hasta 3m de espesor, su color predominante es habano a amarillento y su tamaño de grano es de ceniza y lapilli con esporádicas bombas de hasta 3cm .	K18+876 - K21+290, K26+130 – K29+000, K31+300 – K32+679, K32+679 - K33+960, K34+326 – K36+828, K37+076 – K37+224
Ri: ROCAS IMPERMEABLES CON LIMITADOS RECURSOS DE AGUAS SUBTERRÁNEAS: Rocas en condiciones de porosidad dadas por el fracturamiento.	Lavas **(TQvl)**	Andesitas grisáceas porfiríticas con fenocristales de plagioclasa de hasta 2mm, en matriz es microcristalina que generan suelos orgánicos que alcanzan espesores de hasta 1m.	K1+270 – K1+360, K1+590 - K2+000, K2+550 - K3+057, K3+070 - K3+110, K3+950 - K4+160

Source: (INGETEC, 2016)

taking into account the criteria above mentioned, the different geological formations have been classified according to their aquifer potential by grouping them into three hydrogeologic units that depend on the type of porosity, permeability and the occurrence or not of groundwater (storage capacity). The extension and location of such units are presented in the annex 5.1.8, annex 5. Hydrogeological map (Figure 5.1.134).

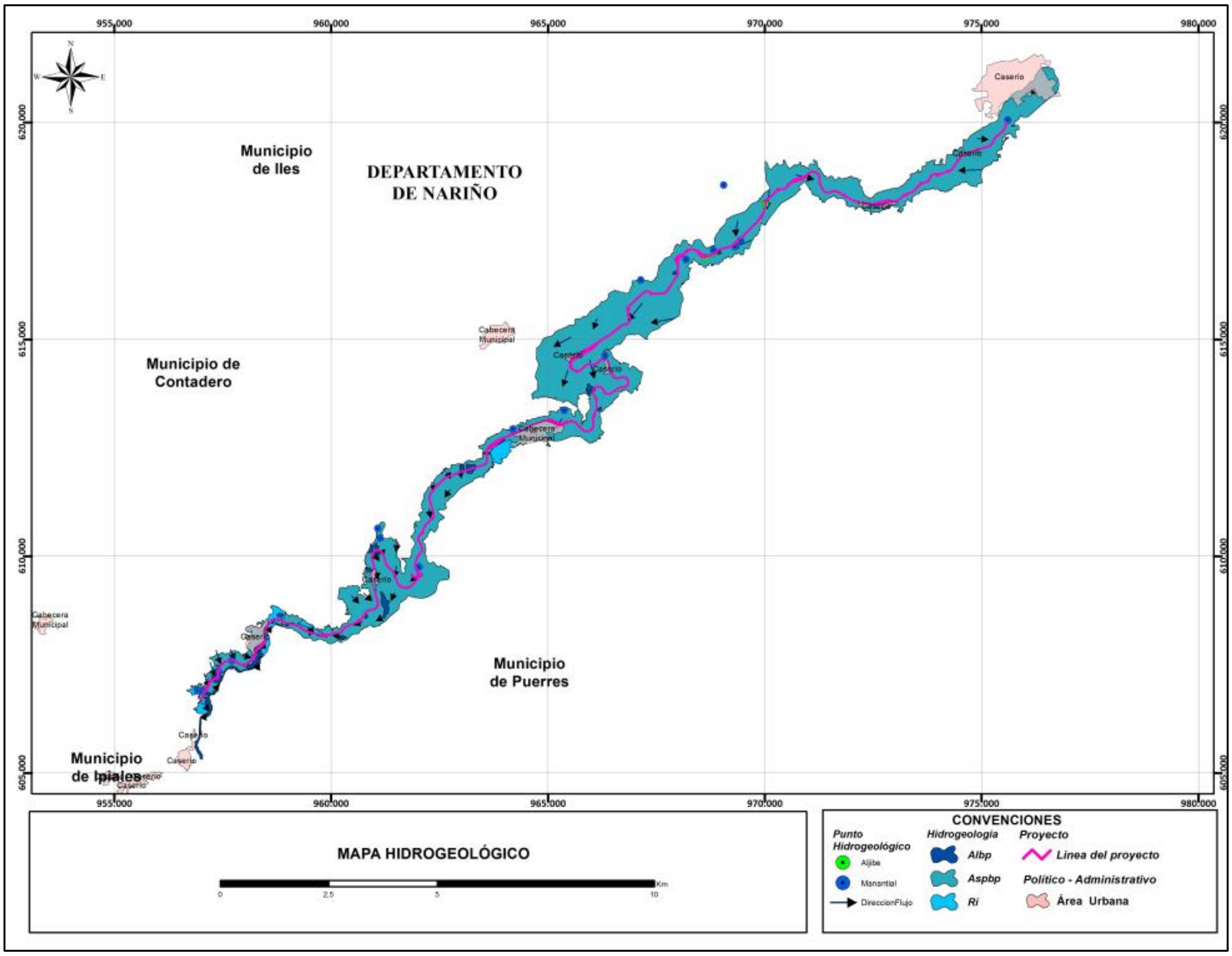


Figure 5.1.118 Hydrogeological map
Source: M & M Team

- *General direction of underground flows* in general, the geomorphological configuration of the study area corresponds to slopes that vary from moderately inclined to totally sheer. In the direction of the abscissas, the terrain configuration corresponds to a downward hillside to the right with the projected road at half-hillside; in some areas, the projected road can be located close to the top of the hillside, while in others it is located at the bottom of it, near the waterway that collects the surface and underground runoff waters from the hillside and which traverses the flows contributed by the corresponding basin.

The underground flows in the study area correspond to the down-flow parallel to the surface of the hillside, from the upper part of it toward its lower part, which in many cases has a stream. In its downward journey, the groundwater table can be found at different depths depending on the characteristics of the rock where the hillside resides.

the concavity of the profile of the slope is a determinant to the depth that the underground water table has. In the higher areas on the hillside, which may exhibit a convex shape near the upper edge, deep water tables may be found, whereas in the lower parts, where concave forms may be found close to the collector channels -towards which both surface waters and groundwaters flow to - the water table may be superficial and even some surface springs may occur.

- *Inputs and outputs of the system*

The system formed by the different hydrogeological units in the study area may receive/ deliver flows due to processes of recharge by precipitation and discharge to streams, in addition to the trivial case corresponding to the flow from / to other hydrogeological units located outside the study area.

o Recharge by Precipitation

The estimated infiltration into the Bobo River sub-basin is 26mm per year, which corresponds to 2.2% of the total mean annual precipitation; these values are representative of the recharge that may be present in the totality of UF4 and UF5 until K26+500, approximately.

In the Pasto River sub-basin the estimated infiltration is 10mm per year, which corresponds to 0,9% of the total mean annual precipitation; these values are representative of the recharge that may be present in UF5 as of K26+500, approximately.

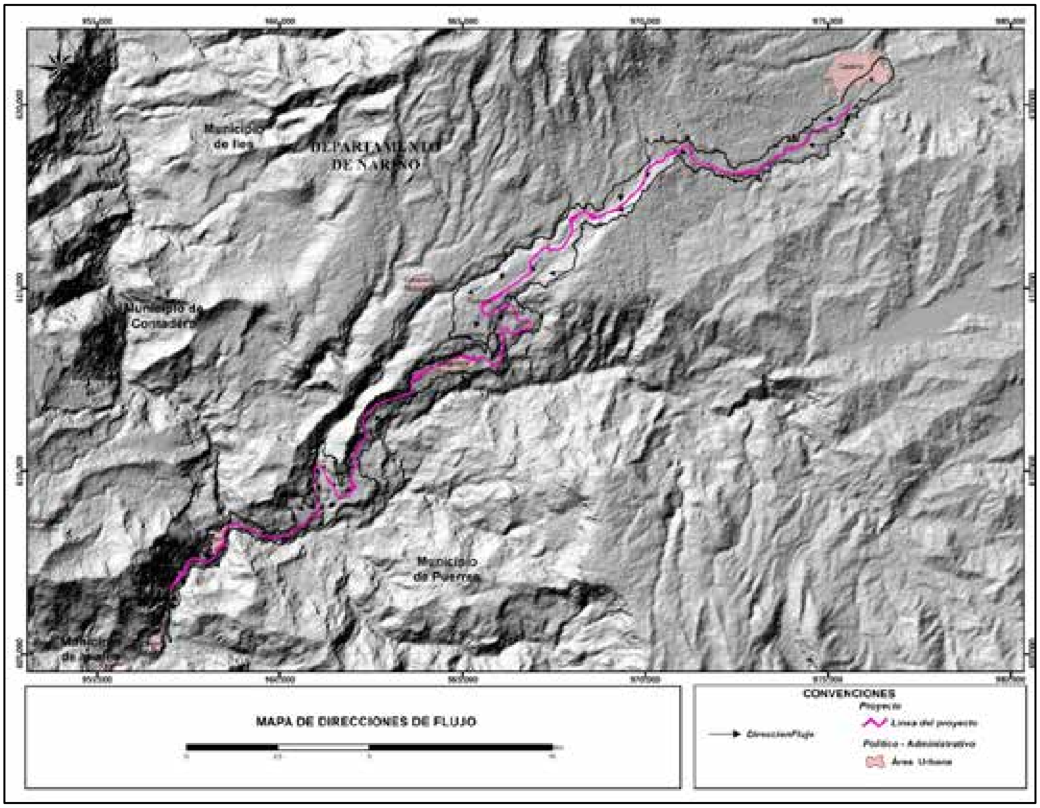


Figure 5.1.119 Direction of flow lines map
Source: M & M Team

- Download to Currents

Given the topographic configuration of the area, the hydraulic gradient associated with the underground water in the hillsides of the valley of the river is falling; This explains that the main exit for the underground waters corresponds to the different superficial currents of the study area, amongst which the Guáitara River, its tributary the Bobo River and the Pasto River outstand.

The different water outcrops found in the development of the work of this study field illustrate the phenomenon.

- *Main flows*

In order to describe the main flows associated with the hydrogeological units system in the study area, four transversal cross sections in each UF have been selected, which are representative of the system's dynamics. The geological configuration of these sections was presented in the numeral 5.1.8.5.2; below we describe the characteristic flows in said sections.

o Section A-A'

The morphology of the section is mountain slopes with gradients between 16° - 20°.

from the West of the section, the water table may be present more or less parallel to the surface of the slope, at a level close to the contact level of the Ash Flows and Pumice (TQvf) unit, of semi-permeable characteristics, and the Lavas (TQvl) unit, of waterproof characteristics. For the most of the time it is likely that the water table in this area is located above the contact between the two formations, insofar as the lower unit is characterized by presenting limited groundwater resources while the upper unit has some productivity, although it is considered low.

Taking into account that survey PEPA-PT-TAL-1 did not report groundwater, but the SEV1 has indications of change in resistivity near the 5 m depth, the flow would be entering the colluvial deposit in the stretch of the section located between both points.

This form of the water table would be coherent with the identification of the water point PA-M-32 at the 1750 level; from this site of upwelling, the water table may be very close to the surface until downloading into the Guáitara River.

o Sección B – B'

The section presents a basin in a "U" valley shape, with medium hillsides with slopes between 15° and 25°, belonging to the La Magdalena creek The materials present on both sides of the Valley are characterized as of low permeability.

taking into account the concavity of the section as well as the water table levels recorded in the field, the water table would be located at a greater depth in the higher areas of the slope, would present upwelling points at the 2045 and 2000 masl on the left and right slopes of the section, respectively, and could be developing very close to the surface from these points downstream to download into the current located at the bottom of the valley. The water table must move from the ground surface in the alluvial deposit associated with the current, deepening insofar as the current levels permit, which would control the final stretches of the water table in this alluvial sector.

This behavior would be evidenced by the results of the SEV2-UF4, according to which the groundwater was identified at 4. 5 m depth, as well as the outcome of surveys PEPA-PET-TAL8 and PEPA-PT-TAL9, presenting the water table 6.0 meters deep.

The upwelling at the levels 2045 and 2000 masl were identified in the water points PA-M-36 and PA-M-34.

The colluvial deposits present on both banks of the La Magdalena creek are classified as discharge areas.

- Section C - C'

Insofar as this section covers the two hillsides of the same mountain, the flow in this section is given in two directions, one NW and the other SE. The morphology of the section is mountain slopes with gradients between 16° - 20°.

at the top of the mountain the water table depths can be expected to be greater than 10 m. The water table that goes toward the SE would commence in the TQvs - Sr+IIA unit and approximately on the abscissa 400 of the section would be entering the colluvial formation that is between the limits 2400 and 2300 metres above sea level, crossing it at depths between 10 m (this is the depth of the phreatic level reported in drilling PEPA-PT-MUR-7) and 6.5 m (this is the depth of the phreatic level in the SEV3-UF4).

The water table should continue in vicinity of the contact between the Burning Aavalanches and Debris (Tqva) unit and the Volcanic Sedimentary La Magdalena (TQsv), until possibly meet the base level of the Bobo river.

- Section D - D'

This section has slopes between 6° - 15°.
It is expected that the water table on the top of the hillside is at depths greater than 10 m, in vicinity of the contact between the TQsv and TQvlp formations, both with low productivity features.

From this area to the area where the SEV4-UF4 was made, it is expected that the water table will gradually approach the surface until it reaches the 9 m depth registered in the mentioned survey.

During survey PEPA-PT-TAL-35 of 22 meters deep and located at 510 meters to the SE of the SEV, the phreatic level was reported at 20.78 m depth, indicating that flow in this area occurs through the TQvlp formation in SE direction.

From this area and continuing to the SE, the water table should be developing basically parallel to the surface of the slope up to the level of the Bobo river.

- Section E - E'

The morphology of this section corresponds to that of an open alluvial valley with low hillsides and slopes between 15° - 20°.

Two flow lines converging in the lowest zone of the section were identified, in the vicinity of perforations PEPA-PT-TAL-16 and PEPA-PT-TAL-17.

the water table in the left side of the section can be starting below the contact between the TQvlp and TQsv formations, both with low productivity features, and would develop in a descending fashion, following in an approximately parallel orientation to the surface of the hillside. In the zone corresponding to SEV1-UF5, it is estimated that the depth of the water table is in the order of 9 m, while that associated with the PEPA-PT-TAL-16 survey is expected to be 15.0 meters deep.

The water table in the right area of the section would have a similar behavior to the water table in the left area of the section but descending not towards the SE but towards the NW, with a parallel trend to the surface of the slope; PEPA-PT-TAL-17 survey located 740 meters to the NE of SEV1-UF5 registered phreatic levels at a depth of 25 meters.

The water tables to the left and right of the section converge in El Quetal creek, located to the SW of the section.

- Section F-F'

in the SEV2-UF5 the phreatic level is 25m deep; in the survey PEPA-PT-TAL-25 located 120 m from the SEV and with a 16 meters depth, the phreatic level is at 19.4 m. The water table has a flow direction to the NW and discharge in water point PA-M-40 at elevation point 3018 meters above sea level, in the area where the hillside slope changes, which is of the order of 20° to the SE and practically horizontal towards the NW.

the morphology of the area is of medium to low hills with slopes between 6° - 20°. The flow direction is towards the NW.

- Section G - G'

the underground water table develops in NE direction. The results obtained in the SEV3-UF5 indicate a water table depth of 5.0 m, with which the flow near that point would be happening through the colluvial formation. This is also confirmed with the results of survey PEPA-PT-TAL-27, located at 40m distance of the SEV, in which the phreatic level was recoreded at 1.2 m deep.

the water table with NE flow direction continues to the base line of the Los Lirios creek. The morphology of the area of the section is of low hills with slopes between 6° - 10°.

- Section H - H'

Both SEV4-UF5 and survey PEPA-PT-TAL-30 of 16m depth, located in the Ashes and Pumice (TQvf) unit reported no phreatic levels. The survey PEPA-PT-PP1 of 13.35m depth andlocated in the Ash Rain (Qvc) unit, recorded the phreatic level at 12.5 m depth and is found between the contact of the mentioned units and presents a flow direction towards the SE, where it will probably reach the base level of the Piedra Pintada creek. The morphology of the area of the section is of low hills with slopes between 6° - 15°.

- *Result of the Conceptual Hydrogeological Model*

The description of the Conceptual Hydrogeological Model of a certain area is controlled by the development of its historical geology and its structural patterns, which in turn become the main support for the way in which its hydrogeological conditions evolve. With this information, guidelines are set to describe the abovementioned model, useful in defining the spatial distribution and in the subsoil of the diverse hydrogeological units with their lithology, thickness, lateral variations and depth units, as well as the behavior of each one of them referred to the underground water storage capacity and its quality and the direction of the groundwater flow. Thus, the groundwater recharge (infiltration) zones, transit zones and discharge zones are identified.

The geologic history for the area of the Rumichaca - Pasto, Pedregal - Pasto segment with a total length of 15.75 kilometers and an area of influence of 3.15 km^2, presents a basement formed by the Migmatitic Complex of La Cocha - Tellez River located to the East of the Loma Larga Ridge.

It is estimated that at the continental accretion and subsequent orogeny; possibly during the Orinoquense event (1200 m.y.) the rocks were subjected to metamorphism of high grade which produced the migmatizacion and apparently formed a granulitic belt in the western part of the Precambrian Shield that correlates with the Migmatitic Complex of La Cocha - Tellez river. Subsequent to the folding of the basement units and according to the bibliographic studies it has been assumed that there was an accumulation of other units in the late Upper Cretaceous, at the end of the Miocene this from the lack of exposure of elements that confirm or refute this hypothesis and that in the area ther have been no reports of rework of units other than volcanic which are the subject to intervention in the road alignment.

Structurally the road alignment is framed within a complex tectonic due to the convergence of the three Colombian mountain ranges, along with narrowing and rising of the inter-Andean depressions of the Magdalena Valley and the Cauca - Patía, having in the area of influence of the road alignment the influence of the Patía-Guacara faults, San Ignacio fault, el Romeral faults system, Magdalena rive faults system, Afiladores fault and Pasto fault.

The Guáitara fault, located to the South of the city of Pasto, southwest of Colombia, presents a volcanic cover of Neogene age. This fault has been associated with the Romeral fault system, with a dextral geometry, in accordance with the common behavior of other nearby Quaternary faults; compatible with the field current compression effort WSW-

ENE, causing deep V-shaped valleys, linear topographic features and controlling the surface and underground drainages. (Paris et al., 2000;) Paris, g., 1993, Paris, g., and Romero, j., 1994)

The San Ignacio fault is located to the East of the road alignment about 5 kilometers away, this fault presents a NE direction through the craters of ancient volcanoes, El Gallo, Ocoyuyo and San Fernando.

According to Paris et al., 2000, The Romeral faults System is one of the most active and continuous faults systems in Colombia. The most ancient name is megashear Guayaquil-Dolores, which implies a whole series of parallel fractures in the Colombian west. Its main layout traverses the Galeras volcano, has a N45°E direction and, southbound tends to N10°E, where it continues its layout by the Guáitara river. The Buesaco fault is associated to this system, it is common to find calderitic complexes in these faults' layout.

The Magdalena river faults system starts fromthe Romeral fault with EW and N30°E direction. This trace starting point is located approximately 1 kilometer from the road layout in the sector K2+300. Cuts the UF 4 layout in the first 5 kilometres in three different sectors.

The Afiladores fault occurs 18 kilometers from the road alignment in the Eastern side and is defined as a thrust fault by Ponce, (1979) more South; and excises tectonic control over the La Cocha Lagoon.

The Pasto fault has a direction of N40°E and N50°E and crosses the road project at he height of kilometer 14.7, without tectonic traces in the outcrops od the zone that may evidence the layout of this lining.

The structural and tectonic conditions that generate the mentioned faults and their convergence in the zone of study generate a high degree of joints and fracturing of the present volcanic rocks in the study zone that can be controlling the underground flows whether like zones of preferential flow or barrier zones or underground dikes.

In the study area outcrop Precambrian metamórficas rocks that conform the basement, where there are discordantly supralying rocks and deposits of recent volcanic affinity, in addition to concentrated superficial sediment deposits in the Guáitara river and its main affluents.

The hydrogeological basement of the area is represented by the Migmatite Complex of La Cocha and volcanic rocks such as the La Magdalena Sedimentary Volcanic unit, Lavas unit, Ash Flows and Pumice unit, Lahars and Pyroclasts unit, all rocks that outcrop along the road alignment UF4 and are largely covered by deposits of recent volcanic origin, as well as residual soil or saprolite produced by in situ weathering and in the foothills of the main surface currents there are alluvial deposits.

This hydrogeological basement develops a secondary porosity by fractures and joints of a very local nature that allows the storage of groundwater, since in the regional context it is considered impermeable. The said basement is then recharged by surface currents and rainfall in those locally fractured areas, giving rise to underground flows following the heterogeneous inclination of fractures and joints, where the storage capacity is dependent on the density of the fracturing, the amplitude of these fractures, their deepening and filling.

In general, considering the tectonics and convergence of the different fault systems, two NNE - SSW preferential directions are manifest, longitudinal and extensive, common throughout the Western Mountain range and smaller transverse systems are manifested in NE - SW direction, the underground flow is controlled by this situation, and their discharge occurs through a small number of springs that contribute to the base flow of small streams, which in turn contribute to the recent alluvial deposit recharge.

The recent deposits in the study area covering in sectors the hydrogeological basement are the volcanic deposits with no differences (TQvsd), the terrace alluvial deposits (Qt), the colluvial deposits (Qc) and the alluvial deposits (Qal), all of which are heterogeneous deposits of dragged materials as a consequence of the strong slopes in the area and varied composition of the different rocks present in the study area, as well as the deposition by the volcanic activity in the area, these deposits develop a primary porosity .

Of these deposits the hydrogeological behavior is homogeneous for volcanic deposits with no differences (TQvsd) and the terrace alluvial deposits (Qt) which do not have great hydrogeological importance since their storage capacity is very low and they do not have the capacity to transmit water . In spite of this hydrogeological condition, springs with very low flows can be developed in the contact of the rock and the deposits, this can occur more frequently in areas of steep slope. The behavior of the flows in these deposits is primarily influenced by the topography in which they are, always considering a direction of flow in the direction of the topography, always from a greater elevation and following the gradient of the topography.

Colluvial deposits (Qc) and alluvial deposits (Qal) are characterized by a predominantly fine lithology composed of a clay material, fine sands, silts and gravels, with very little compacting and without obvious structures; where the minerals of the parent rock have largely disappeared due to oxidation and various weathering processes, these allow the development of a primary porosity. These two units are those of greater hydrogeological importance in the study area by their classification as local aquifers and, in the case of the alluvial deposits these can be considered regional. The colluvial deposits have a flow direction in the direction of the slopes in which they are supported, whereas the alluvial deposits are greatly influenced by the adjacent surface currents, reason why their estimated flow directions are those in the same sense as the surface currents and some recharge flows from the rivers to the reservoirs.

In the study area, it is not possible to determine the hydraulic characterization of the hydrogeological basement represented mainly by the different Volcanic units, due to the absence of intakes that allow the execution of pumping tests, conditions associated to the strong compaction of these rocks that make them regionally impermeable, except for those locally fractured areas characterized by the presence of low flow springs. The extrapolation of known hydraulic parameters in other areas, indicates for these rocks only for the fractured zones average values for the Transmissivity of 0.25 m^2 / day with Hydraulic Conductivity of the order of 0.0015 m / day, estimating a thickness for fractured zones between 10 and 20.0 m, which is why it is classified regionally as Aquiclude (waterproof) but locally as Aquitard as it is subject to fracturing density.

As regards the hydrogeological unit formed by the recent volcanic deposits with no differences (TQvsd) and alluvial terrace deposits (Qt), their hydraulic characterization is estimated based on the lithology presented in the samples obtained from the exploratory drilling, field investigations carried out within the study, of which they may have varying thicknesses ranging from 5 m to 80 m and static levels below 20 m depth. An average Hydraulic Conductivity of 0.0007 m / day and values of Transmissivity ranging from 0.0035 to 0.056 m^2 / day have been estimated. Due to the predominance in this unit of fine granulometry with low values for its hydraulic parameters, it is classified as Aquitard.

With regard to colluvial deposits (Qc) and alluvial deposits (Qal) within the field activities and mainly from the inventory, there are contributions as wells by means of which thicknesses between 5 and 20 m are estimated based on their exploitation and composition Lithological analysis, a Hydraulic Conductivity between 0.50 and 0.1 m/day is estimated, with a Transmissivity between 0.5 and 10 m^2/day, conferring properties of a free-type aquifer, its recharge is due to direct infiltration of rainwater and direct recharge from Surface currents.

Based on the results of the hydrogeochemical interpretation of the three sources of groundwater sampled, water predominantly contains bicarbonates and magnesium and sodium contents, showing that the water stored in the hydrogeological units captured by these three sampled sources is young water with little time of travel and permanence in the rock.

As areas of important recharge in the study area are areas with high fracture density due to tectonic activity, and mainly in the high areas where the addition of water that infiltrates precipitation events, also occurs by condensation of fog for much of the day; For alluvial deposits the recharge is given directly by the interaction with the surface currents.

The discharge of the hydrogeological system of the area occurs through low flow springs, interaction with surface currents and to a lesser extent the evapotranspiration generated by the vegetation present in the area.

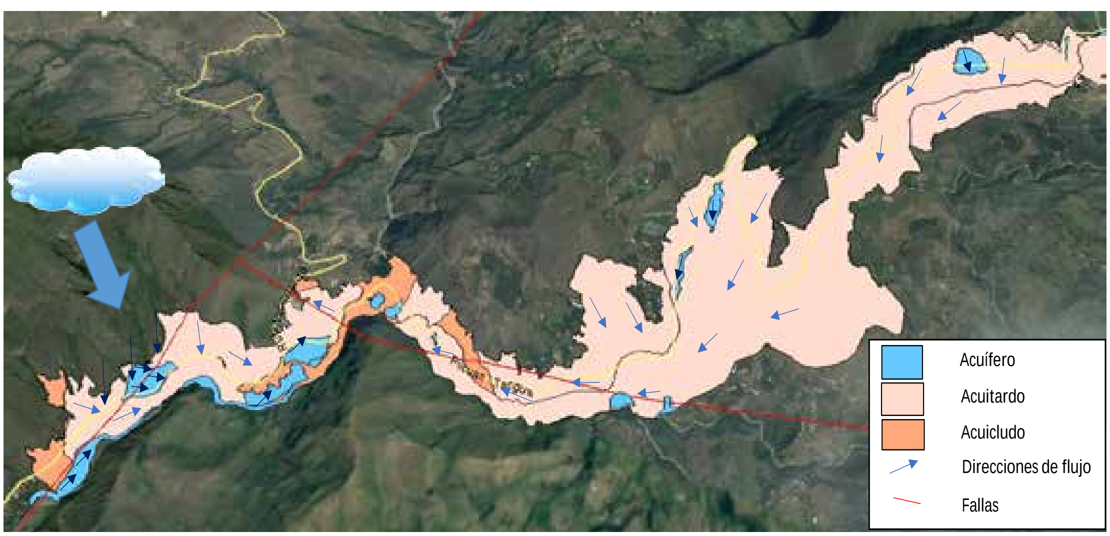


Figure 5.1.120 Behavior of flows in the hydrogeological units of the study area

- Geoelectrical Survey

Within the geophysical methods, the geoelectrical is the mostly applied subsoil study in the exploration and evaluation of aquifer areas due to its low cost, its relative ease of application, and the possibility of correlating its results (resistivity values) with the degree of rocks saturation, lithologic changes and water quality (from brackish to freshwater) which allows permeable and impermeable geological layers, and saturated and unsaturated discriminations.

For the conceptual hydrogeological study of the Pedregal - Pasto road project, a total of 8 vertical electrical surveys (SEV) of 50 meters depth were executed, four SEV's per functional unit.

- *Methodology vertical electrical soundings (SEV)*

The methodology applied in the SEV basically comprises the field data acquisition, information processing and interpretation of the data.

The data acquisition in the executed SEV for this project, was carried out with an Allied Associates resistivity meter with their respective electrodes and wires for current and potential. See Photography 5.1.69.

Photography 5.1.69 Allied Associates resistivity meter
Source: (INGETEC, 2016)

- *Technical specifications of the vertical electrical surveys (SEV)*

An SEV is made via the positioning of four electrodes (points A, B, M, and N in Figure 5.1.103), placed on a surface in a straight line, symmetrically with respect to a central point.

An electric current is then passed through the outer electrodes (A and B) into the subsoil, and this causes a potential drop between the 2 internal electrodes. To start the survey, the current bearing electrodes are placed at a mid-point distance (AB/2) of 1.5 meters and the potential measuring electrodes at a mean distance of 0.5 meters (MN/2). Under the Schlumberger distribution, implemented in this survey, for each survey a series of readings are made, increasing the AB distance each time. The distance between the potential reading electrodes (M and N) expands when the potential fall decreases in such a way that its reading is difficult.

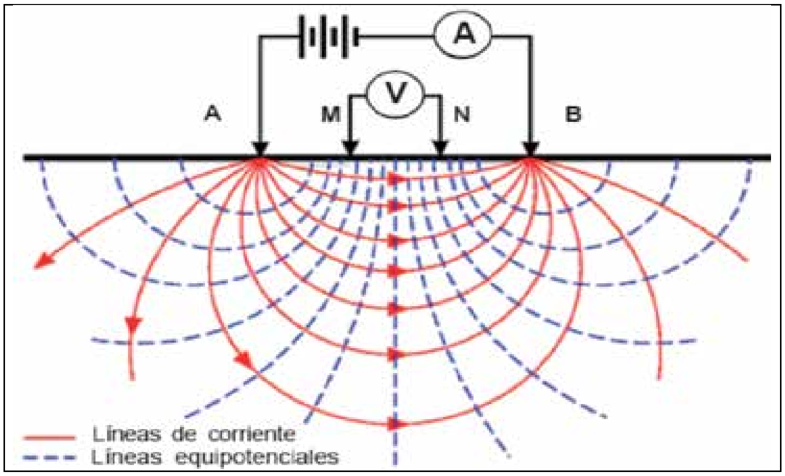


Figure 5.1.103 diagram of a vertical electrical survey SEV or geoelectrical survey
Source: Modified by INGETEC, 2016

- *Interpretation of the vertical electrical surveys*

for the conceptual hydrogeological model of the Rumichaca - Pasto road project, 8 vertical electrical surveys (SEV) with layouts of between 2 and 250 m and distributed in the functional units 4 and 5, which allows information of the resistivities up to 50 m deep. (See Annex 5.1.8, Annex 3. Geological map).

The applied procedure is to compare the resistivities determined for each layer against the theoretical curves established for different types of material. This procedure is done manually when there are 3 or 4 layers in the analysis. (See Table 5.1.58, Figure 5.1.104).

Table 5.1.58 Coordinates of the vertical electrical surveys

UF	SEV	COORDINATES	
		NORTH	EAST
4	UF4-SEV1	607161,0	957309,0
	UF4-SEV2	610090,0	961069,0
	UF4-SEV3	611919,2	962928,8
	UF4-SEV4	613126,0	965610,0
5	UF5-SEV1	613734,0	966067,0
	UF5-SEV2	616923,5	969043,0

UF	SEV	COORDINATES	
		NORTH	EAST
	UF5-SEV3	618385,0	971496,0
	UF5-SEV4	619242,0	974410,0

Source: (INGETEC, 2016)

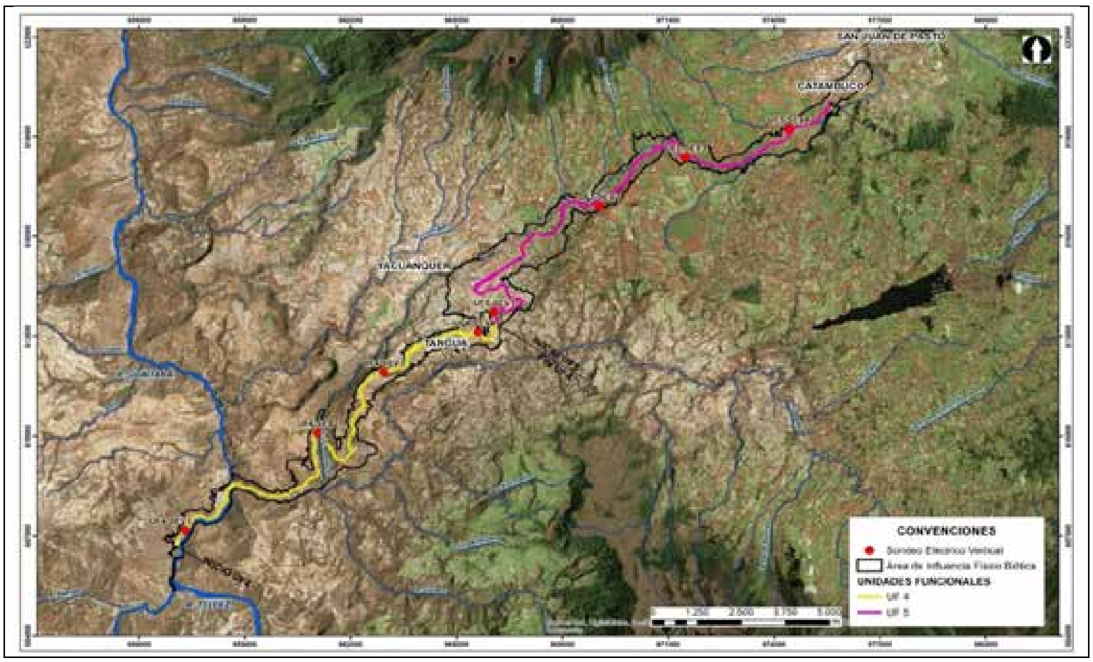


figure 5.1.104 Location of SEV's executed in UF4 and UF5

Source: (INGETEC, 2016)

Below are the results for each of the SEV's executed for this project.

- Functional Unit 4

In the SEV2-UF4, SEV3-UF4 and -SEV4-UF4 low resistivities are observed between 5.0 m and 10.0 m with values between 40 and 60 Ohm. In the UF4-SEV1 the resistivity drop occurs from 25 m depth with values of 10 Ohm (blue color) (Figure 5.1105 and Figure 5.1.106).

The lithology related to the SEV1-UF4 is formed by poorly selected andesites angular fragments, trachites, embedded in glassy matrix, there are some fine ash levels of the Ash Flows and Pumice (TQvf) unit; The SEV2-UF4 and SEV3-UF4 are volcanic agglomerates, embedded in a silty sand matrix composed of plagioclase and volcanic rock lithics from the La Magdalena Volcanic Sedimentary Unit (TQsv); The -SEV5-UF4 was executed in the Lahars and Pyroclasts Unit (TQvlp).

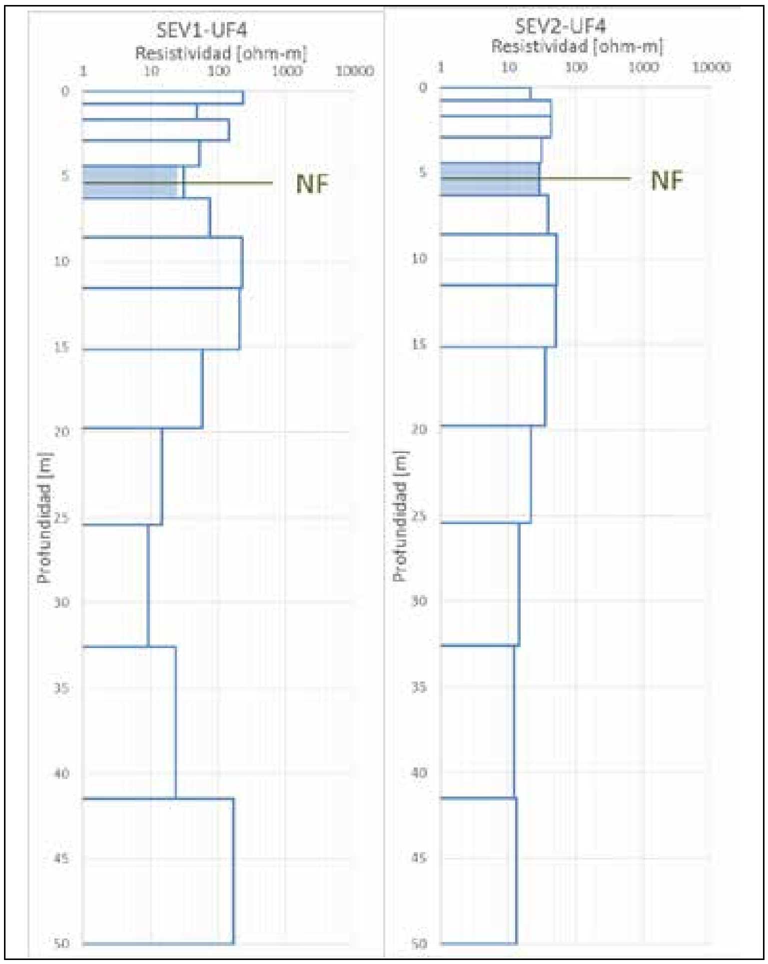


Figure 5.1.121 SEV 1 and 2 Results, functional Unit 4
Source: (INGETEC, 2016)

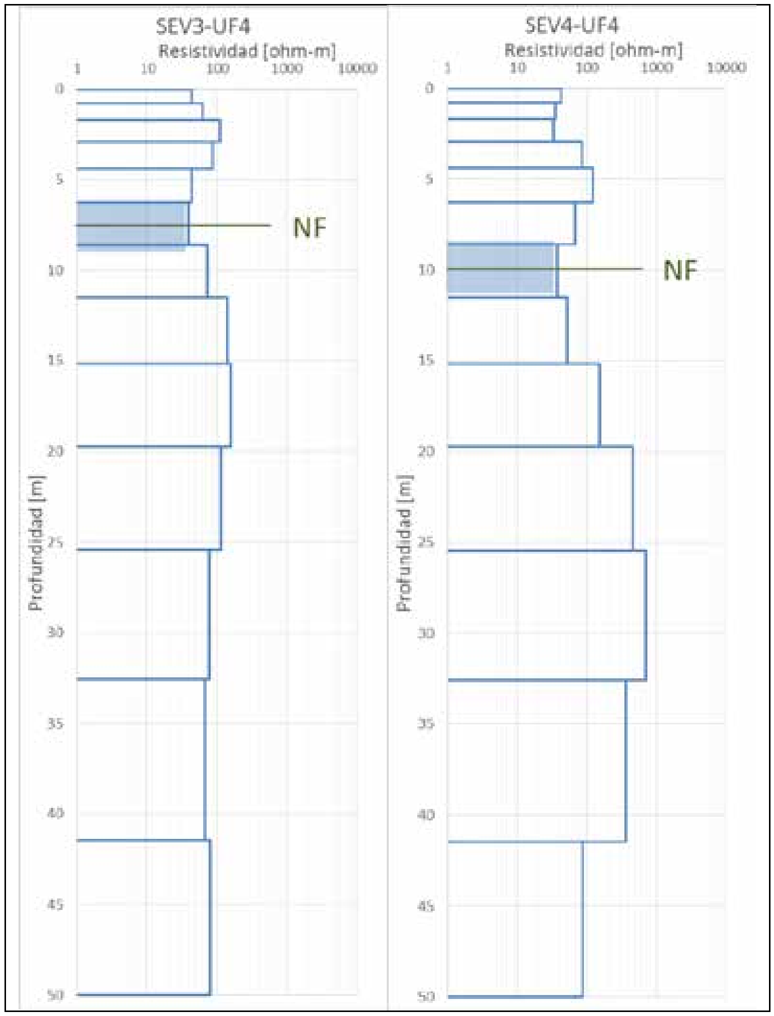


Figure 5.1.122 SEV 3 and 4 Results, Functional Unit 4

Source: (INGETEC, 2016)

- Functional unit 5

In the SEV1-UF5, SEV3-UF5 the resistivity fall occurs between 5.0m and 8.0m with values between 50 and 80 Ohm; In SEV2-UF5, the lowest resistivities occur as of 25 m and 33 m depth with values of 80 Ohm indicating the presence of a saturated permeable zone (blue color) (See Figure 5.1.106 and Figure 5.1.107). SEV2-UF5 does not report saturated areas.

The lythology that is recognized for the SEV1-UF5 is of laharic flows and pyroclastic flows of the Unit (TQvlp); in the SEV2-UF5 the lythology is conformed by ashes of andesitic composition that cover lowly jointed porphyritic andesites, of gray color with plagioclase phenocrysts in a microcrystalline matrix of the Unit of Lavas and Ashes (TQvlc); the UF5-SEV3 presents/displays ashes of lapilli of 4m thickness, weathered andesites with minerals of plagioclase and ferromagnesians in smaller proportion of the Ash Rain Unit (Qvc). The UF5-SEV4 presents fine ashes of andesitic affinity of the Ashes and Pumice Flows (TQvf) unit.

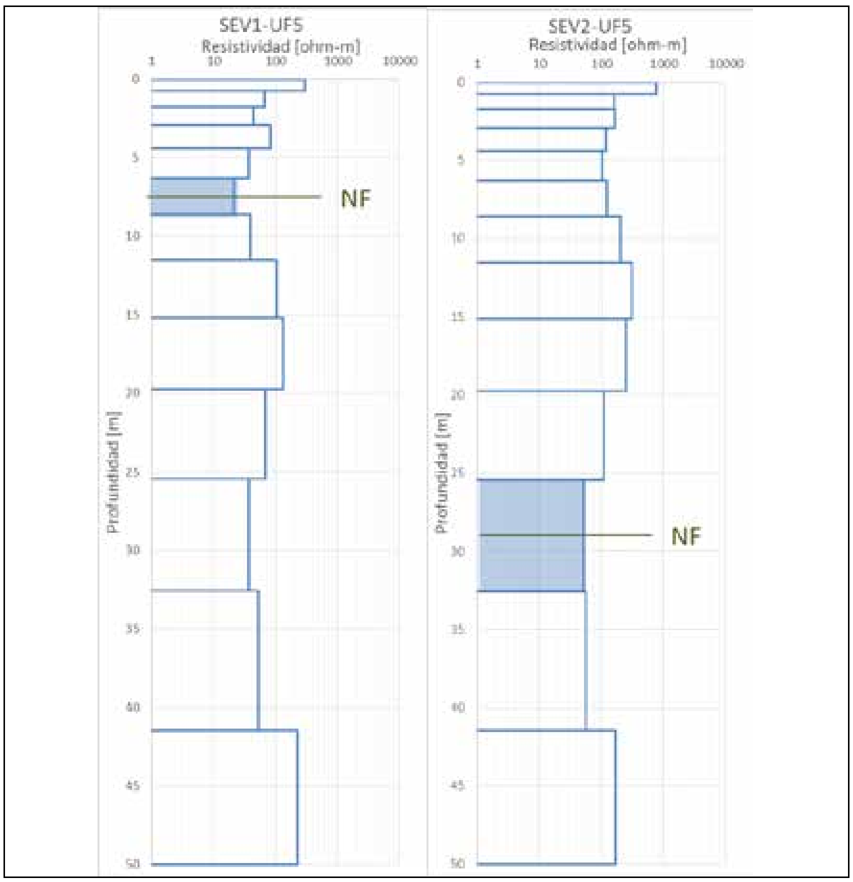


Figure 5.1.123 SEV 1 and 2 Results, functional Unit 5

Source: (INGETEC, 2016)

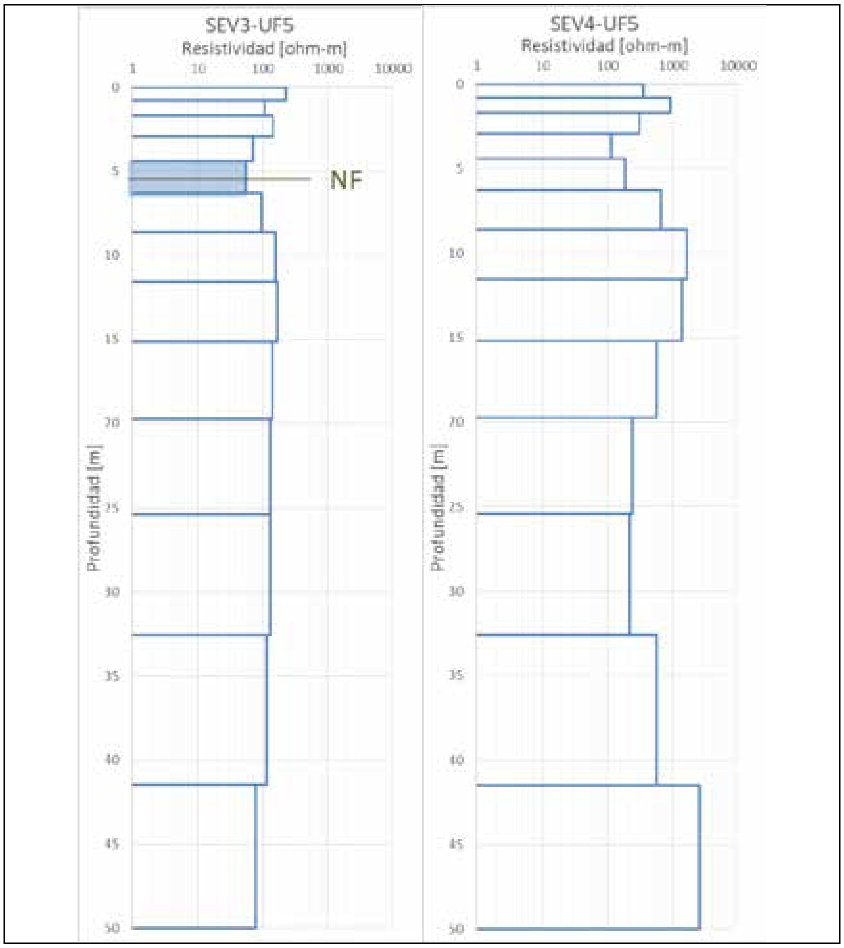


Figure 5.1.124 SEV 3 and 4 Results, Functional Unit 5

Source: (INGETEC, 2016)

- hydrogeochemistry

Based on the inventory of groundwater points described in 5.1.8.2, the groundwater sampling campaign was defined.

The criteria established for the definition of sampling sites correspond to representativeness in functional units, geological units, proximity to works sites, identified uses and users number, thus the sites selected for the UF4 and UF5 are presented in Table 5.1.59.

Table 5.1.45 Sites selected for underground water sampling of UF4 and UF5

UF	POINT	EAST	NORTH	LEVEL	PROPERTY NAME	TYPE OF POINT	TYPE OF MATERIAL	USE
UF4	PA-M-32	957408	607351	1809	La Lima	Spring	Cement	Domestic
UF5	PA-M-38	968632	616880	3030	La Ladera	Well	Outbreak	Irrigation and livestock
	PA-A-09	970017	618118	3155	La Joya	Well	Stone	Domestic and livestock

Source: (INGETEC, 2016)

- *Water quality*

The sampling campaign was carried out on September 28, 2016. Samples acquisition for laboratory analysis, in situ analysis, preservation and transport was performed by technical personnel of the accredited water quality laboratory for simple, composite and integrated sampling (Ambienciq Ingenieros SAS). In Annex 5.1.8, Annex 1. Water quality, laboratory accreditation resolution, calibration certificates of the equipment, field formats and results are presented. A groundwater characterization was made in three points for the functional units UF 4 and UF 5. See Photo 5.1.64.

Photography5.176 Sample acquisition PA-A-09 Functional Unit 5
Source: (INGETEC, 2016)

Figure 5.1.108 shows the location of the sampling sites.

Figure 5.1.125 Location of UF4 and UF5 underground water quality sampling sites

Source: (INGETEC, 2016)

o Results

The parameters sampled correspond to those established in Table 5 of Resolution 0751 of March 26, 2015, under the titles "Water component" and those specific for the interpretation of hydrochemical analyzes. The results obtained are presented in Table 5.1.60

Table 5.1.60 Quality results for underground waters in UF4 and UF5

Parameter	Unit	Quantification limit	UF4	UF5	
			PA-M-32	PA-M-38	PA-A-09
Conductivity at 25°C	µS/cm	0,1	208	149	144,5
pH at 25°C	Units	0,01	6,99	6,04	7,26
Temperature	°C	0,1	21,1	13,7	10,5
Dissolved Oxygen	mg/L	0,01	6,86	5,14	5,58
Color	UPC	5	<5	9	<5
Turbidity	UNT	0,01	1,6	55	1,7
Acidity at pH 8.3	mg/L	9,99	15	20	15
Alkalinity at pH 4.5	mg/L	3,77	92	52	29
Bicarbonates	mg/L	NE	87	51	27
Chlorides	mg/L	5	<5	<5	14
Calcium hardness	mg/L	12	31	36	30
Total hardness	mg/L	5	163	64	89
COD	mg/L	15	<15	<15	<15
BOD	mg/L	3	3	5	7
Oils and Greases	mg/L	0,9	<0,9	<0,9	<0,9
Total Phenols	mg/L	0,01	<0,010	<0,010	<0,010
Total Nitrogen	mg/L	0,5	2,3	2,3	2,3
Total phosphorus	mg/L	0,05	0,27	0,3	0,25
Sulphates	mg/L	3	12	11	11
Total suspended solids	mg/L	6	8	122	<6
Total dissolved solids	mg/L	10	151	140	88

Parameter	Unit	Quantification limit	UF4	UF5	
			PA-M-32	PA-M-38	PA-A-09
Sedimentable solids	mL/L-h	0,1	0,1	1,5	0,3
Arsenic	mg/L	0,005	<0,005	<0,005	<0,005
Barium	mg/L	0,4	<0,4	0,4	<0,4
Cadmium	mg/L	0,0005	<0,0005	<0,0005	<0,0005
Calcium	mg/L	0,1	1,99	1,51	3,5
Copper	mg/L	0,1	<0,10	<0,10	<0,10
Chrome	mg/L	0,1	<0,10	<0,10	<0,10
Magnesium	mg/L	0,01	10,1	5,15	2,85
Mercury	mg/L	0,002	<0,002	<0,002	<0,002
Nickel	mg/L	0,1	<0,10	<0,10	<0,10
Silver	mg/L	0,05	<0,05	<0,05	<0,05
Lead	mg/L	0,001	<0,001	<0,001	<0,001
Potassium	mg/L	0,05	3,7	3,08	4,88
Selenium	mg/L	0,005	<0,005	<0,005	<0,005
Sodium	mg/L	0,05	14,33	11,65	16,85
Zinc	mg/L	0,03	<0,03	<0,03	<0,03
Fecal Coliforms	NMP/100 mL	1	<1,0	200	100

Source: (INGETEC, 2016)

- Analysis of results

The temperature is highlighted within the in situ parameters, with oscillating values between 10 and 21°C, consistent with the climatic conditions of the area. The lowest temperature is present in the PA-A-09 well which is located in the moorland zone (3155 masl). The PA-M-38 recorded a temperature of 13.7 ° C spring located at 3030 masl and the spring identified as PA-M-32 located at the altitude 1809 masl, reported a temperature of 21 ° C.

The term pH is a way of expressing the concentration of the hydrogen ion or, more accurately, the activity of the hydrogen ion. According to the values obtained in the sampling in the study area, pH values between 6.04 and 6.99 were recorded for the springs, and 7.26 units in the well, with a trend towards basicity. (See Figure 5.1.109)

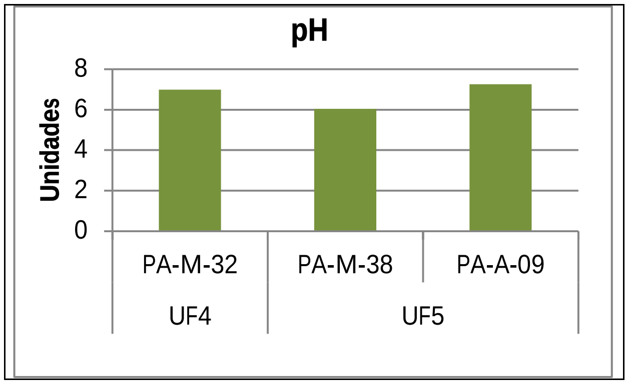


Figure 5.1.126 pH Data for UF4 and UF5
Source: (INGETEC, 2016)

The degree of alkalinity of the waters is determined as follows:

Low Alkalinity: < 50 mg $CaCO_3$/l
Average alkalinity: 50 – 150 mg $CaCO_3$/l
High Alkalinity: > 150 mg $CaCO_3$/l

The alkalinity in water bodies is due to the presence of bicarbonates, carbonates and hydroxides, however, it does not in itself present harmful effects to the consumer. From the results obtained it is concluded that the well sampled in the UF5, identified as PA-A-09, presents low alkalinity and the two PA-M-32 (UF4) and PA-M-38 (UF5) springs report average alkalinity. With regard to acidity, the three groundwater bodies have similar values (between 15 and 20 mg/l) (See Figure 5.1.110).

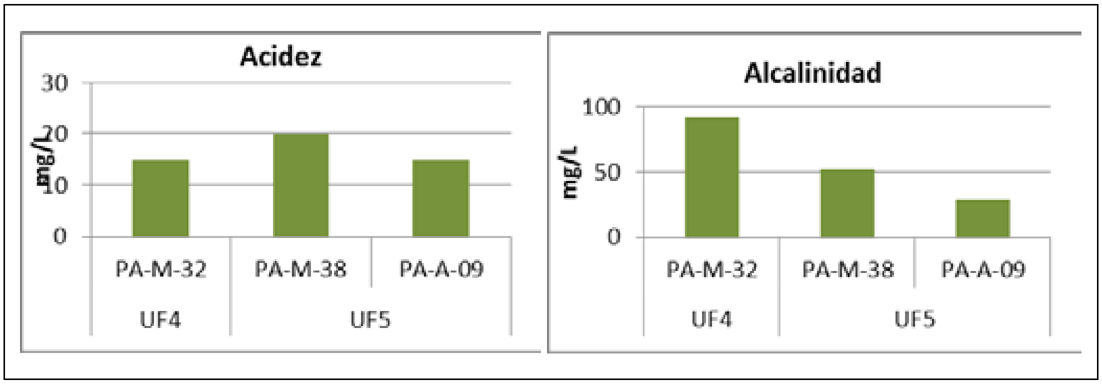


Figure 5.1.127 Acidity and alkalinity UF4 and UF5

Source: (INGETEC, 2016)

The dissolved oxygen at the three sites sampled has concentrations between 5.1 and 6.8 mg/L, considering that there is contact with air in the atmosphere (See Figure 5.1.111).

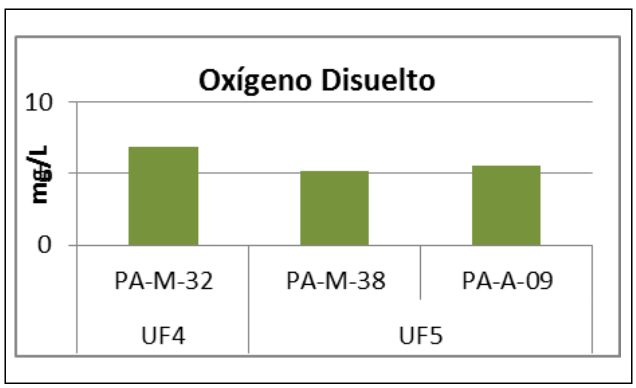


Figure 5.1.128 Dissolved Oxygen UF4 and UF5

Source: (INGETEC, 2016)

The COD in groundwater varies from 1 to 15 mg/L, a range within which the values reported in the three bodies of water sampled for UF 4 and UF5 are found. The biochemical oxygen demand reported higher concentrations in the well identified as PA-A-09 at 1 mg/L, associated with the amount of oxygen needed to eliminate the organic matter contained in water by aerobic biological processes (See Figure 5.1. 112).

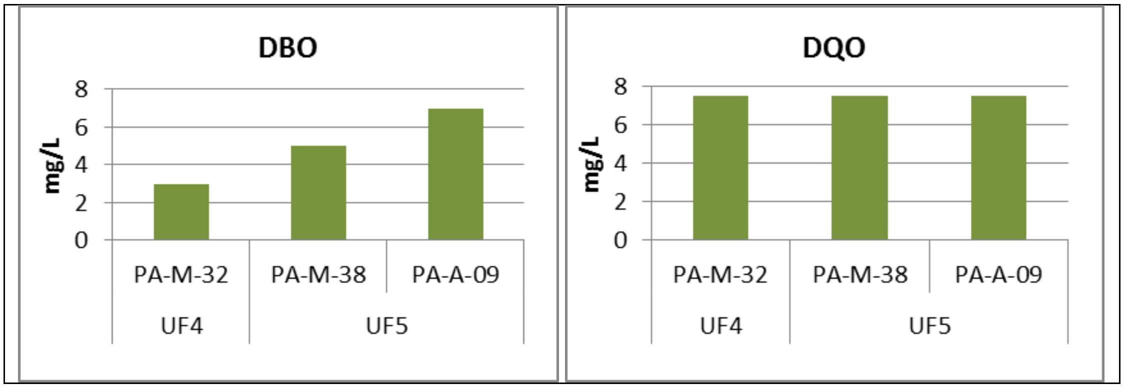


Figure 5.1.129 BOD - COD results for UF4 and UF5

Source: (INGETEC, 2016)

Water conductivity is a numerical expression of its ability to carry an electric current, which depends on the total concentration of dissolved ionized substances in the water. As shown in Figure 5.1.113, the behavior of the conductivity is similar to the behavior of the dissolved solids, obtaining higher values in the spring located in the UF4 identified as PA-M-32 and lower values in the UF5 well identified as PA-A-09.

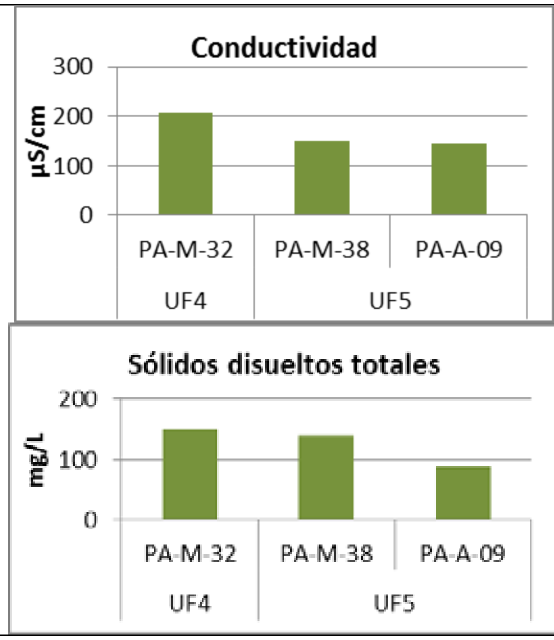


Figure 5.1.130 Conductivity and Total Dissolved Solids Results for UF4 and UF5
Source: (INGETEC, 2016)

The majority of the ions dissolved in the groundwaters correspond to chlorides, bicarbonates, sulphates, calcium, magnesium, sodium and potassium. As shown in Figure 5.1.114, the chlorides in the sampled groundwaters of UF4 and UF5, report low concentrations (14 mg/l in well PA-A-09) and concentrations below the detection limit (<5 mg/l) in the two springs.
The sulfate ion comes from the washing of terrains formed in the marine environment, from the oxidation of sulfides that are widely distributed in igneous and sedimentary rocks and from the decomposition of organic substances. Etc. However, the dissolution of gypsum (CaS0, 2H20) and anhydrite (CaSO) and other types of sulfates dispersed in the ground frequently represent the most significant contribution of this ion to groundwater. The two springs and the sampled well report low sulphate concentrations (11 and 12 mg/L)

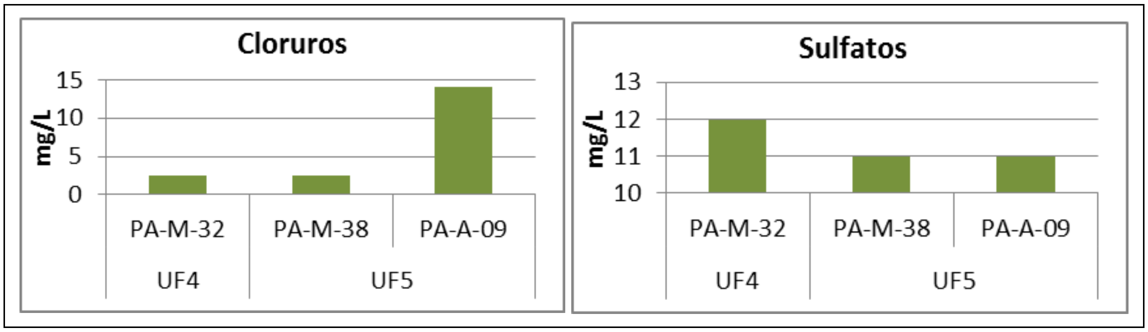


Figure 5.1. 4 131Chlorides and Sulphates results for UF4 and UF5
Source: (INGETEC, 2016)

The calcium ion is usually the main cation in most natural waters due to its widespread diffusion in igneous, sedimentary and metamorphic rocks. The magnesium ion comes from the dissolution of carbonate rocks (dolomites and magnesium limestones), evaporites and the alteration of ferromagnesian silicates. For the three bodies of water sampled, there is evidence of higher concentrations of magnesium compared to calcium (See Figure 5.1.115).

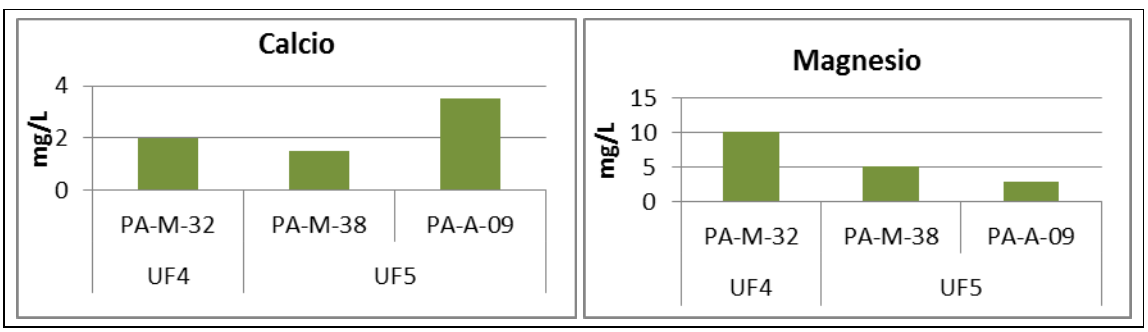


Figure 5.1.132 Calcium and Magnesium Results for UF4 and UF5
Source: (INGETEC, 2016)

Sodium is a very active metal, which does not exist free in nature. All sodium salts are very soluble in water, so it is very common to find waters with sodium. Concentrations ranging from 11.6 mg/L to 16.8 mg/l were reported in the three bodies of water sampled.

Potassium ion comes from the weathering of feldspars and occasionally from the solubilization of evaporite deposits, particularly silvine (KCl) or carnalite (KCl $MgCl_2$) salts. Potassium tends to be irreversibly fixed in clay formation and adsorption processes on the surface of minerals with high ion exchange capacity. In groundwater it usually does not exceed 10 mg/l, which is consistent with the results obtained in the monitoring campaign carried out in the three water bodies of UF4 and UF5 (See Figure 5.1.116).

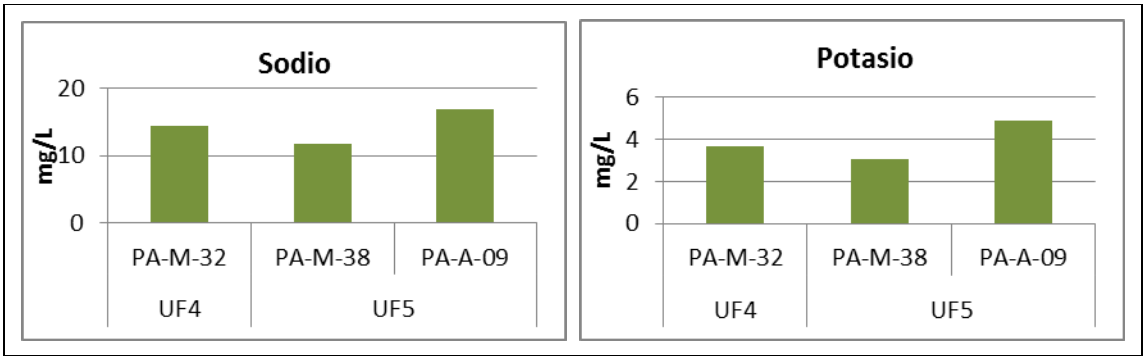


Figure 5.1.1336 Sodium and Potassium results for UF4 and UF5
Source: (INGETEC, 2016)

Phosphorus forms part of a minor constituent of groundwater, is found in lower concentrations considering its tendency to form complex ions and compounds of low solubility with an extensive number of metals and to be adsorbed by hydrolyzed sediments, especially clay minerals, on the ground. The concentrations are between 0.25 and 0.3 mg/L for the three sites sampled.

Total nitrogen is the measure of all the various forms of nitrogen found in a sample. The two springs and the well reported a low concentration corresponding to 2.3 mg/L (See Figure 5.1.117).

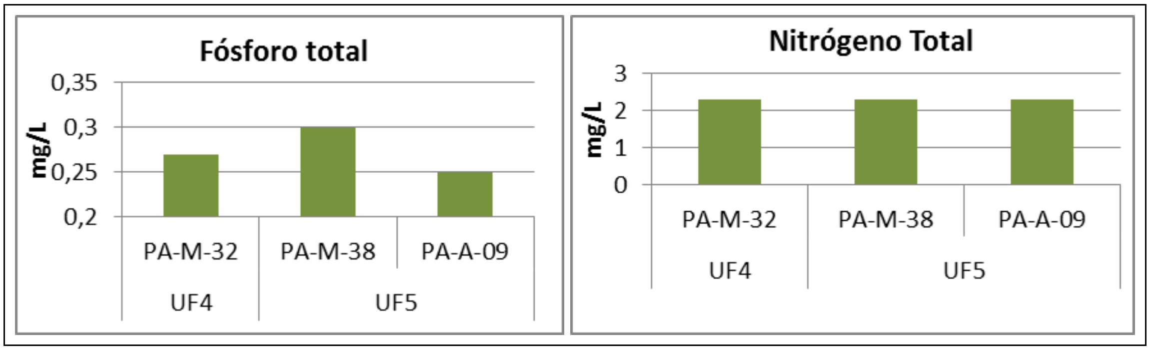


Figure 5.1.134 Phosphorus and Total Nitrogen Results for UF4 and UF5
Source: (INGETEC, 2016)

In terms of hardness, the waters can be classified as:

0 - 75 mg/L	Soft
75 – 150 mg/L	Moderately Soft
150 – 300 mg/L	Hard
>300 mg/L	Very Hard

In view of the foregoing, the spring identified as PA-M-38 is classified as soft water with a concentration of 64 mg/L $CaCO_3$, the well identified as PA-A-09 is classified as moderately soft water with a concentration of 89 mg/L $CaCO_3$ and the spring identified as PA-M-32 is classified as hard water with a concentration of 163 mg/L $CaCO_3$ (See Figure 5.1.118).

The obtained hardness values are considered concordant with the concentrations of calcium and magnesium obtained in the three bodies of water monitored.

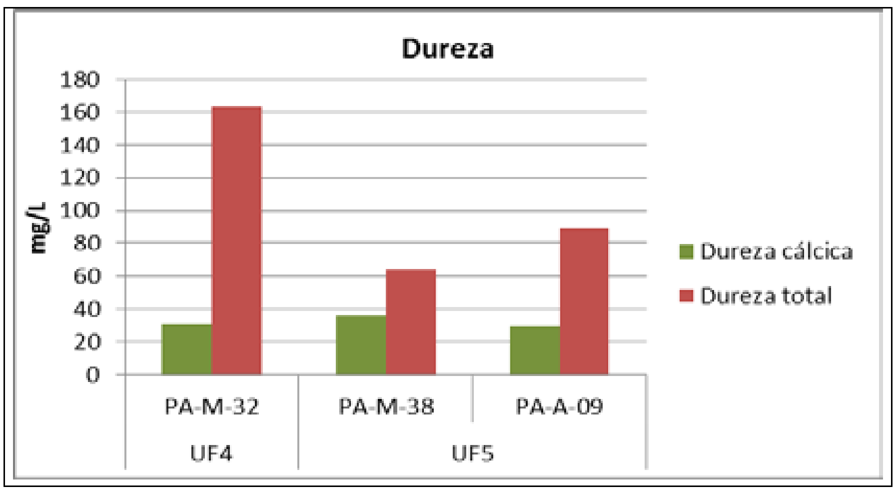


Figure 5.1.135 Calcium and Total Hardness Results for UF4 and UF5
Source: (INGETEC, 2016)

The coliform group includes bacillary, aerobic and facultative anaerobic, Gram-negative, non-spore forming bacteria. Coliforms not only come from human excrement, but can also originate in warm-blooded and cold-blooded animals, and in the soil; Therefore, the presence of coliforms in surface water indicates contamination from human, animal or soil erosion separately, or from a combination of the three sources.

As shown in Figure 5.1.119, the amount of fecal coliforms accounts for less than 1% of the total coliforms, so it is inferred that the contribution of coliforms at the three sampling sites has a predominant soil origin.

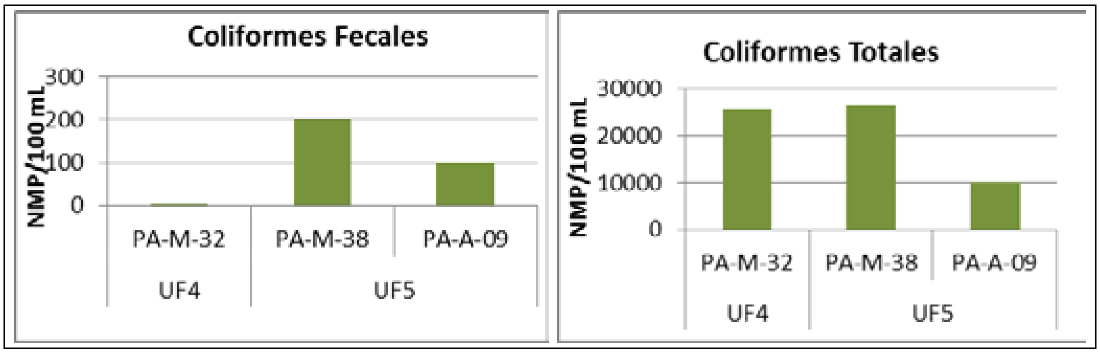


Figure 5.1.136 Fecal coliforms and Total coliforms results for UF4 and UF5
Source: (INGETEC, 2016)

As regards to the heavy metals arsenic, barium, cadmium, copper, chromium, mercury, nickel, silver, lead, selenium and zinc, the sampled groundwater exhibits low values, reporting values below the level of detection according to the technique used.

Table 5.1.61 shows the limit values established in Decree 1594 of 1984 for different uses.

Table 5.1.6 Quality criteria of resource destination for various uses (Decree 1594 of 1984)

Parameter	Human and domestic Treatment. Conventional	Human and domestic Treatment. Disinfection	Agricultural	Livestock	Recreational primary contact	Recreational secondary contact
pH	5 - 9 units	6.5 to 8.5 units	4.5 -9.0 units	------	5 - 9 units	5 - 9 units
Color	75	20 Units	------	------	------	------
Turbidity	------	10 UJT	------	------	------	------
Chlorides	250	250	------	------	------	------
Phenolic compounds	0,002	0,002	------	------	0,002	------
Sulphates	400	400	------	------	------	------

Parameter	Human and domestic Treatment. Conventional	Human and domestic Treatment. Disinfection	Agricultural	Livestock	Recreational primary contact	Recreational secondary contact
Arsenic	0,05	0,05	0,1	0,2	------	------
Barium	1	1	0,1	------	------	------
Cadmium	0,01	0,01	0,01	0,05	------	------
Copper	1	1	0,2	0,5	------	------
Chrome	0,05	0,05	0,1	1	------	------
Mercury	0,002	0,002	------	0,01	------	------
Nickel	------	------	0,2	------	------	------
Silver	0,05	0,05	------	------	------	------
Lead	0,05	0,05	5	0,1	------	------
Selenium	0,01	0,01	0,02	------	------	------
Zinc	15	15	0,05	25	------	------
Total Coliforms	20000	1000	5000	------	1000	5000
Fecal Coliforms	2000	------	1000	------	200	------

Source: Modified by INGETEC, 2016

Based on the results obtained, it is evident that the three bodies of water monitored registered concentrations and values within the ranges established in Decree 1594 of 1984 except for total coliforms, which exceed all the limits established in the regulations, These waters are not suitable for human consumption from the microbiological point of view.

In addition, the pH of the PA-M-38 spring is outside the established range to destine the resource for human and domestic consumption where only disinfection is required for its treatment

- *Hydrogeochemical characterization of water*

The source of groundwater and primary chemical composition is in rainwater, once it is infiltrated it will depend directly on the minerals it comes into contact with in the aquifer, and on the interaction time it has with them, which can be thousands of years. Thus, the longer the retention time in the aquifer, the greater will the amount of salts present in the water, due to the greater dissolution of these. A sequence is then determined, which says that the waters with less time of permanence in the subsoil will be generally bicarbonated, and with the passage of time they become sulfated and finally chloruriated.

Analogously for cations, the waters that are initially calcium loaded become magnesium loaded and then sodium loaded:

$$HCO_3^{-} \rightarrow SO_4^{2-} \rightarrow Cl^{-}$$
$$Ca^{2+} \rightarrow Mg^{2+} \rightarrow Na^{+}$$

The aim of the Hydrogeochemical analysis of groundwater is to determine the main and predominant chemical composition of the water captured in the springs and well of the monitoring campaign for functional units 4 and 5; In addition, to have a vision about the chemical evolution, which occurs once the water enters the process of recharge, transit and later discharge into water points.

This analysis is based on the relation of the cations and major anions of groundwater with the mineralogical composition of the rocks through which it circulates, including also the residence time and transport. The cations analyzed are Calcium (Ca++), Magnesium (Mg++), Sodium (Na+) and Potassium (K+), and the anions analyzed are Bicarbonate (HCO3-), Sulphates (SO4=) and Chlorides (Cl-).

- Classification by Dominant Ions

The classification of groundwaters by dominant ions corresponds to the anion or cation which exceeds 50% of the respective sum. In case of not exceeding 50%, the most abundant ions will be named. For this classification, the Piper and Stiff diagrams are used, as illustrated in Figure 5.1.120.

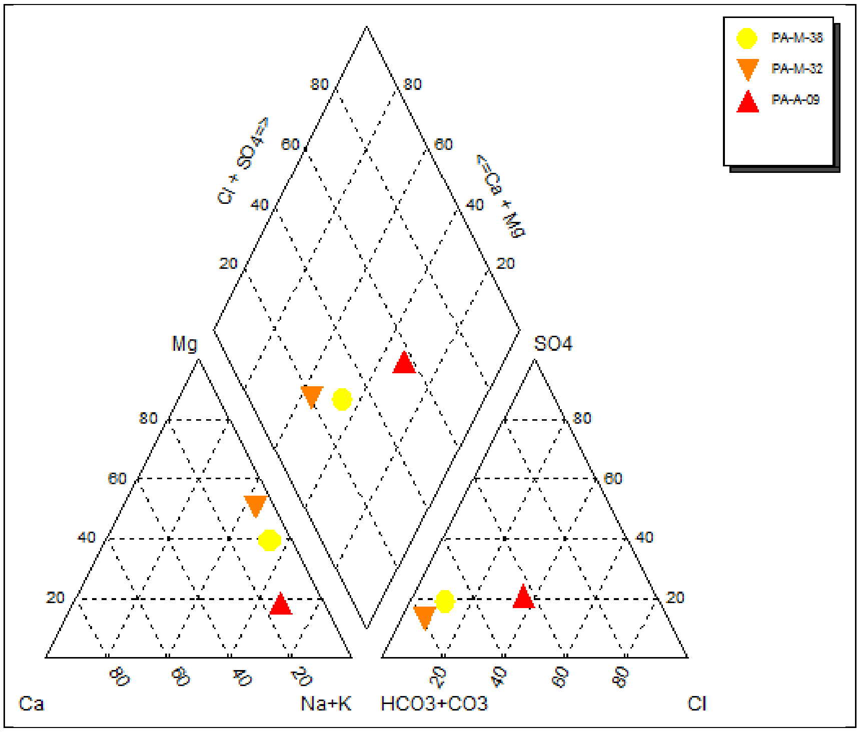


Figure 5.1.137 Piper Diagram for UF4 and UF5
Source: (INGETEC, 2016)

Figure 5.1.104 is representing a water with the following composition for each of the sampled sites of UF4 and UF5 (See Table 5.1.62).

Table 5.1.62 Water composition, Piper diagram

Parameter		Cations			Anions		
		Calcium	**Magnesium**	**Sodium + Potassium**	**Bicarbonates**	**Chlorides**	**Sulphates**
Unit		**%**	**%**	**%**	**%**	**%**	**%**
UF4	**PA-M-32**	5	50	43	80	7	15
UF5	**PA-M-38**	8	40	58	70	10	19
	PA-A-09	18	18	70	45	38	20

Source: (INGETEC, 2016)

Piper's triangular diagram indicates that the water composition of the spring identified as PA-M-32 of UF 4, presents a water chemistry with predominance in calcium and magnesium cations, poor in chlorides and sulfates and predominance in bicarbonates.

The water composition of the spring identified as PA-M-38 of the UF 5, presents similarity to the composition of the spring of the UF4, represented mainly by bicarbonates.

The waters of the PA-A-09 well have chlorinated sodium water and low values of calcium and magnesium cations. (See Figure 5.1.121, Figure 5.1.122 and Figure 5.1.123)

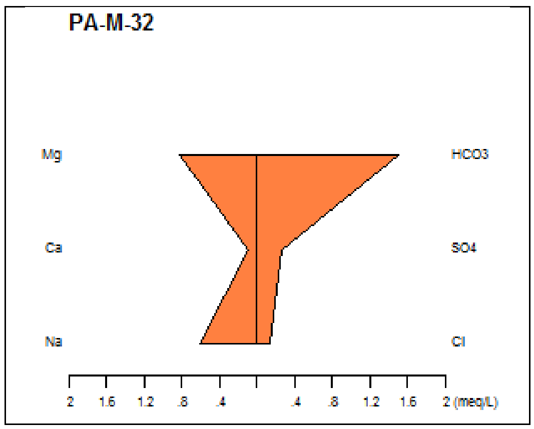


Figure 5.1.138 Stiff Diagram PA-M-32
Source: (INGETEC, 2016)

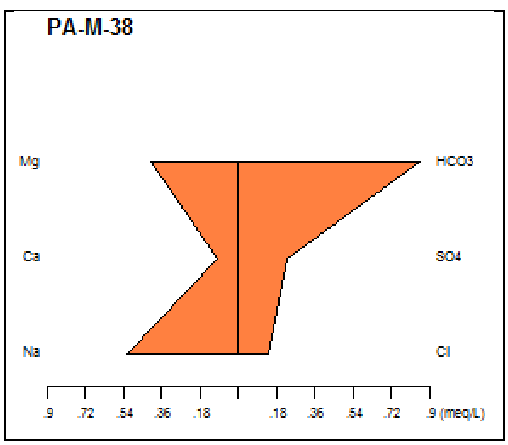


Figure 5.1.139 Stiff Diagram PA-M-38

Source: (INGETEC, 2016)

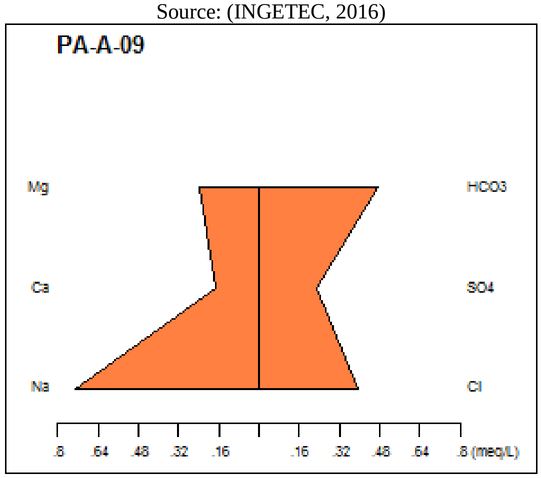


Figure 5.1.140 Stiff Diagram PA-A-09
Source: (INGETEC, 2016)

The Table 5.1.63 shows the classification presented in the Stiff diagrams. In general, it is observed that the waters of the three bodies of water present a sequence with bicarbonate predominance, so it is inferred that it corresponds to waters with less time of permanence in the subsoil.

Table 5.1.63 Water composition, Stiff diagram

UF	POINT	CLASSIFICATION
UF4	PA-M-32	Magnesic bicarbonated
UF5	PA-M-38	Sodic bicarbonated
	PA-A-09	Chlorinated bicarbonated sodic

Source: (INGETEC, 2016)

- Conceptual Hydrogeological Model

To understand the groundwater circulation, it is necessary to define what is known as a conceptual hydrogeological model, which involves the permeability characteristics of the rock, the conditions of recharge and discharge of water, the stratigraphic units and the respective local hydrogeological conditions: directions water flow, hydraulic gradients, transmissivity and storage capacity, etc.

To construct the conceptual hydrogeological model, three stages are followed: 1) define the hydrostratigraphic units present in the project area according to the geological and hydrogeological characteristics of each functional unit within the area of influence, 2) prepare a water balance, 3) define the flow system (Anderson, 1991).

Hydrostratigraphic units include the identification and characterization of geological units with lithological and textural features that are related to similar hydrogeological properties and behaviors. These units are the backbone of the conceptual model. Hydrological information associated with precipitation, evaporation, piezometric data, as well as geochemical data are used to analyze the movement of groundwater throughout the system. The piezometric heads define recharge and discharge zones, connections between aquifers and surface water systems.

- *Hydrogeological units*

A hydrogeological unit is defined as a formation or group of geological formations that exhibit uniformity in their hydrogeological characteristics such as porosity, permeability, infiltration capacity, among others. The units were interpreted from lithology, geological structures and their influence on groundwater flow, the identification of water points, the position of the piezometric levels obtained from the geotechnical explorations of the water phase design and the results of vertical electrical surveys (SEV). Since groundwater flow potential is dependent on lithology (depending on which rocks have primary, secondary, or both types of permeability), hydrogeological units tend to coincide with lithological units in which similar hydraulic properties were observed or assumed.

The types of aquifers identified for the Pedregal - Catambuco road project have certain characteristics or parameters that allow to define and estimate of the hydrodynamic functioning; According to the parameters related in terms of porosity, permeability and storage coefficient for this type of materials, which have been adapted from the literature for the classification of hydrogeological units in the area (See Table 5.1.52) according With IDEAM, 2001, the area does not present hydrogeological interest at the regional level (See Figure 5.1.124).

The permeability varies between one material and another in a significant way, being the granular soils the ones that present greater permeability; While the clayey ones are those that present less permeability. Low-permeability pyroclastic products (mainly lithic tuffs and ash deposits), which are interstratified with lava (rocks with no effective porosity but with secondary permeability), which act as almost horizontal barriers to groundwater flow.

Figure 5.1.125 Relationship between texture and porosity[3]. A) Well classified sediment with high porosity; B) Poorly classified sediment with low porosity; C) Well classified sediment with porous grains; D) Well classified sediment with porosity diminished by cementation; E) Porosity developed by rock dissolution; F) Porosity developed by fracture of the rock.

Due to the lithological diversity and the genesis of the volcanic formations in the area, they present hydrogeological characteristics within the group of semiconsolidated and consolidated rocks and sediments. The factors that determined the storage properties in this type of rocks and deposits are related to the anisotropy and heterogeneity of the formation media, which influences the hydrogeological behavior (permeability - transmissivity) of groundwater in this type of material (See Table 5.1.64).

In addition, the spatial arrangement and geometry of the aquifers is mainly controlled by the geological contrast of the permeable, semipermeable and impermeable formations between the different volcanic and sedimentary materials.

[3] Domenico, FA and Schwartz, FW (1998) Physical and Chemical Hydrogeology; John Wiley & Sons, 506 pp.

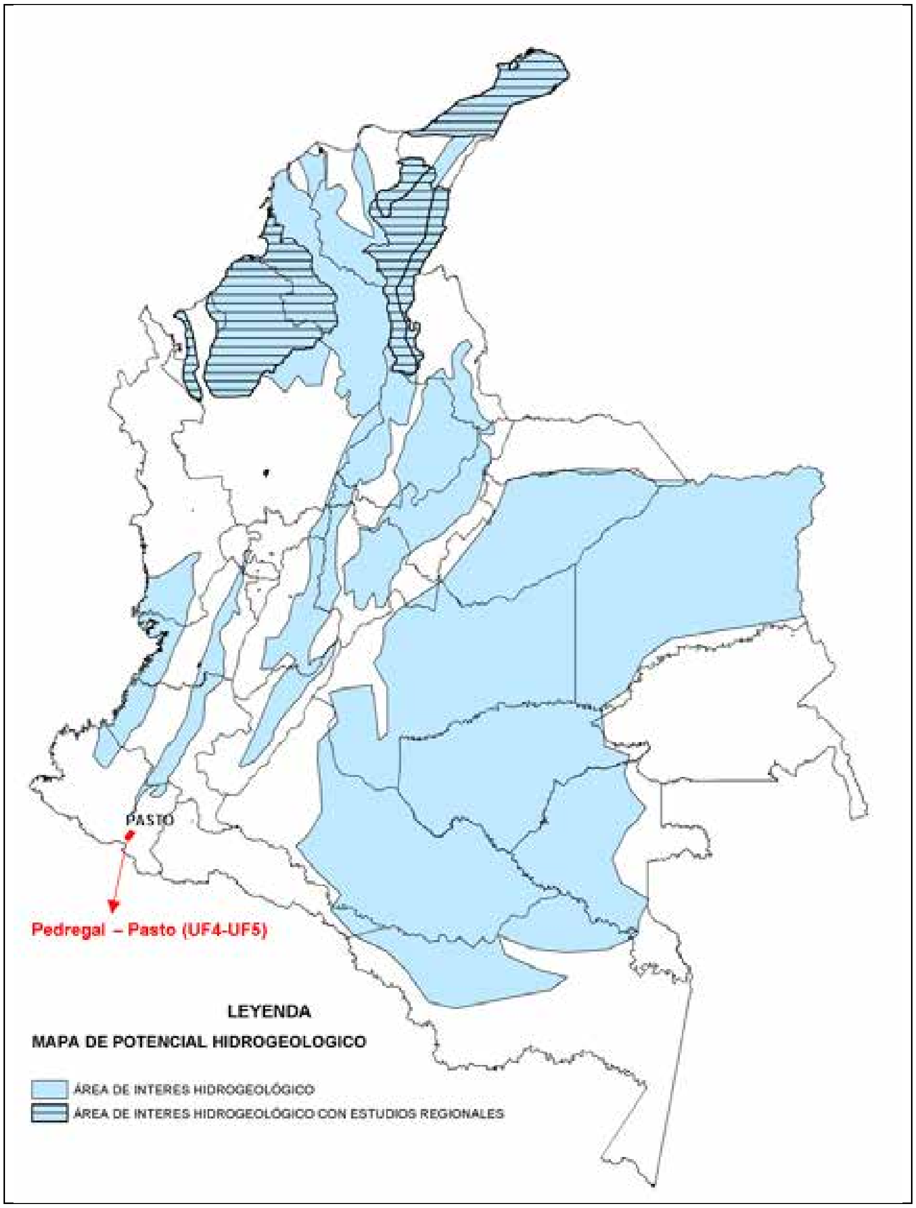


Figure 5.1.141 Hydrogeological potential map of Colombia.

Source: (IDEAM, 2001)

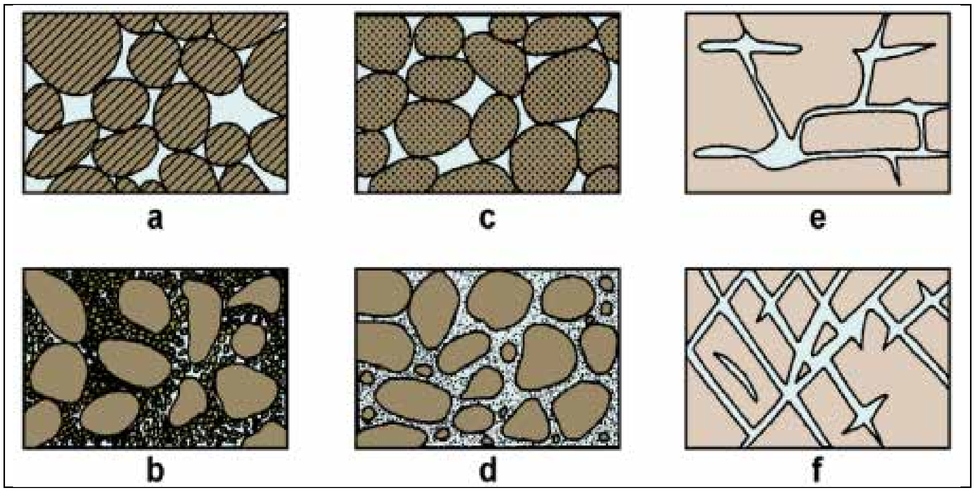


Figure 5.1.142 Relationship between texture and porosity
Source: (INGETEC, 2016)

The definition of hydrogeological units took into account the type of textural packing of the particles that make up each of the units with the greatest storage potential (See Figure 5.1.125); These characteristics determine the pore type and also the porosity as such. The interpretation of the porosity in each of the volcanic deposits takes into account the following classification:

- Deposits of homogeneous granulometry that attribute greater effective porosity.
- Deposits with heterogeneous granulometry and intermediate porosity.
- Deposits with homogeneous granulometry whose porosity has decreased by cementing of their interstices.

The differences in porosity between deposits lie in the following aspects of the hydrogeological analysis:

- Form of the grains that determine the shape and dimensions of the pores.
- Arrangement of the grains.
- Size of the grain, its influence on porosity.

The porosity of the volcanic rocks is very variable depending on the formation process, varying between 10 and 50% in pyroclastic rocks and less than 5% in massive lavas and without vesicles (Custodio, 1978).

Table 5.1,64 Total and effective porosities of diverse geological materials.[4]

Material		Porosidad, n (%)					Porosidad eficaz n_e (%)		
		Valores normales			Valores extraordinarios				
Tipo	Descripción	Media	Máx.	Mín.	Máx.	Mín.	Media	Máx.	Mín.
Rocas masivas	Granito	0.3	4	0.2	9	0.05	< 0.2	0.5	0.0
	Caliza masiva	8	15	0.5	20		< 0.5	1	0.0
	Dolomía	5	10	2			< 0.5	1	0.0
Rocas metamórficas		0.5	5	0.2			< 0.5	2	0.0
Rocas volcánicas	Piroclastos y tobas	30	50	10	60	5	< 5	20	0.0
	Escorias	25	80	10			20	50	1
	Pumitas	85	90	50			< 5	20	0.0
	Basaltos densos, fonolitas	2	5	0.1			< 1	2	0.1
	Basaltos vacuolares	12	30	5			5	10	1
Rocas sedimentarias compactadas	Pizarras	5	15	2	30	0.5	< 2	5	0.0
	Areniscas	15	25	3	30	0.5	10	20	0.0
	Creta blanda	20	50	10			2	5	0.2
	Calizas detríticas	10	30	1.5			3	20	0.5
Sedimentos	Aluviones	25	40	20	45	15	15	35	5
	Dunas	35	40	30			20	30	10
	Gravas	30	40	25	40	20	25	35	15
	Loess	45	55	40			< 5	10	0.1
	Arenas	35	45	20			25	35	10
	Depósitos glaciares	25	35	15			15	30	5
	Limos	40	50	35			10	20	2
	Arcillas sin compactar	45	60	40	85	30	2	10	0.0
	Suelos superiores	50	60	30			10	20	1

Source: (INGETEC, 2016)

- *Geological model for the area of intervention*

4 ITGE (1987) Taluses Engineering Manual; 1st Edition. Technological and Geomining Institute of Spain. pp. 456

There are outcrops of rocks and deposits of Pliocene - Holocene age, as well as colluvial and alluvial deposits of Holocene age in the Pedregal - Catambuco road corridor (Annex 5.1.8, Annex 3. Geological map). The basement is formed by precambrian rocks that correspond to igneous rocks of granodioritic composition affected by blastesis phenomena, and metamorphic mainly gneiss, paragneiss and amphibolites of the Migmatitic Complex of La Cocha unit

the structural style of the region is complex, due to the convergence of large fault systems that define northward the boundaries between the three Colombian mountain ranges. The geological structures demonstrate the tectonic activity that has given the current Northern Los Andes mountainous system their profile, predominantly n-ne high-angle faults, as well as some branching in direction NW - SE.

- *Analysis Sections*

Eight analysis sections were defined for the area of influence of the Pedregal - Catambuco road corridor to complement the hydrogeological analysis, distributing four per functional unit, in order to determine in depth the thickness of the Geology Units for Engineering - UGI (annex 5.1.8, annex 4. Analysis Sections). The information obtained from the geoelectric of Vertical Electric Surveys (SEV) sections, is correlated with information from the geological sections, in order to estimate the depths that are saturated permeable areas according to the contrast of resistivity of different materials. Also included is the information from the phreatic levels obtained from the piezometers in the design stage, and the relationship with the presence of water areas to determine the type of aquifer to which they belong, complemented with porosity and permeability.

In general the water table defined for the different sections of analysis is below 9.0 m in depth and could be linked to the base level of the drainages of major river basins as the rivers Guáitara and Bobo, the La Magdalenacreek and the Hato Viejo Creek near the city of Pasto; it will not be affected by the construction of the divided highway project between Pedregal and Catambuco.

o Functional Unit 4

ü Section A-A

Location: It is located between the coordinates N607302; E957092 and N607067; E957452, direction NW - SE, the section is 450 m long. Scale 1:2500 (see annex 5.1.8, annex 4. Analysis sections) (see Figure 5.1.126).

Geology units for Engineering : The section crosses a 3 m thick colluvial (Qc) deposit, matrix supported with angular fragments of andesites, that lie on top of a stream of debris consisting of poorly selected sharp fragments of andesites, trachytes, embedded in a sandy silty matrix, with some levels of fine ash from the Ash flows and Pumice(TQvf) unit, as can be seen in the survey PEPA-PT-TAL-1. The Ash Flows and Pumice (TQvf) unit lies on top of joined porphyritic andesites (N65 ° W / 77 ° NE), grey colored formed of plagioclase phenocrysts andfeldspar in a microcrystalline matrix of the Lavas (TQvl) unit .

the colluvial deposit (Qc) belongs to the hydrogeological Free Sediment with essentially intergranular flows (Albp) unit. The geological Ash Flows and Pumice (TQvf) unit corresponds to the hydrogeological Rocks and Semipermeables Sediments of low productivity (Aspbp) unit. The geologic Lava (TQvl) unit corresponds to the hydrogeological Impermeable Rocks with Limited underground Water resources (Ri) unit.

The Romeral fault located 200 metres west of the SEV, would be responsible for deepening the phreatic level to 17 meters.

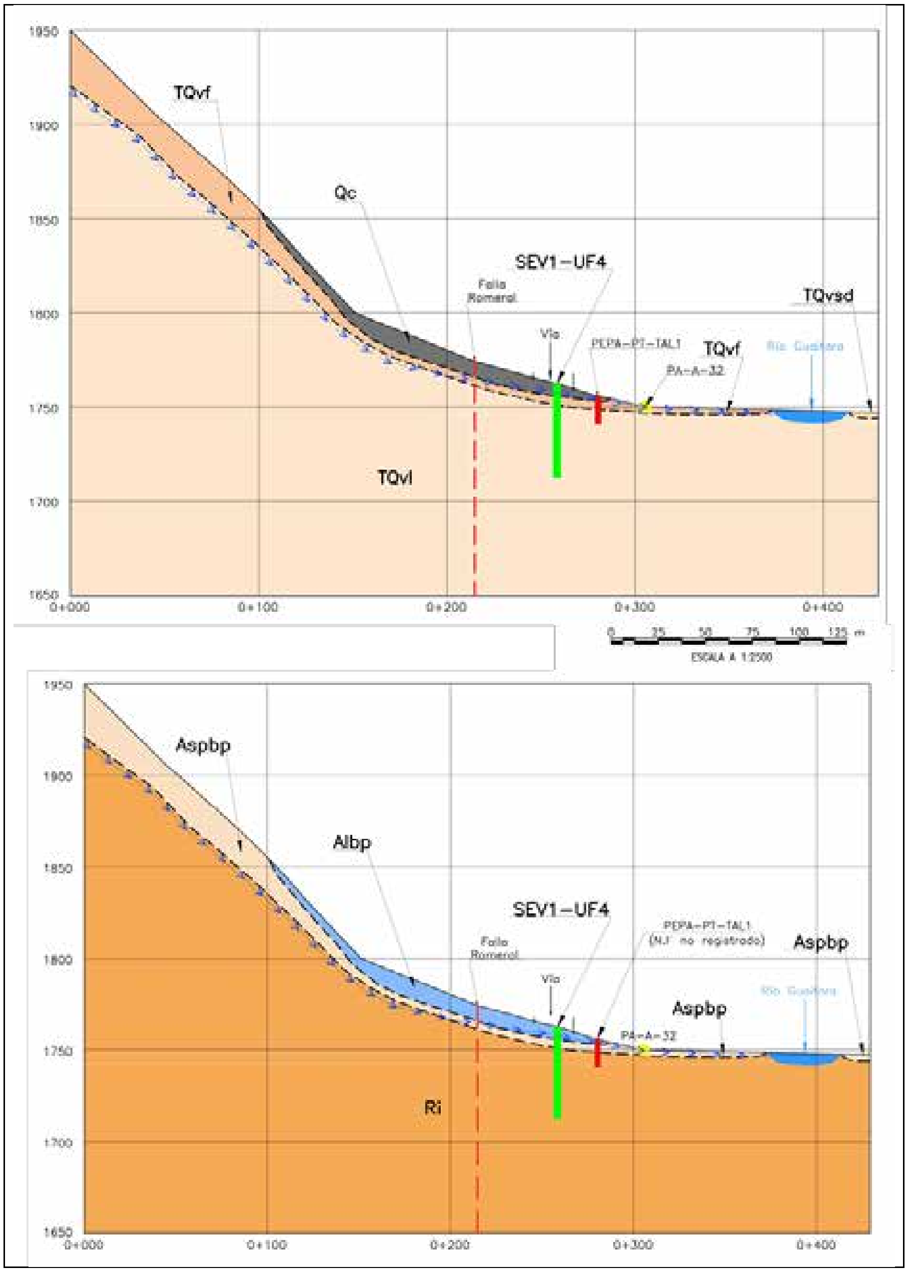


Figure 5.1.143 Analysis section A - A Geological and Hydrogeological

Source: (INGETEC, 2016)

ü Sección B – B

Location: The section is between coordinates N610025; E960657 and N610293; E962457, with SW – NE direction, with a length of 1820 m. Scale 1:5000 (see annex 5.1.8, annex 4. Analysis sections) (see Figure 5.1.127).

Geology Units for Engineering: the lithology spanning the section is lowly lythified volcanic agglomerates lithified and very weathered, the fragments are angular and andesitic and trachytic from the La Magdalena Sedimentary Volcanic unit (TQsv). On both banks of the la Magdalena creek there are two colluvial deposits (Qc) of up to 2m thick, these deposits are composed of angular fragments of volcanic agglomerate, embedded in a Sandy silty matrix composed of plagioclase and volcanic rock rocks.

The colluvial deposits (Qc) belong to the hydrogeological Free Sediment with essentially intergranular flows (Albp) unit. The La Magdalena Sedimentary Volcanic unit (TQsv) geological unit corresponds to the hydrogeological Rocks and Semipermeables Sediments of low productivity (Aspbp) unit..

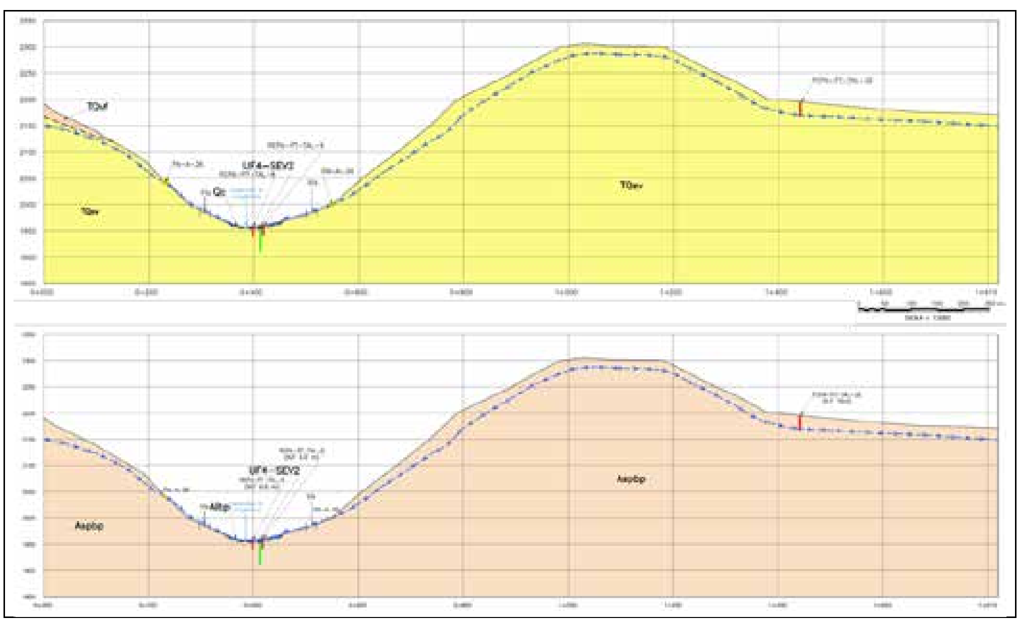


Figure 5.1.144 Analysis Section B - B Geological and Hydrogeological
Source: (INGETEC, 2016)

ü Section C - C

Location: The section is located in coordinates N612195; E962493 and N611673; 963314, with direction NW - SE, with a length of 937 m. Scale 1:5000 (see annex 5.1.8, annex 4. Analysis sections) (see Figure 5.1.128).

Geology units for Engineering : The section in the present route exposes a coluvial deposit (Qc) of 5m of thickness, matrix supported in a silt-sandy factory with some grava sized subangular fragments of volcanic agglomerates and andesites that lies discordantly on top of weathered volcanica gglomerate with andesites and trachytes of the La Magdalena Sedimentary Volcanic unit (TQsv), as can be appreciated in survey PEPA-PT-MUR-7.

The colluvial deposits (Qc) belong to the hydrogeological Free Sediment with essentially intergranular flows (Albp) unit. The La Magdalena Sedimentary Volcanic unit (TQsv) geological unit corresponds to the hydrogeological Rocks and Semipermeables Sediments of low productivity (Aspbp) unit..

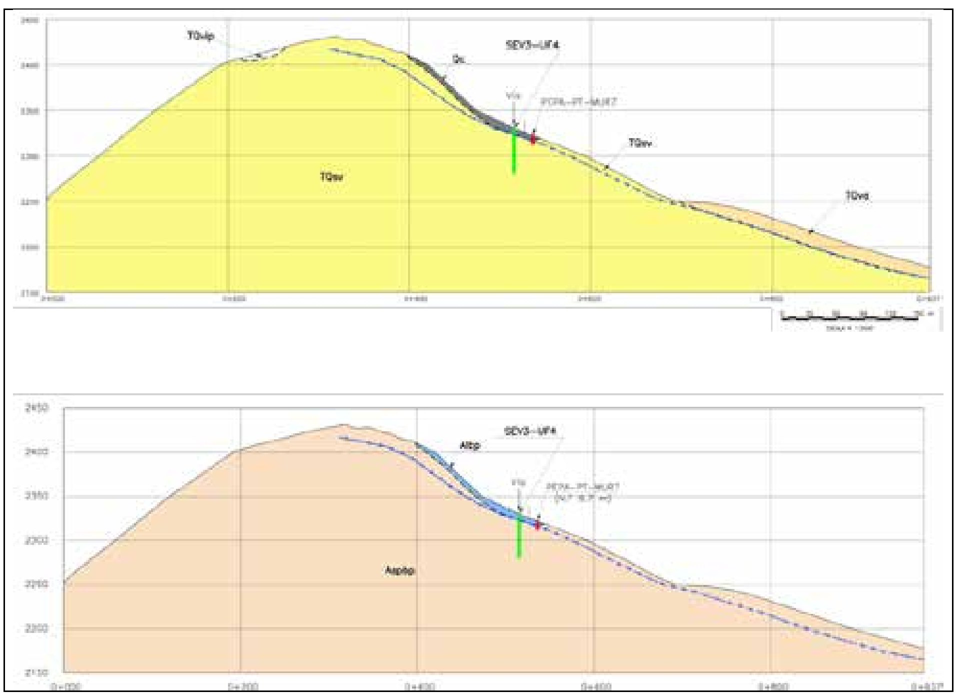


Figure 5.1.145 Analysis Section C - C Geological and Hydrogeological

Source: (INGETEC, 2016)

ü Section D - D

Location: The section is located between the coordinates N613546; E965022 and N612552; E966365, with direction NW – SE, with a length of 450 m. Scale 1:5000 (see annex 5.1.8, annex 4. Analysis sections) (see Figure 5.1.129).

Geology units for Engineering : The outcrops of the present route, present pyroclastic flows of the Lahars and Pyroclasts (TQvlp) unit to the SE of the section, that consist of subrounded bombs of up to 10 cm in diameter in an ash and lapilli matrix as described in survey PEPA-PT-TAL-35; the pyroclastic deposit is on top of the La Magdalena Sedimentary Volcanic unit (TQsv).

The Lahars and Pyroclasts (TQvlp) geological unit and La Magdalena Sedimentary Volcanic (TQsv) geological unit correspond to the hydrogeological Rocks and Semipermeables Sediments of low productivity (Aspbp) unit.

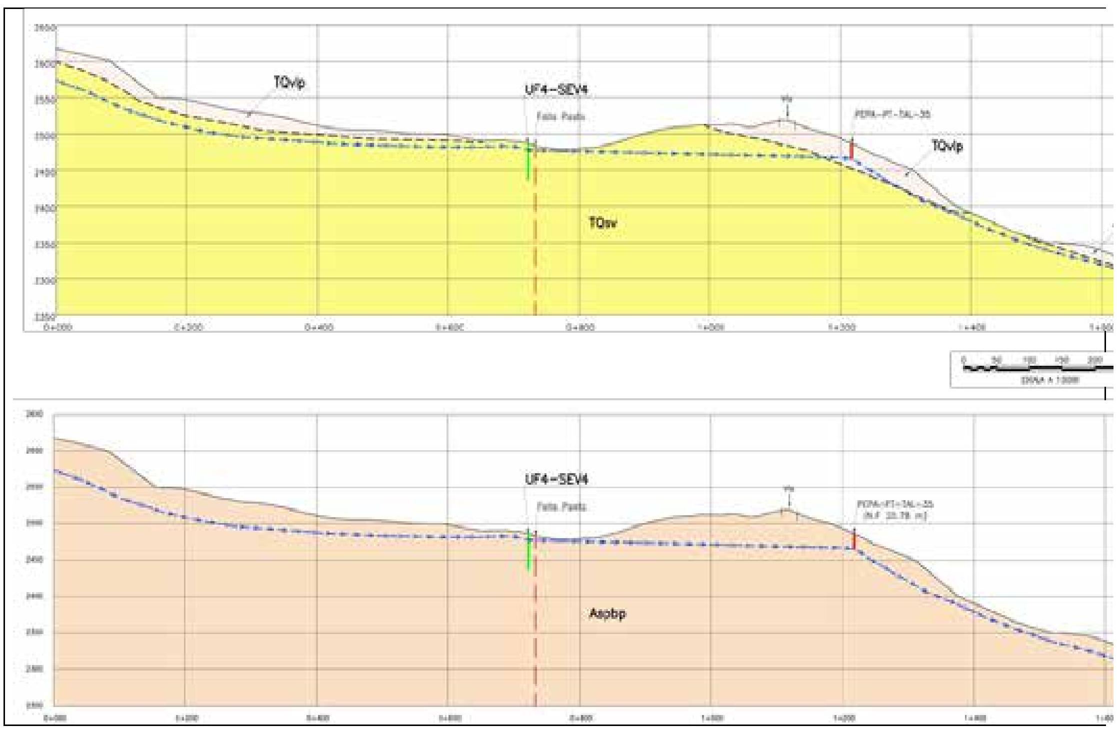


Figure 5.1.146 Analysis Section D - D Geological and Hydrogeological

Source: (INGETEC, 2016)

- Functional unit 5

ü Section E - E'

Location: Is located between the coordinates N613623; E965815 and N614406; E967587, with direction SW - NE, with a length of 1936 m. Scale 1:4000 (see annex 5.1.8, annex 4. Analysis sections) (see Figure 5.1.130).

Geology units for Engineering : On the slopes of cutting the current via emerges unit lahars and pyroclastic rocks (TQvlp), the laharicos flows are composed of angular fragments of up to 40 cm diameter, embedded in silt matrix andesite Sandy to Sandy. The pyroclastic flows are comprised of subrounded bombs of up to 8cm in diameter in an ash and lapilli matrix as described in survey PEPA-PT-TAL16 AND PEPA-PT-TAL-17, these flows are supralying volcanic sedimentary rocks of the La Magdalena Sedimentary Volcanic unit (TQsv).

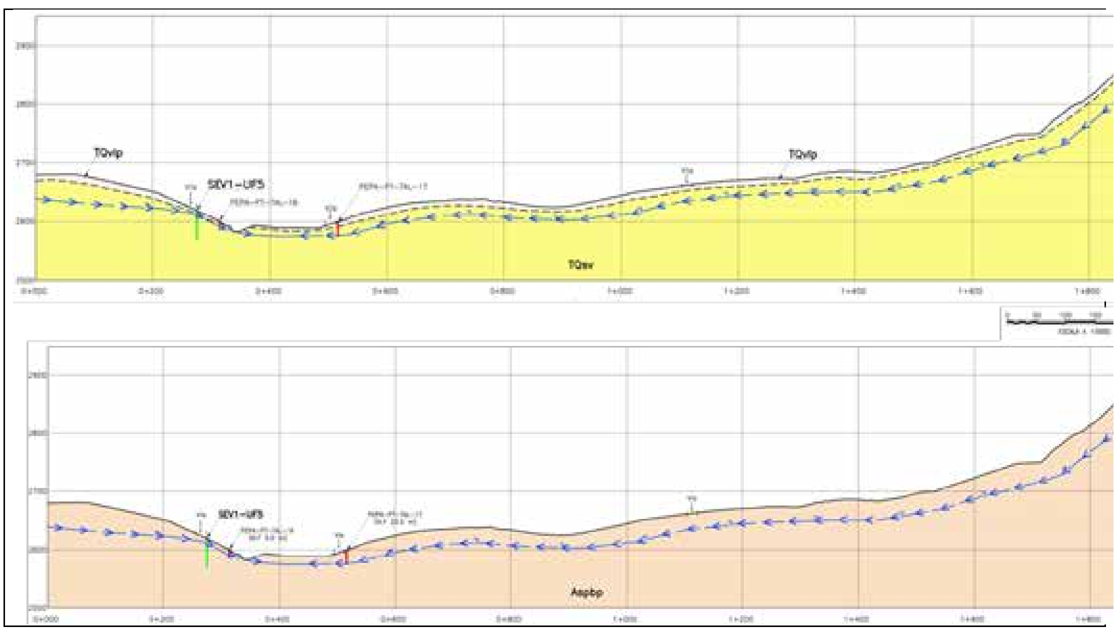


Figure 5.1.147 Analysis Section E - E' Geological and Hydrogeological
Source: (INGETEC, 2016)

The Lahars and Pyroclasts (TQvlp) geological unit and La Magdalena Sedimentary Volcanic (TQsv) geological unit correspond to the hydrogeological Rocks and Semipermeables Sediments of low productivity (Aspbp) unit.

ü Section F-F'

Location: Is located between the coordinates N617129; E968793 and N616893; E969079, with direction NW - SE, with a length of 400 m. Scale 1:1500 (see annex 5.1.8, annex 4. Analysis sections) (see Figure 5.1.130).

Geology units for Engineering : In the outcrops ner the section there are ash deposits of andesitic composition and 16 m thick, formed by felsic minerals and ferromagnesiums to a lesser degree, these have been weatehered and generate 2m thick organic soils as per survey PEPA-PT-TAL-25; these are covering poorly joined porphyritic andesites of a grey color with plagioclase phenocyrsts in a microcrystalline of the Lavas and Ashes (TQvlc) unit.

The SEV2-UF5 reported lower resistivity between 25 m and 33 m with a value of 45 Ohm. Between the surface and 25 m, and from 33 m, resistivity values occur within a range of 60 and 900 Ohm, considering this interval asthe one with less saturation and permeability of the SEV.

The colluvial deposits (Qc) belong to the hydrogeological Free Sediment with essentially intergranular flows (Albp) unit. The geological Lavas and Ashes (TQvlc) unit corresponds to the hydrogeological Rocks and Semipermeables Sediments of low productivity (Aspbp) unit.

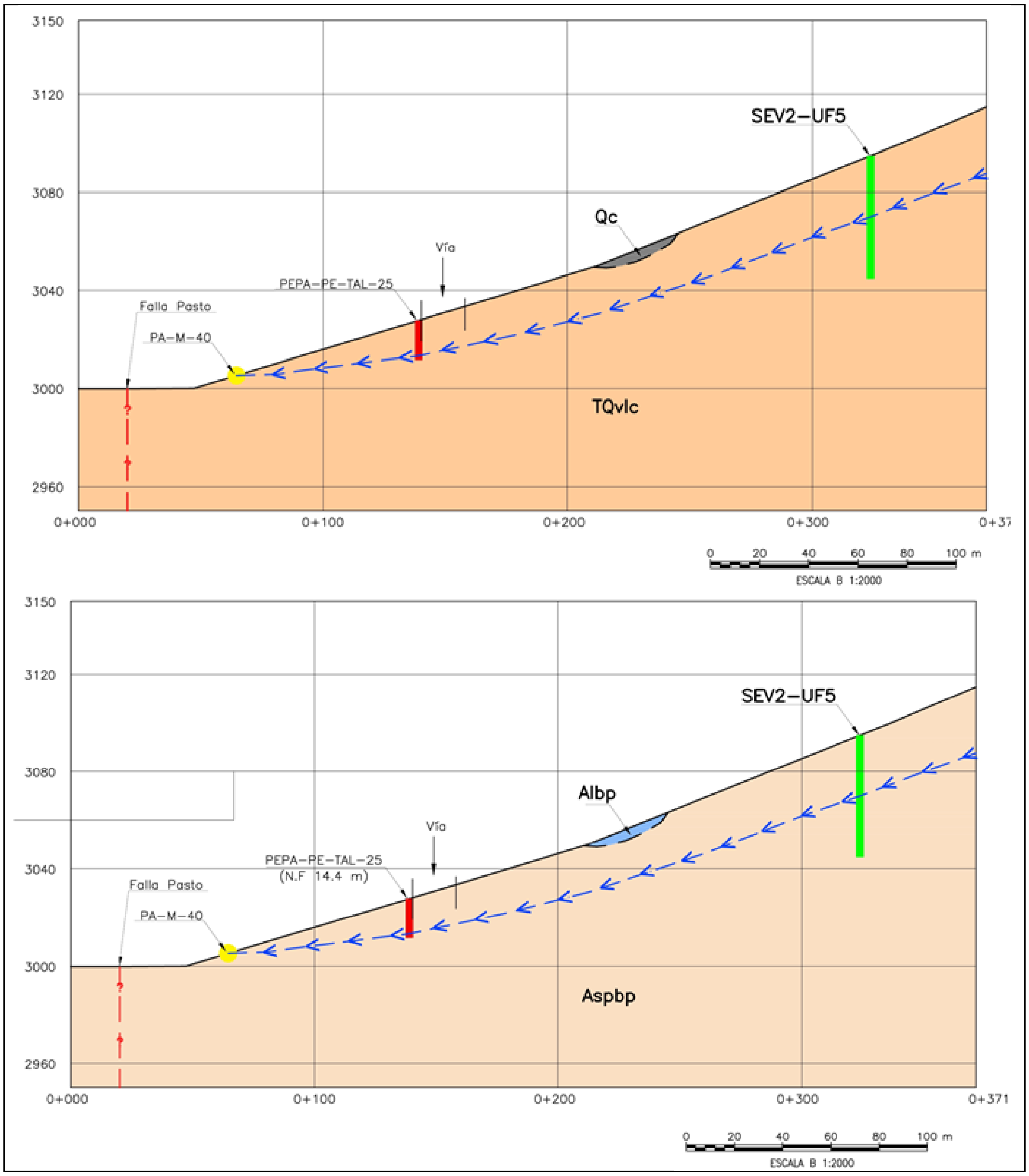


Figure 5.1.148 Analysis Section F - F' Geological and Hydrogeological

Source: (INGETEC, 2016)

ü Section G - G'

Location: Is located between the coordinates N618255; E971241 and N618667; E972170, with direction SW - NE, witha length of 415 m. Scale 1:1500 (see annex 5.1.8, annex 4. Analysis sections) (see Figure 5.1.132).

Geology Units for Engineering: in the sector where the section was drawn there is an outcrop of the Ash Rain (Qvc) unit, comprised of a 4m thick lapilli ash, weathered, of an andesitic with plagioclase and ferromangesium minerals composition, presents iron oxides, as registered by survey PEPA-PT-TAL-27; These ashes are suprayacent to the Lavas and Ashes (TQvlc) unit comprised of porphyritic andesites.

The Ash Rain (Qvc) geological unit and the Lavas and Ashes (TQvlc) geological unit corresponds to the hydrogeological Rocks and Semipermeables Sediments of low productivity (Aspbp) unit.

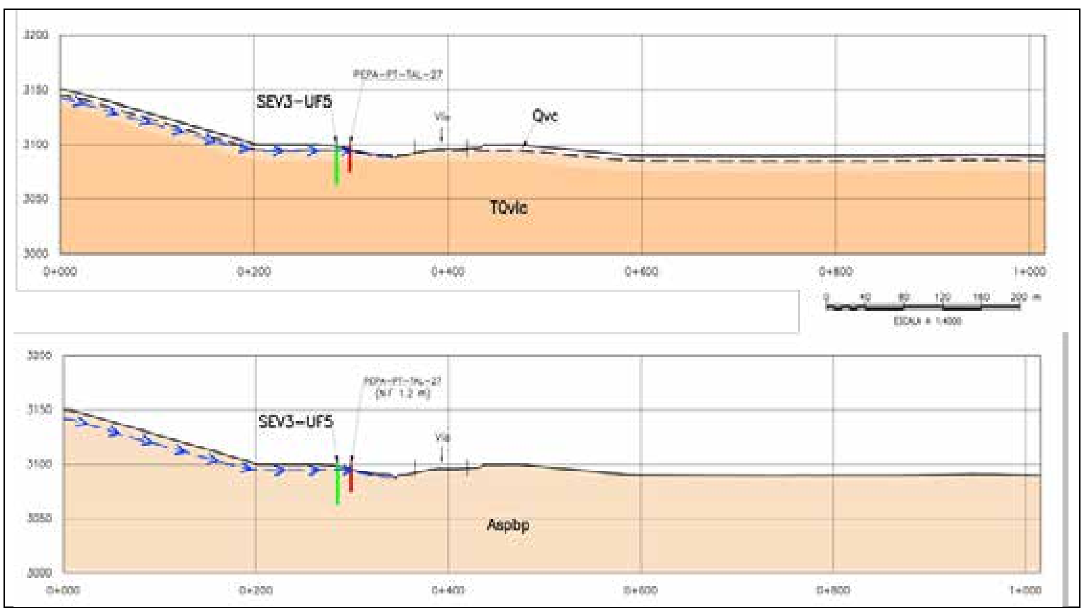


Figure 5.1.149 Analysis Section G - G' Geological and Hydrogeological
Source: (INGETEC, 2016)

ü Section H - H'

Location: The section is located between the coordinates N618405; E974071and N619369; E974520, with direction SW - NE, with a length of 610 m. Scale 1:1500 (see annex 5.1.8, annex 4. Analysis sections) (seeFigure 5.1.133).

Geology units for Engineering : SW of the section the Ashes and Pumice (TQvf) unit outcrops and deposits of fine grained to lapilli ashes of dacitic composition with plagioclase and a few ferromagnesium minerals can be observed; the ashes are weathered with iron oxides producing organic soils of up to 2 m thick which are suprayacent to non-lithified deposits made of subangular fragments of volcanic agglomerate and andesite embedded in a vitreous matrixwith some ash levels, as was recorded in survey PEPA-PT-TAL-30. The Ash Rain (Qvc) unit outcrops to the NW; comprised of lapilli ash with iron oxides and organic matter 3 m thick, as registered in survey PEPA-PT-PP1-1.

The SEV4-UF5 presents resistivities between 110 and 3000 Ohm, considering that they do not have saturated or permeability zones. The Ash Rain (Qvc) geological unit and the Lavas and Ashes (TQvlc) geological unit corresponds to the hydrogeological Rocks and Semipermeables Sediments of low productivity (Aspbp) unit.

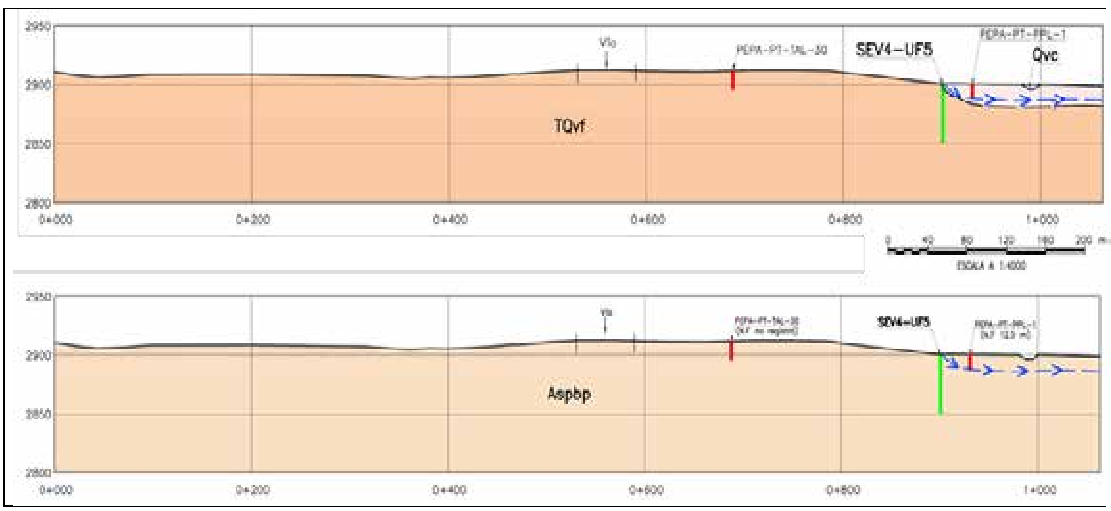


Figure 5.1.150 Analysis Section H - H' Geological and Hydrogeological
Source: (INGETEC, 2016)

Table 5.1.65 Relationship of hydrogeological units with lithostratigraphic units

UNIDAD HIDROGEOLÓGICA	UNIDAD LITOESTRATIGRÁFICA	LITOLOGÍA	ABSCISADO
Albp: SEDIMENTOS LIBRES CON FLUJO ESENCIALMENTE INTERGRANULAR: Acuíferos libres con flujo inetrgranular, doscontinuos de baja productividad y de carácter local.	Depósito Aluvial **(Qal)**	Localizado en las márgenes de la Quebrada La Magdalena. Está conformado por bloques de hasta 2m de espesor de aglomerado volcánico y andesítas en matriz arenolimosa.	K7+000 - k7+060
	Depósito Coluvial **(Qc)**	Depósito no consolidado. Los fragmentos del depósito son generalmente angulares a subangulares de hasta 60cm de diámetro que corresponden a rocas volcánicas extrusivas de composición básica e intermedia. La fábrica tiene una variación de matriz soportada a clasto soportada y es areno limosa. El espesor del depósito coluvial es de hasta 6m y forma suelos orgánicos de hasta 50cm de espesor.	0+450 - 0+910, K6+950 - K7+090, K11+295 - K11+575
Aspbp: ROCAS Y SEDIMENTOS SEMIPERMEABLES DE BAJA PRODUCTIIDAD:Acuitardos semiconfinados a confnados de carácter regional y local, discontinuos de baja productividad.	Conjunto Sedimentario Volcánico La Magdalena **(TQsv)**	En la base Intercalación de areniscas finas, arcillolitas y diatomitas finamente laminadas de color habano, parcialmente meteorizada; hacia el techo aglomerado volcánico poco litificado y muy meteorizado, los fragmentos son angulosos y de composición andesítica y traquitica.	K3+200 – K3+950, K5+150 – K5+700, K5+930 - K6+950, K7+090 - K11+295, K11+575 - K12+620, K14+700 - K15+120, K15+665 - K15+720, K15+722 - K16+050
	Flujo de Cenizas y Pumitas **(TQvf)**	Flujos de detritos con fragmentos de diversos tamaños (hasta 2m de diámetro), intercalados con cenizas volcánicas de color habano de hasta 1.5m de espesor. Los fragmentos son de dacitas y andesitas. La fábrica variable de matriz soportada a clasto soportada, es rica en líticos y pómez de tamaño arena a limo con algunos finos y presenta cambios de color como gris, ocre, rojo, siendo el más común el primer color. Forman suelos orgánicos de hasta 50cm de espesor.	K0+000 – K0+450, K0+910 - K1+265, K1+365 – K1+590, K2+280 – K2+550, K3+110 - K3+200, K4+160 – K5+150, K5+700 – K5+930, K30+030 – K31+300, K33+960 – K34+360, K36+828 – K37+076, K37+224 – K37+947
	Lavas y cenizas **(TQvlc)**	Andesitas porfiriticas cubiertas o intercaladas por cenizas tipo "ash fall" (cenizas y lapilli) y cenizas tipo "ash flow" (bombas piroclásticas de hasta 10cm de diámetro).	K22+250 - K22+540, K24+018 – K26+130, K29+000 – K30+030
	Lahares y Piroclastos **(TQvlp)**	Intercalaciones de flujos lahåricos, flujos piroclásticos y capas de ceniza. Los eventos lahåricos presetan fragmentos angulosos de rocas ígneas extrusivas de composición básica a intermedia de hasta 0.6m de diámetro, embebidos en fábrica matriz soportada compuestas de líticos y pómez varía de tamaño arena a limo con algunos finos. Los flujos piroclásticos contienen bombas subredondeadas de hasta 15cm de diámetro compuestas por lavas soldadas muy duras y la matriz es de composición volcánica generalmente feldespato y plagioclasa. Las cenizas volcánicas de tamaños de finos y lapilli con algunas bombas piroclásticas de hasta 3cm; la ceniza contiene vidrio volcánico, plagioclasa y cuarzo.	K12+620 – K14+700, K15+120 - K15+665, k16+050 - K18+876, K21+2900 - K24+018
	Luvia de Cenizas **(Qvc)**	Estos depósitos representan la actividad explosiva de los diferentes focos volcánicos, se observan suavizando la morfología preexistente y modelan, en gran parte, la actual.Generan suelos orgánicos de hasta 3m de espesor, su color predominante es habano a amarillento y su tamaño de grano es de ceniza y lapilli con esporádicas bombas de hasta 3cm .	K18+876 - K21+290, K26+130 – K29+000, K31+300 – K32+679, K32+679 - K33+960, K34+326 – K36+828, K37+076 – K37+224
Ri: ROCAS IMPERMEABLES CON LIMITADOS RECURSOS DE AGUAS SUBTERRÁNEAS: Rocas en condiciones de porosidad dadas por el fracturamiento.	Lavas **(TQvl)**	Andesitas grisáceas porfiríticas con fenocristales de plagioclasa de hasta 2mm, en matriz es microcristalina que generan suelos orgánicos que alcanzan espesores de hasta 1m.	K1+270 – K1+360, K1+590 - K2+000, K2+550 - K3+057, K3+070 - K3+110, K3+950 - K4+160

Source: (INGETEC, 2016)

taking into account the criteria above mentioned, the different geological formations have been classified according to their aquifer potential by grouping them into three hydrogeologic units that depend on the type of porosity, permeability and the occurrence or not of groundwater (storage capacity). The extension and location of such units are presented in the annex 5.1.8, annex 5. Hydrogeological map (Figure 5.1.134).

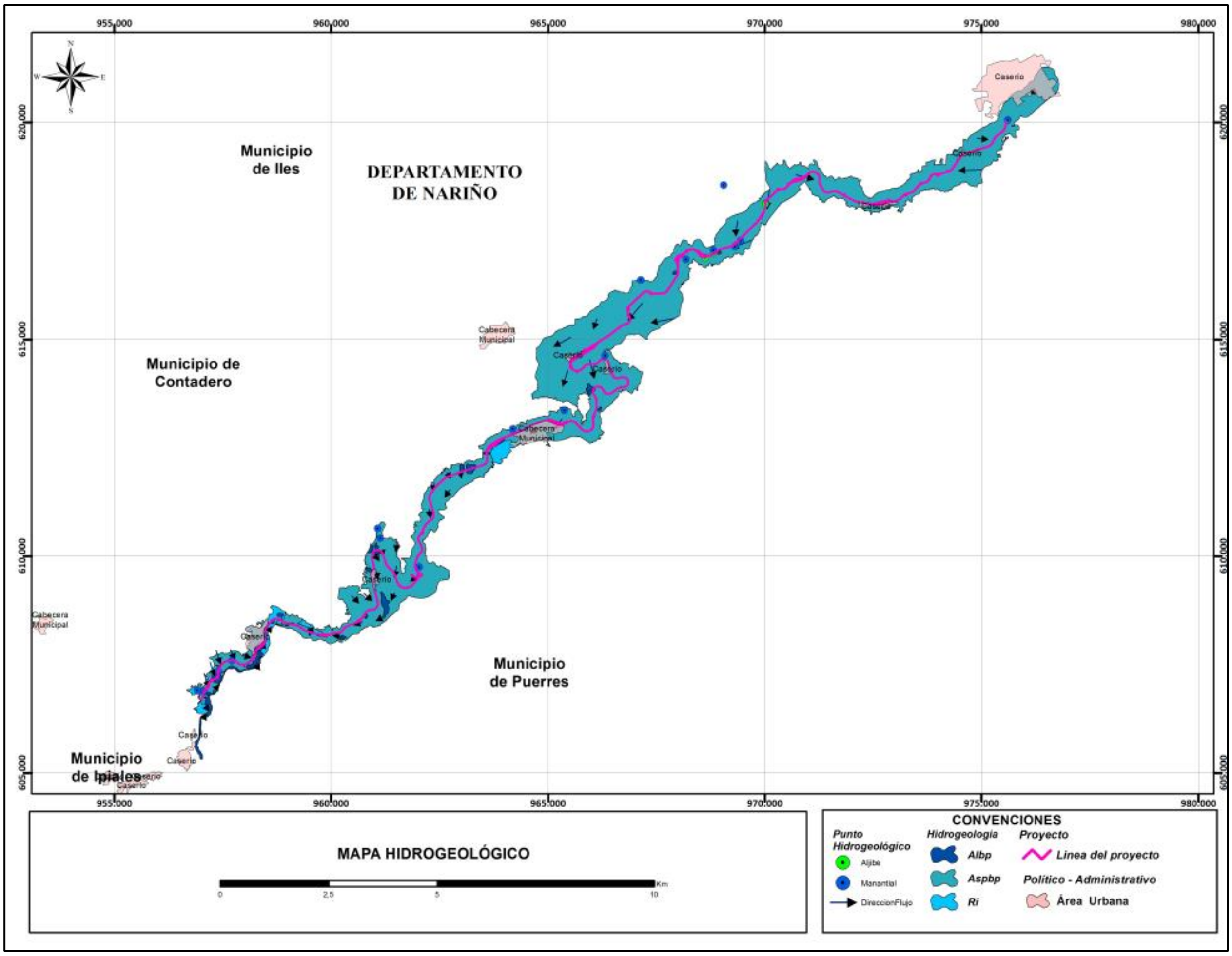


Figure 5.1.151 Hydrogeological map
Source: M & M Team

- *General direction of underground flows* in general, the geomorphological configuration of the study area corresponds to slopes that vary from moderately inclined to totally sheer. In the direction of the abscissas, the terrain configuration corresponds to a downward hillside to the right with the projected road at half-hillside; in some areas, the projected road can be located close to the top of the hillside, while in others it is located at the bottom of it, near the waterway that collects the surface and underground runoff waters from the hillside and which traverses the flows contributed by the corresponding basin.

The underground flows in the study area correspond to the down-flow parallel to the surface of the hillside, from the upper part of it toward its lower part, which in many cases has a stream. In its downward journey, the groundwater table can be found at different depths depending on the characteristics of the rock where the hillside resides.

the concavity of the profile of the slope is a determinant to the depth that the underground water table has. In the higher areas on the hillside, which may exhibit a convex shape near the upper edge, deep water tables may be found, whereas in the lower parts, where concave forms may be found close to the collector channels -towards which both surface waters and groundwaters flow to - the water table may be superficial and even some surface springs may occur.

- *Inputs and outputs of the system*

The system formed by the different hydrogeological units in the study area may receive/ deliver flows due to processes of recharge by precipitation and discharge to streams, in addition to the trivial case corresponding to the flow from / to other hydrogeological units located outside the study area.

o Recharge by Precipitation

The estimated infiltration into the Bobo River sub-basin is 26mm per year, which corresponds to 2.2% of the total mean annual precipitation; these values are representative of the recharge that may be present in the totality of UF4 and UF5 until K26+500, approximately.

In the Pasto River sub-basin the estimated infiltration is 10mm per year, which corresponds to 0,9% of the total mean annual precipitation; these values are representative of the recharge that may be present in UF5 as of K26+500, approximately.

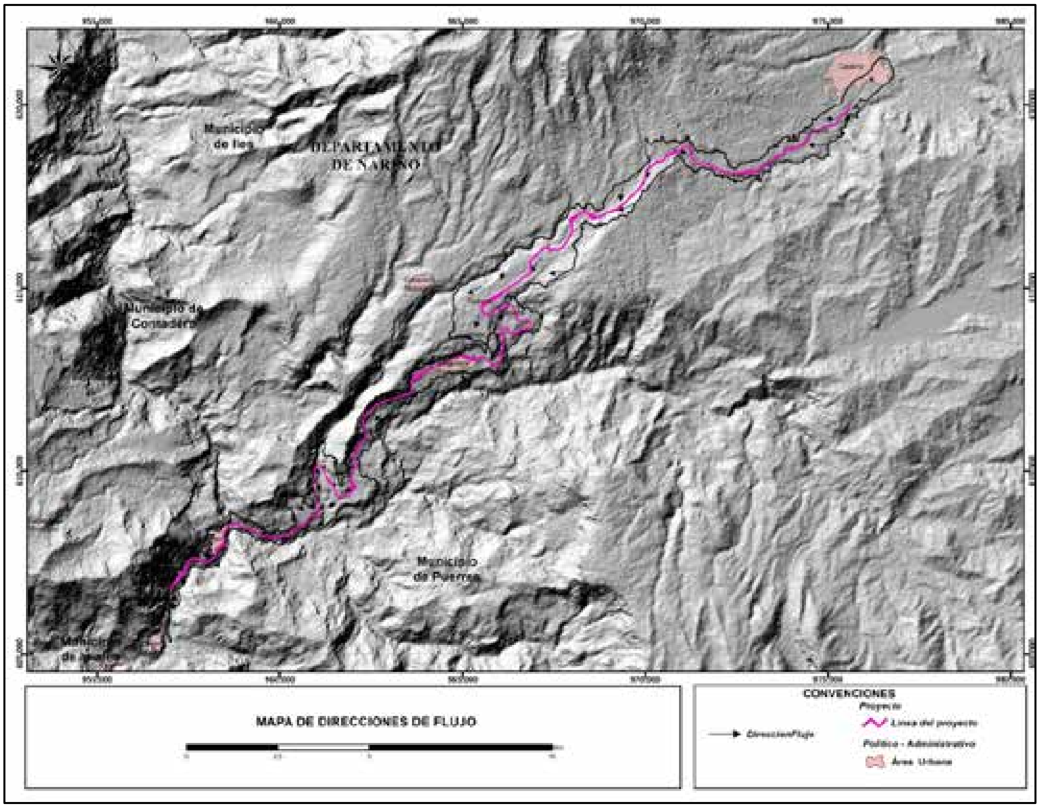


Figure 5.1.152 Direction of flow lines map
Source: M & M Team

- Download to Currents

Given the topographic configuration of the area, the hydraulic gradient associated with the underground water in the hillsides of the valley of the river is falling; This explains that the main exit for the underground waters corresponds to the different superficial currents of the study area, amongst which the Guáitara River, its tributary the Bobo River and the Pasto River outstand.

The different water outcrops found in the development of the work of this study field illustrate the phenomenon.

- *Main flows*

In order to describe the main flows associated with the hydrogeological units system in the study area, four transversal cross sections in each UF have been selected, which are representative of the system's dynamics. The geological configuration of these sections was presented in the numeral 5.1.8.5.2; below we describe the characteristic flows in said sections.

o Section A-A'

The morphology of the section is mountain slopes with gradients between 16° - 20°.

from the West of the section, the water table may be present more or less parallel to the surface of the slope, at a level close to the contact level of the Ash Flows and Pumice (TQvf) unit, of semi-permeable characteristics, and the Lavas (TQvl) unit, of waterproof characteristics. For the most of the time it is likely that the water table in this area is located above the contact between the two formations, insofar as the lower unit is characterized by presenting limited groundwater resources while the upper unit has some productivity, although it is considered low.

Taking into account that survey PEPA-PT-TAL-1 did not report groundwater, but the SEV1 has indications of change in resistivity near the 5 m depth, the flow would be entering the colluvial deposit in the stretch of the section located between both points.

This form of the water table would be coherent with the identification of the water point PA-M-32 at the 1750 level; from this site of upwelling, the water table may be very close to the surface until downloading into the Guáitara River.

o Sección B – B'

The section presents a basin in a "U" valley shape, with medium hillsides with slopes between 15° and 25°, belonging to the La Magdalena creek The materials present on both sides of the Valley are characterized as of low permeability.

taking into account the concavity of the section as well as the water table levels recorded in the field, the water table would be located at a greater depth in the higher areas of the slope, would present upwelling points at the 2045 and 2000 masl on the left and right slopes of the section, respectively, and could be developing very close to the surface from these points downstream to download into the current located at the bottom of the valley. The water table must move from the ground surface in the alluvial deposit associated with the current, deepening insofar as the current levels permit, which would control the final stretches of the water table in this alluvial sector.

This behavior would be evidenced by the results of the SEV2-UF4, according to which the groundwater was identified at 4. 5 m depth, as well as the outcome of surveys PEPA-PET-TAL8 and PEPA-PT-TAL9, presenting the water table 6.0 meters deep.

The upwelling at the levels 2045 and 2000 masl were identified in the water points PA-M-36 and PA-M-34.

The colluvial deposits present on both banks of the La Magdalena creek are classified as discharge areas.

o Section C - C'

Insofar as this section covers the two hillsides of the same mountain, the flow in this section is given in two directions, one NW and the other SE. The morphology of the section is mountain slopes with gradients between 16° - 20°.

at the top of the mountain the water table depths can be expected to be greater than 10 m. The water table that goes toward the SE would commence in the TQvs - Sr+IIA unit and approximately on the abscissa 400 of the section would be entering the colluvial formation that is between the limits 2400 and 2300 metres above sea level, crossing it at depths between 10 m (this is the depth of the phreatic level reported in drilling PEPA-PT-MUR-7) and 6.5 m (this is the depth of the phreatic level in the SEV3-UF4).

The water table should continue in vicinity of the contact between the Burning Aavalanches and Debris (Tqva) unit and the Volcanic Sedimentary La Magdalena (TQsv), until possibly meet the base level of the Bobo river.

o Section D - D'

This section has slopes between 6° - 15°.
It is expected that the water table on the top of the hillside is at depths greater than 10 m, in vicinity of the contact between the TQsv and TQvlp formations, both with low productivity features.

From this area to the area where the SEV4-UF4 was made, it is expected that the water table will gradually approach the surface until it reaches the 9 m depth registered in the mentioned survey.

During survey PEPA-PT-TAL-35 of 22 meters deep and located at 510 meters to the SE of the SEV, the phreatic level was reported at 20.78 m depth, indicating that flow in this area occurs through the TQvlp formation in SE direction.

From this area and continuing to the SE, the water table should be developing basically parallel to the surface of the slope up to the level of the Bobo river.

- Section E - E'

The morphology of this section corresponds to that of an open alluvial valley with low hillsides and slopes between 15° - 20°.

Two flow lines converging in the lowest zone of the section were identified, in the vicinity of perforations PEPA-PT-TAL-16 and PEPA-PT-TAL-17.

the water table in the left side of the section can be starting below the contact between the TQvlp and TQsv formations, both with low productivity features, and would develop in a descending fashion, following in an approximately parallel orientation to the surface of the hillside. In the zone corresponding to SEV1-UF5, it is estimated that the depth of the water table is in the order of 9 m, while that associated with the PEPA-PT-TAL-16 survey is expected to be 15.0 meters deep.

The water table in the right area of the section would have a similar behavior to the water table in the left area of the section but descending not towards the SE but towards the NW, with a parallel trend to the surface of the slope; PEPA-PT-TAL-17 survey located 740 meters to the NE of SEV1-UF5 registered phreatic levels at a depth of 25 meters.

The water tables to the left and right of the section converge in El Quetal creek, located to the SW of the section.

- Section F-F'

in the SEV2-UF5 the phreatic level is 25m deep; in the survey PEPA-PT-TAL-25 located 120 m from the SEV and with a 16 meters depth, the phreatic level is at 19.4 m. The water table has a flow direction to the NW and discharge in water point PA-M-40 at elevation point 3018 meters above sea level, in the area where the hillside slope changes, which is of the order of 20° to the SE and practically horizontal towards the NW.

the morphology of the area is of medium to low hills with slopes between 6° - 20°. The flow direction is towards the NW.

- Section G - G'

the underground water table develops in NE direction. The results obtained in the SEV3-UF5 indicate a water table depth of 5.0 m, with which the flow near that point would be happening through the colluvial formation. This is also confirmed with the results of survey PEPA-PT-TAL-27, located at 40m distance of the SEV, in which the phreatic level was recoreded at 1.2 m deep.

the water table with NE flow direction continues to the base line of the Los Lirios creek. The morphology of the area of the section is of low hills with slopes between 6° - 10°.

- Section H - H'

Both SEV4-UF5 and survey PEPA-PT-TAL-30 of 16m depth, located in the Ashes and Pumice (TQvf) unit reported no phreatic levels. The survey PEPA-PT-PP1 of 13.35m depth andlocated in the Ash Rain (Qvc) unit, recorded the phreatic level at 12.5 m depth and is found between the contact of the mentioned units and presents a flow direction towards the SE, where it will probably reach the base level of the Piedra Pintada creek. The morphology of the area of the section is of low hills with slopes between 6° - 15°.

- *Result of the Conceptual Hydrogeological Model*

The description of the Conceptual Hydrogeological Model of a certain area is controlled by the development of its historical geology and its structural patterns, which in turn become the main support for the way in which its hydrogeological conditions evolve. With this information, guidelines are set to describe the abovementioned model, useful in defining the spatial distribution and in the subsoil of the diverse hydrogeological units with their lithology, thickness, lateral variations and depth units, as well as the behavior of each one of them referred to the underground water storage capacity and its quality and the direction of the groundwater flow. Thus, the groundwater recharge (infiltration) zones, transit zones and discharge zones are identified.

The geologic history for the area of the Rumichaca - Pasto, Pedregal - Pasto segment with a total length of 15.75 kilometers and an area of influence of 3.15 km^2, presents a basement formed by the Migmatitic Complex of La Cocha - Tellez River located to the East of the Loma Larga Ridge.

It is estimated that at the continental accretion and subsequent orogeny; possibly during the Orinoquense event (1200 m.y.) the rocks were subjected to metamorphism of high grade which produced the migmatizacion and apparently formed a granulitic belt in the western part of the Precambrian Shield that correlates with the Migmatitic Complex of La Cocha - Tellez river. Subsequent to the folding of the basement units and according to the bibliographic studies it has been assumed that there was an accumulation of other units in the late Upper Cretaceous, at the end of the Miocene this from the lack of exposure of elements that confirm or refute this hypothesis and that in the area ther have been no reports of rework of units other than volcanic which are the subject to intervention in the road alignment.

Structurally the road alignment is framed within a complex tectonic due to the convergence of the three Colombian mountain ranges, along with narrowing and rising of the inter-Andean depressions of the Magdalena Valley and the Cauca - Patía, having in the area of influence of the road alignment the influence of the Patía-Guacara faults, San Ignacio fault, el Romeral faults system, Magdalena rive faults system, Afiladores fault and Pasto fault.

The Guáitara fault, located to the South of the city of Pasto, southwest of Colombia, presents a volcanic cover of Neogene age. This fault has been associated with the Romeral fault system, with a dextral geometry, in accordance with the common behavior of other nearby Quaternary faults; compatible with the field current compression effort WSW-

ENE, causing deep V-shaped valleys, linear topographic features and controlling the surface and underground drainages. (Paris et al., 2000;) Paris, g., 1993, Paris, g., and Romero, j., 1994)

The San Ignacio fault is located to the East of the road alignment about 5 kilometers away, this fault presents a NE direction through the craters of ancient volcanoes, El Gallo, Ocoyuyo and San Fernando.

According to Paris et al., 2000, The Romeral faults System is one of the most active and continuous faults systems in Colombia. The most ancient name is megashear Guayaquil-Dolores, which implies a whole series of parallel fractures in the Colombian west. Its main layout traverses the Galeras volcano, has a N45°E direction and, southbound tends to N10°E, where it continues its layout by the Guáitara river. The Buesaco fault is associated to this system, it is common to find calderitic complexes in these faults' layout.

The Magdalena river faults system starts fromthe Romeral fault with EW and N30°E direction. This trace starting point is located approximately 1 kilometer from the road layout in the sector K2+300. Cuts the UF 4 layout in the first 5 kilometres in three different sectors.

The Afiladores fault occurs 18 kilometers from the road alignment in the Eastern side and is defined as a thrust fault by Ponce, (1979) more South; and excises tectonic control over the La Cocha Lagoon.

The Pasto fault has a direction of N40°E and N50°E and crosses the road project at he height of kilometer 14.7, without tectonic traces in the outcrops od the zone that may evidence the layout of this lining.

The structural and tectonic conditions that generate the mentioned faults and their convergence in the zone of study generate a high degree of joints and fracturing of the present volcanic rocks in the study zone that can be controlling the underground flows whether like zones of preferential flow or barrier zones or underground dikes.

In the study area outcrop Precambrian metamórficas rocks that conform the basement, where there are discordantly supralying rocks and deposits of recent volcanic affinity, in addition to concentrated superficial sediment deposits in the Guáitara river and its main affluents.

The hydrogeological basement of the area is represented by the Migmatite Complex of La Cocha and volcanic rocks such as the La Magdalena Sedimentary Volcanic unit, Lavas unit, Ash Flows and Pumice unit, Lahars and Pyroclasts unit, all rocks that outcrop along the road alignment UF4 and are largely covered by deposits of recent volcanic origin, as well as residual soil or saprolite produced by in situ weathering and in the foothills of the main surface currents there are alluvial deposits.

This hydrogeological basement develops a secondary porosity by fractures and joints of a very local nature that allows the storage of groundwater, since in the regional context it is considered impermeable. The said basement is then recharged by surface currents and rainfall in those locally fractured areas, giving rise to underground flows following the heterogeneous inclination of fractures and joints, where the storage capacity is dependent on the density of the fracturing, the amplitude of these fractures, their deepening and filling.

In general, considering the tectonics and convergence of the different fault systems, two NNE - SSW preferential directions are manifest, longitudinal and extensive, common throughout the Western Mountain range and smaller transverse systems are manifested in NE - SW direction, the underground flow is controlled by this situation, and their discharge occurs through a small number of springs that contribute to the base flow of small streams, which in turn contribute to the recent alluvial deposit recharge.

The recent deposits in the study area covering in sectors the hydrogeological basement are the volcanic deposits with no differences (TQvsd), the terrace alluvial deposits (Qt), the colluvial deposits (Qc) and the alluvial deposits (Qal), all of which are heterogeneous deposits of dragged materials as a consequence of the strong slopes in the area and varied composition of the different rocks present in the study area, as well as the deposition by the volcanic activity in the area, these deposits develop a primary porosity .

Of these deposits the hydrogeological behavior is homogeneous for volcanic deposits with no differences (TQvsd) and the terrace alluvial deposits (Qt) which do not have great hydrogeological importance since their storage capacity is very low and they do not have the capacity to transmit water . In spite of this hydrogeological condition, springs with very low flows can be developed in the contact of the rock and the deposits, this can occur more frequently in areas of steep slope. The behavior of the flows in these deposits is primarily influenced by the topography in which they are, always considering a direction of flow in the direction of the topography, always from a greater elevation and following the gradient of the topography.

Colluvial deposits (Qc) and alluvial deposits (Qal) are characterized by a predominantly fine lithology composed of a clay material, fine sands, silts and gravels, with very little compacting and without obvious structures; where the minerals of the parent rock have largely disappeared due to oxidation and various weathering processes, these allow the development of a primary porosity. These two units are those of greater hydrogeological importance in the study area by their classification as local aquifers and, in the case of the alluvial deposits these can be considered regional. The colluvial deposits have a flow direction in the direction of the slopes in which they are supported, whereas the alluvial deposits are greatly influenced by the adjacent surface currents, reason why their estimated flow directions are those in the same sense as the surface currents and some recharge flows from the rivers to the reservoirs.

In the study area, it is not possible to determine the hydraulic characterization of the hydrogeological basement represented mainly by the different Volcanic units, due to the absence of intakes that allow the execution of pumping tests, conditions associated to the strong compaction of these rocks that make them regionally impermeable, except for those locally fractured areas characterized by the presence of low flow springs. The extrapolation of known hydraulic parameters in other areas, indicates for these rocks only for the fractured zones average values for the Transmissivity of 0.25 m^2 / day with Hydraulic Conductivity of the order of 0.0015 m / day, estimating a thickness for fractured zones between 10 and 20.0 m, which is why it is classified regionally as Aquiclude (waterproof) but locally as Aquitard as it is subject to fracturing density.

As regards the hydrogeological unit formed by the recent volcanic deposits with no differences (TQvsd) and alluvial terrace deposits (Qt), their hydraulic characterization is estimated based on the lithology presented in the samples obtained from the exploratory drilling, field investigations carried out within the study, of which they may have varying thicknesses ranging from 5 m to 80 m and static levels below 20 m depth. An average Hydraulic Conductivity of 0.0007 m / day and values of Transmissivity ranging from 0.0035 to 0.056 m^2 / day have been estimated. Due to the predominance in this unit of fine granulometry with low values for its hydraulic parameters, it is classified as Aquitard.

With regard to colluvial deposits (Qc) and alluvial deposits (Qal) within the field activities and mainly from the inventory, there are contributions as wells by means of which thicknesses between 5 and 20 m are estimated based on their exploitation and composition Lithological analysis, a Hydraulic Conductivity between 0.50 and 0.1 m/day is estimated, with a Transmissivity between 0.5 and 10 m^2/day, conferring properties of a free-type aquifer, its recharge is due to direct infiltration of rainwater and direct recharge from Surface currents.

Based on the results of the hydrogeochemical interpretation of the three sources of groundwater sampled, water predominantly contains bicarbonates and magnesium and sodium contents, showing that the water stored in the hydrogeological units captured by these three sampled sources is young water with little time of travel and permanence in the rock.

As areas of important recharge in the study area are areas with high fracture density due to tectonic activity, and mainly in the high areas where the addition of water that infiltrates precipitation events, also occurs by condensation of fog for much of the day; For alluvial deposits the recharge is given directly by the interaction with the surface currents.

The discharge of the hydrogeological system of the area occurs through low flow springs, interaction with surface currents and to a lesser extent the evapotranspiration generated by the vegetation present in the area.

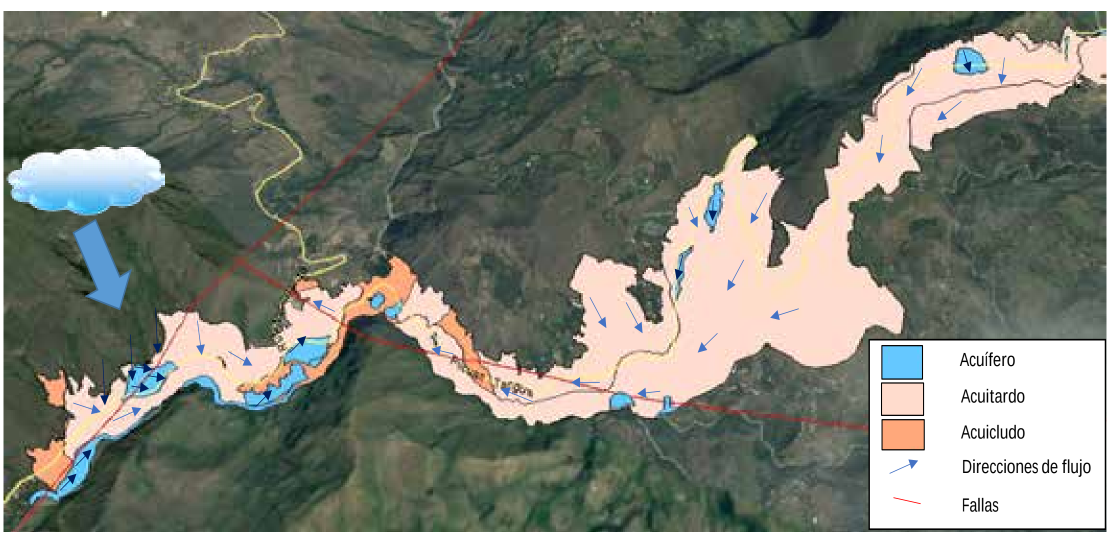


Figure 5.1.153 Behavior of flows in the hydrogeological units of the study area

- *Conceptual analysis of the effect of the works on the groundwaters system*

As indicated in the past paragraphs of this chapter, the typical geomorphological / hydrogeological configuration of the area of the project consists of hillsides with different slope levels under which surface the underground water generates a more or less deep water mantle level, depending on the specific shape of the section, the hydrogeological characteristics of the existing geological formations and the presence of water bodies.

The works of the project basically consist in shaping a road at mid-hillside, for which excavations will be made on the side of the road where the hillside presents its highest levels.

Figure 5.1.137 shows in blue the schematic configuration of the system prior to the implementation of the project; We have considered the case of a left-inclined downward hillside. The surface runoff and the water mantle level can be distinguished in the schematics, with a more or less parallel orientation to the surface of the hillside, ending their path on the river bed closing the slope below.

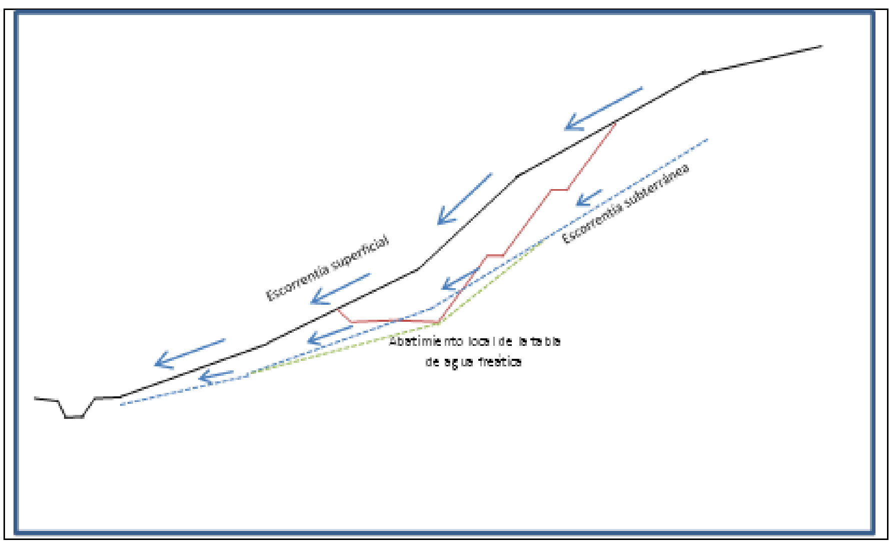


Figure 5.1.154 Schematic configuration of the system without project
Source: (INGETEC, 2016)

The projected surface has been represented with a continuous red line, with high cuts to the right and bottom to the left. The schematic shows the case in which the resulting surfaces of the associated excavations for the making of the road cut through the groundwater mantle prior to the project. This may or may not happen, depending on the depth at which the groundwater mantle is and the depth of the excavations.

A study of the depth of the water mantle levels in the study area was made as part of the intrinsic vulnerability assessment for the aquifers in the study area. This analysis started from the data available for water points and groundwater depth measurements and included an evaluation of slopes and concave / convex surfaces in order to zone the study area according to the expected depths of the groundwaters. The study area was divided into areas with depths of underground water mantle levels of between 5 and 10 m and between 10 and 20 m, noting that the latter may be the most frequent.

In areas where the water mantle level is below the zone intervened by the project, the effect on the groundwater would correspond to a reduction in recharge by precipitation associated with the waterproofing of a part of the surface of the slope, whether by paving or excavation surface coating; insofar as the area associated with this type of interventions is of little significance with respect to the area which may currently be the process of infiltration and recharge, this effect is considered very insignificant. In addition, it is pertinent to mention here that the flows that are no longer infiltrated will be drained and delivered to the same flow receivers as runoff waters.

in the areas in which the excavations do intercept the underground water mantle level, as in the case which is shown in Figure 5.1.120, in addition to the recently-discussed effect on the recharge of the system there would be an effect on water mantle levels as well as to the amount of groundwater.

The effect on water mantle levels is illustrated in a conceptual way in Figure 5.1.120 by the green lines: as a consequence of an interrupton to the underground water mantle level due to excavation, an abatement of said water mantle would follow. This abatement will be local and will be associated with that the intercepted groundwaters will come to surface at the first level of interception, but in the long run at the lowest point of the excavated section of the upstream side of the groundwater flow. Taking into account the low conductivity characteristics of formations in the area, the abatement must be local, limited primarily to the area located beneath the surface of the excavation area and a few meters upstream and downstream of said surface.

As to the amount of water, the surfacing of the groundwaters associated with the excavation will involve a transformation of the underground flows into surface runoff flows. Taking into account the characteristics of low hydraulic conductivity and low porosity of the formations in the area, as well as the consequent low values of recharge by precipitation, and considering that the flows that could be emerging to the surface would be of little significance on the hydrological dynamics of the system (the estimated percentages of recharging regarding the total downfall are less than 3%) and it is estimated that its effect in regards to base flows on the receiving currents would be imperceptible.

- Intrinsic vulnerability of aquifers to pollution

This document presents the definitions of the main concepts related to the vulnerability of aquifers and the methodology for evaluation for the Pedregal - Catambuco Segment.

the International Association of Hydrogeologists - AIH[5], uses and recommends the use of the term vulnerability as an intrinsic property of a hydrogeological system that depends on the sensitivity of the system to the impacts of natural and human origin. The characterization of vulnerability is a qualitative and not quantitative approach. The selection of the GOD method, obeys to the amount, quality and availability of information. In Colombia, the methodology choice is limited due to the scarcity of hydrogeological information.

This document focuses on the GOD index method, given its wide recognition and use. This method evaluates the vulnerability to a surface-placed polluting load (descendent vertical flows).

According to Custodio[6], the vulnerability corresponds to a qualitative or quantitative measurement of the greater or lesser easyness with which a prejudice can be caused (damage, deterioration or degradation). It refers to a concrete potential prejudice and the susceptibility that a determined natural environment has of being affected by such prejudice. Therefore the intrinsic vulnerability addresses the sensitivity of an aquifer to a certain action or form of action and not the intensity, opportunity and application of

[5] Vrba, j. and Zaporozec, A.: International Association of Hydrogeologists (IAH), 1994
[6] Emilio Custodio, Ramon Llamas. Groundwater Hydrology. [ed.] Omega. 1994 vol. II.

this action, whose factors conform the risk. For the specific case of aquifers, it is to protect the groundwater.

- *Assessment of the vulnerability of aquifers*

o Methodology

the methodologic proposal is based on the combination of different parameters (lythology, ground, thickness of the nonsaturated zone, etc.), and are used for the evaluation of the intrinsic vulnerability. Each parameter is scored quantitatively and is assigned a different weighting value to determine the final result which is a numerical index of vulnerability (iV). For a method n of parameters P and n ponderation factors fP, the index of vulnerability iV is calculated as follows:

$$iV = \sum_{j=1}^{n} fP_j \times P_j$$

Once this value iV is obtained, and depending on the method used, the vulnerability of the aquifers may be classified from low, medium, high, very high and up to extreme, as defined in Table 5.1.66 .

Table 5.1,66 Definition of the vulnerability classes[7]

VULNERABILITY CLASS	DEFINITION
Very high	Vulnerable to most of the polluting agents with impact fast in many contamination scenarios
High	Vulnerable to many pollutants (except to those which are strongly absorbed or easily transformed) in many scenarios of contamination
Moderate	Vulnerable to contaminants only when they are continuously downloaded or leached
Low	Only vulnerable to conservative contaminants when such are downloaded in a wide and continuous way during long periods of time
Very Low or Negligible	The presence of confining layers in which the vertical flow

[7] Assessing and mapping to groundwater vulnerability to contamination: The Italian combined approach. Civita, Massimo and Maio, Marina de. 1990.In ANLA Methodological proposal, 2010.

	(percolation) is insignificant

Source: Modified by INGETEC, 2016

the results of the calculation of the *iV* may vary < 0,1 to 1,0, obtaining the categories of aquifers intrinsic vulnerability to pollution, presented in the Table 5.1.67 .

Table 5.1.46 Vulnerability categories for the GOD method

SCORE	VULNERABILITY
0.7 – 1.0	Very high
0.5 0.7	High
0.3 – 0.5	Moderate
0.1 – 0.3	Low
<0.1	Very Low or Negligible

Source: Modified by INGETEC, 2016

the contamination vulnerability map for aquifers represents sectors of homogenous vulnerability for the area of associated influence to the Pedregal - Catambuco Segment, as resulting from the application of the GOD described methodology. This map represents the capacity the environment has to protect the aquifers from contamination. It is worth clarifying that this map represents the vulnerability of the aquifer and not of the specific intake points (protection perimeters) and, therefore, looks to protect the underground hydric resource and not the intake points.

The vulnerability map corresponds to a first approach to the potential risk of groundwater contamination for the area of influence associated with the Pedregal - Catambuco Segment; and it should be regularly updated as the information feeding the model is updated or expanded. The map involves the geological model for the influence area asociated to the the Pedregal - Catambuco Segment and its coresponding hydrogeological units represented according to the type of associated aquifer.

o Results

The methodology for the assessment of the intrinsic vulnerability, is focused on the most shallow aquifers or the shallowest part of the aquifers of interest (shallow and deep aquifers - aquifers with intergranular flow - zone of associated recharge basin of the Bobo river and the La Magdalena creek), as it is considered that the characteristics of the non-saturated area are those finally determining the degree of protection because those are the most susceptible to be adversely affected by contaminant loads and once contaminated, this phenomenon can be induced easily towards the deep horizons.

The hydraulic regime for the influence area of Pedregal - Catambuco is represented by free to confined aquifers. The depth of the underground water varies in the free aquifers between 3 to 7 m depth (moderate vulnerability) and confined aquifers between 8 and 30 m (low to very low vulnerability). For the latter this implies that the transit time for a contaminant to reach the groundwater will be greater too, which provides more attenuation possibilities for a certain pollutant load by degradation or natural retention. The lithological characteristics determine the areas associated with the Quaternary deposits as a means to aquifers with particle sizes not litificadas more with less attenuation of the unsaturated zone capacity or semiconfinantes layers to the polluting elements.

The direct intervention zone of the Pedregal - Catambuco layout and its associated works are mainly located on units with very low to moderate vulnerability, whose prevalence is focused on very low vulnerability associated with confined aquifers with few to limited resources of underground waters, without intrinsic vulnerability to aquifer contamination effects given the diagnostic characteristics described in this document (See annex 5.1.8 Annex 5. Hydrogeological map 6. Aquifers Vulnerability map).

The most shallow aquifer is free, even though with some clayey lenses that produce very localized confinements; since it is not hydraulically connected, it is assigned an index of 0.8 on the "G" Parameter, considering it regionally in non-confined conditions. It is conformed by alluvial deposits (Qal), corresponds to silt and sand sediments and gravels, the fragments are made of porphyritic andesites and volcanic agglomerate and belongs to the La Magdalena creek basin. This alluvial deposit is considered as a free aquifer with high permeability, but controlled by the lateral hillsides of the "U" valley. Other alluvial deposits are associate to the Guáitara, Bobo and Sapuyes rivers. Another free aquifer in the AID, includes the coluviales deposits (Qc) characterized by presenting a low permeability, and are conformed aquifers of local and discontinuous extension. In general these are heterometric, poorly selected, of a heterogeneous granulometry and intermediate porosity.

this aquifer has variations in the horizontal and vertical fasciae and in the sediments thickness, increasing towards the central part of the valley of the Bobo river and the La Magdalena creek; the basement of this aquifer, corresponds to deposits of ash and pumice and rocks of the Volcanic Sedimentary Complex of La Magdalena. The aquifer is essentially confined to semiconfined. The distribution of vulnerability to low contamination is distributed between the abscissas K0+450-K0+910, K2+000-K2+280, K3+060-K3+070, K3+500-K3+550, K6+035-K6+520, K3+150-K3+170, K24+050-K24+150, K27+400-K27+420 and inl K31+390-K31+405.

The areas of low vulnerability to contamination indicate that the unsaturated zone is very thick and containing a with a high content of semipermeables with low storage capacity and transmissivity.

The moderate vulnerability areas are associated to more shallow aquifers that since those are non-confined and lythologically more permeable, are the most susceptible to be adversely affected by a pollutant load (Aquifers Vulnerability Map see Annex 5.1.8, annex 6. The moderate vulnerability is distributed between the abscissas K6+960-K7+070, K11+295-K11+575, K12+400-k12+450 which lythologically correspond to colluvial deposits and on the abscissa K12+850-K13+000 in anthropic deposits, but the interventions in these areas during construction activities correspond to embankments, cuts and improvement of structural works such as bridge foundations.

The moderate vulnerability represents in the Pedregal - Catambuco Segment that the saturated zone is formed by layers and / or horizons of low thickness sediments whose lythological predominance includes sediments with textures with high sand content, high permeability gravel and storage capacity.

Distribution of the types of intrinsic vulnerability evaluated for the area of influence of the Pedregal - Catambuco Segment.

the distribution of the vulnerability categories present in the Pedregal - Catambuco Segment, are described below. (See Table 5.1.68 and Figure 5.1.139).

Table 5.1.47 Vulnerability Categories in the Pedregal - Catambuco Segment

TYPE OF VULNERABILITY	Description:	AREA (m2)
Low	Aquifers vulnerable to very mobile and persistent pollutants and continuous pollution events for extended periods of time.	699,4
Moderate	Aquifers vulnerable to relatively mobile and/or persistent pollutants or continuous pollution events for extended periods of time.	281,7

Very low	Confining layers that represent an obstacle that impairs in a high degree asignificant flow of polluting agents towards the aquifer.	18.355,0

Source: Modified by INGETEC, 2016

Based on the characterization of the study area it is considered as a zone with low hydrogeologicpotential, insofar as it is covered to a great extent by hydrogeological units of low productivity or by impermeable rocks with limited resources of underground waters; additionally as it was mentioned in most of the study area the depths of the water mantle level are greater than 10 m, whereas the estimated values of charge by precipitation are inferior to 3%.

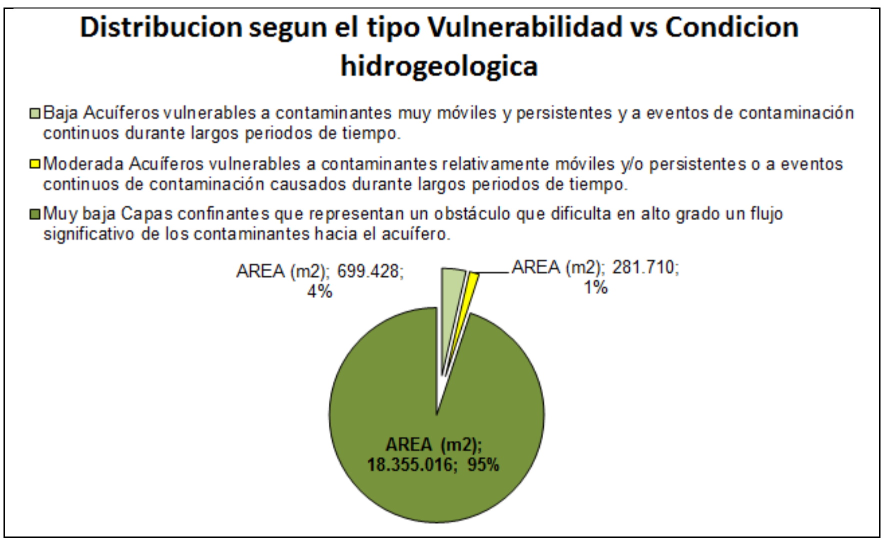


Figure 5.1.1550 Distribution according to type of Vulnerability versus Hydrogeological Condition

Source: (INGETEC, 2016)

According to the prior, no significant effect of the project is expected upon the underground hydric system of the study area. Given the effect of the waterproofing of surfaces associated with the project there would be a reduction of the recharge area by infiltration; This effect is considered not significant since the proportion of the area intervened to the area in which the recharging process currently takes place is very small.

In specific areas where the excavation surfaces could intercept the water mantle level, there could be local abatements on the phreatic level around the excavated surface and outcroping of the underground water flows whose water mantle level has been intercepted. This effect is considered non significant because the abatements would occur basically under the same excavated surfaces or some meters away from the same and that the volumes of the underground runoffs - whose contribution to the currents of the zone of study can be considered of low relevance due to the low recharge estimated values - would not be lost, but transformed into superficial runoff flows.

the hydraulic regime in the area of influence Pedregal - Catambuco segment is represented by free to confined water mantles, where the depth of the underground water varies in the free aquifers to a superficial level of up to 7 m depth is considered that these present a moderate vulnerability, whereas for the confined aquifers it varies between 8 and 30 m, and considered of low to very low vulnerability. For the latter this implies that the transit time for a pollutant to reach the groundwater will be greater, which provides more attenuation possibilities for a certain pollutant load by degradation or natural retention. The lithological characteristics determine the areas associated to the Quaternary deposits as the intermediate water mantles with non lythified major granulometries less attenuation of the unsaturated zone or the semi confining layers to the pollutants, construing the zones with greater sensitivity to the pollutant load and lesser attenuation capability.

The areas of low vulnerability to contamination indicate that the unsaturated zone is very thick and containing a high proportion of semi-permeable material with low storage capacity and transmissivity, mainly associated to aquifers with low permeability, confined groundwater levels between 10 and 20 m depth located in areas with high runoff and low storage capacity consistent with the surface water balance of the basin of the Bobo and La Magdalena rivers. The moderate vulnerability represents in the Pedregal - Catambuco Segment that the saturated zone is formed by layers and / or horizons of low thickness sediments whose lithological predominance includes sediments with textures with high sand content, high permeability gravel and storage capacity.

The very low vulnerability of aquifers to pollutants in the Pedregal - Catambuco Segment is predominant in 95% of the intervention area, followed by low vulnerability with 4% and finally moderate vulnerability by 1%.

5.1.9. Geotechnics

- Zoning and geotechnical cartography

The stability characteristics of the terrains that will be affected by the cuts, fills, and other types of occupation or new use, are essential to establish measures of geoenvironmental type along the corridor and in the areas of infrastructure associated with the road project Rumichaca - Pasto Pedregal - Catambuco segment.

The linear and continuous nature of the future new highway Pedregal - Catambuco, induces to implement strategies of geotechnical characterization by homogeneous sectors attending the comprehensive analysis of geological hydroclimatic and morphological subcomponents, along with the engineering behavior expected for different types of materials (soils and rock massifs) that exist along the projected road corridor.

The categorizations of stability associated with geomorphology, geological units, erosion, slope of the terrain and other geoenvironmental features of the territory will be used.

The zoning and geotechnical mapping was carried out based on geological, edaphological, geomorphological and meteorological information. According to information in the GDB from the EIA, the following parameters were used:

Table 5.1.48 Parameters used in the GDB ofl EIA

Component	Parameter GDB
Geology	Geological Unit
Topography	Slopes
Geomorphology	Erosion, Geomorphological Unit
Meteorology	Climatic zoning

Source (Geminis Environmental Consultants, 2016)

For the respective classification procedure were assigned values of 1 to 5 where 1 is very good aptitude and 5 is very poor aptitude against the stability of the ground

Geology: The Geotechnical stability in the area was established through the information provided by the formation or geological unit, in the following manner. (See Table 5.1.69)

Table 5.1.49 Classification by geological unit

Geologic Unit	*Description:*	*Degree of Instability*	*Aptitude vs. Stability*
Ash Flows and Pumice (TQvf)	Laháricos flows made up of fragments of pumice, andesite, brecciae in sand silt matrix with some volcanic ash interleaves	3	Low
Lavas and ashes (TQvlc)	Andesitic lava interspersed with ashes type “ash fall” and “ash flow”	3	Low
Lahars and Pyroclasts (TQvlp)	Interspersed lahars with pyroclastic flows	2	Medium
Lavas (TQvl)	Interspersed andesitic lava, tuffs and volcanic brecciae.	2	Medium
La Magdalena Sedimentary Volcanic unit (TQsv)	Thin interleaves of claystones, siltstones and fine grained sandstones of clear clear colors with remnants of diatomaceous earths.	3	Low
Burning Aavalanches and Debris (Tqva)	Tuffs of lapilli and agglomerates produced from volcanic emissions of violet color.	2	Medium
Alluvial Deposits (Qal)	River based sediments, associated to the Guáitara river levels	3	Low
Ash Rain (Qvc)	"Ash fall" ashes that model the current topography, current paleo floors levels.	3	Low
Colluvial deposits (Qc)	Matrix supported deposits with angular fragments of intrusive volcanic rock of basic to intermediate composition.	3	Low
Anthropic fill (Qant)	Artificial accumulation of natural soils, rock fragments or waste material.	2	Medium

Source (Geminis Environmental Consultants, 2016)

Soil erosion: The soil erosion level was established by the parameter Soils. (See Table 5.1.70)

Table 5.1.70 (20) Classification according to the soil erosion.

Soil Erosion;	*Description:*	*Degree of Stability*	*Aptitude vs. Stability*
Without erosion	No erosive or sedimentation processes are identified. These are stable zones that present an acceptable condition. Given the regional trend towards deforestation, it is recommended that environmental protection measures for waters and soils be implemented.	1	High
Severe	Advanced absence of vegetable top coat and extreme deterioration of soils due to natural erosion, dry weather and/or anthropic activities. Loss >; 75% of horizon A. These areas are not apt for intervention. Very high degree of erosion.	3	Low
Active sedimentation	There are no erosive processes Medium erosion degree	2	Medium

Source (Geminis Environmental Consultants, 2016)

Slope: The terrain's inclinational value was determined via a DEM (Digital Terrain Model) asociated to the geomorphology of the GDB. (See Table Table 5.1.71)

table 5.1.71 classification bysoil slope

Slope of the land	*Description:*	*Degree of Stability*	*Aptitude vs. Stability*
Slope of 0 to 8°	Flat land slightly inclined, the morphodynamic processes are mainly aggradational.	1	High

Slope of the land	*Description:*	*Degree of Stability*	*Aptitude vs. Stability*
Slope of 0 to 8°	Inclined land.	1	High
Slope of 15° to 25°	Terrain strongly inclined susceptible to landslide phenomena.	2	Medium
Slope of 25° to 45°	Highly steep land susceptible to landslide phenomena.	3	Low
Slope >; 45°	Land not suitable for construction of infrastructure.	3	Low

Source (Geminis Environmental Consultants, 2016)

Geomorphology: It was established by the profile of the area. (See Table 5.1.72)

table 5.1.72 classification by geomorphology.

Landform	*Description*	*Degree of Stability*	*Aptitude vs. Stability*
Low hills of pyroclastic deposits	Landforms of volcanic and denudational origin which exhibit wavy to flat outlines, with low slopes.	1	High
Pyroclastic mantle joined hills	Landforms of volcanic and denudational origin which exhibit wavy to flat outlines, with medium slopes.	2	Medium
Denuded slopes of steep slope	Landform of denudational origin over deposits of lavas and pyroclastic rocks which form steep hills, with high slopes prone to landslide phenomena and advanced erosion.	3	Low
Coluvio-alluvial little valley of deep dissection	Coluvio-alluvial valleys in "V" shape product of the hydric erosion on slopes and hills of the area.	3	Low

Landform	*Description*	*Degree of Stability*	*Aptitude vs. Stability*
Pronounced alluvial valley	V-shaped alluvial valley with high slopes product of fluvial processes that mainly cause erosion on the lithology of the area even though it also includes lenticle bodies and erosion processes caused by runoff.	3	Low
Anthropic bodies	Anthropic bodies which exhibit flat outlines with slopes less than 12%.	1	High
Colluvium	Sedimentary bodies of irregular shapes topographically located in low and intermediate areas with regard to the outline of the area. They exhibit a topography from inclined to relatively flat.	2	Medium
Landslides, crowns and erosion	These correspond to sliding bodies, mud flows, landslides and erosive surfaces phenomena.	3	Low

Source (Geminis Environmental Consultants, 2016)

- Geotechnical description

For the obtaining of results the cartographic information was crossed by means of the following logical structure. (See Table 5.1.73)

Table 5.1,73 logical Structure of qualification of the aptitude as opposed to the stability of the land.

Value 1	*Value 2*	*Final value*
High	Medium	High
High	Low	Medium
High	Very Low	Low
Medium	Low	Medium
Medium	Very Low	Low
Low	Very Low	Very Low
Very High	High	Very High
Very High	Medium	High

Value 1	*Value 2*	*Final value*
Very High	Low	Medium
Very High	Very Low	Low

Source (Geminis Environmental Consultants, 2016)

After crossing the thematic layers of information thanks to the cartography developed in each component explained in the preceding sections, the results are obtained summarized in Table 5.1.74, where three "geotechnical units" (nomenclature other than the one of "functional units") with differentials of behavior as far as their stability are defined.

Table 5.1,74 General geotechnical results

Geotechnical unit	Aptitude as opposed to total geotechnical stability	Degree of total geotechnical stability	Aptitude as opposed to total susceptibility	Degree of stability total susceptibility	Type Of Material	Total area (%)
Unit 1	High	1	Low	3	Volcanic deposits, rock	35%
Unit 2	Low	3	High	1	Deposits Quaternary	15%
Unit 3	Medium	2	Medium	2	Volcanic deposits	50%

Source (Geminis Environmental Consultants, 2016)

Susceptibility, see table 5.1.75

table 5.1.75 classification by susceptibility of the land for the project.

	Descripción	*Estabilidad del terreno*	*Medidas correctivas o preventivas*
Muy Alta	La probabilidad de colapso del terreno y ocurrencia de movimientos de material es muy alta debido a sus características físicas	Totalmente inestable	Zonas no aptas para construcción de infraestructura.
Alta	La probabilidad de colapso del terreno y ocurrencia de movimientos de material es alta debido a sus características físicas.	Parcialmente inestable	Estabilización de taludes mediante terracéo, manejo adecuado de drenajes y reforestación de los mismos. Esto previene la erosión y reduce la capacidad de socavación del agua. Ocasionalmente se pueden construir gaviones o jarillones para contener el movimiento del material.
Media	El colapso del terreno y ocurrencia de movimientos de material es ocasional y puntual.	Estable con medidas correctivas	Las medidas correctivas deben ir enfocadas a la reforestación de taludes, mantenimiento de los canales de desagüe y disminución de la velocidad del agua de escorrentía.
Baja	Se presentan movimientos de material aislados.	Estable	En este caso deben tomarse preventivas como evitar la deforestación, formación de surcos que faciliten la disección del suelo y la desviación de cauces.
Muy Baja	La probabilidad de colapso del terreno y ocurrencia de movimientos de material es muy alta debido a sus características físicas	Totalmente estable	Ninguno. Se deben tomar medidas preventivas como en el caso anterior.

Source: (Geminis Consultants S.A.S, 2016) subsequent to the verification of the data it could be inferred that the geotechnical stability in its large percentage is defined between low and middle, this explained to a large extent to what elements such as threat by earthquake and landslides in the area is high and middle respectively. Erosion due to loss of topsoil and sedimentation (only on the banks of the river) was identified. The more stable areas presenting an acceptable condition are where the slope is very low or the quality of the rock is well established (Tqva and TQsv), in addition to this, this type of material has a low permeability which prevents the percolation of rainwater which promotes the stability of the ground, however arise material movements due to the different drainage patterns favored by steep slopes in some areas of the path for this reason they have to implement adequate drainage systems so the porosity given by joint (secondary porosity) will not affect the stability of the work as well as taking preventive measures to avoid deforestation in order that the rock is not exposed to weathering and erosional processes can be generated in the future (formation of furrows and gullies) at any time. However when the slope is sheer, even with this lithology a low stability would be present.

On the other hand zones of greater instability are located where there are Quaternary deposits (Movements in mass) since they present/y undermining processes because the material is not consolidated, which makes it vulnerable to slidings. Beside sthis, some sections can be observed which exhibit a moderate to high slope i which it would be common to find landslides in any of the mentioned Quaternary deposits (volcanic or alluvial) for these zones with high instability it is recommendable to incurr in talus stabilization processes and reforestation in order to counter the effects that the landslides can produce. Nevertheless most of the area of the project would be classified like a geotechnical stability average due to the set of consolidated lithology (Tqva, TQsv and TQvl) and little consolidated (Qvc, TQvf and TQvlp), low and somewhat moderate slopes, erosion where there is no vegetal cover and denudational landforms (Figure 5.1.141).

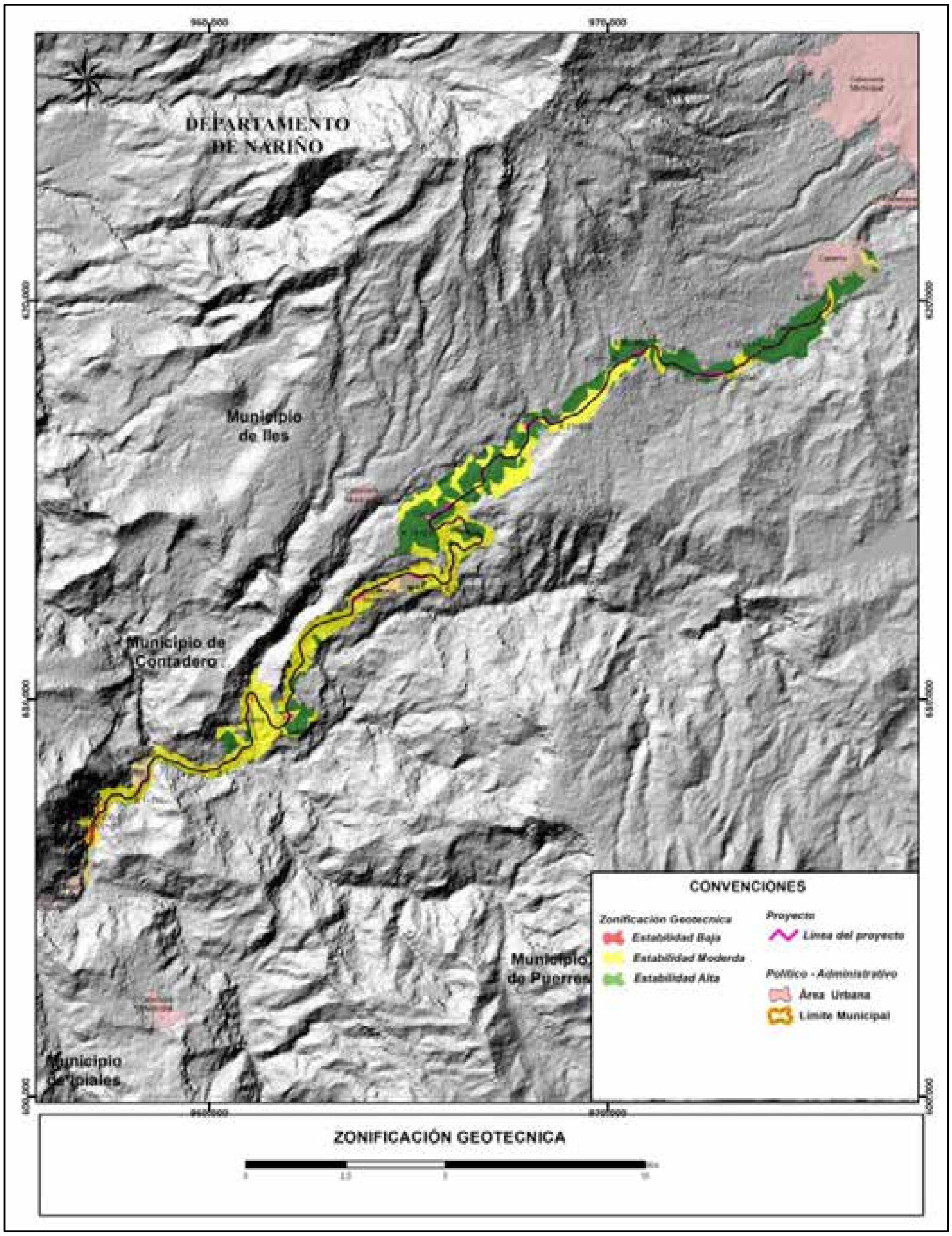

DEPARTAMENTO DE NARIÑO
Municipio de Iles
Municipio de Contadero
Municipio de Puerres
Municipio de Ipiales
CONVENCIONES
Zonificacion Geotecnica
Estabilidad Baja
Estabilidad Moderda
Estabilidad Alta
Proyecto
Linea del proyecto
Politico - Administrativo
Área Urbana
Limite Municipal
ZONIFICACIÓN GEOTECNICA

Figure 5.1.156 Geotechnical zoning Pedregal - Catambuco Segment
Source: M & M Team

Atmosphere

This study aims to present the current situation and issues concerning climate and weather conditions, sources of emissions, local air and noise quality, as well as conditions, monitoring and overview of the different variables and parameters influencing the climate behavior in the area of influence of the project.

5.1.10.1 Meteorology

To determine the behavior of the different meteorological and climate variables, weather stations were selected using the following criteria:

- Geographic proximity: the stations close to the area of influence of the project awere identified nd spatially localized, to determine the distance to the area thereof.
- Representativity, homogeneous distribution over the study area and type of station: a representation study of the project area was conducted based on the type of station, allowing discarding stations that recorded the smallest number of weather parameters (pluviometric and pluviographic).
- Duration of time series: in above mentioned preselected stations, the recorded period duration was analyzed, discarding those that were suspended or with short registers. (See detail in GDB / mapping / PDF / EIADCRP_PC_016).

The climatological analysis for the Pedregal-Catambuco section used IDEAM stations which make up the existing official meteorological network in the department of Nariño. (See Table 5.1.76).

Table 5.1.50 Weather Stations Pedregal-Catambuco section

CODE	NAME	MUNICIPALITY	TYPE*	ELEVATION masl	GEOGRAPHICAL COORDINATES	
					LENGTH	LATITUDE
52055040	Botana	Pasto	AM	2820	977,596.783	620,034.667
52045010	Obonuco	Pasto	AM	2710	975,237.610	624,236.710
52057010	Pilcuán	Imués	LG	2550	953,087.191	608,426.705
52055090	Sindagua	Tangua	CP	2800	965,331.117	614,175.231

CODE	NAME	MUNICIPALITY	TYPE*	ELEVATION masl	GEOGRAPHICAL COORDINATES	
					LENGTH	LATITUDE
52050080	Tangua	Tangua	PM	2420	965,108.364	612,737.762

SP: Main Synoptic Station, AM: AgroMeteorological Station, LG: Water Level Recording Station, PM: Rainfall Station, CO: Ordinary Weather Station, CP: Main Weather Station

Source: IDEAM 2016

To analyze the different climatic variables in the study area, the stations that provided sufficient information were taken into account, i.e. reliability of data collection, continuity of the series and representativeness of the area. (See Figure 5.1.142).

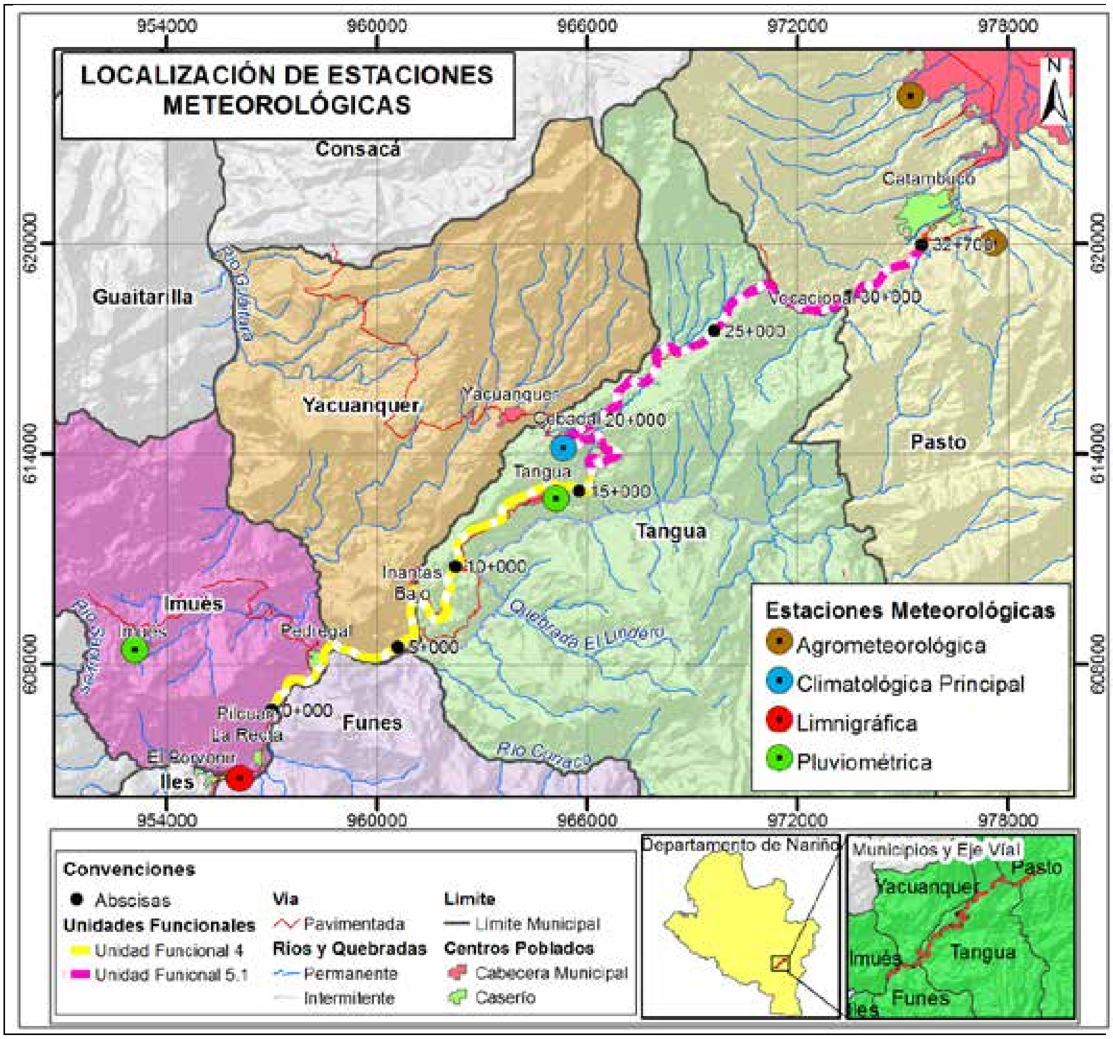


Figure 5.1.157 Weather Stations Pedregal- Catambuco Section
Source (Gemini Environmental Consultants, 2016)

The monthly averages of each station are approximately the last twenty-nine years (29), estimated from 1987 to 2015. Climatic parameters to be evaluated and operated by the IDEAM are:

- Temperature

- Atmospheric pressure
- Precipitation
- RH
- Wind
- Solar radiation
- Cloudiness
- Evaporation

Follows the weather analysis for above-named variables:

- *Temperature*

Temperature is a parameter of the thermal state of the matter. This variable is determined as a physical quantity which characterizes the mean random movement and presents a variability in function of the elevation. (See annex GDB / mapping / PDF / EIADCRP_IP_018).

The temperature behavior was obtained from information from meteorological stations located in the study area for a period of 29 years in order to ensure the reliability of the information:

Table 5.1.51 Monthly average temperature (° C)

STATIONS	MONTHS OF THE YEAR												ANNUAL VALUE
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Botana	12,50	12,60	12,80	12,80	12,30	11.80	11.80	12,20	12,60	12,50	12,40	12,40	12,40
Obonuco	12,90	13.10	13.10	13,30	13.40	12,90	12,50	12,50	12,90	13.07	12,90	12,90	13,00
Sindagua	13.05	13.10	13.10	13,20	13,20	13.08	12,80	12,90	13,20	13,20	12,90	13.01	13.10

Source: Adapted IDEAM, 2016

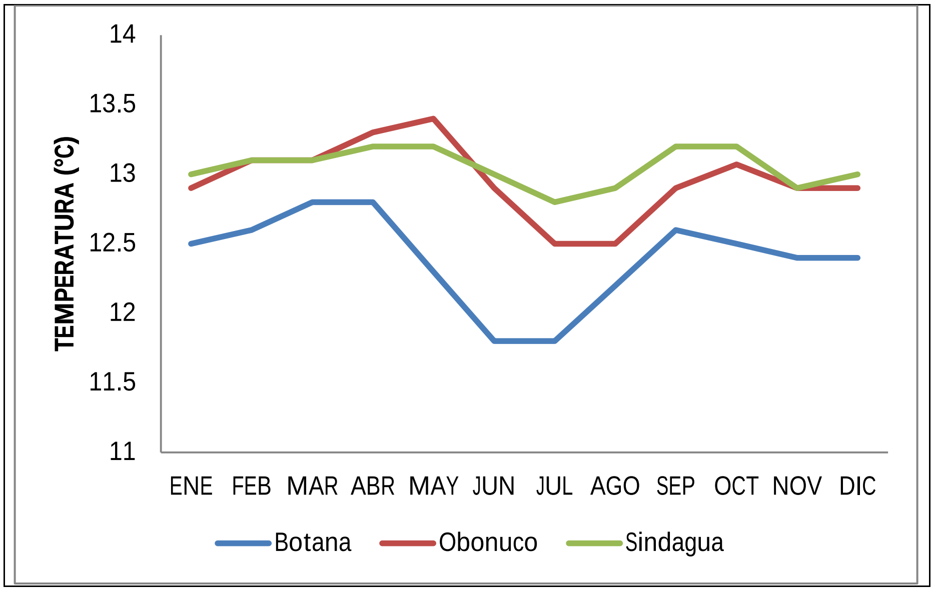


Figure 5.1.158 Linear frequency graph for temperature values recorded in the Botana, Obonuco and Sindagua stations

Source: Gemini Environmental Consultants, 2016

Figure 5.1.144 shows the mean monthly temperature distribution for three (3) selected stations for the analysis over a period of 29 years. Graphically the month of May reaches a maximum value of 13.40 °C and a minimum value in the months of June and July of 11,80 °C. Isotherms were generated in order to visualize the spatial behavior of temperature, using reference values recorded by the stations located in the project area, which show temperature indexes ranging from 11 °C to 13 °C which shows an annual increasing behavior.

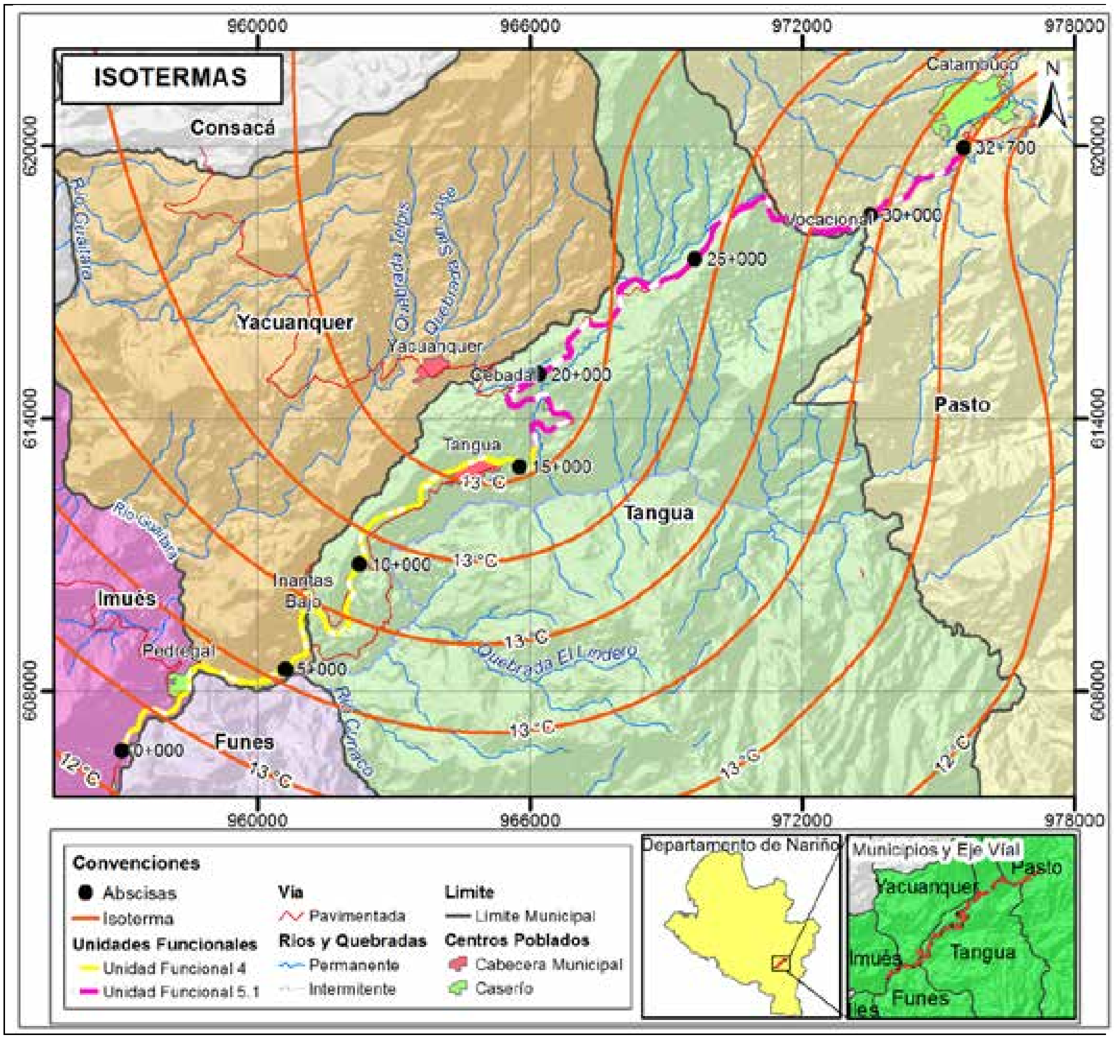


Figure 5.1.159 Isotherms, Pedregal - Catambuco Section
Source (Gemini Environmental Consultants, 2016)

- *Atmospheric pressure*

The atmospheric pressure parameter is reported only for some airports in Colombia (IDEAM, 2011) reason why it is not taken into account for this study, since the weather station that is recorded in this diagnosis in the Department of Nariño is located outside the area of influence of the project.

However, according to secondary information query, the atmospheric pressure for the city of Pasto is 614.68 mmHg (Worldmeteo, 2016).

- *Precipitation*

Precipitation is defined as hydrometeors fall that ultimately reach the ground and is a meteorological variable with high spatial and temporal variability. Precipitation behavior is projected using as a reference the information recorded by the Botana, Imués, Obonuco, Sindagua and Tangua stations, in a period of 29 years, as seen in Table 5.1.78. (See detail in GDB / mapping / PDF / EIADCRP_IP_017).

Table 5.1.52 Mean monthly precipitation values (mm)

STATIONS	MONTHS OF THE YEAR												ANNUAL VALUE
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Botana	80.30	75.30	92.60	96.60	85.70	64.80	54,00	38.30	42.40	90.06	107.90	93.30	921.70
Obonuco	72.80	68.80	82.90	87.40	80.90	46,20	35,60	23.70	31.50	96.90	100.30	85.30	812.70
Sindagua	94.40	81.90	94.20	112,10	94.90	53.50	33,60	21.20	45.70	107.80	132.90	108.20	980.80
Tangua	96.10	78.90	102,90	121.30	103.90	44.70	29.70	19,40	44.80	121.40	137.10	104.20	1,004.90
Imués	88.40	85.50	106.10	123.40	97.70	47.50	31.50	26.30	45.70	111.70	127.10	112.50	1,003.80

Source: Adapted IDEAM, 2016

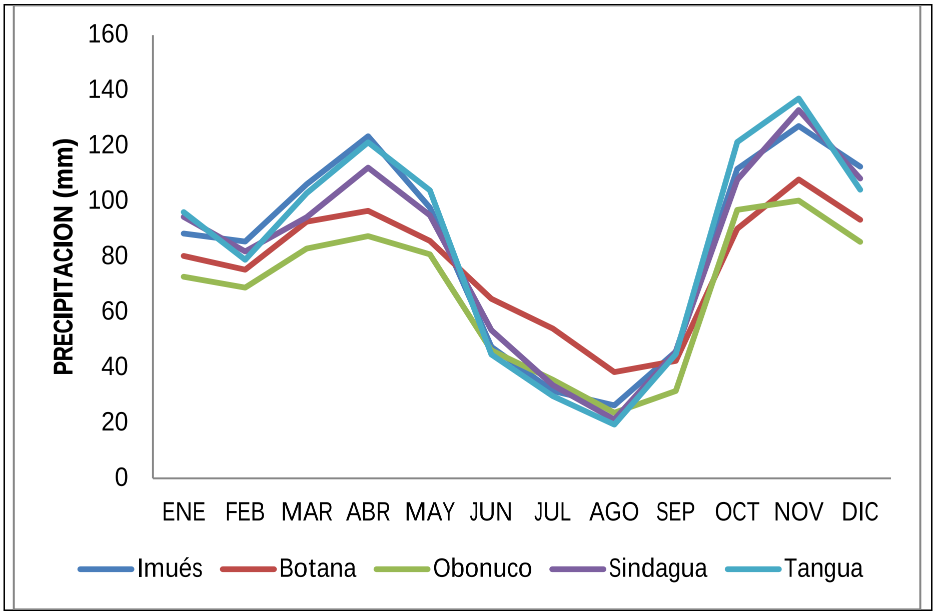


Figure 5.1.160 Histogram for precipitation values registered in the Botana, Obonuco, Sindagua, Tangua and Imués stations
Source: Gemini Environmental Consultants, 2016

As shown in Figure 5.1.145, precipitation presents a monomode behavior, with a rainy period between the months of October to May, with the month of November showing a maximum value of 137.10 mm. On the other hand, the dry period is recorded between the months of June through September with August showing the lower precipitation, with a minimum value of 19.40 mm.

In order to visualize the distribution and spatial behavior of precipitation and using values recorded by the stations located within the project as reference, isohyets were generated showing a system of ascending precipitation of 880mm to 1000mm with the latter value aa a peak, and once this peak is reached, the rate of precipitation decreases equally to 820mm.

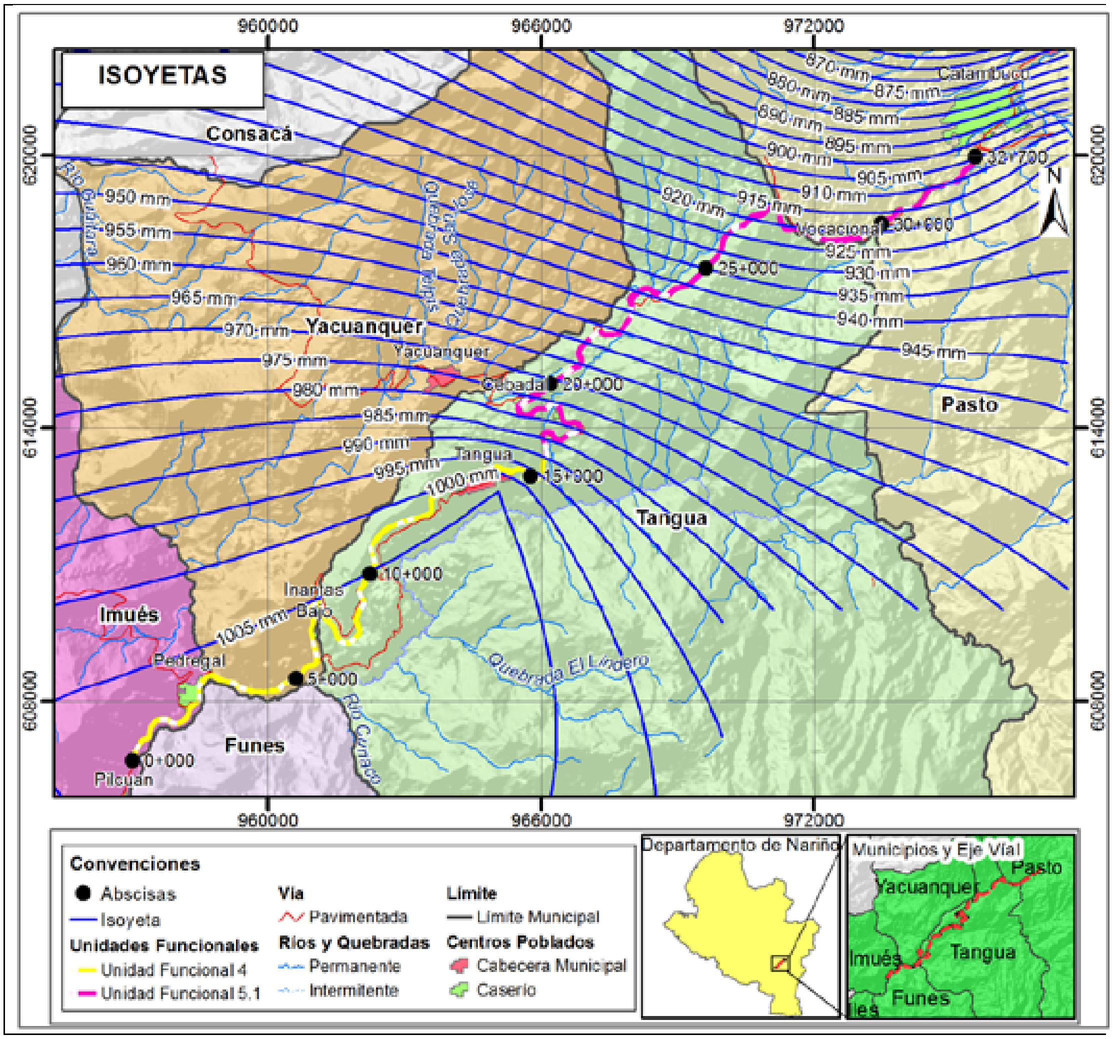


Figure 5.1.161 Isohyets, Pedregal - Catambuco Section
Source (Gemini Environmental Consultants, 2016)

- *RH*

Moisture is a weather element having a close relationship with the atmospheric stability component and therefore with the occurrence and distribution of precipitation in an area or land portion. Generally, moisture does not have strong mean value due to the high content that usually occurs in the tropics. From relative humidity records from the

Botana, Obonuco and Sindagua stations in the area of influence of the project, Pedregal-Catambuco section

Table 5.1.53 Monthly average Relative Humidity (%)

STATIONS	MONTHS OF THE YEAR												ANNUAL VALUE
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Botana	80	80	81	80	79	78	77	74	74	78	81	82	79
Obonuco	81	82	82	81	80	78	76	74	74	79	83	83	80
Sindagua	80	80	80	80	80	79	77	75	74	78	82	81	79

Source: Adapted IDEAM, 2016

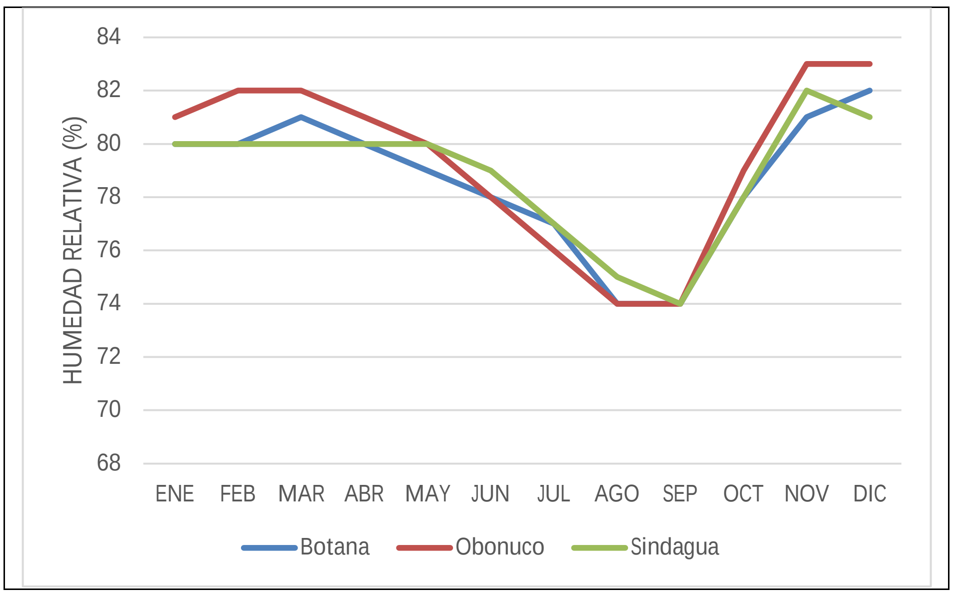


Figure 5.1.162 Frequency linear graph for relative humidity values recorded in the Botana, Obonuco and Sindagua stations
Source: Gemini Environmental Consultants, 2016

An annual average relative humidity of 79.3% is established which means that this is a humid region (See Table 5.1.179). Graphically it can said that the higher mean values for high rainfall are the months of November and December with 83% respectively, while the lowest are present in relatively dry or low rainfall in the months of August and September with a value of 74%. (See Figure 5.1.147).

- *Wind rose*

The wind rose shown in Figure 5.1.148 for the Obonuco station shows a strongly predominating wind behavior from the south, with speeds over 3 m / s during most of the time.

In general, the trade winds from the south are the prevailing winds, which gather force towards the third quarter between July and September. The prevailing wind direction is to the southeast.

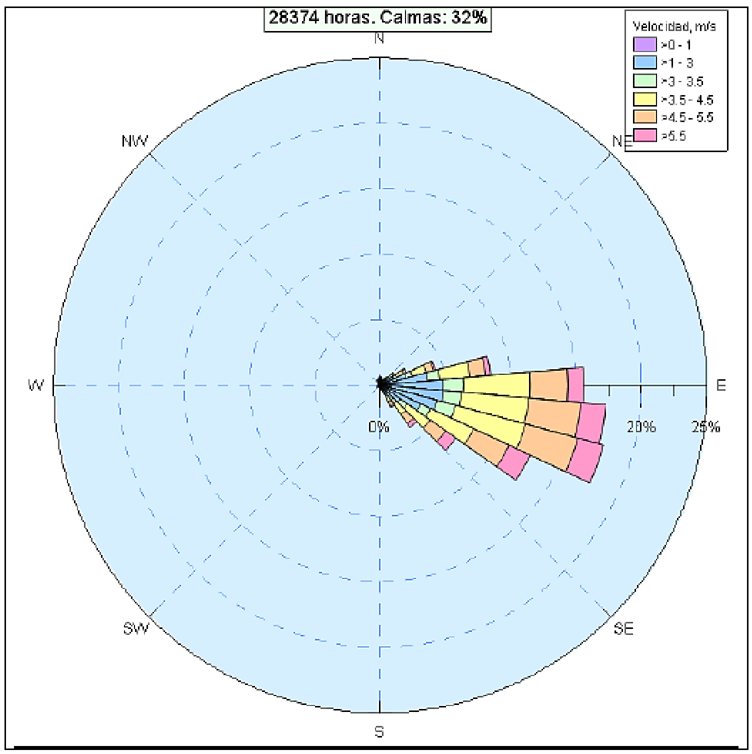


Figure 5.1.163 Time wind rose, Obonuco station IDEAM

- *Sunshine*

Sunshine is one of the most important factors in determining the climate of any area. The distribution of the values of this parameter is inversely related to other elements such as cloudiness and precipitation.

Follows sunshine records for the Botana, Obonuco and Sindagua stations for the area of influence of the project for a time period of 29 years. (See Table 01/05/80)

Table 5.180 Monthly sunshine values (hours)

STATIONS	MONTHS OF THE YEAR												ANNUAL VALUE
	JAN	FEB	MAY	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Botana	100.6	88.5	72.2	79.5	88.5	88.3	110.3	123.6	116.7	106.7	96.4	78.0	1149.4
Obonuco	110	83.9	76.0	81.3	94.2	100.4	110.2	113.6	60.4	106.3	99.4	107.4	1143.0
Sindagua	121.4	106.6	93.1	99.3	112.9	121.8	156.0	159.2	131.5	122.5	149.9	112.3	1486.3

Source: Adapted IDEAM, 2016

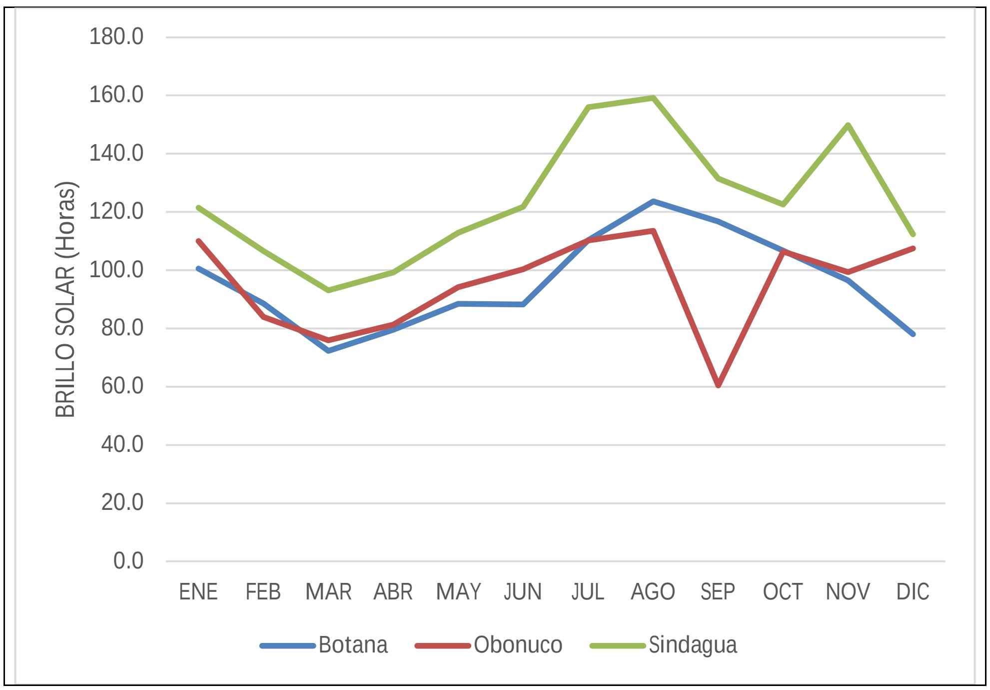


Figure 5.1.164 Frequency linear graph for solar brightness values registered in the Botana, Obonuco and Sindagua stations

Source: Gemini Environmental Consultants, 2016

Figure 5.1.165 shows that higher values are presented in the months of July, August and November, and the lowest value during the rainy seasons months of March and September.

The Sindagua station has highest records with 159,2 hours of sunshine in August and 149.9 hours in November respectively. The lowest values were observed in the Obonuco and Botana stations, with 60 to 72,2 horas of sun for the months of March and September, observing the influence of relief and therefore greater presence of clouds.

- *Cloudiness*

Cloudiness measurement, i.e.. the amount of cloud cover observed in a given moment in the sky occurs in oktas, to this end the sky is divided into eight (8) portions as seen in Table 5.1.81

Table 5.1.81 Definition of oktas to categorize the weather

OKTAS	DEFINITION	CATEGORY
0	Clear	Without clouds
1	1/8 of sky covered or less, but not zero	Slightly cloudy
2	2/8 of sky covered	Slightly cloudy
3	3/8 of sky covered	Slightly cloudy
4	4/8 of sky covered	Partly cloudy
5	5/8 of sky covered	Mostly cloudy
6	6/8 of sky covered	Mostly cloudy
7	7/8 of sky covered or more, but not 8/8	Mostly cloudy
8	8/8 completely overcast sky, no clears	Covered

Source: www.titulosnauticos.net/metereologia. German adaptation Bernal

To analize cloudiness, the cover data recorded by the Botana and Sindagua stations respectively were taken into account. (Seetable 05/01/82).

Table 5.10.82 Monthly cloudiness values (oktas)

STATIONS	MONTHS OF THE YEAR												ANNUAL VALUE
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Botana	6.5	6.6	6.6	6.6	6.6	6.6	6.5	6.2	6.1	6.4	6.6	6.5	6.5
Sindagua	3.5	3.7	3.8	3.6	3.3	2.9	2.7	2.6	2.7	3.3	4	3.7	3.3

Source: Adapted IDEAM, 2016

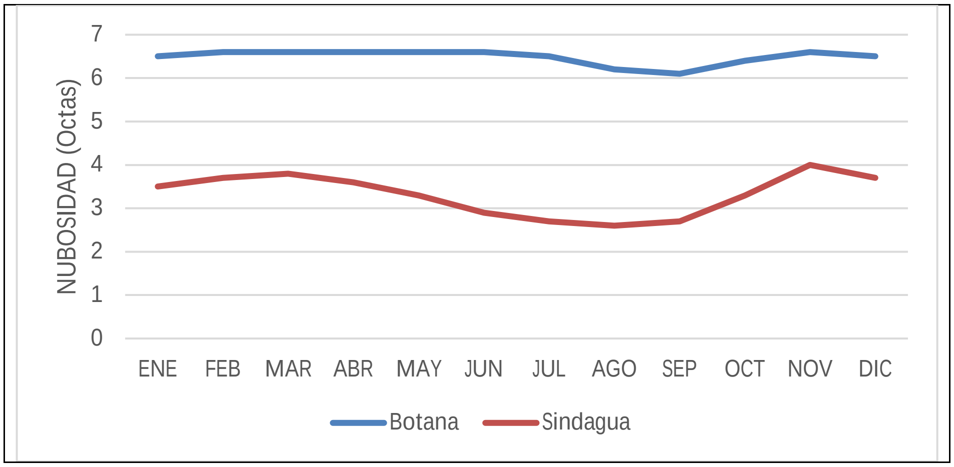


Figure 5.1.166 Linear frequency graph for cloudiness values recorded in the Botana and Sindagua stations

Source: Gemini Environmental Consultants, 2016

Figure 5.1.167 shows cloudiness behavior in the area of influence of the project, for such end a maximum value of 6.6 oktas in November were estimated, supporting a mostly cloudy sky corresponding to 6/8 overcast, but in contrast, in the month of August presents a minimum value of 2.6 oktas, which expresses a value corresponding to 2/8 overcast slightly cloudy sky.

- *Evaporation*

Evaporation is a physical process whereby water from a wet, or a free water surface area is introduced into the air as vapor at a temperature below the boiling point, the stations listed below are those with greater reliability of information. (Seetable 5.1.83).

Table 5.1.543 Monthly mean evaporation values (mm)

STATIONS	MONTHS OF THE YEAR												ANNUAL VALUE
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Botana	73.7	68.2	69.5	67.6	70.4	66.2	75.5	82.5	83.5	83.7	74.1	70.3	885.9
Obonuco	88.1	76.71	79.41	78.8	83.1	83.4	91.7	101.8	47.9	96.1	82.6	81.3	986.1
Sindagua	86.9	80.8	80.3	83	79.6	86.7	100.1	110.9	106.4	98.9	83.7	84	1081.8

Source: Adapted IDEAM, 2016

The evaporation index is defined as the amount of water lost by a surface unit in a time unit; millimeters (mm) of water evaporated are measured.

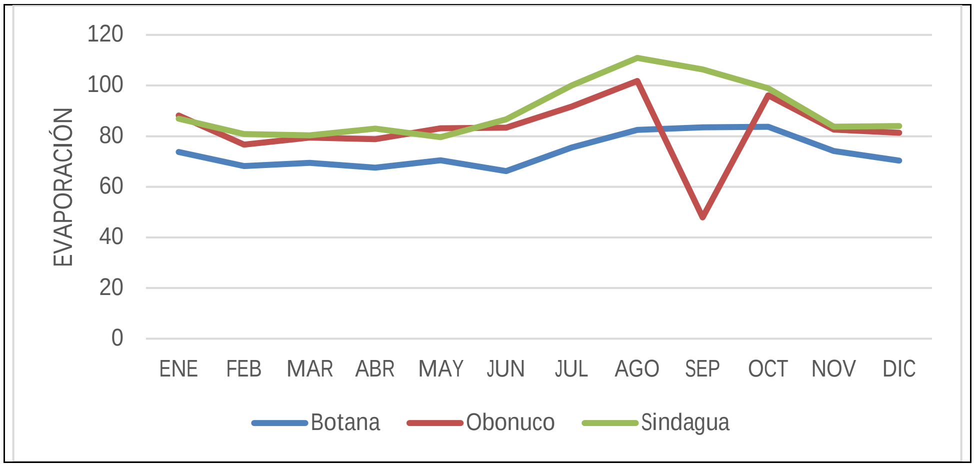


Figure 5.1.168 Lineal frequency graph of evaporation values recorded in the Botana, Obonuco and Sindagua stations

Source: Gemini Environmental Consultants, 2016

Figure 5.1.169 shows evaporation with a maximum value of 110.9 mm in the month of August in accordance with the inverse precipitation and relative humidity ratio, the month of September has a minimum evaporation value of 47.9 mm, considered the rainiest month.

- *Wind path*

To analyze the average wind path, information from the Botana, Obonuco and Sindagua stations was used. (See Table 5.1.84).

Table 5.1.84 Monthly wind path values (km / s)

STATIONS	MONTHS OF THE YEAR												ANNUAL VALUE
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Botana	3575.7	3349.6	3581.0	3612.6	3866.9	4477.0	5117.2	5255.9	4592.1	3865.3	3195.8	3262.2	44,431.8
Obonuco	4327.3	3923.2	4099.6	3920.3	4533.4	5513.5	6554.1	7150.0	5679.6	4625.0	3747.6	3953.5	54632.6
Sindagua	3353.1	3010.0	3149.6	2992.4	3062.8	3830.8	4638.3	5057.7	4469.6	3511.8	2891.3	3121.0	40545.7

Source: Adapted IDEAM, 2016

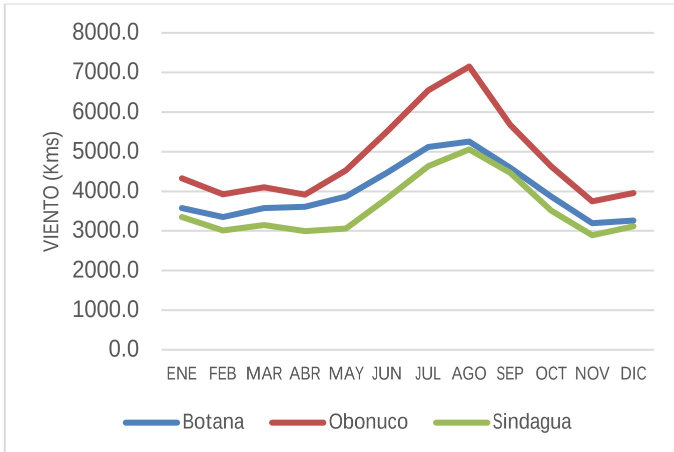


Figure 5.1.151 Line graph for frequency values registered in the Botana, Obonuco and Sindagua stations

Source: Gemini Environmental Consultants, 2016

According to data of Figure 5.1.151 the wind path behavior is monomodal, it begins to increase in April with 3920, 3 km/s, peaking in August with a value of 7150 km / s with prevailing south-southeast tradewinds since the intertropical convergence zone (ITCZ) is displaced to the north of Ecuador and therefore recording its highest velocity values.

5.1.10.2 Identifying sources of emissions

The project has three classes of existing air emissions sources in the area of influence which are fixed, mobile and area. (See annex GDB / mapping / PDF / EIADCRP_IP_021)

- *Stationary sources*

Are those operating in a fixed point, i.e., the emission source does not move autonomously in time, an example of such sources include industrial furnaces and domestic fireplaces, Table 05/01/85 shows the relationship of stationary sources present in the project. (See Figure 5.1.152)

Table 5.1.85 Dtationary sources tatio, Pedregal - Catambuco Section

SOURCE TYPE	INDUSTRIAL ACTIVITY	PLANAR COORDINATE Magna Sirgas Origin West	
		EAST	NORTH
Fixed source	Crematorium oven Jardines Cristo Rey	976,047.12	620,671.47
Fixed source	Brickworks	965,858.96	614,741.21
Fixed source	Brickworks	965,982.95	614,821.70

Source: (Gemini Environmental Consultants, 2016)

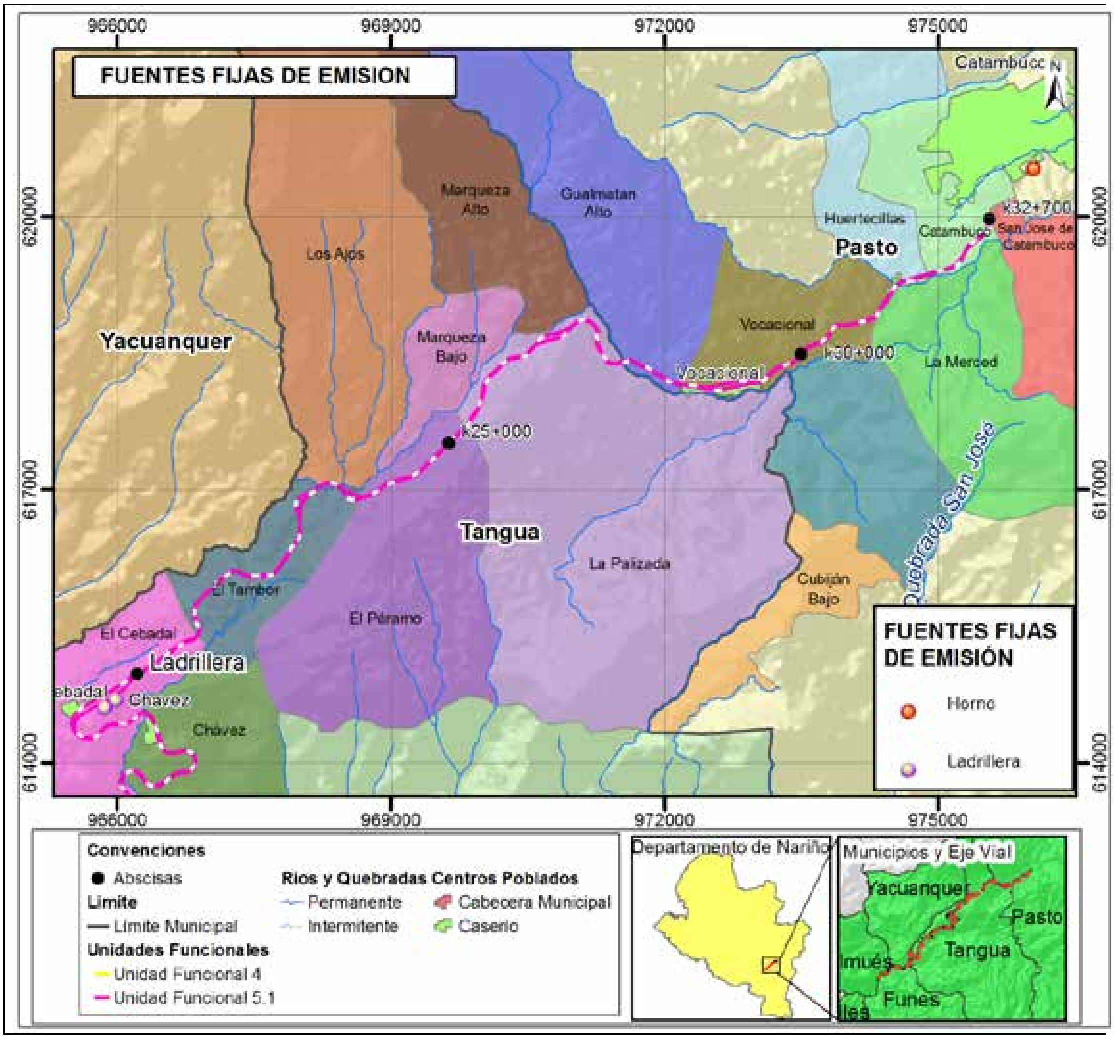


Figure 5.1.170 Fixed emission sources
Source (Gemini Environmental Consultants, 2016)

- Crematorium oven

The crematory oven (see Photograph 5.1.570) has two chambers: a primary loader, combustion and ignition of waste with a minimum temperature of 850 °C and a secondary post-combustion where the flue gases are burned with a minimum temperature of 1200

°C. Wwaste is fed to the chambers only when these temperatures are reached and maintained.

- The residence time of the gases in the afterburner chamber are at least two 2 seconds.
- Each of the chambers operate with its own independent burner and automatic temperature control.
- The incinerator must automatically register the operating temperature in both chambers.

Regarding atmospheric emissions emitted by the crematorium, a concentration of carbon monoxide (CO), articulated material (MP), total hydrocarbons (THC) and benzopyrene and Dibenzo are established.

Photograph 5.1.770 Creatorium Cristo Rey (976047.12X - 620671.47)
Source: (Gemini Environmental Consultants, 2016)

o Brickworks

As shown in Table 5.1.86, the most representative industrial activities in the AID project are the brickworks. Follows a description of the brick manufacturing process.

- Storage of raw materials: consists of storing piles of clay for brick making.

- Grinding and mixing: Given that the manufacturing process is artisan, a wet type grinder with rolling mills to be trampled repeatedly bu equines. Clay, once ground can be mixed with various additives (sand, barium carbonate etc.) as required by quality of the final product.
- Forming: The forming is the brick pattern, the clay passes through a perforated mold pushed by a rotating propeller, this clay extrudes the profile of the incorporated nozzle being able to change depending on the type of brick to be produced.
- Drying: This is done by storing the naturally shaped brick indoors which by wind and sun effects moisture is reduced.
- Cooking: Is the stage where all brick moisture is removed, which can be carried out in a rustic opencast masonry kiln (see Photograph 5.1.58). The energy material used for cooking is firewood or wood that is continuously fired for about 30 hours, up to about 1000 °C temperature producing carbon dioxide ($CO2$), smoke, ash and particulate matter.

Photograph 5.1.78 Rustic kiln for baking bricks (965982.96X - 614821.70 Y)
Source (Gemini Environmental Consultants, 2016)

- *Mobile sources*

These are the ones that can move autonomously, emitting pollutants in their path. Vehicles traveling on the Rumichaca - Pasto road corridor are cars, trucks, 16-wheel drives, motorcycles and buses designed to operate on public roads. In most urban areas motor vehicles directly influence air quality with CO, NOx, SOx particulates.

The inventory of mobile sources taveling the corridor was obtained from the traffic study, capacity and service levels Corridor 3: Rumichaca- Pasto. (See Table 5.1.87).

Table 5.1.557 Inventory of mobile sources in the area of influence Rumichaca - Pasto dual carriageway road project, Pedregal - Catambuco section

SECTOR	VEHICLES / DAY	VEHICLE TYPE	CATEGORY
Pedregal - Catambuco	177	Buses	Category II
	1,526	Cars	Category I

Source: Adapted Traffic Study **Capacity and service levels Rumichaca -Pasto**

- *Potential recipients*

The potential recipients of emission sources for the Pedregal - Catambuco section are constituted mainly by the presence of population settlements, as shown in the following figure. (See Figure 5.1.153).

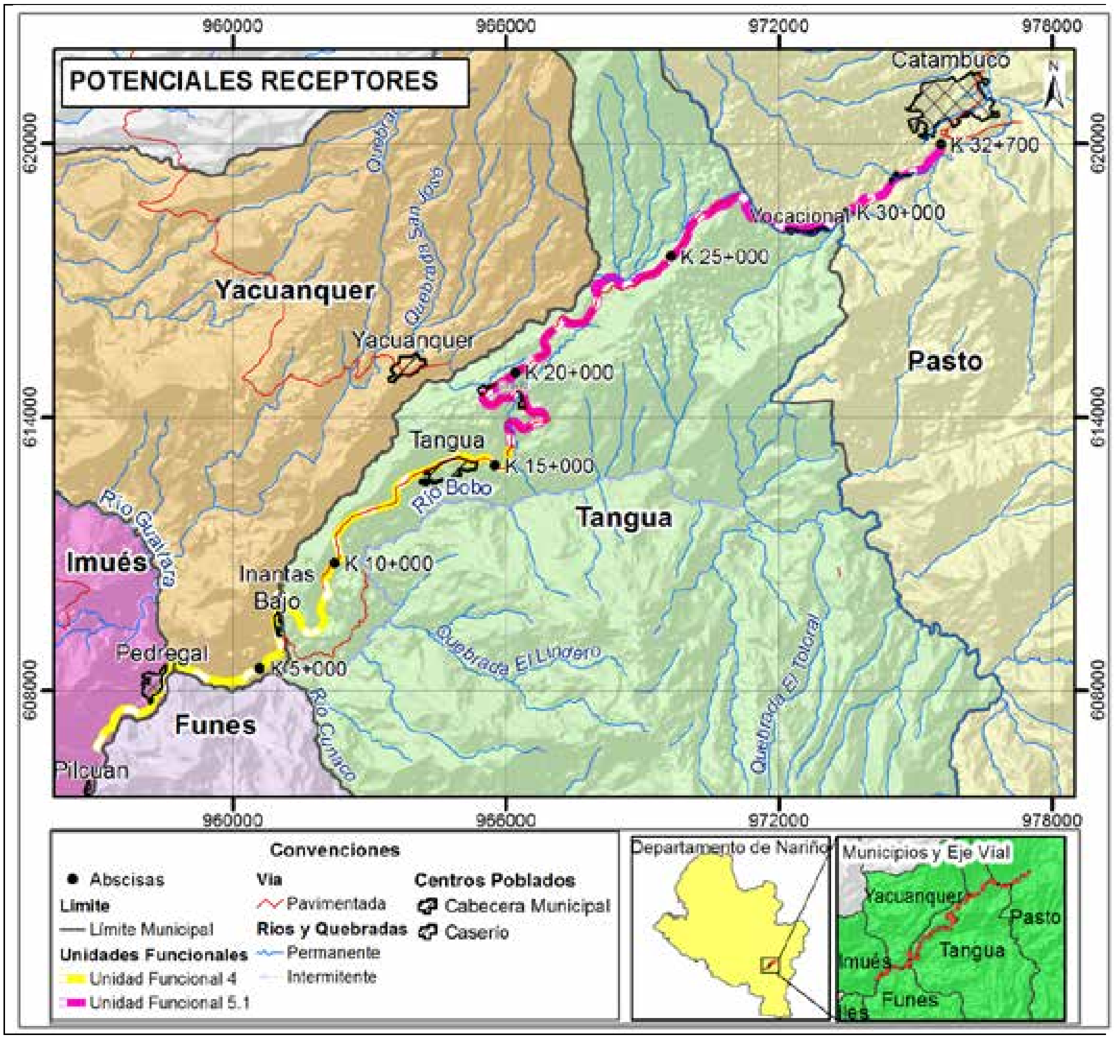


Figure 5.1.171: Potential recipients

Source: (Gemini Environmental Consultants, 2016)

Among the major population centers identified in the study section, listed as potential recipients, we have Pedregal, municipal seat of Tangua and Catambuco, which are on the area of influence of the project.

Table 5.1.88 show results of PM10, sulfur dioxide, nitrogen dioxide and carbon monoxide concentration to potential recipients.

Table 5.1.56 Concentration of potential contaminant receptors

Parameter	Pedregal	Tangua municipal seat	Catambuco
PM10	27.26	27.13	87.54
Sulfur dioxide	16.72	20,65	30.22
Nitrogen dioxide	2,61	15.91	4,29
Carbon monoxide	1,54	1,46	1,68

Source: (ASOAM, 2016)

5.1.10.3 Air quality

To determine the air quality in the study area, concentration levels of pollutant particles below 10 microns (PM10), sulfur oxides (SOx), nitrogen oxides (Nox) and carbon monoxide (CO) were monitored. The results allowed knowing current air quality conditions and characteristics and major sources of emissions that contribute pollutants to the atmosphere.

Having taken field samples, analized in the laboratory and approved by the quality supervisor, it is determined whether the samples meet all validating requirements to be taken into account in the statistical treatment.

PM10 monitoring obtained from Hi-Vol for Particulate Matter (Hi-Vol) equipment using the gravimetric analysis method and the NOx and SOx results were obtained from RAC three gases equipment with spectrophotometric analysis method.

Annex 5.1.10.3 shows the air quality report with all monitoring variables used for the stations and the concentrations present in monitored pollutants.

Based on current regulations and in accordance with the monitoring and tracking of air quality protocol, five monitoring particulate matter and gases stations will be installed, taking into account the following considerations:

- Installing industrial camps where the asphalt and crushing plants will be located.

- Population centers (listed as potential recipients) that could be affected by project development activities.

The parameters evaluated in accordance with the Follow-up and Air Quality Monitoring Protocol are shown in Table 05/01/89 that describes the general characteristics of the parameters evaluated.

Table 5.1.57 General characteristics of evaluated parameters

PARAMETER	DEFINITION	SOURCES	EFFECTS	VARIOUS
Particulates	Any solid or liquid finely divided material other than uncombined water, as measured by federal reference methods (40 CFR 53	Furnaces, crushers, mills, grinders, stoves, calciners, boilers, incinerators, conveyor belts, textile finishing, mixers and hoppers, cupolas, processors, spray booths, digesters, forest fires, among other equipment.	Effects on breathing and the airways, worsening of existing cardiovascular and respiratory diseases, lung tissue damage, carcinogenesis and premature mortality.	Examples: dust, smoke, oil droplets, beryllium asbestos
Carbon monoxide	Colorless, odorless, poisonous gas, lighter than air, produced by incomplete combustion of carbon present in the fuel.	Stationary and mobile sources that burn fuel (internal combustion engines, primarily gasoline engines). It is produced in much smaller quantities in domestic sources, volcanic gases, swamp emanating gases, coal mines, thunderstorms, photo dissociation of CO2 in the upper atmosphere, fires and water and land animals, among others.	They can be fatal in a short time in enclosed areas. Reacts with hemoglobin in the blood, preventing the transfer of oxygen.	It is in the atmosphere in concentrations of 0.1 ppm average
Nitrogen oxides	NO, NO2, N2O, N2O3, N2O4, N2O5: six kinds	Produced by burning fuel at very high temperatures from	Reduced visibility, irritation of the nose and eyes,	Excessive concentrations of NO and NO2

PARAMETER	DEFINITION	SOURCES	EFFECTS	VARIOUS
	of nitrogen oxides are identified. At the air pollution level reference is only made to NO and NO2 (colorless gases) and are typically reported as Nox.	nitrogen in the air. They are also produced from carbon nitrogen and heavy oils: large power generators, large industrial boilers, internal combustion engines, nitric acid plants.	pulmonary edema, bronchitis and pneumonia; VOCs react under the influence of light to form ozone. Nitrogen oxides are important potential contributors of harmful phenomena such as acid rain and eutrophication in coastal areas.	in the lower atmosphere causing a brownish color due to light absorption in the blue-green spectrum band.
Sulfur oxides	Acre, corrosive, toxic gases when sulfur-containing fuel is burned.	Electrical items, industrial boilers, smelters, oil refineries, vehicle sources, residential and commercial water heaters.	Difficulty breathing when dissolved in the nose and the upper airway; chronic cough and mucus secretion. Contributes to acid rain and reduced visibility phenomena (according to its concentration).	Sulfur oxides (SOX), generally formed by the combustion of sulfur-containing substances (coal and oil), particularly for steelmaking. It is perceived by smell in concentrations of 3 ppm (0.003%) to 5 ppm (0.005%). When at levels of 1 to 10 ppm it induces increased respiratory blood rate.

Source: Resolution 2154 Protocol Monitoring and Monitoring Air Quality.

The air quality monitoring for the Pedregal - Catambuco section were performed by placing five stations in the area of influence of the project for a period of 18 calendar days 24 hours a day.

During this time PM10, nitrogen dioxides and sulfur dioxides parameters were evaluated. The location of the monitoring stations established for the project are shown in Table 5.1.90 that specifies the county name and municipality the station belongs to andthe respective coordinates; the general location of the station points in the study area are also shown. (See Figure 5.1.154).

Table 5.1.90 Location of air quality monitoring stations, Pedregal - Catambuco section

SECTOR	AIR QUALITY POINT	COUNTY	MUNICIPALITY	PLANAR COORDINATED MAGNA SIRGAS ORIGIN WEST	
				EAST	NORTH
Pedregal - Catambuco	6	Pedregal	Imués	958,439.945	608,235.425
	7	Municipal seat	Tangua	964,268.717	612,785.492
	8	Chávez	Tangua	966,837.780	614,411.568
	9	El Tambor	Tangua	967,320.276	616,111.612
	10	Catambuco	Grass	975,477.928	620,217.086

Source: (Gemini Environmental Consultants, 2016)

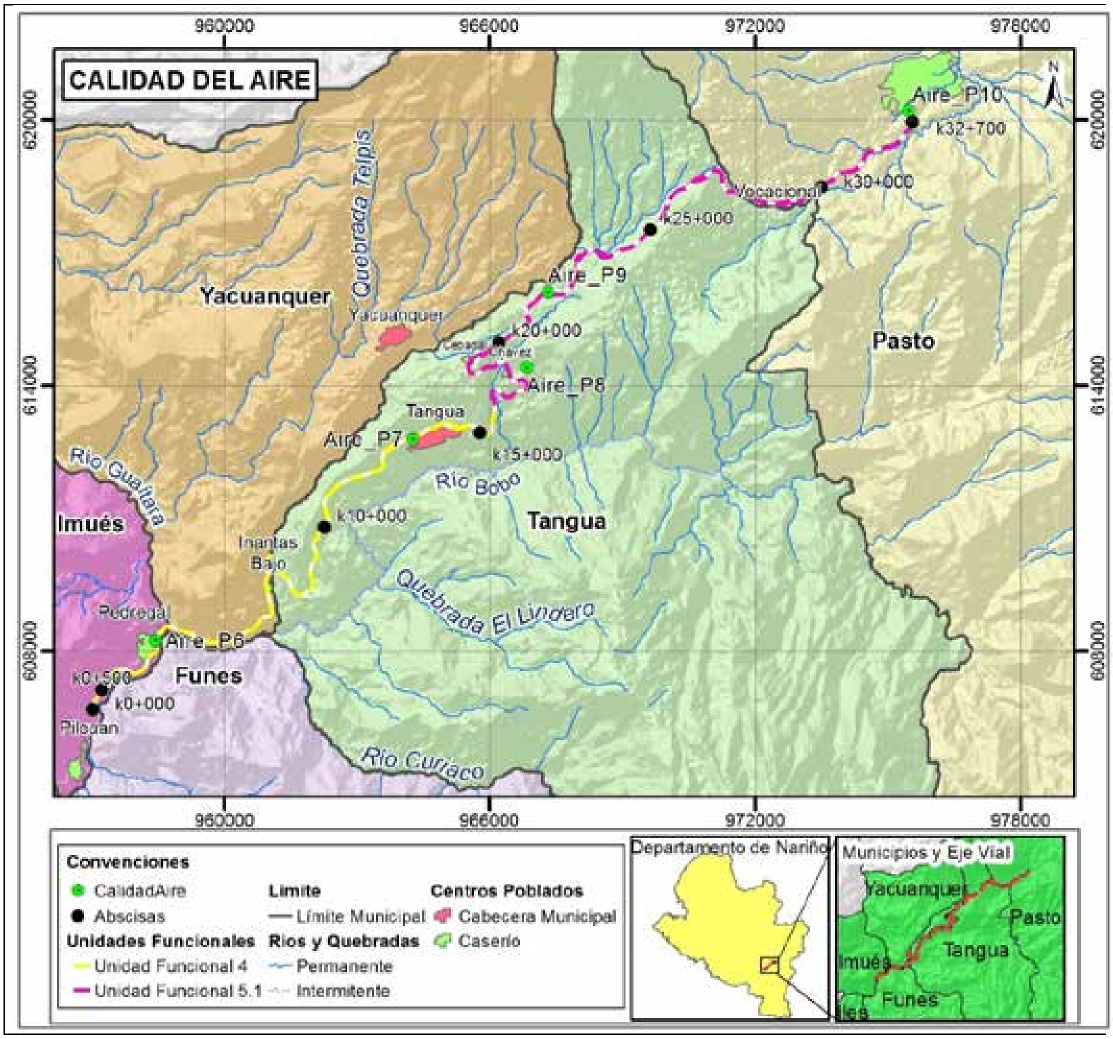


Figure 5.1.172 Air quality monitoring points, Pedregal - Catmabuco Section
Source (Gemini Environmental Consultants, 2016)

Follows the air quality concentrations (PM10, SOx and NOx) results obtained for each evaluated relate.

- *PM10 monitoring results*

Daily particulate (PM10) analysis results for five (5) monitoring stations are shown. As seen, maximum values obtained are below the ceiling set by Resolution 610 of 2010 the Ministry of Environment, Housing and Territorial Development (MAVDT) of 100 µg / m3 for a period of 24 hours. (See Table 05/01/91)

Table 5.1.91 Results PM10 Rumichaca - Pasto road project, Pedregal - Catambuco section

DATE	POINT 6	POINT 7	POINT 8	POINT 9	POINT 10
	µg / m3	µg / m3	µg / m3	µg / m3	µg / m3
21/04/2016	6.59	4.94	---	18.56	53.04
04/22/2016	5,35	4	22,99	Discarded	Discarded
23/04/2016	2.15	22.76	Discarded	5.42	42.77
24/04/2016	2.8	13.51	3,02	0,92	40.78
25/04/2016	9.85	10.26	2.37	8.47	41.68
26/04/2016	Discarded	14.09	Discarded	5.18	32.14
04/27/2016	8.67	23.5	9.05	5.88	38.82
04/28/2016	6.64	12.24	2,98	Discarded	33.06
04/29/2016	9.09	11.4	2,62	1,16	32,35
04/30/2016	8.48	6.84	3,32	4.31	37.29
01/05/2016	7.24	10.93	4.47	Discarded	26.42
05/02/2016	10.39	13.17	8.36	5.64	74.75
05/03/2016	15.18	Discarded	11.52	10.47	Discarded
05/04/2016	14.56	11.78	11.17	Discarded	87.54
05/05/2016	Discarded	27.13	Discarded	9.71	9.93
06/05/2016	11.94	Discarded	8.71	11.13	Discarded
07/05/2016	27.26	20.1	15.05	11.06	22.76
08/05/2016	17.33	4.04	20.76	4.82	37.63
09/05/2016	---	---	19,05	---	---
Maximum	**27.26**	**27.13**	**22,99**	**18.56**	**87.54**
Minimum	**2.15**	**4**	**2.37**	**0,92**	**9.93**
Average	**10.22**	**13.17**	**9.7**	**7.34**	**40.73**
Range	**25.11**	**23.13**	**20.62**	**17.64**	**77.61**

Source: (ASOAM, 2016)

Figure 5.1.155 shows individual PM10 data per day obtained in each of the five (5) stations. According to this information we can see that the stations did not exceed the legal limit daily (100 µg / m3).

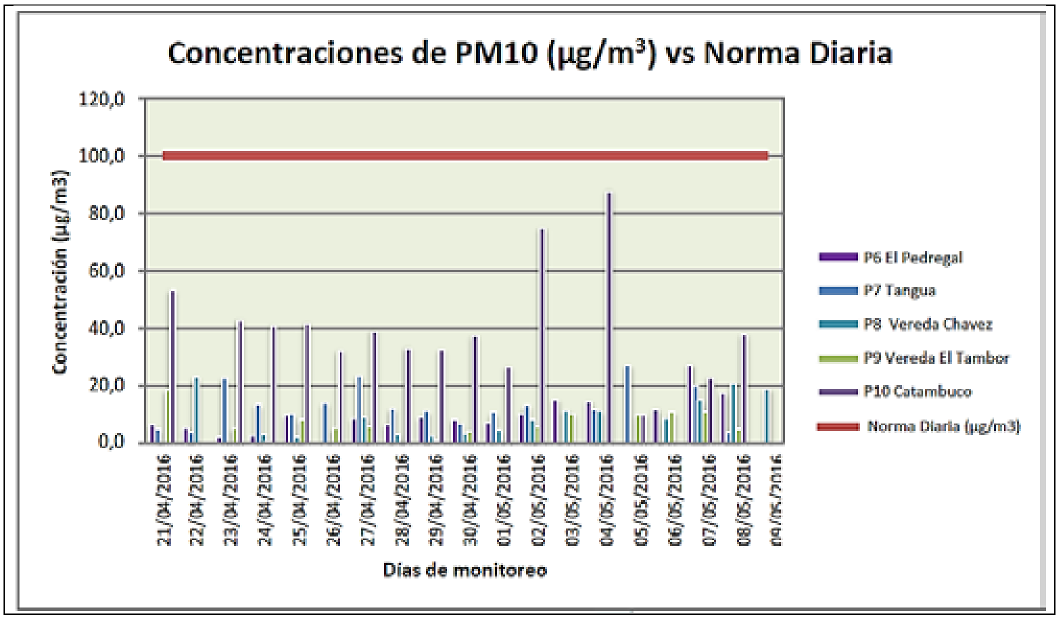


Figure 5.1.173 PM10 air quality data vs Resolution 610 2010
Source (ASOAM, 2016)

Figure 5.1.156 shows concentrations maximum values of particles smaller than 10 microns (PM10) obtained for each station and the comparison with the standard (Resolution 610, 2010); data analysis shows that the greatest concentration was in the P10 Catambuco station with a maximum value of 87.54 µg / m3, while the lowest concentration was recorded in station P9 El Tambor with a minimum value of 18 , 56 µg / m3.

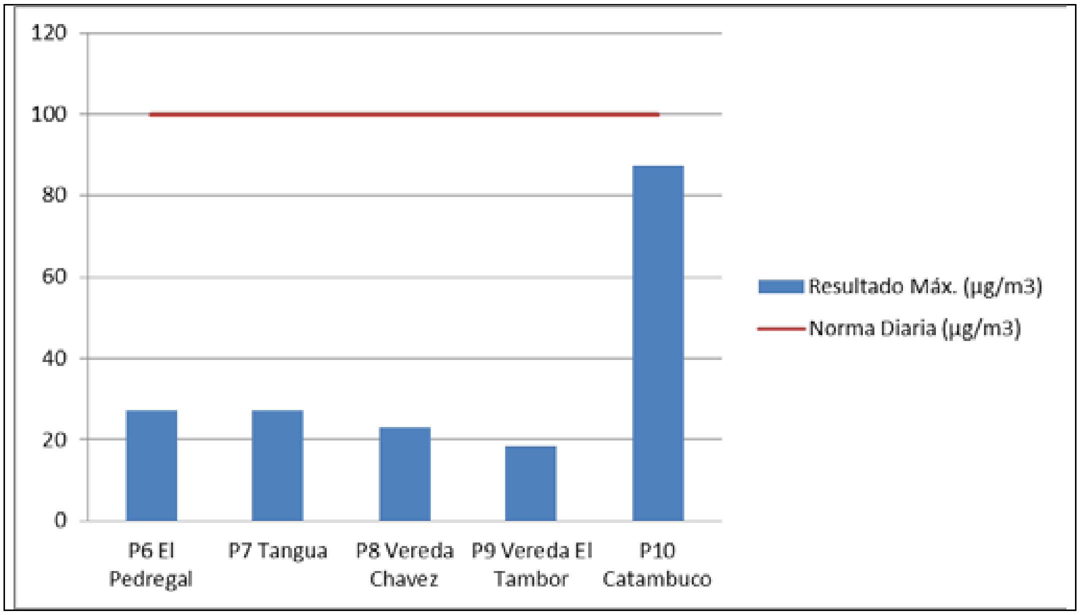


Figure 5.1.174 Maximum PM10 concentrations (µg / m3) vs Standard Daily (Res. 610, 2010)
Source: (ASOAM, 2016)

Concentrations of particles smaller than 10 microns (PM10) for five (5) monitoring stations located in the Pedragal - Catambuco section, are below the reference values established in resolution 610 2010 for daily exposure time (100 µg / m3).

Suspended particles encompasses a broad spectrum of organic or inorganic substances dispersed in the air, which come from natural and artificial sources (artisanal brickworks, vehicles, crematorium, etc). Fossil fuel combustion from traffic (heavy and light vehicles) is a major source of particulate contamination along the corridor and area of influence that can produce various kinds of particles: large particles, by releasing unburned materials (fly ash), fine particles formed by the condensation of vaporized materials during combustion, and secondary particles, through atmospheric reactions of removed contaminants such as gases. Regarding their health effects PM10,
"thoracic" particles lower than 10 µm that can penetrate airways can be distinguished.

- *Monitoring Sox results*

Table 05.01.92 show Sulfur dioxide (Sox) daily test results for five (5) monitoring stations. When comparing Sox concentration values obtained with that of Resolution 610 of 24 March 2010 from MAVDT, we can point out that they do not exceed the maximum limit of 250 µg / m3 for a period of 24 hours.

Table 5.1.92 Results Sox Rumichaca – Pasto road project, Pedregal - Catambuco section

DATE	POINT 6	POINT 7	POINT 8	POINT 9	POINT 10
	µg / m3	µg / m3	µg / m3	µg / m3	µg / m3
21/04/2016	16.72	18.08	13.37	Discarded	10.6
04/22/2016	13.08	20,65	15.68	17,11	18,15
23/04/2016	6.68	14.25	12.81	7.37	10.39
24/04/2016	8.57	Discarded	12.83	Discarded	30.22
25/04/2016	12.5	14.42	3.78	3.76	14.24
26/04/2016	12.49	2,21	6,75	13.14	14.38
04/27/2016	6.73	6.73	7.14	5,98	5.23
04/28/2016	11.69	11.75	7.29	5.92	7.3
04/29/2016	7.7	8.06	5.25	6.76	12.18
04/30/2016	4,99	5,98	8.28	4,48	8.39
01/05/2016	3.61	7.24	5.97	3.78	9.06
05/02/2016	8.2	9.47	5,14	8.94	8.22
05/03/2016	4.61	3.73	2,98	5.22	5.2
05/04/2016	3	5,35	5,98	4.44	4.5
05/05/2016	3.85	5,99	6.77	4.65	2,99
06/05/2016	9.1	5.36	3,79	5.25	4,49
07/05/2016	2.96	6,75	3.7	2,98	6.96
08/05/2016	4.5	4,49	4.5	4.65	5.25
Maximum	**16.72**	**20,65**	**15.68**	**17,11**	**30.22**
Minimum	**2.96**	**2,21**	**2,98**	**2,98**	**2,99**
Average	**7.83**	**8.85**	**7.33**	**6.53**	**9.87**
Range	**13.76**	**18.44**	**12.7**	**14.13**	**27.23**

Source: (ASOAMSAS, 2016)

Figure 5.1.157 shows maximum Sox concentration values obtained for each station, where a higher concentration in station P10 Catambuco can be identified with a maximum value of 30.22 µg / m3 while the lowest concentration was recorded for P8 Vereda Chavez station with a maximum value of 15.68 µg/ m3.

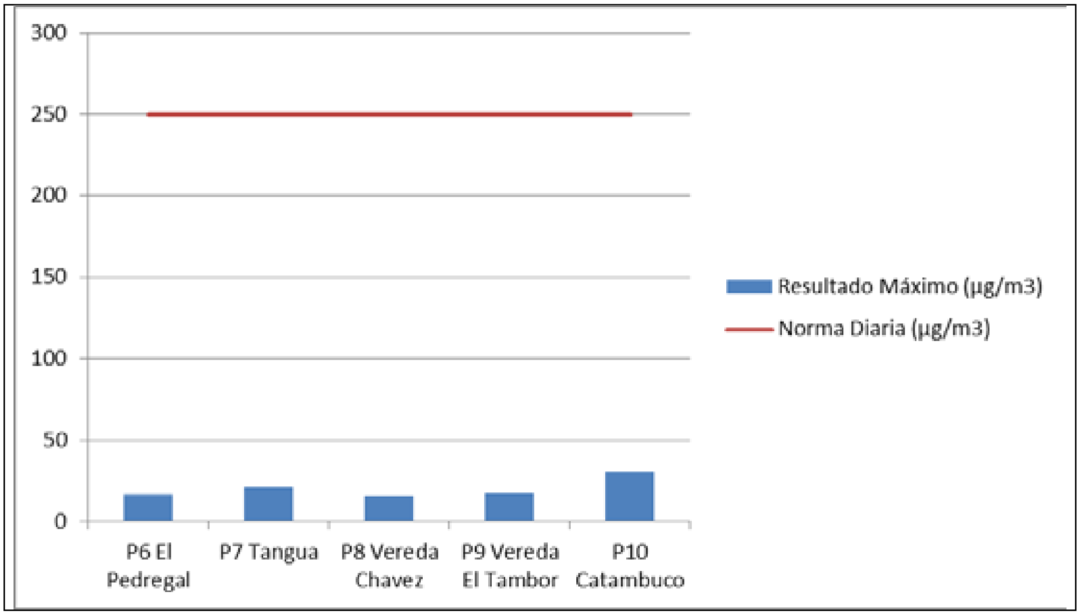


Figure 5.1.175 Maximum Sox concentrations (µg / m3) vs Daily Standard (Res. 2010, 2010)

Source: (ASOAM, 2016)

Sulfur dioxide (SOx) concentrations for the study area are below the reference values established in resolution 610 to 2010 for daily exposure time (250 µg / m3).

Identified external emission sources influencing the results obtained for sulfur dioxide are the crematorium furnace, the artisanal brickworks and mobile sources (heavy and light vehicles transiting the road). The environmental impact generated by this compound comes especially from burning sulphurous fossil fuels like coal, oil, natural gas, etc. and traffic.

- *Monitoring Nox results*

Table 01/05/93 shows the daily Nitrogen dioxide (NOx) test results for five (5) monitoring stations. When comparing Nox concentration values obtained with Resolution 610 of 24 March 2010 of the MAVDT, we note that these are below the maximum limit of 150 µg / m3 for a period of 24 hours.

Table 5.1.93 Nox Results Rumichaca - Pasto road project Pedregal - Catambuco section

DATE	POINT 6	POINT 7	POINT 8	POINT 9	POINT 10
	µg / m3	µg / m3	µg / m3	µg / m3	µg / m3
21/04/2016	1,97	2,33	2,01	2,08	2,05
04/22/2016	2,09	2.15	2,13	2,02	2,14
23/04/2016	2,01	2,03	2,18	2	2,01
24/04/2016	1.94	Discarded	2,05	Discarded	2,16
25/04/2016	2,12	2,17	2,05	2,04	4,29
26/04/2016	1,99	2	2,03	2.1	3.59
04/27/2016	2,03	2,03	1.94	2,03	3,33
04/28/2016	1,98	2,66	1,98	2,64	1,98
04/29/2016	2,34	15.91	2,03	2,57	2,62
04/30/2016	2,21	2,03	2,04	2,03	2.07
01/05/2016	1,96	2.54	2,02	2,05	2,05
05/02/2016	2,61	1,97	1,99	2,53	2.86
05/03/2016	2,08	2,02	2,02	2,48	2,02
05/04/2016	2,03	2.07	2,03	2,01	2,03
05/05/2016	2,09	2,03	2,04	2.1	2,02
06/05/2016	2,06	2,08	2,06	2,03	2,03
07/05/2016	2	2,03	2,01	2,02	2,57
08/05/2016	2,03	2,03	2,03	4.3	2,36
Maximum	**2,61**	**15.91**	**2,18**	**4.30**	**4,29**
Minimum	**1.94**	**1,97**	**1.94**	**2.00**	**1,98**
Average	**2,09**	**2.95**	**2,03**	**2,29**	**2,45**
Range	**0,68**	**13.94**	**0.24**	**2.3**	**2,31**

Source: (ASOAMSAS, 2016)

Figure 5.1.158 shows maximum Nox concentration values for each station, where we can see a higher concentration in the P7 Tangua station with a maximum value of 15.91 µg/m3 whole the lowest concentration was recorded in P8 Vereda Chavez station with a maximum value of 2.18 µg/m3.

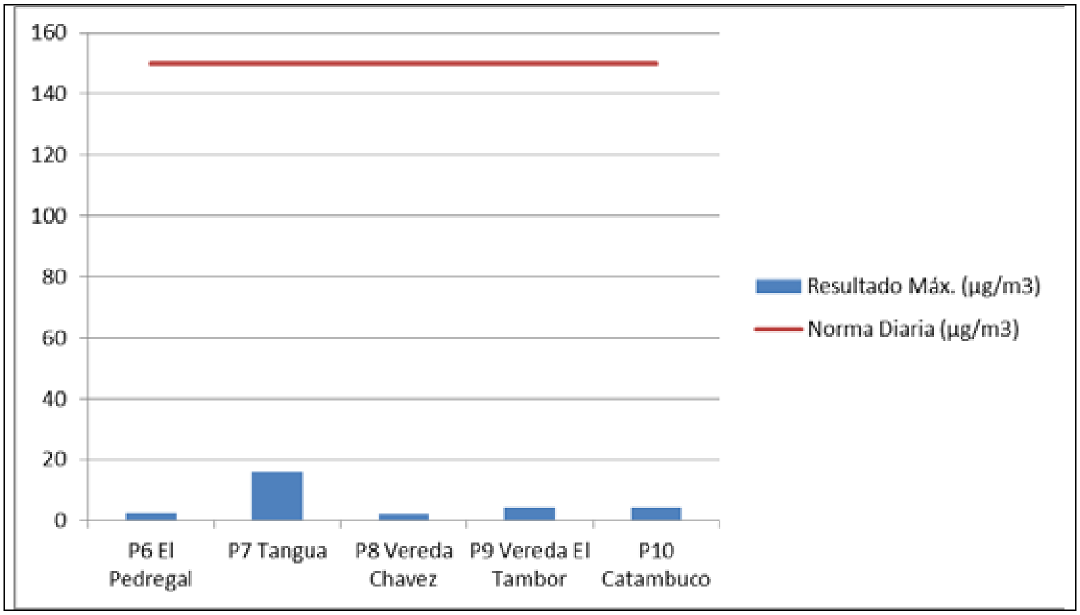


Figure 5.1.176 Maximum Nox (µg / m3) concentrations vs Daily Standard
Source: (ASOAM, 2016)

Nitrogen dioxide (NOx) concentrations for the study area are below the reference values established in resolution 610 2010 for daily exposure time (150 µg / m3).

The external emission sources identified that influence the results obtained for nitrogen dioxide are the crematorium, the artisanal brickworks and mobile sources (heavy and light vehicles traveling the road).

Nitrogen oxides rapidly degrade in the atmosphere when reacting with other substances commonly found in the air. The reaction of nitrogen dioxide with chemicals produced by sunlight leads to the formation of nitric acid, the major constituent of acid rain. Nitrogen dioxide reacts with sunlight, leading to the formation of ozone and smog in the air we breathe. When released into the soil, small amounts of nitrogen oxides may evaporate into air. However, most will be converted to nitric acid or other compounds. (Diseases, 2016)

- CO monitoring results

Table 05/01/94 shows the daily Carbon monoxide (CO) test results for five (5) monitoring stations. When comparing the CO concentration values obtained with resolution 610 of March 24, 2010 from MAVDT, note that these are below the maximum limit of 40 µg / m3 for an exposure period of 1 hour.

Table 5.1.94 CO results Rumichaca - Pasto road project, Pedregal - Catambuco section

Measurements #	Point 6 (mg / m3)	Point 7 (mg / m3)	Point 8 (mg / m3)	Point 9 (mg / m3)	Point 10 (mg / m3)
1	1,54	1,16	1,57	0,59	0,83
2	0.6	1,46	1,17	0.95	1,49
3	0,79	1.26	1,67	0,83	1,68
4	1,07	0.99	0,59	0,81	0,58
5	1,37	1,04	1.4	0,64	0,87
6	0,74	0,62	1,19	1.35	1.41
7	0,61	0,81	1,67	1,69	1,51
8	0.9	.67	1,16	1,23	0.95
Maximum	**1,54**	**1,46**	**1,67**	**1,69**	**1,68**
Minimum	**0.6**	**0,62**	**0,59**	**0,59**	**0,58**
Average	**0.95**	**1**	**1.3**	**1.01**	**1,17**
Range	**0,94**	**0,84**	**1.08**	**1.1**	**1.1**

Source: (ASOAMSAS, 2016)

Figure 5.1.159 shows the maximum CO concentration values obtained for each station, where we can see a higher concentration in the P8 Vereda El Tambor station with a maximum value of 1.69 µg / m3, while the lowest concentration was recorded in P7 Tangua station with a maximum value of 1.46 µg / m3.

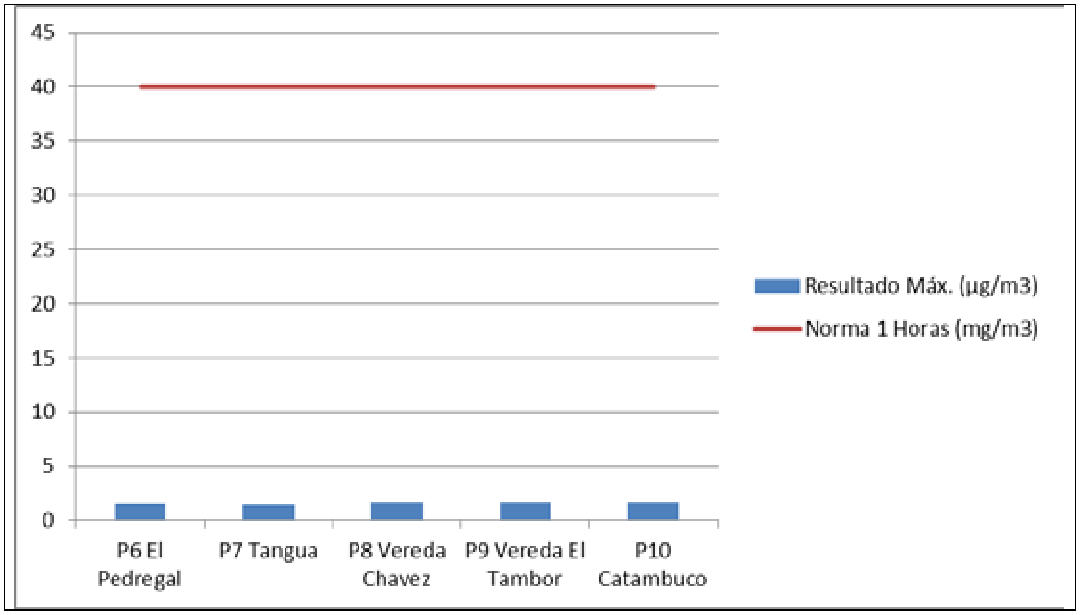


Figure 5.1.15.9 Maximum CO (µg / m3) concentrations vs 1 Hour Standard
Source: (ASOAM, 2016)

Nitrogen dioxide (NOx) concentrations for the study area are below the reference values established in the resolution for an exposure time of 1 hour (40 µg / m3).

The main producing sources of this pollutant are motor vehicles using gasoline for light vehicles or diesel fuel for heavy vehicles traveling through the road and industrial processes such as artisanal brickworks present in the study area. Motor vehicles and industrial processes are responsible for about 80% of carbon monoxide emissions into the atmosphere.

From the air quality study made we can conclude that:

- Concentrations of particles smaller than 10 microns (PM10) for the stations of the EIA (UF4, UF5) studies are below the reference values established in resolution 610 of 2010 for both the daily (100 µg / m3) and annual (50 µg / m3) exposure times.

- Sulfur oxide (SOx) concentrations for EIA (UF4, UF5) studies are below the reference values established in Resolution 610 of 2010 daily (250 µg / m3) and annual (80 µg / m3) exposure times.

- Nitrogen oxide (NOx) concentrations for EIA (UF4, UF5) studies are below the reference values established in Resolution 610 of 2010 daily (150 µg / m3) and annual (100 µg / m3) exposure times.

- Carbon monoxide (CO) concentrations for EIA (UF4, UF5) studies are below the allowable standard values established by resolution 610 of 2010 for an exposure time of 8 hours.

5.1.10.4 Noise

- *Generating sources*

Different ambient noise generating sources were identified along the Project corridor, as well as settlements and social infrastructure.

The Pedregal sector, of the municipality of Imués, municipal capital of Tangua and Tangua province are among the main population centers. In relation to social infraestuctura we have schools, churches, health centers and sports arenas (See annex GDB / mapping / PDF / EIADCRP_PC_022).

The following table shows the main noise emission sources identified during daytime and nightime noise monitoring. (See Table 5.1.95)

Table 5.1.95 Noise generating sources Ipiales - Pedregal

Sound sources	Type of emission	Description
Road traffic	Engine noise: belonging to vehicles with vibrating elements involved in propulsion such as engine, transmission, brakes, suspension and leaks etc. Aerodynamic noise: produced by the interaction	Impact of constant noise generated by motorcycles, light and heavy vehicles, being responsible for increased noise levels in the monitored points.

	between the vehicle body and air and rolling noise: from interaction between the tires and the pavement	
Community	Domestic noise	Noise from domestic activities generated in surrounding housing
Fauna	Wildlife noise	Wild and domestic animals live in this area, which come from the area surrounding the area of influence, some of them particularly noisy, like dogs barking, birds, etc.

Source: SERAMBIENTE SAS, 2016

o Vehicular noise

Directly or indirectly we all contribute to generating environmental noise. The large masses of people who commute daily by primary and secondary road networks traveling increasing distances, also foster an increasing use of individual or collective transport units producing noise in various ways.

It is shown that circulating motor vehicles are the main environment noise pollutants. The increasing number of vehicles with predominance of noise produced by tire contact with the pavement (Territorial, 2016)

The noise emitted by vehicles on the roads depends on factors such as vehicle characteristics, the speed and rate of circulation and the characteristics of the tread. From the acoustic point of view, the noise of a motor vehicle depends on the type, mass, engine power, its combustion technology and its state of preservation, etc. Regarding their noise emission, vehicles can be classified into:

- Light vehicles, those with a weight load of less 3.5 tons
- Heavy vehicles with load weight of more than 3.5 tons
- Motorized two-wheelers (ECHAZARRETA, 2016)

o Urban noise

It is the predominant background noise in a community. It consists of sounds from many near and distant sources associated with the customs of the people, and observe social trends that are irreversible such as population growth, densification of certain areas at the expense of others who lose population and increased urban areas, creating in turn sparse spaces and with very few inhabitants. (Territorial, 2016) In an urban center noise varies significantly from the quietest suburban areas to the areas bordered by heavy traffic roads and commercial establishments. The noise varies according to the hour according to the prevailing activities. The discomfort caused by noise is the main cause of citizenship complaint. (Cauca, 2016)

Noise is an increasingly element tied to our civilization and is present in one way or another, in different spaces. Consecuential to the functional specialization of our societies different forms of noise have emerged, which accommodate and correspond to the characteristics of these spaces. (Territorial, 2016)

o Industrial noise

The noise generated by civil works is another frequent source of urban and rural noise, and high local impact to nearby villagers. In general, noise is emitted by processing machinery and transport vehicles moving freight; some machines like pile drivers and jackhammers, generate high levels of sound pressure accompanied by mechanical vibrations that affect the areas surrounding the works. There are also construction works on land interspersed in residential and office areas, which are a frequent cause of complaints from generation of noise, vibration and emissions to the atmosphere. Construction noise in general may be constant for long periods or considerably fluctuate and increase in specific (Territorial, 2016)

· Noise monitoring

In order to evaluate the behavior of environmental noise in areas identified as environmental points of reference, due to the susceptibility of these areas to noise level increments, the noise monitoring was developed to thereby characterize noise emissions from specific sources and determine their impact on the evaluation and environmental interest areas.

The noise measurement was performed in five (5) stations distributed throughout the study area, with daytime and nightime monitoring as stipulated in Resolution 627 of 2006, taking five (5) measurements of three (3) minutes at each point, with intervals of nine (9) minutes, on a tripod four meters above the ground and with a 4 meters radii without interference, as shown in the next picture. (See Photograph 5.1.59)

Photograph 5.1.79 Environmental noise measurement
(Coordinates: 964230.5 X - 614418 Y)
Source: Gemini Environmental Consultants, 2016

For the road project Pedregal - Catambuco section a total of five (5) noise monitoring stations were placed, taking the potential recipients identified on the area of influence and projected areas for the installation of camps and processing plants; all monitoring points are in Sector D. Quiet suburban or rural area and moderate noise with admisbles maximum allowable in this sector of 55 dBA and 45 dBA for daytime and night respectively.

Annex 5.1.10.4 shows the observed ambient noise report with all variables obtained from monitoring stations and the concentrations present in monitored pollutants.

The location of monitoring stations established for the project are shown in Table 5.1.96 where the identifying name is identified as well as the county, the municipality it belongs to and respective coordinates. Figure 5.1.160 shows the general location of the station points in the study area.

Table 5.1.586 Location of Noise Monitoring Stations Rumichaca – Pasto road project, Pedregal - Catambuco section

SECTOR	AIR QUALITY POINT	COUNTY	MUNICIPALITY	NORTH	EAST
Pedregal - Catambuco	6	Pedregal	Imués	608,240.807	958,421.386
	7	Municipal seat	Tangua	612,790.996	964,250.115
	8	Chávez	Tangua	614,417.118	966,819.165
	9	El Tambor	Tangua	616,117.179	967,301.637
	10	Catambuco	Pasto	620,222.805	975,459.265

Source: (Gemini Environmental Consultants, 2016)

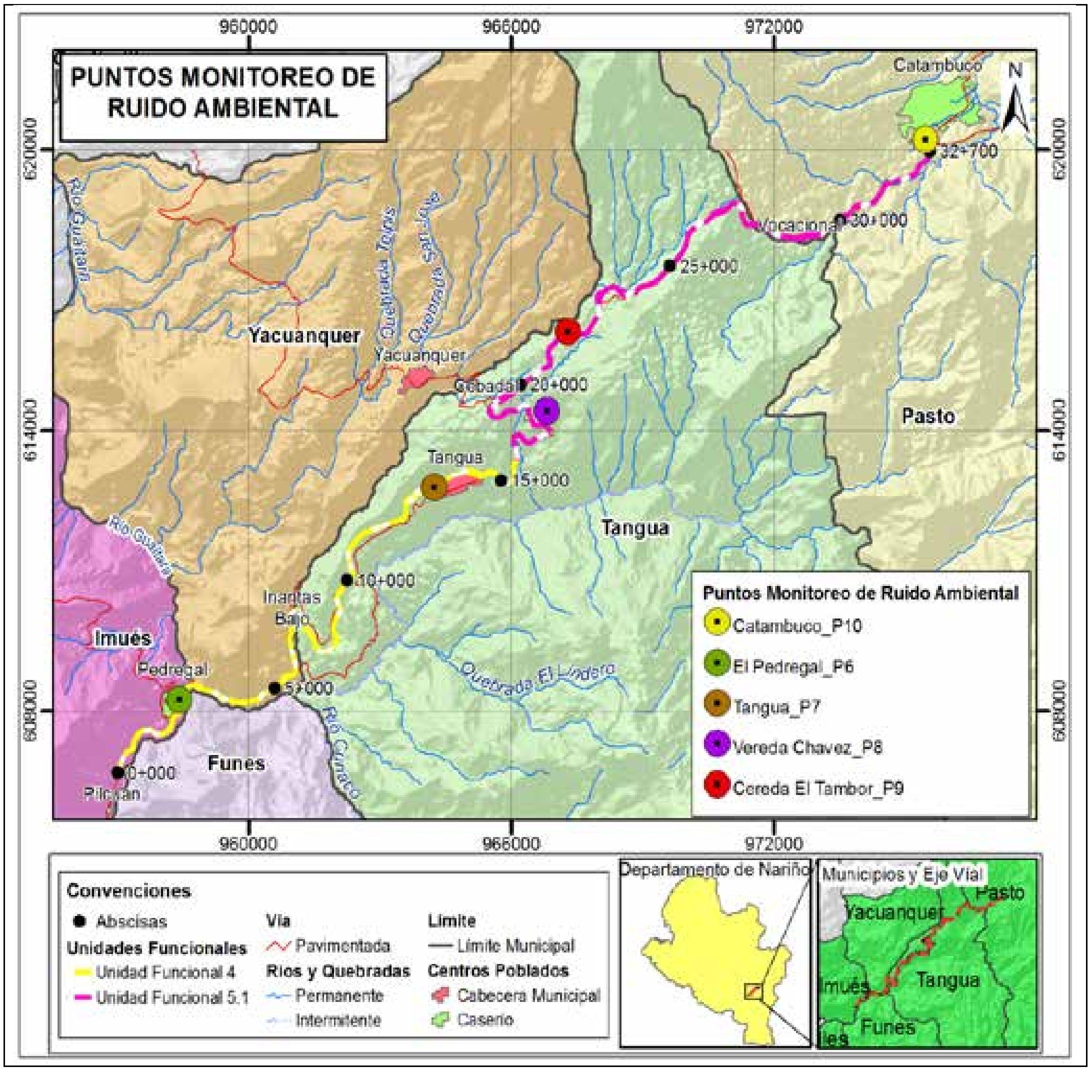


Figure 5.1.177 Noise monitoring points, Pedregal - Catambuco section
Source (Gemini Environmental Consultants, 2016)

- *Results daytime noise monitoring*

Table 5.1.97 shows Laeq Corr, Lmax Lmin noise results obtained for each point as well as their respective comparison with daytime standard. We can observe that for the five (5) points monitored 4 do not meet the allowable limit exceeding 55 dB (A) for daytime hours.

Table 5.1.59 Environmental Noise and Comparison with Standard results

Environmental Noise Daytime					
Point	**Laeq Corr**	**Lmax**	**Lmin**	**Daytime standard**	**Compliance**
P6 El	73.85	76.30	51.60	55	NO
P7 Tangua	64.63	71.30	57.70	55	NO
P8 Chavez	52.35	59.70	46.10	55	YES
P9 El Tambor	70.45	71.60	66,50	55	NO
P10	74.09	71.30	66.10	55	NO

Source: (ASOAMSAS, 2016)

Annex 5.1.10.4 shows evidenced of raw sampling reports, along with the memory of summation levels and application of K adjustments.

Figure 5.1.161 grafically shows the results obtained for the respective monitoring station and their variations respective compliance compared to the standard. These results are influenced by the high traffic flow in the area, the sound emitted by domestic and wild animals and the movement of people near the points; the only point meeting the parameters established in the standard is P8 Vereda Chávez with 52.35 dB.

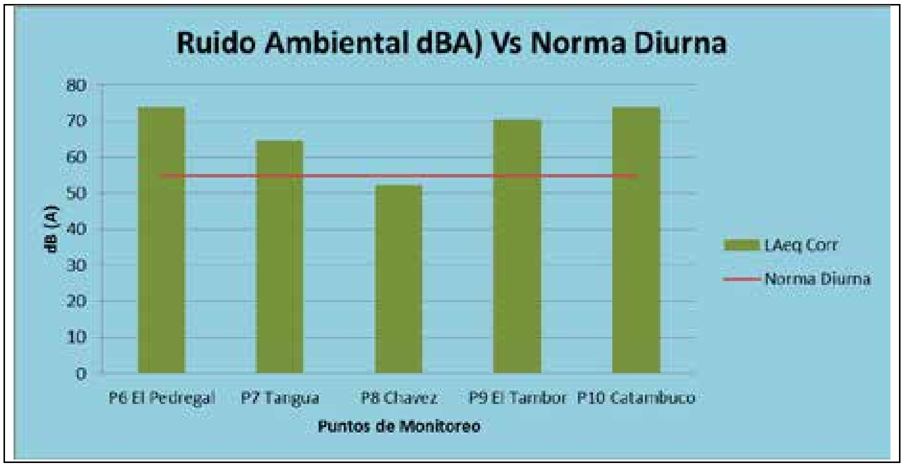


Figure 5.1.178 Environmental Noise results and their comparison with the Standard

Source: (Gemini Environmental Consultants, 2016)

Noise results obtained are influenced by the high traffic flow passing through the area, the sound emitted by wild and domestic animals and transit of people near the monitored sites.

- *Monitoring results nighttime noise*

According to the results of Figure 5.1.162, nighttime noise shows that four (4) of the five (5) points monitored do not meet the allowable for nightime (45dB (A)) limit; the maximum noise level is presented in P6 Pedregal corresponding to a value of 66.8 dB, P8 Chavez county has a value of 42.35 in compliance with established standard.

Results results may be influenced by high traffic flow in the area, the sound emitted by domestic and wild animals and transit of people near the points.

Table 5.1.60 Results Nighttime Noise and Comparison with the Standard

Environmental Noise Daytime					
Point	**Laeq Corr**	**Lmax**	**Lmin**	**Nighttime standard**	**Compliance**
P6 El Pedregal	66.85	66.3	44.6	45	NO
P7 Tangua	57.63	64.3	47.7	45	NO
P8 Chavez	42.35	49.7	39.1	45	YES
P9 El Tambor	63.45	64.6	56.5	45	NO
P10 Catambuco	64.09	63.3	66.1	45	NO

Source: (ASOAMSAS, 2016)

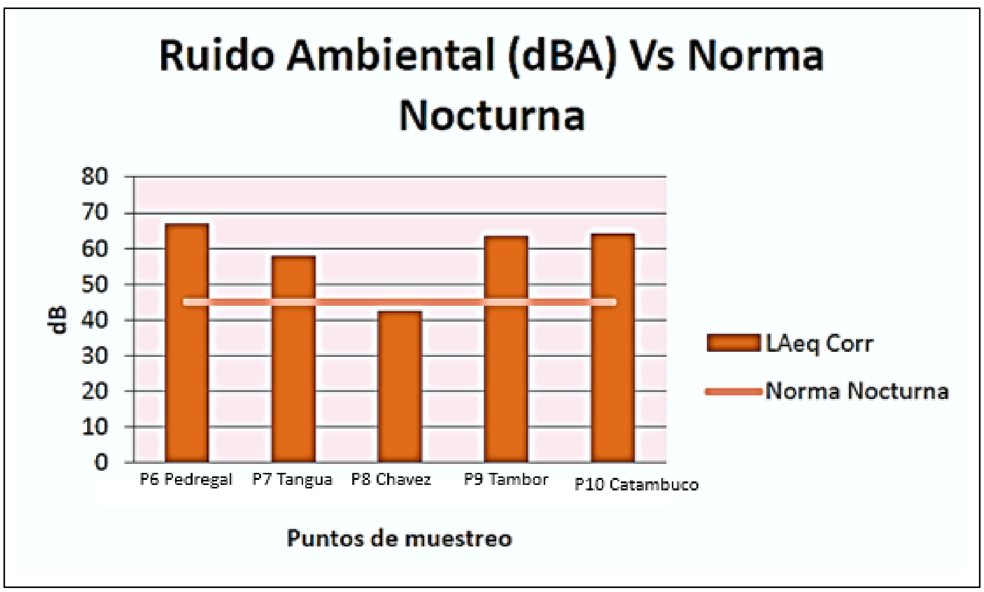


Figure 5.1.179 Results nighttime noise and Comparison with the Standard
Source: (Gemini Environmental Consultants, 2016)

- *Daytime noise ve nighttime noise*

For the project, environmental noise was monitored in keeping with resolution 627 of 2006 considering that the following schedules were established for purposes of this resolution; Daytime 7:01 to 21:00 and nightime 21:01 to 7:00 pm.

The maximum allowable environmental noise level standards expressed in weighted A decibels (dB (A)) are established as well as the sector and sub-sector to which it belongs; see Table 5.1.99 for maximum allowable standards

Table 5.1.619 Maximum allowable standards

Sector	Subsector	Maximum allowable ambient noise levels standards in dB (A)	
		Daytime	Nightime
Sector D. Suburban or rural tranquility and moderate noise area	Suburban residential.	55	45
	Rural inhabited used for agricultural exploitation.		
	Recreation and relaxation areas, such as parks and nature reserves.		

According to the standard, the maximum allowable value for daytime is 55 dB and 45 dB for nighttime; the point meeting the established range values is the Chavez county of the municipality of Tangua see Figure 5.1.163 Daytime vs. Nightime Noise due to aforementioned reasons.

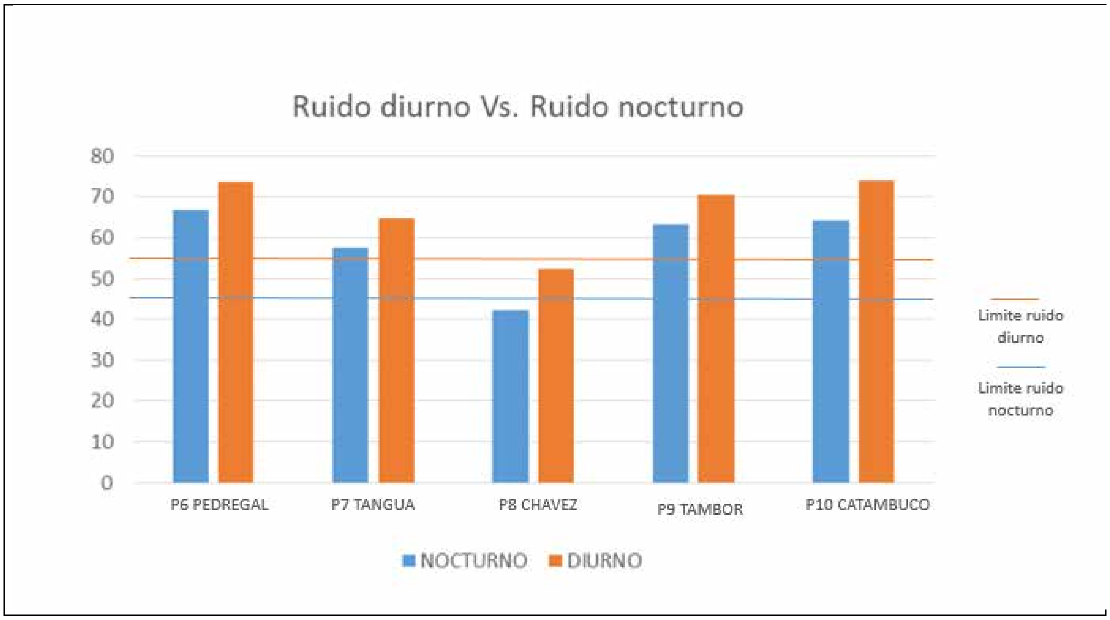


Figure 5.1.180 Daytime Vs. Nightime noise
Source (Gemini Environmental Consultants, 2016)

- *Results daytime noise holiday monitoring*

Table 5.1.100 shows the results during holidays noise obtained for each point, and their respective comparison with current standards. As observed, from five (5) monitored points four (4) are not in compliance with the allowable limit exceeding 55 dB (A) maximum allowable standard.

Table 5.1.100 Results Environmental Noise Vs Comparison with Standard

Environmental Noise Daytime Holiday					
Point	**Laeq Corr**	**Lmax**	**Lmin**	**Daytime standard**	**Compliance**
P6 El Pedregal	69.79	74.62	60.39	55	NO
P7 Tangua	55.54	63.35	48.27	55	NO
P8 Chavez	47.79	52.52	45.90	55	YES

Environmental Noise Daytime Holiday					
P9 El Tambor	62.58	69.02	56.25	55	NO
P10	68.71	70.34	63.85	55	NO

Source: (ASOAMSAS, 2016)

Annex 5.1.10.4 shows raw sampling reports together with the memory of summation levels and the application of K adjustments.

Figure 5.1.164 graphically shows results obtained and compared to their respective compliance with the standard. The increased noise levels in the four (4) points is usually caused by motorcycles, light and heavy vehicles, as well as domestic activities surrounding the monitored area of influence. The point meeting current environmental regulations is P8 located in the county of Chavez municipality of Tangua registering a value of 47,79dB.

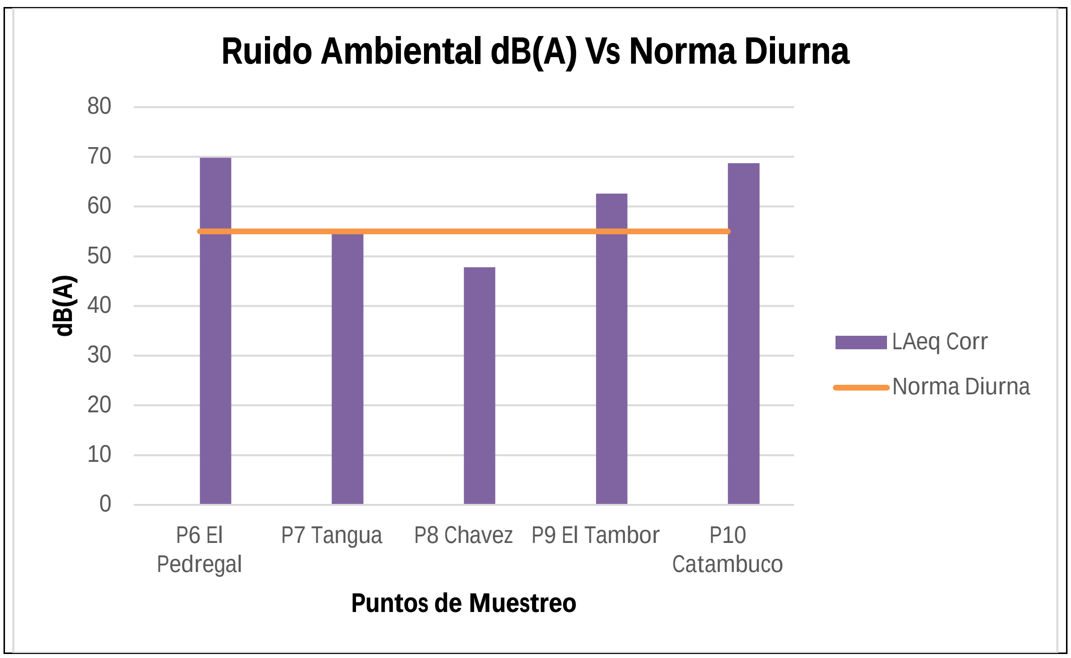


Figure 5.1.181 Environmental Noise results Vs Comparison with the Standard
Source: (Gemini Environmental Consultants, 2016)

- *Results nightime noise monitoring holidays*

Table 5.1.101 shows Laeq Corr, Lmax and Lmin noise results obtained for each point and their respective comparison with the standards for holiday nightime period. As seen five (5) out of four (4) monitored points do not meet the allowable limit exceeding 45 dB (A) maximum allowable standard, results may be influenced by the high traffic flow in the area, the sound from domestic and wild animals and transit of people near the points. Figure 5.1.165 graphycally shows that for daytime hurs the only sample point that meets the maximum allowable value as established by current environmental regulations is point 8 (P8) located in the Chavez county municipality of Tangua with values of 39,93dB.

Table 5.1.101 Nightime Noise Results Vs . Comparison with the Standard

Environmental Nighttime Noise Holiday					
Point	**Laeq Corr**	**Lmax**	**Lmin**	**Nightime standard**	**Compliance**
P6 El Pedregal	61.81	66.63	52.45	45	NO
P7 Tangua	47.57	55.03	40.32	45	NO
P8 Chavez	39.93	44.55	38.08	45	YES
P9 El Tambor	54.42	60.86	48.49	45	NO
P10 Catambuco	60.71	62.54	55.94	45	NO

Source: (ASOAMSAS, 2016)

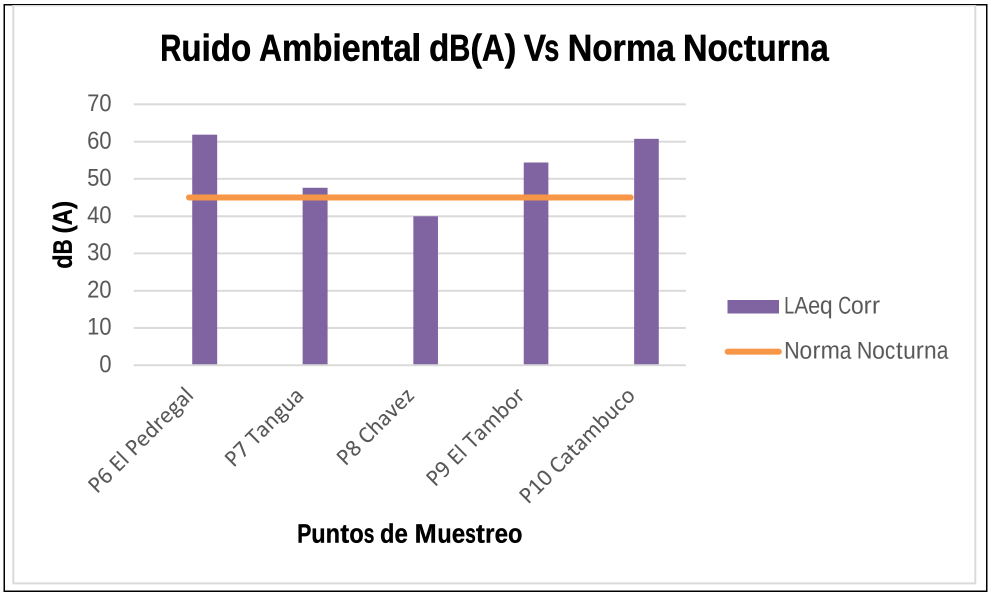


Figure 5.1.182 Nighttime Noise Results Vs Comparison with the Standard
Source: (Gemini Environmental Consultants, 2016)

- *Nightime noise during holidays vs daytime noise during holidays*

Resolution 0627 of 2006 from the MAVDT establishes maximum allowable standards for both daytime schedules from 7:01 to 21:00 (55dB) and for nighttime periods from 21:01 to 7:00 pm (45dB), see Table 5.1.102 Maximum Allowable Standards. However, and considering the results of monitored points only eight points (P8) comply with standard requirements for both cases as shown in Figure 5.1.166 therefore this may be classified as a sector D, i.e. a calm suburban or rural area with moderate noise.

Table 5.1.102 Maximum Allowable Standards

Sector	Subsector	Maximum allowable standards ambient noise levels in dB (A)	
		Daytime	Nightime
	Suburban residential.	55	45

Sector D. Suburban or rural calm with moderate noise area	Rural inhabited used for agricultural exploitation.		
	Recreation and relaxation areas, such as parks and nature reserves.		

Moreover, one can say that regardless of the monitoring period, whether daytime or nighttime, variations in area behavior are vey significant because this is a main access road, and these increases will be supported by constant traffic flow (motorcycles, light and heavy vehicles), domestic activities surrounding the area of influence of the project as well as wild and domestic animals.

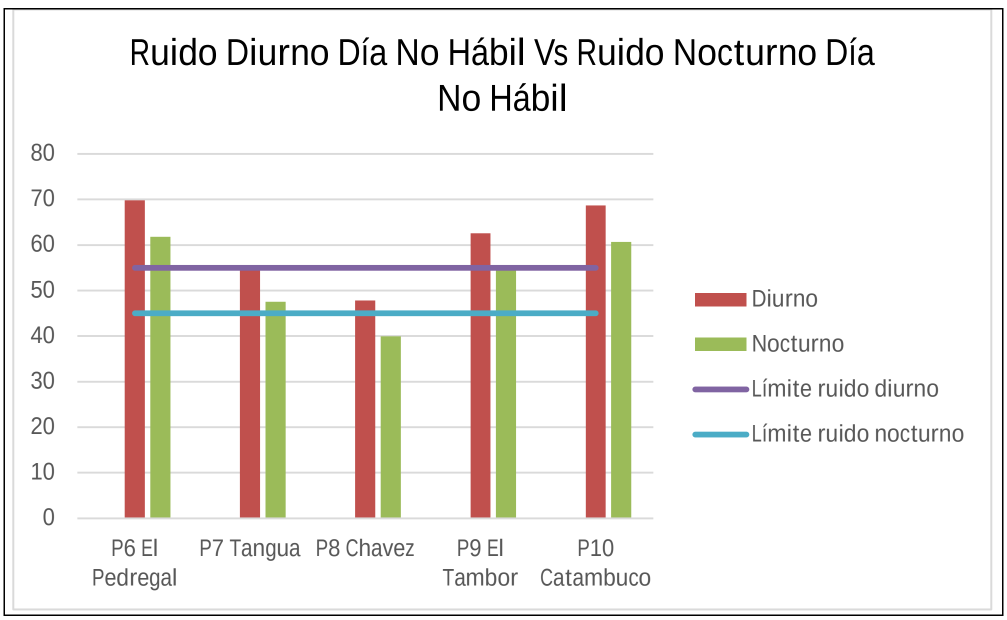


Figure 5.1.183 Daytime holiday noise vs Nighttime holiday noise

Source (Gemini Environmental Consultants, 2016)

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