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5 CHARACTERIZATION OF THE AREA OF INFLUENCE

5.1 ABIOTIC ENVIRONMENT

This chapter describes the components that are part of the abiotic environment in the area of influence, related to geology, geomorphology, landscape, Soil and land use, Hydrology, Water quality, Water uses, Hydrogeology, Geotechnics and Atmosphere, which constitute the baseline of the environmental impact study for the Rumichaca - Pasto divided highway project, San Juan - Pedregal segment.

5.1.1 Geology.

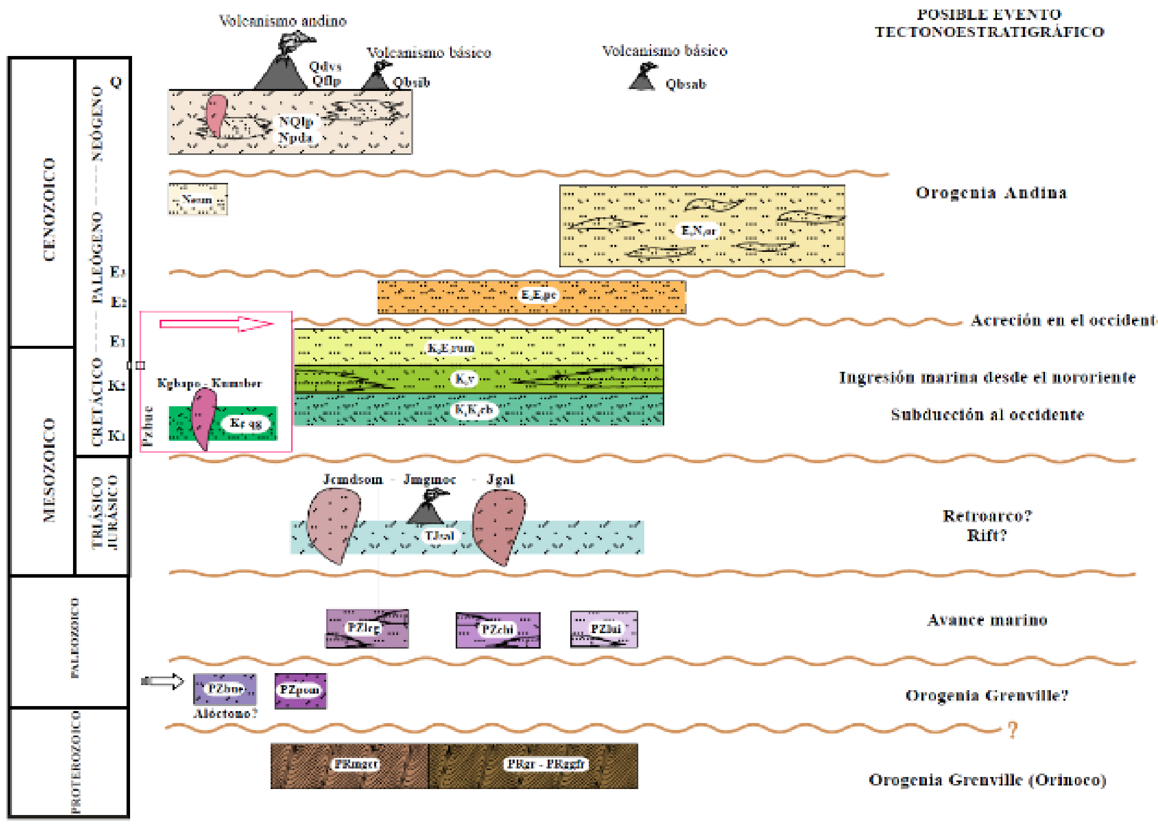
The following describes the lithostratigraphic units and the structural features, belonging to the area of influence, defined from the analysis of secondary information, analysis of satellite images and the work developed in the field phase.

5.1.1.1 Regional geology.

For the description of the geological component at the regional level, reference was made to the plates 429 Pasto, 448 Monopamba and 447 - Ipiales, made by the Colombian Geological Survey - SGC, scale 1: 100,000 (see **Figure 5.2** and **Figure 5.3**). In this sense, the oldest rocks correspond to those of the La Cocha Migmatite Complex of the precambrean era, which form part of the basement of the sector and are in discordant contact with the igneous and sedimentary rocks of the Neogene - Quaternary, resulting from the Andean volcanism, such as the volcano-sedimentary deposits, and of the river dynamics associated with the current channels.

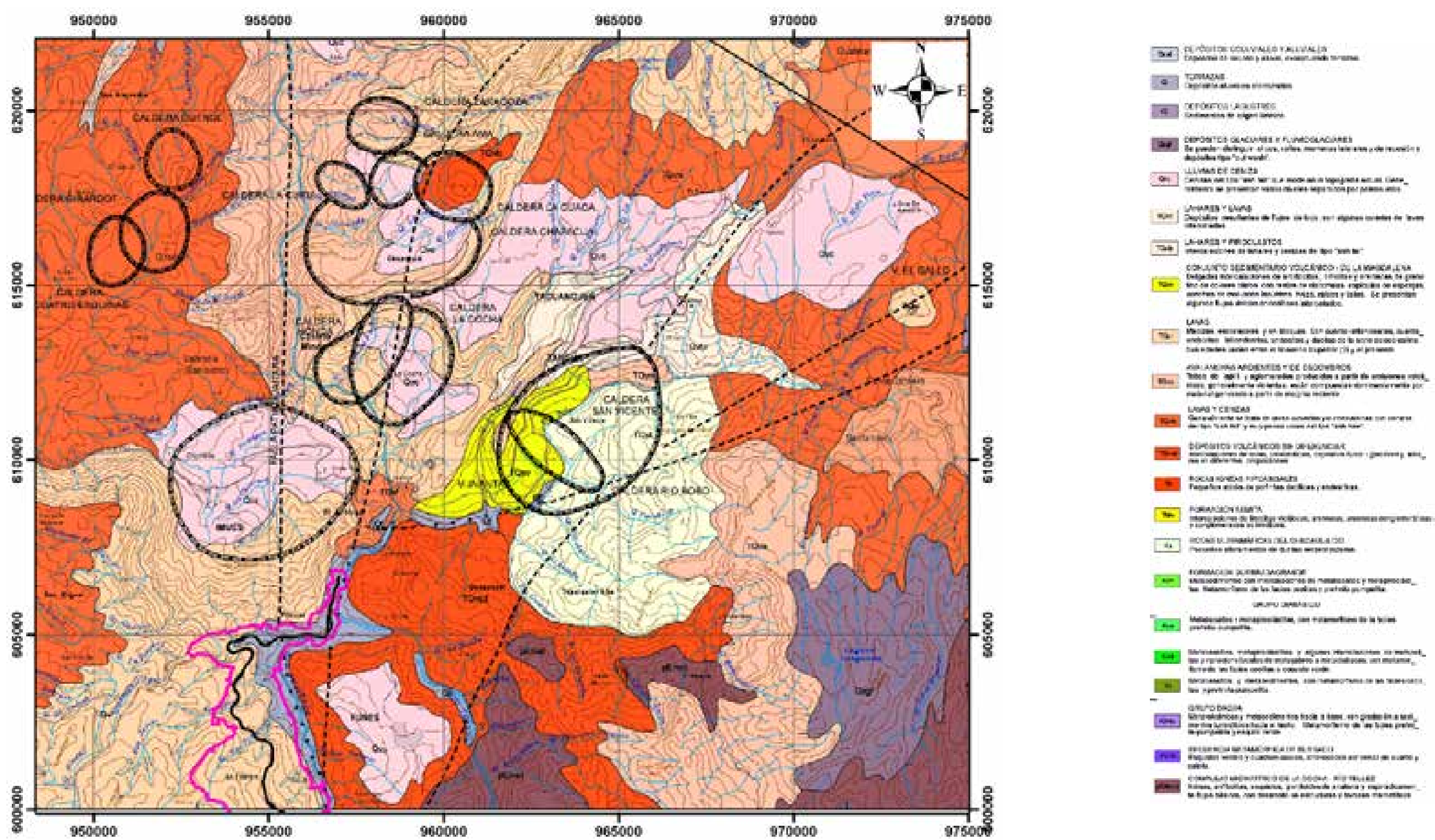
Geotectonically, the present geological and physiographic features have allowed to establish three (3) structural units, which frame the regional geology, these are: The Western Cordillera, the Inter-Andean Depression and the Central-Eastern Cordillera. The first of these is limited by the Cauca river reverse fault system and the Chocó fault megasystem; the associated rocks are metasediments with metamorphism of green schist facies and volcano - sedimentary sequences with incipient metamorphism of prehnite - pumpellyite facies, which are overlying the ancient oceanic crust. The second one is interpreted as a graben limited by the faults system of Romeral and the fault system of the Cauca river, which sets out the interaction between the Pacific plate of oceanic origin and the South American plate, of continental origin. The filling of this valley has a molassic affinity in the basal part, of hypoabolic rocks for the Miocene - Pliocene and of volcanic deposits, associated to the surrounding volcanoes for the Quaternary. Finally, the Central-Eastern Cordillera is defined between two major structural features and two depressions; to the west, the Interandean depression and the Romeral fault system, and to the east the Frontal Andean fault and the Eastern Andean Foothill. The core of this mountain range is composed of Precambrian migmatites and Paleozoic metamorphic sequences; in addition, the eastern flank dominates the volcano-sedimentary and plutonic jura-triasic rocks, and to the west are the deposits associated with quaternary volcanism and hypo-palisal rocks of paleo-neogenous age. **Figure 5.1,** includes a summary of tectonostratigraphic evolution for the area where the rock units and related, and the corresponding geotectonic processes.

Figure 5.1 Tectono-stratigraphic scheme of the southern end of the Central-Eastern Cordillera.



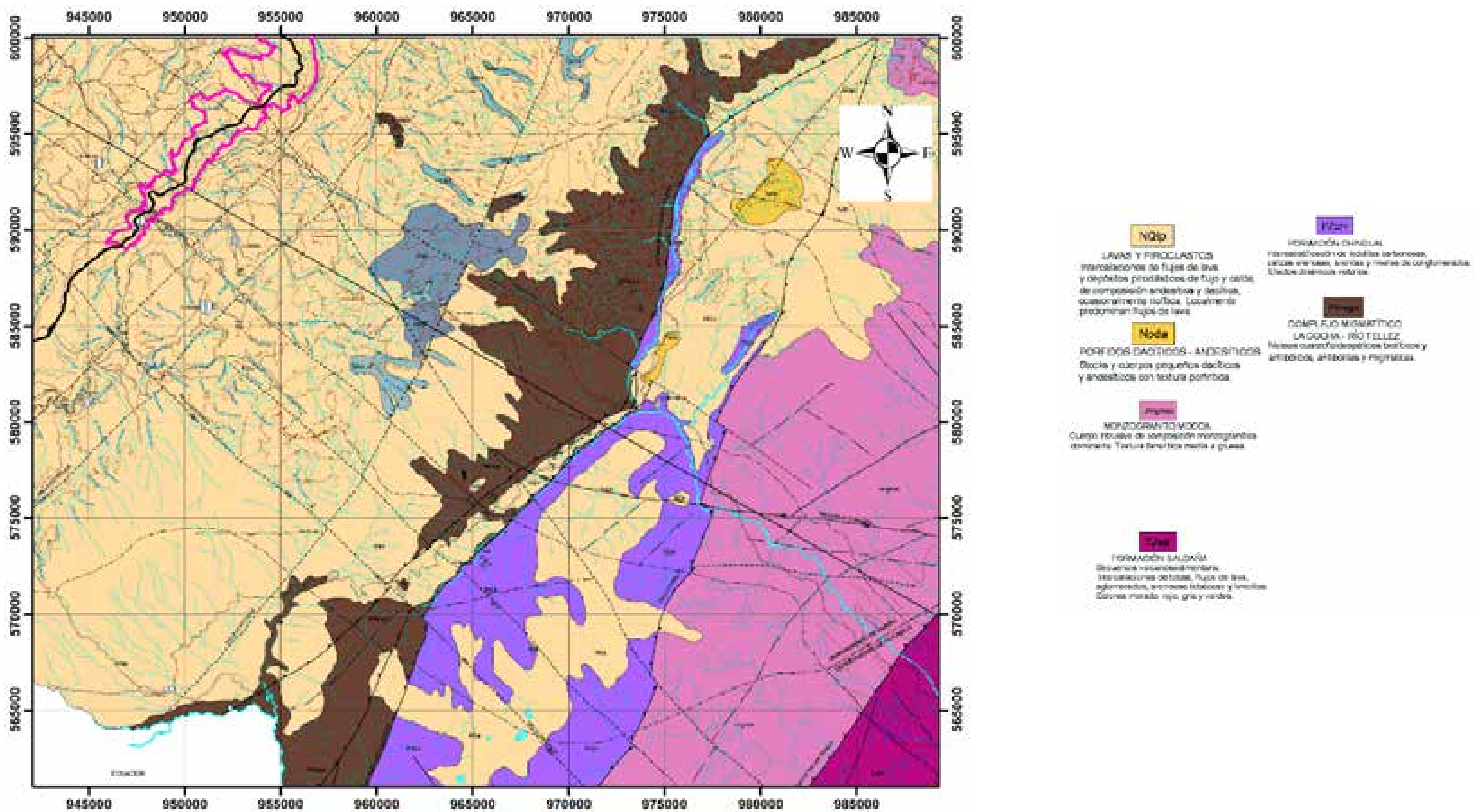
Source: Taken from INGEOMINAS, 2003.

Figure 5.2 Regional geology belonging to plate 429 - Pasto.



Source: Taken from INGEOMINAS, 2003.

Figure 5.3 Regional geology belonging to plate 448 - Monopamba.



Source: Taken from INGEOMINAS, 2003.

5.1.1.1.1 Regional stratigraphy.

The regional stratigraphy, comprising the geological environment, is composed of volcanic, volcano-sedimentary and sedimentary units of continental origin, which overlap the Mesozoic, Paleozoic and Precambrian rocks present. The stratigraphic description is presented below, starting from the oldest rocks to the most recent ones, namely:

- **Precambrian.**
  - **Migmatitic Complex of La Cocha (PRmgct).**

This geological unit is included in plates 429 and 448 of the Colombian Geological Service, appearing towards the northwestern side of the Afiladores Fault System. Basically, it is formed by metamorphic rocks, mainly migmatites, schists, neises and amphibolites, together with rocks of granitoid aspect, affected by blastesis. Migmatite structures are very common, easy to recognize in existing outcrops; **Table 5.1** includes a description of the relevant aspects.

Table 5.1 General characteristics of the Migchatic Complex of La Cocha.

CHARACTERISTICS	DESCRIPTION
Name	Migmatitic Complex of La Cocha (PRmgct).
Lithology	Set of metamorphic rocks, mainly migmatites, schists, neises and amphibolites, together with rocks of granitoid aspect, affected by blastesis. Migmatite structures are very common, easy to recognize in outcrops.
Contacts	The contacts between the different lithologies of this unit are net to transitional, discordant with the cenozoic rocks of volcanic origin, and faulted against the system of the Afiladores Fault.
Age	Precambrian
Metamorphism	Amphibolite Facies.

Source: GEOCOL CONSULTORES S.A., 2017. Taken from INGEOMINAS, 1991.

- **Paleozoic.**
  - **Chingual Formation.**

Unit of sedimentary origin, included in plate 448 of the Colombian Geological Survey (INGEOMINAS 2003), where it outcrops thanks to the presence of two inverse structures: the Afiladores Fault System and the Chingual Fault. This unit is a set of sedimentary rocks, affected by the black and green, quarta-like cataclases, with porphyroclastic texture, sinuous bands of quartz, interspersed with bands of clay minerals and finogranular pyrite, with interlaminations of gray and black quartzites. In some sectors, an interlayer with siliceous carbonaceous lodolites, sandy limestones and levels of conglomerates with siliceous silica clasts, milky quartz, sandy limolites and green schists are observed. B**Table 5.2** below describes its main aspects.

Table 5.2 General characteristics of the Chingual Formation.

CHARACTERISTICS	DESCRIPTION
Name	Chingual Formation (PZchi)
Author	Ponce (1979), Arango & Ponce (1982 a and b), INGEOMINAS & Geoestudios (2000c)
Lithology	Set of sedimentary rocks, affected by the black and green, quarta-like cataclases, with porphyroclastic texture, sinuous bands of quartz, interspersed with bands of clay minerals and finogranular pyrite, with interlaminations of gray and black quartzites. In some sectors, an interlayer with siliceous carbonaceous lodolites, sandy limestones and levels of conglomerates with siliceous silica clasts, milky quartz, sandy limolites and green schists are observed.
Contacts	Faulted contact with the Migmatitic Complex of La Cocha - Téllez River and with the Monzogranite of Mocoa. For the more recent rocks (of the Neogene and Quaternary), there is a contact in angular discordance with the volcano-sedimentary deposits.
Thickness	It is not determined by the lack of knowledge of its stratigraphic limits
Age	Early Paleozoic.
Environment	Accumulation below the level of waves in a marine environment, subsequently affected by dynamic metamorphism.

Source: GEOCOL CONSULTORES S.A., 2017. Taken from INGEOMINAS, 2003.

· **Cenozoic.**

o **Neogene.**

The Neogene is represented by extrusive rocks, belonging to the Cenozoic volcanism of the Western Cordillera, which constitute denuded pliocene volcanic buildings. This group includes the volcanic structures composed by the Andesites of Guáitara (N2agt), Porphyritic Andesites of the Cerro Negro del Encino (N2acne) and Andesites of Pajablanca (N2apb and N2fppb), described in **Table 5.3**, **Table 5.4** and **Table 5.5**, respectively. These units are located on Plate 447 - Ipiales, towards the eastern side; just north of the municipality of Ipiales are the Pajablanca Andesites, while towards the south of the same municipality are the Guáitara Andesites and those of Cerro Negro del Encino.

Table 5.3 General characteristics of the Guáitara Andesites.

CHARACTERISTICS	DESCRIPTION
Name	Guáitara Andesites
Lithology	It is a massive rock of dark gray with porphyritic texture, where some millimeter crystals of plagioclase stand out and a smaller proportion of crystals, smaller than 1 mm of dark green color (pyroxenes). The matrix, also dark gray, represents nearly 60% of the rock. It is classified as Andesite.
Contacts	Discordant contact with thick pyroclastic and wind deposits of quaternary age
Age	Pre-Pliocene age, relative to a close dating.
Source	Due to the absence of vesicles and the high proportion of crystals with respect to glass, they are classified as low viscous lava flows with very low gas content.

Source: GEOCOL CONSULTORES S.A., 2017. Taken from INGEOMINAS, 2004..

Table 5.4 General characteristics of the Porphyritic Andesites of Cerro Negro del Encino.

CHARACTERISTICS	DESCRIPTION
Name	Porphyritic Andesites of the Cerro Negro del Encino
Lithology	Massive, unequigranular lavages with porphyritic structure of dark gray color, mottled light gray, with 65% phenocrysts, mostly tabular plagioclase, up to 4 mm in length; ferromagnesians are black to greenish-black, short, about 2 mm. The matrix is aphanitic, dark gray
Contacts	Discordant contact with thick pyroclastic and wind deposits of quaternary age
Age	Pre-Pliocene age; but a little more recent than the Andesites of Guáitara, interpreted because its morphology is more conserved.
Source	Presumed to form part of the same volcanism that gave rise to the Andesites of Guáitara.

Source: GEOCOL CONSULTORES S.A., 2017. Taken from INGEOMINAS, 2004..

Table 5.5 General characteristics of the Pajablanca Andesites.

CHARACTERISTICS	DESCRIPTION
Name	Pajablanca Andesites
Lithology	It is a volcano compound, where lava flows were alternated with pyroclastic flows. The Pajablanca lava is presented as solid dark-greenish-gray rocks, with a porphyritic structure with plagioclase phenocrysts and to a lesser extent, pyroxenes in aphanetic gray matrix. The pyroclastic flows are more than 5 m thick, with decimetrical, subangular blocks, surrounded by a matrix of ash and lapilli partially weathered, light brown to reddish color where some pumice stones and lytic fragments are conserved. The blocks consist of massive andesites, and andesites with brecciated texture and slightly vesiculated matrix.
Contacts	Discordant contact with thick pyroclastic and wind deposits of quaternary age
Age	Taking into account the partial conservation of the volcanic structure, the thickness of the weathering profile of nearly 4 m and the subangular shape of its slopes, it can be deduced that its age is slightly smaller than that of the Tufiño muffin, that is to say, younger than 4.6 Ma.
Source	Given the characteristics of most of the phenocrysts, it can be interpreted that in the final stages of their growth, there was an enrichment in iron and water vapor in the magma chamber, which resulted in contamination of the edges of the plagioclase and hydration of the augites to transform them into hornblende and biotite.

Source: GEOCOL CONSULTORES S.A., 2017. Taken from INGEOMINAS, 2004..

o **Tertiary - Quaternary.**

During this period, rocks corresponding to tertiary - quaternary volcanic activity, covering more than 75% of Plate 429 - Pasto are developed, and are related to different eruptive centers, associated to faults located in the Altiplano Nariñense and to the Western and Central - Eastern Cordilleras. These units include Lavas (TQvl) (**Table 5.6**), Burning avalanches and / or burning clouds (TQva) (**Table 5.7**), Lavas and Ashes (TQvlc) **(Table 5.8**), Unstressed volcanic deposits (TQvsd) (**Table 5.9**) and other Pyroclastic Deposits (Qvc) (**Table 5.10**).

Table 5.6 General Lava characteristics:

CHARACTERISTICS	DESCRIPTION

Name	Lavas
Lithology	The different flows tend to have tabular forms, with thicknesses generally not exceeding 15 m. Commonly, they rest in the valleys and ravines, forming an abrupt topography. In fresh state, these rocks present gray, black or green colors of a porphyritic texture, with oriented phenocrysts. In general, these lavas are classified as dacites, plagidacites, quartz - latiandesites, quartz - andesites, latiandesites and andesites
Contacts	Discordant contact with preexisting units
Age	From the Middle Miocene, related to the Andean Orogeny to the present day.
Source	Large-scale faulting tectonics is associated with the subduction processes present in the active continental margin of the Andes; these lavas being the result of the fusion of the subducted plate and the mantle wedge present on such plate. The magmatic series to which these lavas belong are calc-alkaline, supersaturated in silica.

Source: GEOCOL CONSULTORES S.A., 2017. Taken from INGEOMINAS, 1991.

Table 5.7 General Characteristics of Burning Avalanches and / or Burning Clouds.

CHARACTERISTICS	DESCRIPTION
Name	Burning avalanches and / or burning clouds
Lithology	There are two types of burning avalanches: One associated with the Galeras Volcanic Complex, which presents a sandy appearance, made up of fragmented material and disintegrated lava boulders. The other type of avalanche is the most widespread and corresponds to lapilli tuffs and agglomerates embedded in a matrix of light red to pink ash. There are some pomice rock boulders and fragments of dacitic - andesitic, angular lavas.
Contacts	Discordant contact with preexisting units
Age	Plio - Pleistocene, associated with domes and boilers.
Source	In general, they are generated by the collapse of a dome or other structure of the Galeras Volcanic Complex, which generates an explosive and destructive flow that travels great distances, due to the expansion of gases

Source: GEOCOL CONSULTORES S.A., 2017. Taken from INGEOMINAS, 1991.

Table 5.8 General Lava and Ash characteristics:

CHARACTERISTICS	DESCRIPTION
Name	Lavas and Ashes
Lithology	In fresh state, lavas present gray, black or green colors of a porphyritic texture, with oriented phenocrysts. In general, they are classified as dacites, plagidacites, quartz - latiandesites, quartz - andesites, latiandesites and andesites Ash flows and ash fall can develop into tens of meters of altered thickness.
Contacts	Discordant contact with preexisting units
Age	Tertiary - Quaternary associated with the volcanic activity present in the area.
Source	Generated by the changes in facies given by the stratovolcano nature of some nearby volcanic foci.

Source: GEOCOL CONSULTORES S.A., 2017. Taken from INGEOMINAS, 1991.

Table 5.9 General characteristics of the Volcanic deposits without differentiating

CHARACTERISTICS	DESCRIPTION
Name	Volcanic deposits without differences

Lithology	These deposits appear mixed and interdigitated and, hence, it has not been possible to differentiate them. In general, lava, ashes, burning avalanches, lahars and deposits of fluvio-glacial origin appear; also, deposits of non-stratified detrital sediments, corresponding to old avalanches and flows of volcanic mud, are found.
Contacts	Discordant contact with preexisting units
Age	Plio - Pleistocene, associated with domes and boilers.
Source	They are mainly associated to the different boilers present in the area, such as the upper part of the Galeras Volcanic Complex, the Guaca volcano and the south of Tangua.

Source: GEOCOL CONSULTORES S.A., 2017. Taken from INGEOMINAS, 1991.

Table 5.10 General characteristics of other Pyroclastic Deposits.

CHARACTERISTICS	DESCRIPTION
Name	Other Pyroclastic Deposits (Qvc)
Lithology	Rain or ash deposits responsible for softening the preexisting morphology, and their thickness can range from a few centimeters to a few meters. They mainly consist of glass, biotite, plagioclase, hornblende, quartz, potassium feldspar and fragments of pumice stone. In general, they are altered to clays of yellow and reddish colors. They have a dacitic composition.
Contacts	Discordant contact with preexisting units
Age	These are deposits of more recent age, evidencing different phases of emission, which normally develop paleosoils.
Source	Generated by the most violent state of the volcanoes, which expel finely fragmented material at great distances from the emission center.

Source: GEOCOL CONSULTORES S.A., 2017. Taken from INGEOMINAS, 1991.

5.1.1.2 Local geology.

The geology of the area of influence was analyzed and described in the field where the project was laid down; the composition of the rock, the temporal relation of the events and the contacts where there are lithological contrasts were observed, grouping the units to a 1: 10000 working scale; 68 stations were carried out in these routes, as described in **Table 5.11** below:

Table 5.11 Stations made in the field.

POINT	X	Y	LANDMARK	STATION ID
1	957035	606573	1766	Pm1
2	954774	604986	1855	Pg9
3	954840	605081	1802	Pg8
4	956876	604375	1891	Pg7
5	956697	605091	1806	Pg6
6	948304	590912	2499	Pg57
7	947908	591764	2544	Pg56
8	948527	592057	2658	Pg55
9	949234	592222	2672	Pg54
10	948708	592374	2721	Pg531
11	949570	593226	2855	Pg53

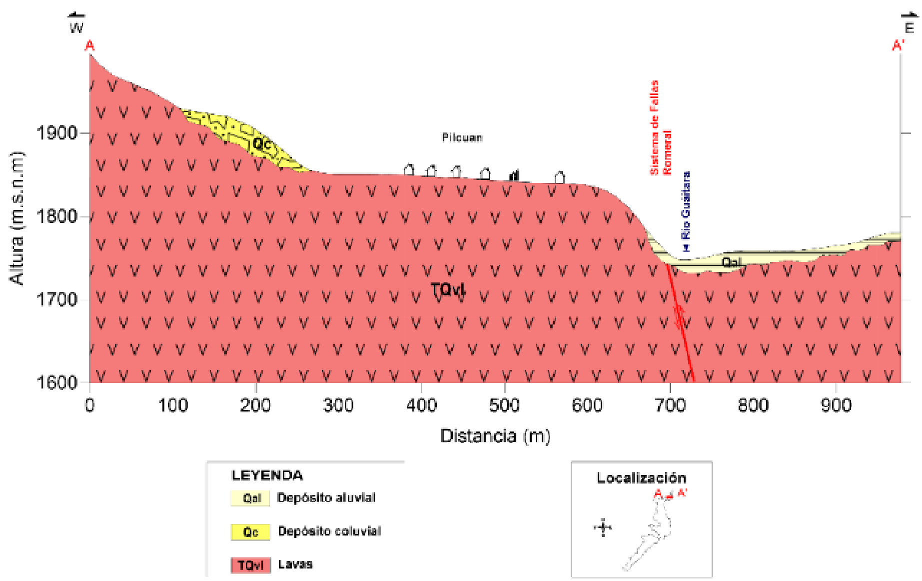
POINT	X	Y	LANDMARK	STATION ID
12	949999	593637	2876	Pg51
13	950627	594516	2873	Pg50
14	956696	605508	1793	Pg5
15	950858	594509	2930	Pg49
16	951330	595549	3033	Pg48
17	951689	595979	3052	Pg47
18	952329	595798	2988	Pg46
19	951956	594912	2859	Pg45
20	951784	594774	2836	Pg44
21	954013	596441	2846	Pg43
22	954906	597003	2762	Pg42
23	954992	596945	2754	Pg41
24	955429	598186	2815	Pg40
25	956774	605767	1779	Pg4
26	955806	598281	2740	Pg39
27	955380	597447	2734	Pg38
28	955199	596968	2717	Pg37
29	955388	596479	2724	Pg36
30	955702	595799	2387	Pg35
31	956223	600511	2116	Pg34
32	955995	600503	2149	Pg33
33	953987	601955	2526	Pg32
34	954415	601628	2463	Pg31
35	954924	601937	2363	Pg30
36	956829	605994	1773	Pg3
37	955191	601385	2309	Pg28
38	955135	600975	2274	Pg27
39	955352	601161	2226	Pg26
40	955438	601226	2219	Pg25
41	955357	602207	2092	Pg24
42	955351	602309	2083	Pg23
43	955290	602355	2078	Pg22
44	955222	602376	2073	Pg21
45	954846	602417	2047	Pg20
46	957015	606514	1765	Pg2
47	955126	603304	1961	Pg19
48	954598	603414	1933	Pg18
49	954332	603491	2017	Pg17
50	954607	604427	2039	Pg16
51	954582	604966	1936	Pg15
52	954672	604693	1959	Pg141
53	954668	604392	2023	Pg14
54	954713	604470	1966	Pg13
55	954704	604531	1949	Pg12
56	953964	604770	1900	Pg11
57	954244	605159	1866	Pg10
58	955128	601807	2340	P29

POINT	X	Y	LANDMARK	STATION ID
59	951669	595973	3091	Gm7
60	951323	595526	3064	Gm6
61	953707	598516	2829	Gm5
62	952617	598783	2920	Gm4
63	954991	604371	1855	Gm3
64	955240	604795	1831	Gm2
65	955228	604910	1797	Gm1
66	957002	606623	1783	G3
67	957016	606659	1784	G2
68	957054	606779	1786	G1

Source: GEOCOL CONSULTORES S.A., 2017.

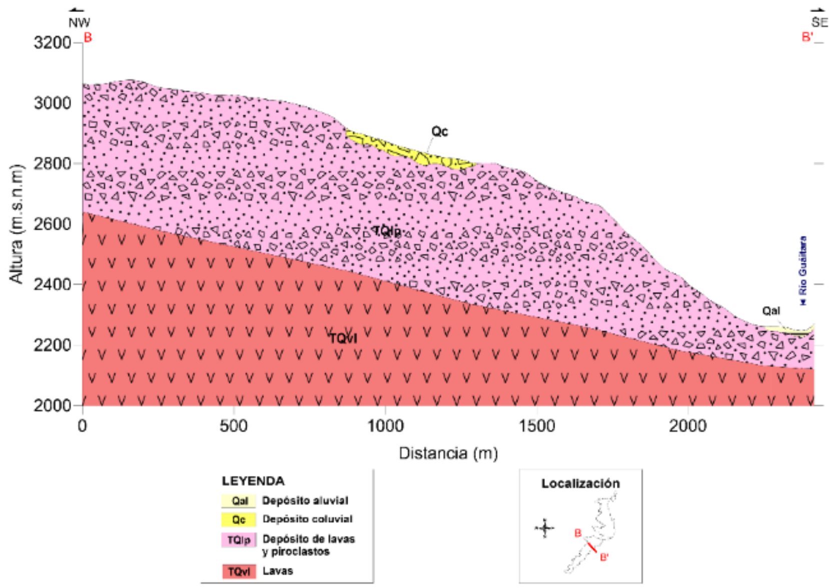
Locally, the area of influence is predominantly covered by volcano-sedimentary and volcanic deposits (**Figure 5.4** and **Figure 5.5**) which, in general, are associated with eruptions of extinct or active volcanoes, such as the Galeras Volcano; this sequence is described below, from the oldest to the most recent (**Figure 5.7**), and is presented in the **Cartographic Annex, Map N ° 5. Geology**.

Figure 5.4 Representative geological profile 1, Rumichaca - Pasto, San Juan - Pedregal Segment divided highway project.



Source: GEOCOL CONSULTORES S.A., 2017.

Figure 5.5 Representative geological profile 2, Rumichaca - Pasto, San Juan - Pedregal Segment divided highway project.



Source: GEOCOL CONSULTORES S.A., 2017.

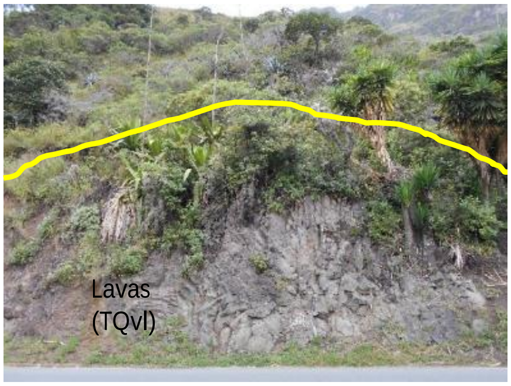
5.1.1.2.1 Lavas (TQvl).

The lavas identified are located on Pedregal road leading to Pilcuan Viejo, for the route from PK 45 + 00 to PK 42 + 00, forming the Caldera de Imués, which still conserves its volcanic morphology. The different flows tend to have tabular forms, commonly resting in the valleys of the Sapuyes and Guáitara rivers, modeling an abrupt topography, consisting of V, very narrow, deep and staggered valleys. Within the area of influence, it represents 2.5%, corresponding to 99.4 ha approximately.

They are interbedded with other lava flows or with flow pyroclastic deposits and are generally presented as massive and block lavas. The main structures, shown by the different flows, are fracturing, by laminar flow in plastic or semi-solid state, and columnar fracturing, by cooling (**Photo 5.1**); during the field work, two main families of diaclases predominant in this geological unit were identified, one with a N64 ° E / 79SE arrangement and another with N17 ° W / 85NE arrangement (**Photo 5.2**).

In fresh condition, these rocks show a strong melanocratic affinity, therefore they exhibit colors between gray, green and black; when weathering, the resulting colors are yellow to brown, due to the oxidation of mafic minerals. In general, porphyritic textures predominate, with aphanetic matrix and subhedral phenocrysts, which rarely exceed 2 mm in their greatest length, and correspond to plagioclase, amphibole, biotite, pyroxenes and scarcely quartz (**Photo 5.3**). Depending on the variation in quartz content, they are generally classified as andesites or dacites. The lavas belonging to this volcanic activity are related to the regional hiatus existing in southern Colombia and associated with the Andean Orogeny.

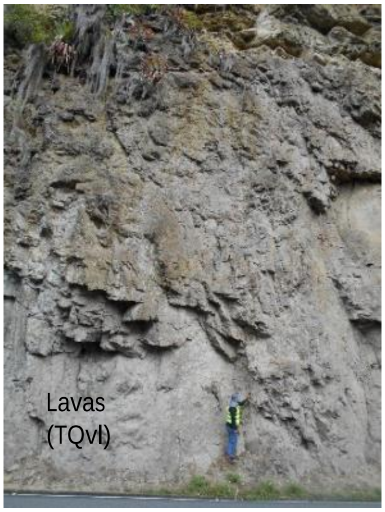
Photo 5-1 Lava Flows with Cooling Flow Structures.



Location X: 957016, Y: 606659. Municipality of Imues

Source: GEOCOL CONSULTORES S.A., 2017.

Photo 5-2 Severely fractured andesitic lavas.



Location X: 955240, Y: 604795. Municipality of Iles

Source: GEOCOL CONSULTORES S.A., 2017.

Photo 5-3 Melanocratic rock with amphibole phenocrystal embedded in aphanotic matrix.

Location X: 955240, Y: 604795. Municipality of Iles

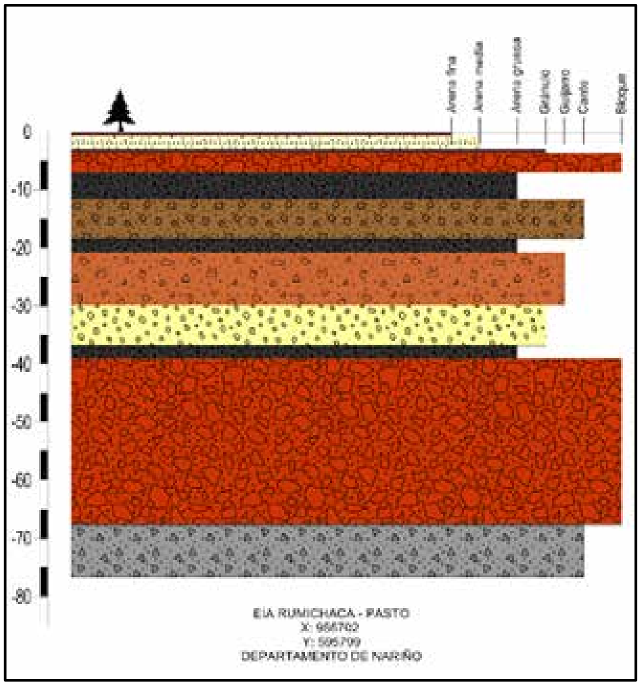
Source: GEOCOL CONSULTORES S.A., 2017.

5.1.1.2.2 Lavas and pyroclasts (NQlp).

More than half of the route in which the road corridor is projected (85.5%), the presence of this geological unit is evidenced, comprised of flow and fall pyroclastic deposits that are generally in an advanced weathering state, generating residual brown, gray and white clayey residual soils; some of the pyroclastic deposits have an increase of feldspars within their composition, reason why they develop kaolinite material; in turn, this unit generates terraced morphologies, which have been deeply undermined by the Guáitara river.

Interstratified with these pyroclastic deposits, or thereunder, there are lava flows of considerable thickness, which, sometimes appear as isolated outcrops, like windows, under the pyroclastic deposits, and in others, they are extensions covering several kilometers (**Photo 5.4**). Piroclast accumulations, in general, show leucocratic rocks, which make up ashes and tuffs, with abundant pumice rock fragments, angular to subrounded, of variable size between ash and bomb, which generally have oxidized lytics with a reddish tone, due to the oxidation of ferromagnesian minerals (**Photo 5.5**), mainly those associated with dacites, rhyolites and pumice rocks; these are supported matrices, which in some sectors are found as pyroclastic agglomerates, while in others they seem to be pyroclastic gaps (**Figure 5.6**).

Figure 5.6 Lithostratigraphic column specific to pyroclastic deposits.



Source: GEOCOL CONSULTORES S.A., 2017.

Lavas basically have an andesitic composition, gray in color, with different shades of green, aphanotic to porphyritic texture. In phenocrysts, plagioclase predominates and have hornblende and pyroxene as accessories, occasionally biotite. The matrix is aphatic to vitreous (**Photo 5.6**).

Photo 5-4 Outcropping of lavas and pyroclastic deposits.

Location X: 957002, Y: 606623. Municipality of Imues. - Location X: 955061, Y: 604071. Municipality of Iles

Source: GEOCOL CONSULTORES S.A., 2017.

Photo 5-5 Detail of lithology in pyroclastic deposits.

Location X: 954668, Y: 604392. Municipality of Iles

Source: GEOCOL CONSULTORES S.A, 2017.

Photo 5-6 Detail of lithology in lavas.

Location X: 954668, Y: 604392. Municipality of Iles

Source: GEOCOL CONSULTORES S.A, 2017.

5.1.1.2.3 Rumichaca Ash Deposits (Qdcr).

These volcano-sedimentary deposits belong to several generations of sandy and silt-sandy sediments, with intercalations of falling pumice stones. The thickness of this sequence can reach 200 m in the Guáitara river canyon, south of the municipality of Ipiales. This unit is characterized by smoothing the topography, especially of the less sloped areas and, in general, occupies an area of 136.4 ha, corresponding to 1.4% of the area of influence of this EIA.

The strata, in general, are comprised of layers of decimetrical to centimetric thickness, formed by fine sands and silts, resulting from the wind transport of volcanic ash, which reveals dry climatic conditions during their deposition, which are intercalated with deposits of fallen ash and pumice stone of variable thickness, between a few centimeters and more than two meters. The episodes of pumice stone fall show intense quaternary volcanism in the area; said pumice stone is highly vesiculated, white, with some hornblende and biotite crystals.

5.1.1.2.4 Colluvial deposits (Qcl).

These deposits are constituted by angular debris of different size, poorly selected and with low matrix content. In general, they are clasto-supported and a single lithology predominates within the deposit (**Photo 5.7**). These accumulations are recent and continue to occur as a result of terrestrial dynamics, climate and anthropic activity. For this reason its occurrence is common, especially in the mountainous zone, due to its gravitational origin or to mass removal processes; they are related to strong morphological changes, with sectors where the units of rocks are intensely weathered or where the rocks have a high fracturing degree. Within the area of influence, they represents 1.5%, corresponding to 156.2 ha approximately. Generally, this geological unit maintains a low degree of consolidation due to its heterogeneous composition, because given its volcanic origin, these materials tend to be more vulnerable to weathering; according to the above, these deposits can trigger mass removal processes mainly in areas of accumulation of sub-surface waters and high slopes.

Photo 5-7 Panoramic view to a colluvium deposit.

Location X: 955240, Y: 604795. Municipality of Iles

Source: GEOCOL CONSULTORES S.A, 2017.

5.1.1.2.5 Alluvial deposits (Qal).

The alluvial sediments found in the area of influence of this EIA are associated with the main river and ravine channels, where their extent and thickness are inversely proportional to the depth and narrowness of the generated valley, so that in the V-shaped valleys, incised and closed, decimetric thicknesses are generated, which cover very small areas; while in the wider V-shaped valleys, the thicknesses are metric and the areas covering these sediments are more than 50 m in average, as seen in the area of the mouth of the Sapuyes River over the Guáitara River, where there is a development of alluvial terraces, which were deposited while the channels were dissecting the topography. The morphology of the terraces is flat, wide and the lithology is made up of gravels, from block to pebble size, with a very variable composition and medium to thick sand matrix; these deposits are sporadically formed only by coarse sand (**Photo 5.8** and **Photo 5.9**).

Photo 5-8 Alluvial deposit Guáitara river.

Location X: 957002, Y: 606623. Municipality of Imues

Source: GEOCOL CONSULTORES S.A, 2017.

Photo 5-9 Elongate alluvial deposit.

Location X: 957002, Y: 606623. Municipality of Imues

Source: GEOCOL CONSULTORES S.A, 2017.

In general, the alluvial deposits comprise subangular to sub-rounded particles (depending on the transport to which they were subjected), ranging from blocks to pebbles, with or without matrix, of varied lithological composition, corresponding mostly to volcanic and volcano-sedimentary rocks that cover the area where the channel drains. When the matrix is present, it corresponds to a silty - clayish mixture (70-30% ratio), they are imbricated and organized in a fining downward grain size (**Photo 5.10**). The thickness of the alluvial deposits in the area of influence can reach thicknesses up to 5 m, according to field observations. Due to the nature of the deposit environment that generated them, the permeabilities in this type of deposits are usually high, with a high porosity, although they can vary according to the amount of matrix present in the deposit.

Photo 5-10 Alluvial deposit of sediments of igneous composition that were reworked by the stream; a fining downward grain size inside the deposit is observed.

Location X: 957054, Y: 606779. Municipality of Imues

Source: GEOCOL CONSULTORES S.A, 2017.

5.1.1.3 Structural geology.

The area of influence of this EIA is located in the Nudo de los Pastos, where they begin to divide two of the three Colombian mountain ranges; this makes the tectonics of the sector complex, because of the convergence of megaestructures, which are masked by large thicknesses of volcanic deposits and volcanic sedimentary neogens and quaternaries, which makes identification difficult. Its structural style is dominated by high-angle N-NE direction faults, which produce a notorious deformation in the Western Cordillera, due to the continuous process of accretion and subduction of the oceanic plateau (**Figure 5.7**).

The geological structures, mapped in this area, show the tectonic activity that has given the current expression of the mountainous system of the Northern Andes, especially the portion that corresponds to the differentiation between the Andes of Ecuador and the Andes of Colombia. These tectonic processes have been interpreted as originated by different geodynamic mechanisms, such as the migration of the sub-Andean ridge system, which began in the Mesozoic and continued progressively during the Cenozoic, and even in the Quaternary (Noblet et al., 1996, in Velandia, 2001), or tectonism of the foreland folding, with main advance towards the east, from Peru, towards Ecuador and Colombia (Butler, 1983; Mojica & Franco, 1992; Coney & Evenchick, 1994, in Velandia, 2001).

5.1.1.3.1 System of the Romeral Faults.

In general, this fault system is the morphological expression of a paleosuture formed during the Jurassic - Lower Cretaceous subduction, which in the sector connects the Nariñense Altiplano with the Central - Eastern Cordillera and tectonically controls the Caldera Imúes and the Guáitara river, to the north, after Pilcuán Viejo. Its trajectory has a high angle dip and an N - S course, which brings the oldest rocks of the Precambrian (La Cocha - Tellez River) to the rocks of the Cretaceous Diabassic Group and the Neogene - Quaternary rocks of Volcanic origin.

5.1.1.3.2 Patía - Guáitara Fault.

This fault controls the trajectory of the Guáitara river to the south, after Pilcuán Viejo to the mouth of the Angasmayo river, with an N35 ° W direction and a high degree of dip; this fault connects the rocks of metasediments and metabasalts of the Cretaceous Diabassic Group, with metamorphism of zeolite, prenhita - pumpellita facies and green schist facies, with hypoabisal igneous stocks, with dacitic and andesitic composition of tertiary age and sedimentary detrital rocks of the Esmita Formation.

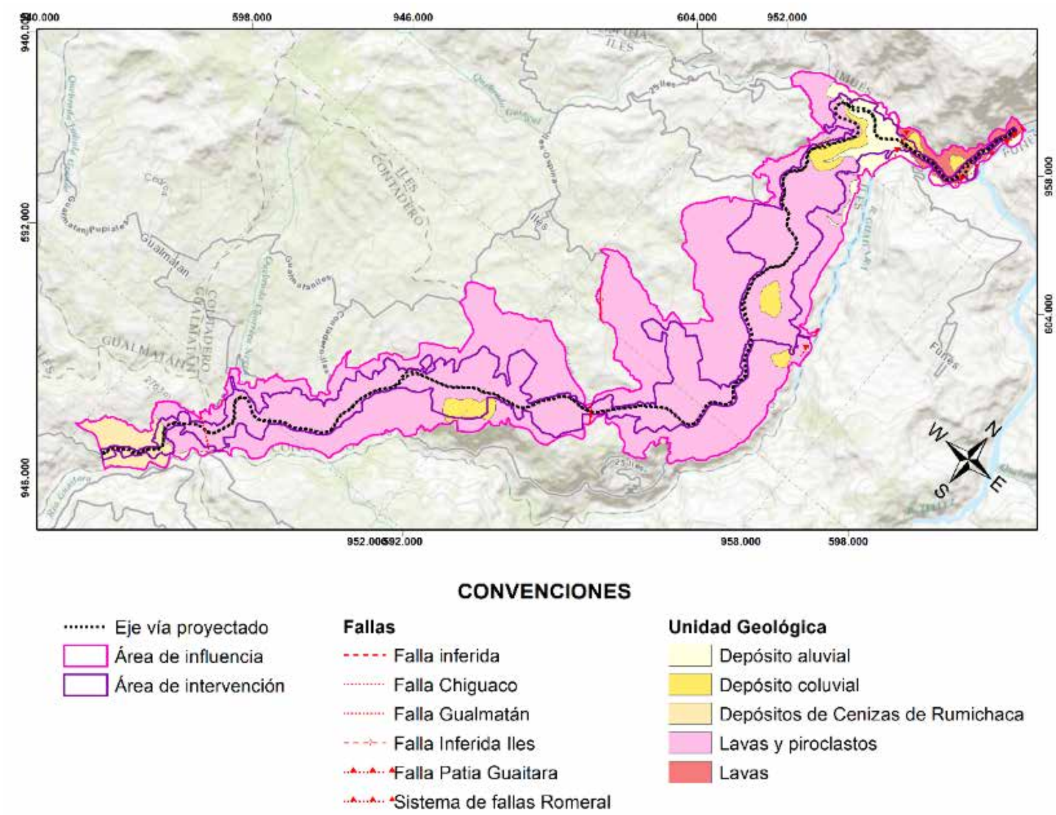
5.1.1.3.3 Iles Fault

A sinistral course failure, considered to be a fault of the basement with NW-SE direction, which cuts and displaces older units at depth and more recent structures, which have NE-SW direction; its trace, in general, is covered by the pyroclastic and flow deposits that soften the ground, making its photogeological identification complex.

5.1.1.3.4 Gualmatán Fault.

A high-angle fault with a south-easterly dip with a NW-SE normal component; this fault is controlling the course of the Boquerón river, which passes between the municipality of Contadero and the San Juan township, municipality of Ipiales; evidencing straight sections and a physical control over the channel.

Figure 5.7 Geological units and local structures for the area of influence, Rumichacha - Pasto divided highway project, San Juan - Pedregal Segment.



Source: GEOCOL CONSULTORES S.A., 2017.

5.1.1.4 Threats.

5.1.1.4.1 Seismic threat.

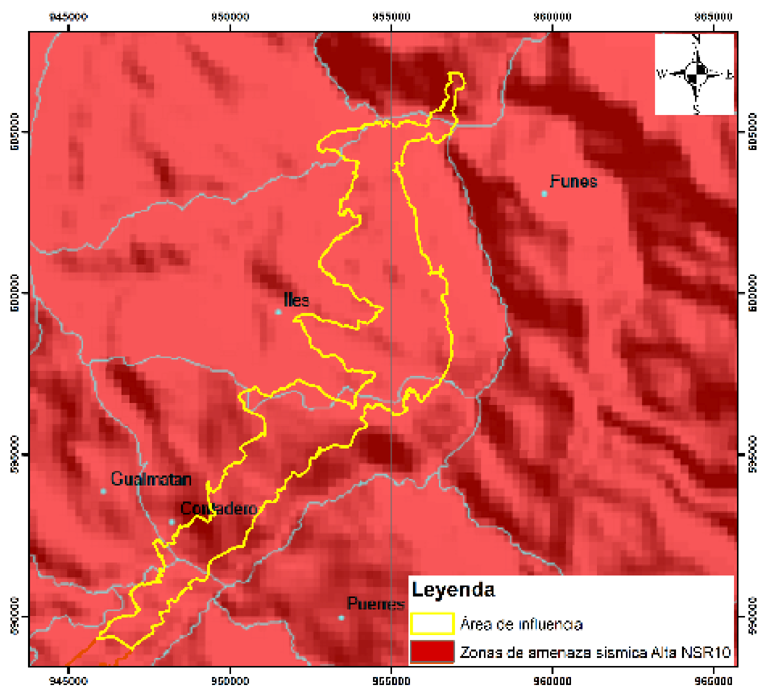
The area of influence is seismically active. Due to the volcanic activity that has occurred there, very strong tremors are expected over the years, with effective acceleration between 0.30 and 0.35, it is considered a highly seismic zone (**Figure 5.8**). The effective peak acceleration (Aa) corresponds to the horizontal accelerations of the design earthquake, as contemplated in the Colombian Standards for Earthquake Resistant

Design and Construction (NSR-98), as a percentage of the acceleration of terrestrial gravity (g = 980 cm / s). The value of the parameter Aa is used to define the seismic loads of design required by the regulation on Earthquake Resistant Constructions.

According to the map of maximum seismic intensity (2015) observed for the area of influence of this EIA, it is defined that earthquakes have occurred, the intensity of which can generate moderate damage (**Figure 5.9**).

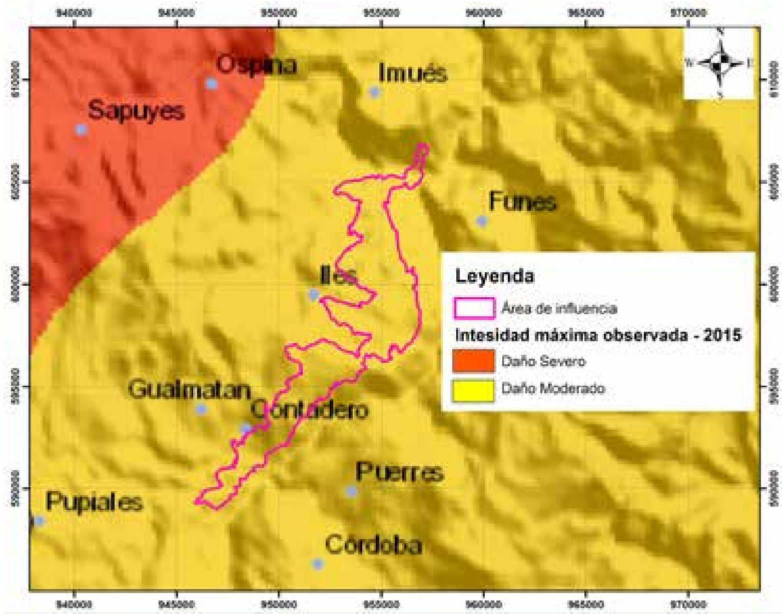
The seismic hazard map, represents a probabilistic model for the movement of the terrain, which could be expected by the occurrence of earthquakes in Colombia; this movement of the terrain is calculated in terms of maximum horizontal acceleration in rock (PGA), and it is estimated for probabilities of 2%, 10% or 50% of being exceeded in a time of 50 years, which is the estimated useful life of a current construction. These probabilities are associated with the frequency of occurrence (or period of return) of potentially destructive earthquakes: Exceptional occurrence (period of return of 2475 years), frequent (period of return of 475 years) or very frequent (period of return of 75 years). For the region where the area of influence is located, it is estimated that the movement of the terrain in terms of horizontal rock acceleration (PGA) is between 200 and 250 cm / sg2, for a return period of 475 years (**Figure 5.10**).

Figure 5.8 Values of Aa (peak and effective acceleration) in the EIA for the Rumichaca - Pasto divided highway project, San Juan - Pedregal Segment.



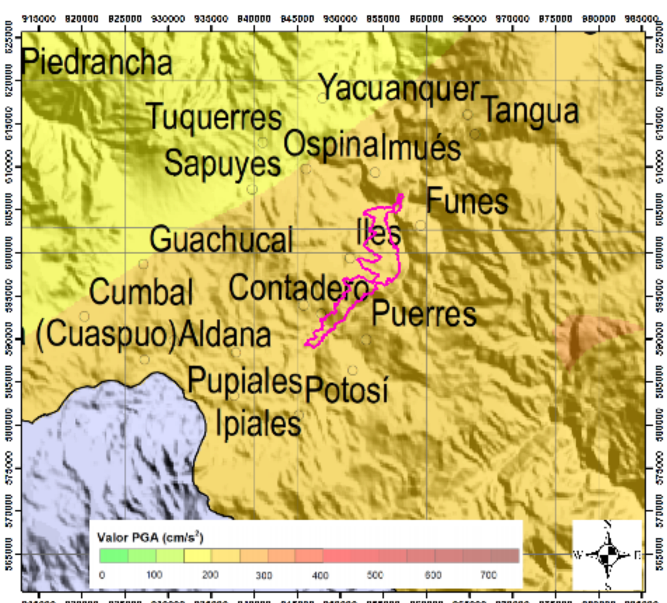
Source: Colombian Geological Survey, 2016.

Figure 5.9 Maximum observed seismic intensity, 2015.



Source: Colombian Geological Survey, 2016.

Figure 5.10 Seismic threat of the area of influence in a return period of 475 years.



Source: INGEOMINAS, 2010.

On the other hand, and according to the National Seismological Network of the Colombian Geological Service, between 1993 and 2017, earthquakes with magnitudes between 1.1 and 3.4 occurred in the municipalities of Contadero, Funes and Iles. **Table 5.12.**.

Table 5.12 History of earthquakes in the area of influence EIA for the Rumichaca - Pasto divided highway project, San Juan - Pedregal Segment.

DATE	UTC TIME	EXTENT	LENGTH	LATITUDE	MUNICIPALITY	DEPTH	STATUS
yyy/mm/dd	hh:mm:ss	Ml	Degrees	Degrees		km	
25/05/1999	0:24:33	3.4	-77.585	0.977	ILES	0	Revised
4/03/2011	7:43:01	2.1	-77.566	0.966	ILES	3,9	Revised
4/03/2011	7:57:46	2	-77.578	0.983	ILES	4	Revised
11/06/2013	5:37:59	2.1	-77.531	0.98	ILES	0	Revised
11/08/2013	5:30:38	1.6	-77.511	0.963	ILES	4	Revised
28/02/2017	2:02:59	1.4	-77.54	0.944	ILES	4,1	Preliminary
25/09/1993	20:41:37	2	-77.34	0.993	FUNES	1,1	Revised
31/03/1994	10:39:40	2.8	-77.392	1.008	FUNES	0	Revised
20/11/1995	10:25:29	1.8	-77.426	1.028	FUNES	100	Revised
15/03/1998	15:45:00	2.3	-77.489	1	FUNES	9,3	Revised
17/11/1998	4:54:03	1.6	-77.413	1.022	FUNES	11	Revised
14/11/2000	21:03:17	3	-77.395	0.96	FUNES	0	Revised
15/08/2007	20:17:18	2.4	-77.44	0.98	FUNES	69,9	Revised
5/04/2010	5:29:37	1.9	-77.297	0.943	FUNES	21,4	Revised
12/06/2010	5:27:15	2.7	-77.362	0.908	FUNES	24,5	Revised
12/08/2010	9:06:18	1.4	-77.292	0.901	FUNES	0	Revised
24/09/2010	6:22:42	1.9	-77.304	0.88	FUNES	0,5	Revised
25/09/2010	10:07:50	0.9	-77.285	0.894	FUNES	0	Revised
1/10/2010	20:38:30	1.7	-77.328	0.921	FUNES	4,2	Revised
20/07/2011	3:21:56	1.1	-77.308	0.98	FUNES	0	Revised
1/10/2012	18:57:05	2.6	-77.285	0.898	FUNES	4	Revised
17/05/2013	11:53:51	2.7	-77.311	0.872	FUNES	4	Revised
17/05/2013	12:12:07	2.7	-77.366	0.934	FUNES	0	Revised
17/05/2013	12:26:01	2.2	-77.401	0.953	FUNES	22	Revised
17/05/2013	12:45:41	1.9	-77.428	0.969	FUNES	31,1	Revised
17/05/2013	14:51:06	2.8	-77.325	0.883	FUNES	3,7	Revised
18/05/2013	7:49:21	1.6	-77.286	0.886	FUNES	0,1	Revised
20/05/2013	12:33:24	1.8	-77.275	0.929	FUNES	0,4	Revised
20/05/2013	20:24:30	2.7	-77.324	0.876	FUNES	3,6	Revised
16/01/2014	16:49:59	2	-77.4	1.018	FUNES	0	Revised
6/05/2014	15:04:41	3.7	-77.239	0.861	FUNES	4,2	Revised
14/05/2014	8:42:16	2.5	-77.32	0.917	FUNES	4,1	Revised
21/06/2014	5:59:17	2.1	-77.312	0.941	FUNES	3,9	Revised
27/04/2015	3:32:28	3.1	-77.308	0.917	FUNES	4	Revised
25/09/2015	8:51:01	2.2	-77.18	0.83	FUNES	16,5	Revised
1/03/2016	0:02:37	1.4	-77.327	0.902	FUNES	0	Revised
17/10/2016	4:50:26	1.8	-77.335	0.943	FUNES	3,7	Revised
28/02/2017	2:13:14	1.5	-77.532	0.924	CONTADERO	4	Preliminary

Source: National Seismological Network, 2017, Adapted by IGP, 2017.

5.1.1.4.2 Geological Threats

Geological threats in the area of influence are associated with volcanism in the region, including pyroclastic flows, pyroclastic falls, mud flows, lava flows, ballistic projectiles, volcanic gases and volcanic earthquakes, mainly.

- **Volcanic threat.**

The main geological threats to which the area of influence is exposed is the proximity to the Galeras, Azuflal, Chiles, Cumbal and Cerro Negro volcanoes (**Table 5.13**). It should be noted that for the area of influence of this EIA only the Galeras, Chiles and Cerro Negro volcanoes represent a threat.

Table 5.13. Characteristics of volcanoes adjacent to the study area.

NAME	HEIGHT (M.a.s.l.)	CLASSIFICATION	LAST ERUPTION
Galeras Volcano	4276	Stratovolcano - crater	2014
Azufral Volcano	4070	Stratovolcano - crater	930 a.C.
Chiles Volcano	4748	Stratovolcano, dsominantly effusive with evidence of highly explosive stages	Pleistocene
Cumbal Volcano	4764	Stratovolcano	2014
Cerro Negro	4470	Stratovolcano, dsominantly effusive with evidence of highly explosive stages	1999

Source: SGC, Pasto volcanological observatory, 2017.

The Galeras volcano is one of the most active in Colombia, located in the department of Nariño, about 9 km west of the city of Pasto. In the zone of influence of the volcano, there are more than six (6) municipalities, including Iles, Ipiales, Funes and Contador, and more than seven (7) townships. The Galeras is an andesitic stratovolcano, with an activity that has been characterized by eruptions of an explosive type.

The main threats to the area of influence of the Galeras, Chiles and Cerro Negro volcanoes are the following:

o **Pyroclastic Flows.**

It is one of the greatest threats to the community that lives in the vicinity of volcanoes, and are mixtures of rock fragments, pyroclastic debris and gases that move by gravity, can be dry and hot, and are accompanied by pyroclastic clouds, which can reach very far places; the speed of these flows can reach 200 m / s, which makes them even more dangerous. In the region where the area of influence is located, the threat can be medium to high, due to the mixture of these gases.

o **Pyroclastic Falls.**

They are fragments of rocks and pumice, thrown from the volcano crater with sizes varying from <2 mm to 64 mm. These fragments can cause fires and are highly toxic to the respiratory health of living beings. The Galeras volcano represents a low threat herein, while for the Cerro Negro and Chiles volcanoes, the threat is high to medium, due to pyroclasts (ash and lapilli) that may be airborne.

- **Sludge Flows (Lahares).**

They are mixtures of volcanic material and the active material of the rivers. Its hazardous nature lies in the grain size, the slope or boxing of the valleys, and the water content. This event is caused by the melting of glaciers or snow mountains, associated with the volcano where the eruption occurs, in addition to prolonged rains. The area of influence, in its southern part, could be reached by these mud flows, in the zone of influence of the Chiles volcano.

- **Lava Flows.**

They correspond to currents of molten rock, expelled through the volcano crater or cracks in its flanks. These flows tend to be channeled into the valleys, their fluidity depends on the composition of the lava and the morphology by which they are transported. In the area of influence this threat is considered low.

- **Ballistic projectiles.**

They are fragments of rock, which can reach several meters in diameter, expelled from the volcano, with a parabolic movement. They are strong enough to impact the surface roughly and cause major damage to buildings and living things. Due to the remoteness of the craters, in the area of influence the threat by projectiles is low for the Galeras and Cerro Negro volcanos; however, it can be average for the Chiles volcano.

- **Volcanic gases**

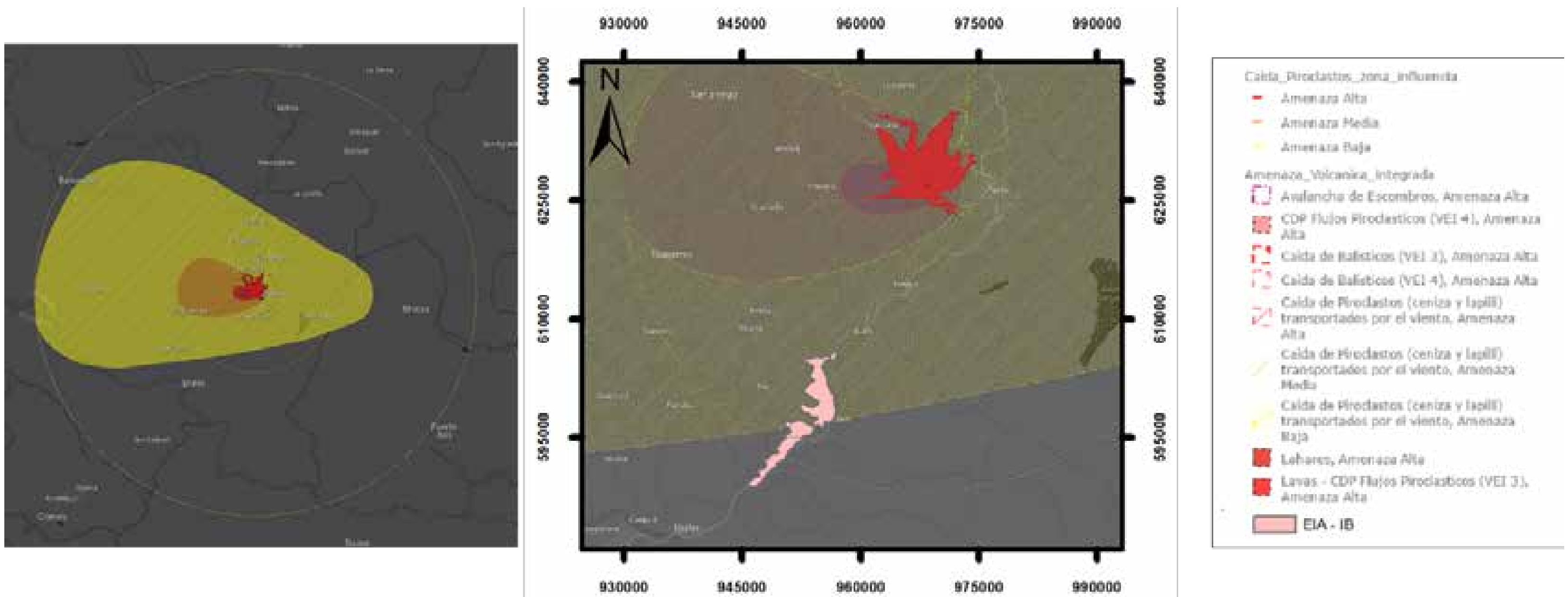
These are gases that are in the interior of the volcano and are expelled in the eruptions; they are highly harmful to human health, especially the hydrofluoric acid (HF), which in high concentrations causes suffocation in people and animals. Other gases expelled are dioxide and carbon monoxide, water vapor, sulfur dioxide, hydrogen sulfide, and chlorine, lethal in high concentrations. Because of their characteristics, these gases could reach the area of influence of this EIA.

- **Volcanic Earthquakes.**

Earthquakes caused before and during the eruption of the volcano, in areas away from the crater, do not cause severe damage and are monitored by the volcano monitoring instruments. In the area of influence, these earthquakes take place with magnitudes from 1.1 to 3.4ml.

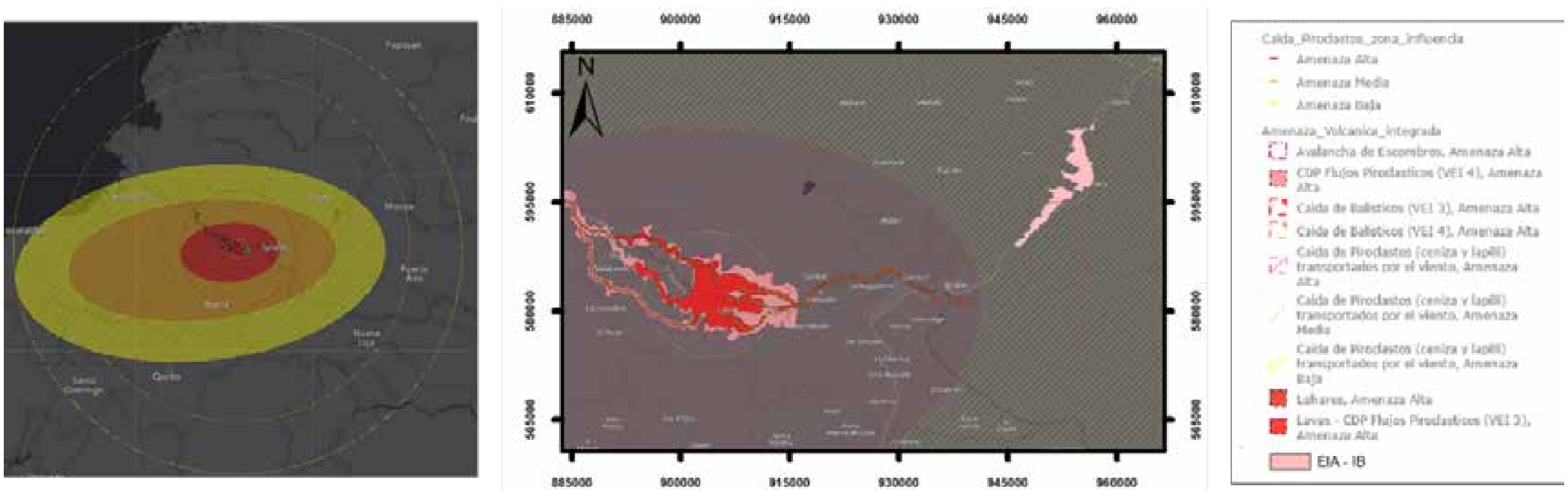
Below are the threat maps of the Chiles, Galeras and Cerro Negro volcanoes (**Figure 5.11, Figure 5.12** and **Figure 5.13**), prepared based on the overlapping of events of pyroclastic flows, lava, pyroclastic fall and sludge flows (lahares), and the determination of the severity of each by the Colombian Geological Survey in 2016 (latest upgrade).

Figure 5.11 Volcanic threat - area of influence of the Galeras Volcano.



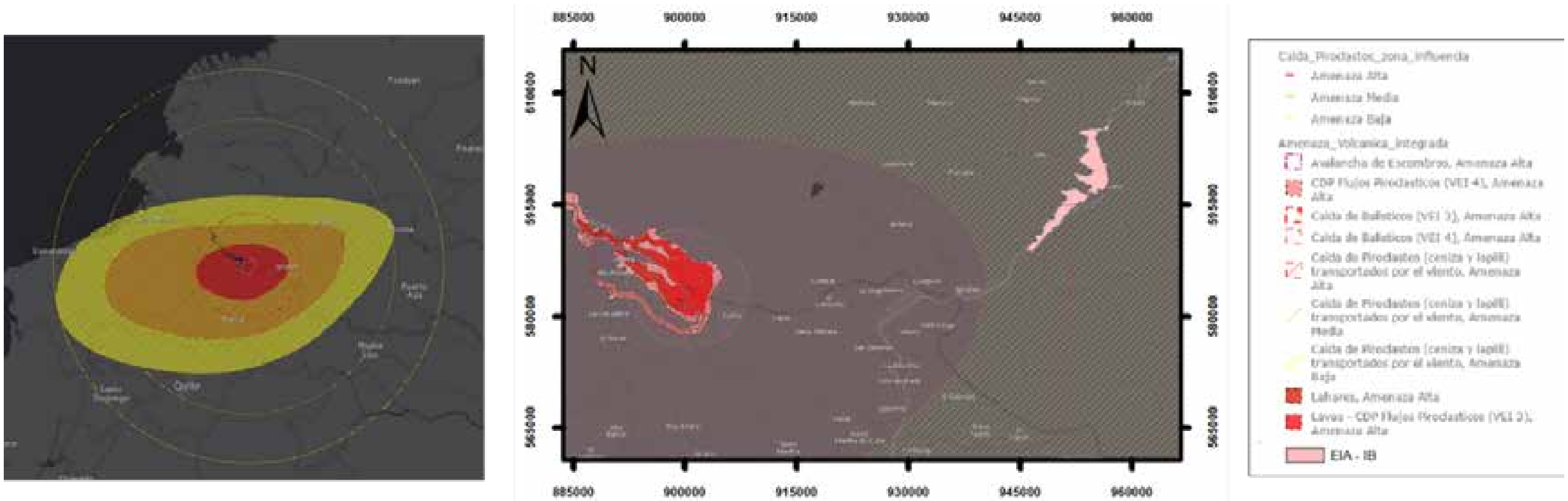
Source: Colombian Geological Survey, 2016.

Figure 5.12 Volcanic threat - area of influence of Chiles Volcano.



Source: Colombian Geological Survey, 2016.

Figure 5.13 Volcanic threat - area of influence of the Cerro Negro Volcano.



Source: Colombian Geological Survey, 2016.

5.1.2 Geomorphology.

The variety of geoforms identified in the area of influence, are due to the dynamic interaction of different factors, whether geological, hydrological, erosive processes, among others, framed in the time variable; these shape the relief resulting in different types of landscape.

For the geomorphological analysis, the following information was used:

- Methodological proposal for the standardization of geomorphological mapping in Colombia, prepared by (Carvajal 2012).
- A 4-band multispectral Worldview image (includes: natural color, infrared color, 4-band pan-sharpened, 4-band bundle) dated August 19, 2015, with spatial resolution of 0.5 m covering the northern area.
- A 5-band multispectral Rapideye image, dated January 27, 2016, with spatial resolution of 5 m, covering the center area.

The analysis of the geomorphological component, in the area of influence of the present EIA, begins with the consultation of the aerial photos that cover the area of influence; however, the scale at which they were acquired does not help to recognize the units at the level of detail required and suggested in the methodology proposed by (Carvajal, 2012), for which the aspects of morphography, morphodynamics, morphostructure and morphogenesis were analyzed. In **Table 5.14** you will find the list of flights consulted, the year, the number of envelope and the scale of acquisition.

Table 5.14 Flights and envelopes consulted from the Agustín Codazzi Geographic Institute.

PERIOD	FLIGHT	ON	SCALE	OBSERVATION
2001 - 2010	C-2770	S-40342		Specific flight over the urban area of Iles.
		S-40343		Specific flight over the urban area of Córdoba.
		S-40344		Specific flight over the urban area of Puerres.
1991 - 1995	C-2572-58-95	S-3764	1:58100	
	C-2572-62-95	S-37367	1:57300	
	C-2541-40-94	S-37008	1:40000	
	C-2541-45.8-94	S-37001	1:46400	
	C2449-63-91	S-36056	1:62500	
	C-2154-22-84	S-32368	1:23800	
	C-2144-24-84	S-32297	1:23700	
	C-2144-23-84	S-32296	1:21450	
	C-2144-24-84	S-32297	1:23100	
	C-2144-21-84	S-32299	1:21450	
	C-2191-34-85	S-32798	1:34400	
	C-2191-34-85	S-32802	1:34450	
	C-2191-38-85	S-32801	1:32100	
	C-2191-33-85	S-32803	1:32700	
	C-2128-19-84	S-32142	1:18500	
	C-2128-18-84	S-32143	1:18400	

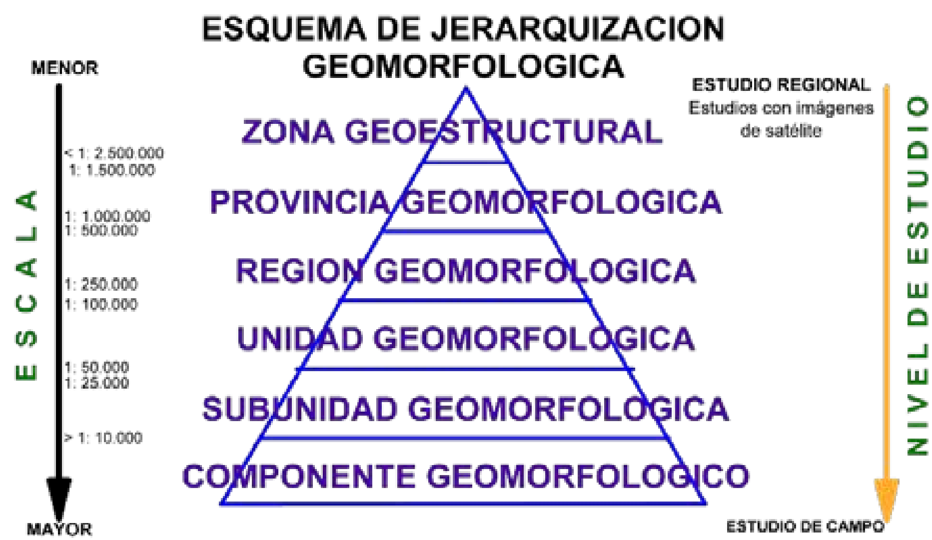
Source: GEOCOL CONSULTORES S.A., 2017.

Taking into account that the aerial Photos listed in **Table 5.14** were taken at very large scales, they become an ineffective tool to undertake a multitemporal analysis. On the other hand, during the field trips, there was no evidence of ancient mass removal processes indicating unstable slope and slope behavior. It is worth noting that the unstable processes identified are recent and are associated with cuts on roads mainly by anthropic intervention.

5.1.2.1 Classification and geomorphological categorization.

To facilitate the geomorphological analysis of a given area, the geomorphological hierarchy proposed by Carvajal (2012) has been adopted; the levels of the geomorphological subdivision applied to the work scale of the present study are described below (**Figure 5.14**).

Figure 5.14 Scheme of geomorphological hierarchy.



Source: Carvajal, 2012.

According to the geomorphological hierarchy and the work scale used, the geomorphological subunit (1: 10,000, 1: 25,000) is used as a reference; this category is fundamentally defined by the morphometric contrasts, which relate the lithostratigraphic differences with the corresponding topography of the terrain and the different active morphodynamic processes.

5.1.2.1.1 Geomorphostructure or geostructural zone.

It refers to large geographic areas or wide continental or intra-continental spaces, characterized and defined by regional geological and topographic structures (tectonic megageoforms), being established by a scale of 1: 2,500,000 (Carvajal, 2012). For the evaluation area, this corresponds mainly to a mountainous geomorph structure, related to the Nudo de Los Pastos and the Andean orogenic system.

5.1.2.1.2 Geomorphological province.

It corresponds to a set of regions with similar geoforms and defined by a macro relief and a similar geologic genesis. Locally, it is related to the natural regions and to the geological lands of Colombia, which are delimited by the trace of megafractures and defined or inferred sutures. The shapes of the relief are differentiated and delimited, based on their geological, morphological and geographic characteristics, being established for scales between 1: 1,000,000 - 1: 500,000 (Carvajal, 2012). For the region where the area of influence of this EIA is located, a (1) geomorphological province, constituted by the Central Mountain Range, is separated by the megafracture of the Romeral Fault System and, to the east, defined by the Fault System of the Piedemonte, which is represented in this region by the Afiladores Faults System.

5.1.2.1.3 Geomorphological regions.

It is the grouping of geoforms genetically and geographically related. They are defined by morphogenetic and geological environments, affected by similar geomorphological processes. The work scale is defined between 1: 250.000 and 1: 500.000 (Carvajal, 2012). According to the above, in the area of influence four (4) geomorphological regions were differentiated: 1) Alluvial Plains, 2) Denudational mountain ranges, 3) Volcanic structures and 4) Anthropic Plains.

5.1.2.2 General description of geomorphological characteristics.

For the 1:10.000 work scale, the following aspects were analyzed: a) Morphography or analysis of the forms of slopes, ridges and valleys, b) Morphogenesis or analysis of the origin of the different units, c) Morphostructure or analysis of the Structural type forms; and d) Morphodynamics or analysis of active dynamic processes on the surface of the terrain.

5.1.2.2.1 Morphography

The morphographic properties of the geoforms are qualitative and quantitative attributes of the landscape and are derived from the elevation of the terrain and the drainage network that accompanies it. For the analysis and morphographic classification, cartographic processing is used, generating and categorizing digital elevation models (DEM), thus obtaining the values of descriptive geomorphological parameters, such as terrain inclination, density and drainage frequency, among others .

For the analysis of the area of influence of this EIA, the morphographic attributes presented in the methodological document described above were taken into account; furthermore, other aspects considered important were considered, such as the drainage pattern and roughness of the terrain.

- **Relief types and relief contrast index.**

Morphologically, the area of influence presents a relief that varies from hilly to mountainous, with relative elevations from 50 m, in the lower areas, to >500 m in the highest zone. The relief contrast index is from low (<29 m) to extremely high (> 500 m), with slopes mainly abrupt (16 ° -20 °) and very abrupt (21 ° -30 °). The morphogenetic zones that exhibit the highest slopes are the volcanics (V), and some denudational (D), which have the influence of competent volcanic rocks.

- **Forms of slopes, ridges and valleys.**

The Denudational (D) morphogenetic environment, associated with pyroclastic deposits and with pyroclastic deposits and lava, represented mainly by a relief of hills and sporadically mountains, presents in general convex and irregular slopes, in some sectors; the crests are mostly rounded and, to a lesser extent, flat. On this sector, the valleys of the water bodies that drain the area are "U" shaped, in the hilly areas, with low to moderate degree of incision, due to the lithology of low competition. In the mountainous areas, valleys are "V" shaped, with a moderate to high degree of incision.

On the Fluvial (F) morphogenetic environment, associated with alluvial deposits, and where the predominant terrain is the terraces and some deposits associated with the dynamics of the channels, with low and very low relief contrast index, the slopes are characterized for being straight and flat ridges. On this sector, the valleys of the rivers and ravines that drain the zone are "V"-shaped.

On the volcanic (V) morphogenetic environment, associated with andesitic lavas, with predominantly mountainous and hilly relief, the slopes are generally straight and the crests are acute, flat or widely convex. In this sector, the valleys of the bodies of water that drain the area are "V" shaped, with a moderate to high degree of incision, due to the greater inclination of the slopes.

- **Length of sidehills.**

The length of the sidehills of the different geomorphological units, located within the area of influence of the present EIA, are the response to the competition of the lithological material of the constituent rock and the tectonic activity present in the area that, together with the meteoric agents, have generated different types and slope lengths, depending on the morphogenetic environment.

The flat and sloped sidehills of the fluvial (F) morphogenetic environment have moderate lengths (251 - 500 m). The sidehills of the Denudacional (D) morphogenetic environment hills have short (51-250 m) to moderate (251-500 m) lengths. The sidehills of the mountainous and hilly relief of the volcanic (V) morphogenetic environment have long (501-1000 m) to moderate (251-500 m) lengths.

- **Relative Relief.**

This factor represents the natural roughness of the terrain, which is defined as the greatest difference of heights per unit area, and is calculated by the following formula:

$$RR = \frac{(altura\ máxima - altura\ mínima)}{unidad\ de\ área}$$

The relative relief (Rr) values can also be expressed as slope values, since with the input data, they are calculated in degrees or in percentage. Once the relative relief has been calculated, the weight value thereof is assigned in **Table 5.15**.

Table 5.15 Classification of Relative Relief.

RELATIVE RELIEF (M / km^2)	SLOPE (%)	SLOPE IN GRADES	QUALIFYING
0 – 75	0 7.5	0 -4.29	Very Low

RELATIVE RELIEF (M / km²)	SLOPE (%)	SLOPE IN GRADES	QUALIFYING
76 – 175	7.6 – 17.5	4.30 – 9.93	Low
176 – 300	17.6 – 30	9.94 – 16.7	Moderate
301 – 500	30.1 – 50	16.71 – 26.57	Medium
501 – 800	50.1 – 80	26.58 – 38.66	High
> 800	> 80.1	> 38.66	Very High

Source: Modified from SNET, 2004.

The relative relief of the area of influence is observed in **Figure 5.15**, and the current percentages of each unit are observed in **Table 5.16**.

Table 5.16 Relative relief in the area of influence.

QUALIFYING	AREA (ha)	%
Very Low	140,8	3,5
Low	626,3	15,5
Moderate	1012,5	25,1
Medium	1139,7	28,2
High	710,9	17,6
Very High	411,7	10,2

Source: GEOCOL CONSULTORES S.A, 2017.

For the calculation of this parameter, height values of the ASTER GDEM were processed, and were classified with the ranges of **Table 5.15**. As shown in **Table 5.16**, there is a predominance of areas with medium (28.2%) and moderate (25.1%) relative relief.

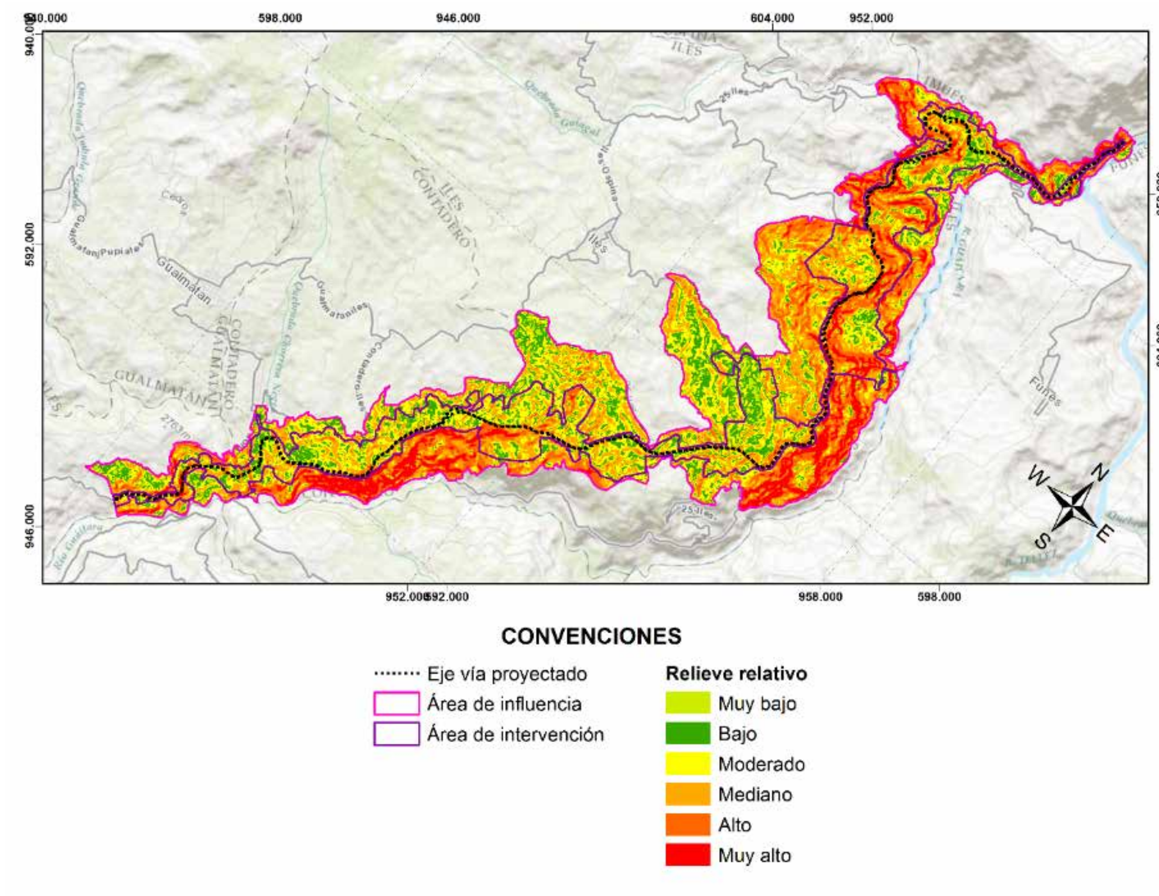
- **Slopes**

The terrain slope degree is a factor that limits the development of activities on the ground; and is also a tool for determining of susceptibility to erosion, mass removal and flooding processes. In order to calculate the slopes of the area of influence of this EIA, the slope ranges set out in **Table 5.17** were used.

Morphologically, there is a predominance of strongly inclined slopes in 37.4% of the area of influence, 25% corresponds to moderately inclined slopes (7% - 12%), 15.8% belong to slightly steep slopes (25% 50%), 6.3% are slopes slightly inclined (3% - 7%), 3.4% slopes slightly flat (1% - 3%) and 7.3% slopes moderately steep (50% - 75%), 4.9% corresponds to strongly steep slopes (75% - 100%) and 0.1% level slopes (0-1%).

Most of these high slopes correspond to, or are associated with the inflection points of geoforms of volcanic origin, the most outstanding are the strongly inclined ones, highlighted in orange, which are mainly related to the areas formed by the most competent lithologies. The second type of slope is characterized by the presence of moderately sloping areas, highlighted in yellow, and mainly related to the reliefs of hills that characterize the central and western part of the area of influence. The third type of slope, characteristic of the area of influence, includes areas of slightly steep slopes, identified within the figure with intense orange color, which occupies an area of 638.9 ha (**Figure 5.16** and **Cartographic Annex, Map No. 6, Slopes**).

Figure 5.15 Relative relief for the area of influence of the Rumichaca - Pasto divided highway project, San Juan - Pedregal Segment.



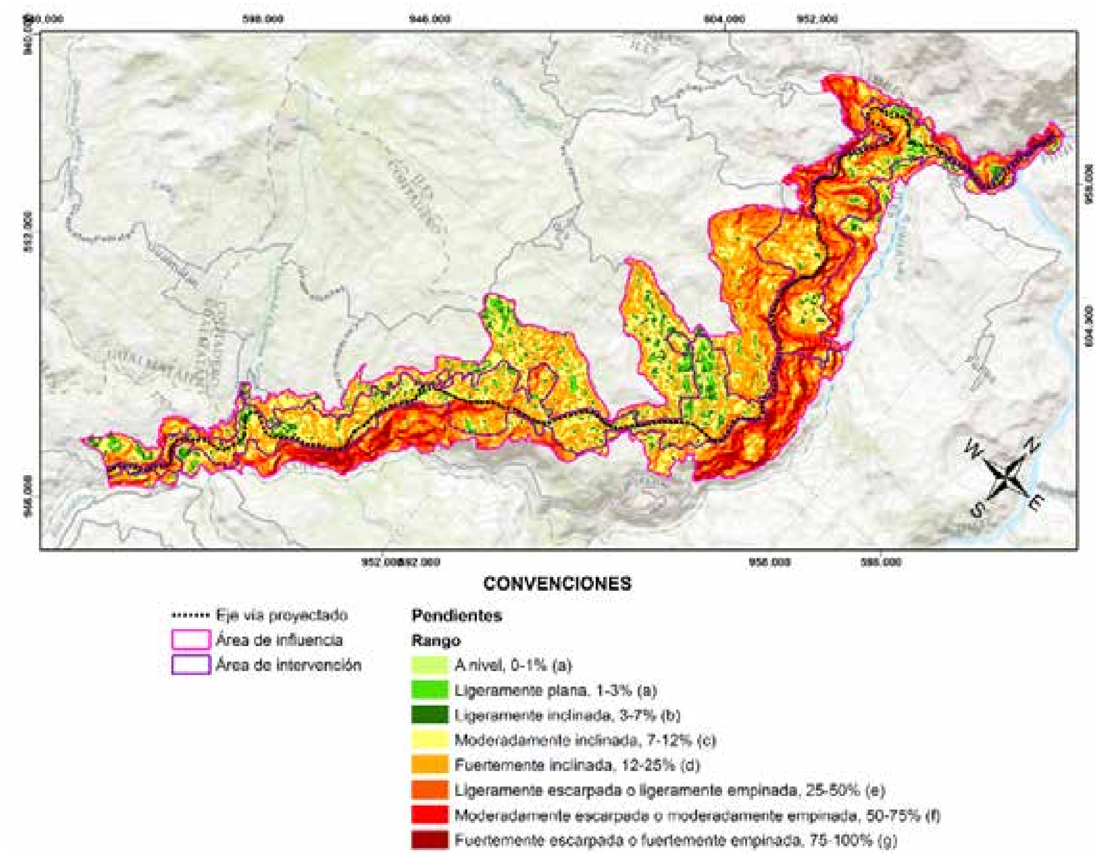
Source: GEOCOL CONSULTORES S.A, 2017.

Table 5.17 Range of slopes.

RANGE (%)	DESCRIPTION	AREA (Ha)	%
0 – 1%	Level	2,4	0,1
1% – 3%	Slightly flat	138,8	3,4
3% – 7%	Slightly Inclined	252,9	6,3
7% – 12%	Moderately Inclined	1008,8	25,0
12% – 25%	Strongly Inclined	1509,4	37,4
25% – 50%	Slightly inclined or slightly steep	638,9	15,8
50% – 75%	Moderately inclined or moderately steep	293,1	7,3
75% - 100%	Strongly inclined or strongly steep	196,5	4,9

Source: GEOCOL CONSULTORES S.A, 2017.

Figure 5.16 Map of Slopes in the area of influence EIA for the Rumichaca - Pasto divided highway project, San Juan - Pedregal Segment.



Source: GEOCOL CONSULTORES S.A., 2017.

5.1.2.2.2 Morphogenesis.

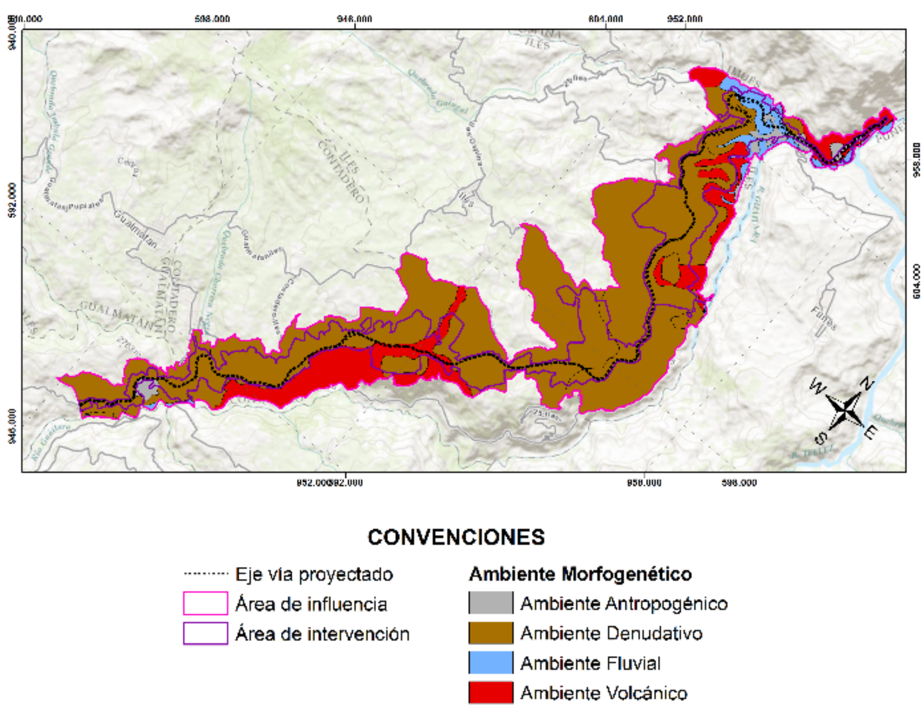
The morphogenesis defines the origin of the geoforms of the land; in this sense, the origin of a landscape is based on the processes and agents that act on the terrestrial surface, in different proportions and intensities, during a geological time interval (Carvajal, 2012).

In the area of influence of the present EIA, geoforms are presented, which have been modeled by diverse exogenous and endogenous processes, generating geomorphological units (**Figure 5.18** and **Cartographic Annex, Map No. 8. Geomorphological Units**) of four environments: mainly Fluvial (F), Denudacional (D), Volcanic (V) and, to a lesser extent, Anthropic (A).

- **Morphogenetic Environments.**

Morphogenetic environments are areas where geoforms have been modeled by the conjunction of morphostructure, geotectonism and geoclimatology. Hence, for the area of influence, four (4) of these environments are presented, which determine the occurrence and distribution of the different geomorphological units, then **Figure 5.17** shows the distribution of these environments within the area of influence.

Figure 5.17 Map of morphogenetic environments in the area of influence of the EIA for the Rumichaca - Pasto divided highway project, San Juan - Pedregal Segment.



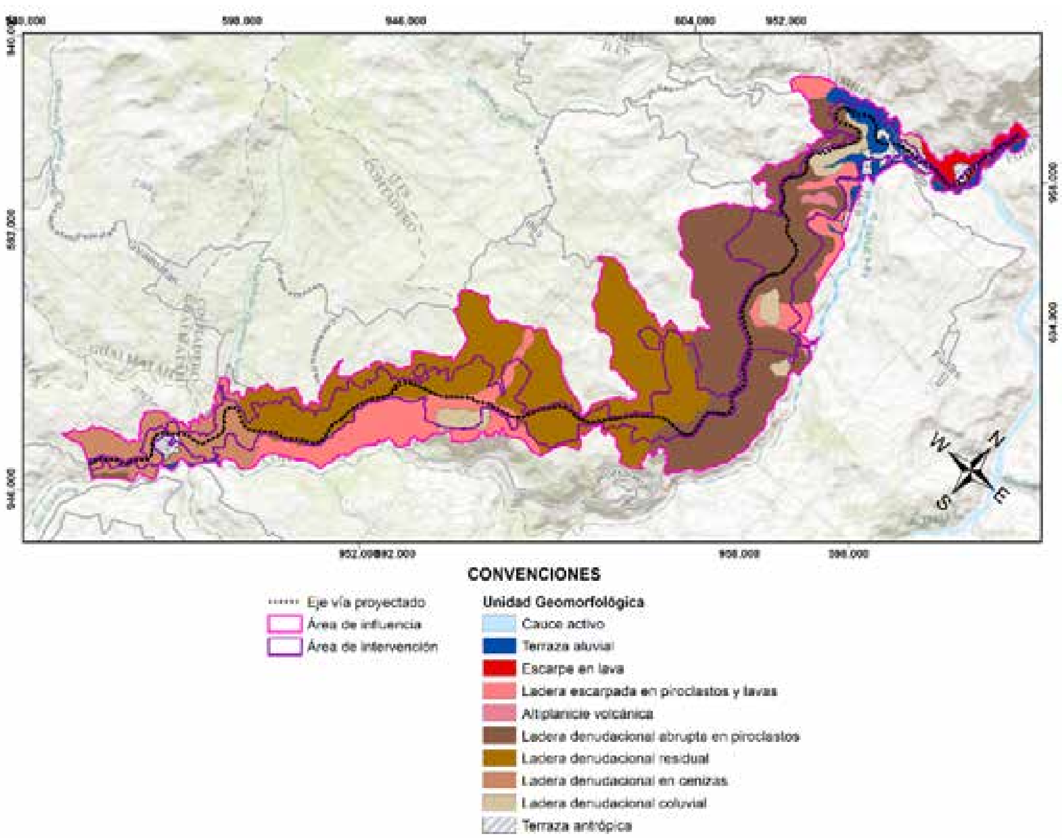
Source: GEOCOL CONSULTORES S.A., 2017.

o **Fluvial Environment (F).**

The geoforms originated by fluvial modeling are presented mainly in the areas of recent deposition of the Guáitara and Sapuyes rivers, giving rise to valleys with abrupt topography and areas of overflow during rainy season. In addition, it corresponds to the reliefs of flat morphology, horizontal to sub-horizontal and distributed parallel to the main rivers of the region, mainly related to quaternary deposits of alluvial origin. The geoforms associated to this environment were produced by sediment accumulation associated with river dynamics. Geoforms of Fluvial environment account for approximately 0.3% of the area.

This environment is dominated by the action of water currents and the transport of sediments on the terrestrial surface. The rivers are responsible for transporting their liquid and solid cargo throughout the river system, generating erosion and accumulation processes, depending on their slope, flow and sediment load. These processes lead to the formation of geoforms, characteristic of the fluvial system; in the area of influence, mainly, the alluvial terraces and the active channel are evidenced (Instituto de Hidrología, Meteorología y Estudios Ambientales de Colombia - IDEAM 2013).

Figure 5.18 Geomorphology units prevailing on the area of influence, Rumichaca - Pasto divided highway project, San Juan - Pedregal Segment.



Source: GEOCOL CONSULTORES S.A., 2017.

§ **Active channel (Fca).**

Geoform of fluvial origin, corresponding to the areas where the permanent water currents flow, associated mainly to the Guaítara and Sapuyes rivers (**Photo 5-11**). It is restricted to the deepest zone of the valleys and bordered by the banks, generally, in vertical slopes that are subjected to the action of morphodynamic processes like lateral undermining and active bar areas, whose material moves during the floods of the rivers.

Photo 5-11 Active channel, Guáitara river

Location X: 957054, Y: 606779. Municipality of Iles

Source: GEOCOL CONSULTORES S.A., 2017.

§ **Alluvial terrace (Fta).**

Geoform of fluvial origin, formed by alluvial deposits, product of the dynamics of the rivers that drain the area, with flat to slightly inclined morphologies reaching considerable thicknesses (**Photo 5-12**). The morphodynamic processes acting in this unit are associated with diffuse erosive processes and mass removal processes of smaller magnitude, on the surrounding slopes.

o **Denudational Environment.**

This environment is characterized by soft reliefs and is developed mainly from the neogenous rocks, deposits associated with the strong volcanic activity of the area. The geoforms associated with this environment were produced by the weathering and erosion of rocks, where water and wind have been the erosive agents that have shaped the surface in these sectors, generating hills or mountains, depending on the competition of the material. Denudational environment geoforms occupy approximately 78% of the area of influence.

The dissection of the landscapes, by the exogenous agents, is manifested in water erosive and gravitational processes or a combination of the two. Under dry climatic conditions, the minor erosive forms prevail; while in wet conditions, it favors the weathering of the subsoil and the gravitational movements with landslides, flows of soils and rocks. Undoubtedly, the two processes interact to produce a number of combinations. Even so, water erosion and mass removal processes constitute the two dominant sub-environments of the Denudational Environment (Instituto de Hidrología, Meteorología y Estudios Ambientales de Colombia - IDEAM 2013).

Photo 5-12 Alluvial terrace on the banks of the Guáitara river.

Location X: 955228, Y: 604910. Municipality of Iles.

Source: GEOCOL CONSULTORES S.A., 2017.

§ **Abrupt denudational slope of pyroclasts (Dlap)**

Geoform of denudational origin conformed by pyroclastic flows with low degree of weatherization, where residual soils of little thickness develop with slopes between 15 and 30 °. The slopes are elongated, concave and convex, where a relief of hills prevails (**Photo 5.13**).

Photo 5-13 Abrupt denudational slope of pyroclasts.

Location X: 954781, Y: 589720. Municipality of Iles

Source: GEOCOL CONSULTORES S.A., 2017.

§ **Residual denudacional sidehill (rdr).**

Geoform of denudational origin comprised of pyroclastic flows with high degree of weatherization, where residual soils are developed with thicknesses that reach up to 15 m approximately, and slopes between 5 and 20° (**Photo 5.14**). The slopes are elongated, concave and convex, where a hilly relief prevails. The morphodynamic processes acting in this unit are associated with erosive processes and mass removal of smaller magnitude, and incipient erosive processes.

Photography 5-14 Residual denudational hillside.

Location X: 954014, Y: 596441. Municipality of Iles

Source: GEOCOL CONSULTORES S.A., 2017.

§ **Denudational hillside of ashes (Dlce).**

Geoform of denudational origin, formed by pyroclastic flows, with predominance of volcanic ash; a moderate degree of weathering is evidenced, slopes maintain an inclination between 5 and 20 °, of elongated form, predominating a hilly relief.**Photo 5-15**) The morphodynamic processes acting on this unit are associated with erosive and mass removal processes of smaller magnitude.

§ **Coluvial denudacional hillside (Dlco).**

Geoform of denudational origin, formed by clasto-supported sloped deposits, with thicknesses ranging from 5 to 30 m, rectilinear slopes that maintain an inclination, following the slope of deposit (**Photo 5-16**). The morphodynamic processes acting in this unit are associated with erosive processes and mass removals.

Photo 5-15 Ash denudational hillside.

Location X: 946600, Y: 589479. Municipality of Ipiales

Source: GEOCOL CONSULTORES S.A., 2017.

Photo 5-16 Colluvial denudational hillside.

Location X: 955228, Y: 604916. Municipality of Iles

Source: GEOCOL CONSULTORES S.A., 2017.

- **Volcanic Environment.**

The volcanic environment is characterized by geoforms, constructed from magmatic eruptions of a lava and / or explosive nature and its products. Volcanic geoforms occur in all sizes, from metric-sized craters to lava plateaus thousands of kilometers long. Also, the different types of magmas affect the behavior of the volcanic geoforms, differentiating the explosive trends of the boiler (rhyolithic magmas), the calm volcanic tendencies of the shield volcanoes (basaltic magma) and the mixed processes of the stratovolcanoes (andesitic magma). The most notable sub-environments are related to the different explosive volcanic processes and the generation of craters, volcanic slopes, pyroclastic mantles or lava flows, among others. Also, geoforms may result from combined processes such as pyroclastic and fluvio-volcanic flows or "lahars" (Instituto de Hidrología, Meteorología y Estudios Ambientales de Colombia - IDEAM 2013).

- **Escarps of lava (Vel).**

Geoform of volcanic origin, made up of lavas from andesitic to dacitic, massive fractures that form escarpments with inclinations that surpass 45°, their slopes are elongated and convex, mainly (**Photo 5.17**). The morphodynamic processes acting on this unit are associated with block fall and mainly laminar erosive processes.

Photo 5-17 Lava carps.

Location X: 945093, Y: 604105. Municipality of Iles.

Source: GEOCOL CONSULTORES S.A., 2017.

§ **Steep slopes of pyroclasts and lavas (Vlepl).**

Geoform of volcanic origin, formed by pyroclastic flows and lava windows of mafic composition; slopes with inclinations greater than 45°, elongated, concave and convex (**Photo 5.18**). The morphodynamic processes acting in this unit are associated with erosive processes and mass removals to a lesser extent.

§ **Volcanic plateau (Vav).**

Geoform of volcanic origin, formed by pyroclastic flows, belonging to different events, characterized by a flat morphology in all its extension, limited by steep inclined slopes (**Photo 5.19**). The active morphodynamic processes correspond to laminar erosion.

Photo 5-18 Steep slope of pyroclasts and lava.

Location X: 9553045, Y: 604951. Municipality of Iles

Source: GEOCOL CONSULTORES S.A., 2017.

Photo 5-19 Volcanic Plateau.

Location X: 954516, Y: 602856. Municipality of Iles

Source: GEOCOL CONSULTORES S.A., 2017.

o **Anthropic Environment.**

This environment is characterized by the geoforms, generated by the significant alteration of the terrestrial surface, due to the action of man. These processes include artificial fillings, sanitary landfills and excavations, generally associated with open pit mining and artificial reservoirs. Although urban areas also represent an important modification of the land surface, especially the permeability of urban soil, it is considered as a secondary alteration in the basic morphology of the terrain, an aspect to be treated in more detailed surveys (Instituto de Hidrología, Meteorología y Estudios Ambientales de Colombia - IDEAM 2013).

§ **Antropic Terrace (Ata).**

Geoform originated from the intervention of man, due to urban development, roads, mining development and agricultural work, mainly. The topography resulting from this geoform is flat to smoothly rounded and usually exposes the constituent materials to weathering; for this reason, morphodynamic processes of erosive laminar and / or differential type and mass removal processes of smaller magnitude are associated (**Photo 5.20**).

Photo 5-20 Mid-hillside anthropic terrace.

Location X: 955702, Y: 595799. Municipality of Iles

Source: GEOCOL CONSULTORES S.A., 2017.

5.1.2.2.3 Morphostructure.

The point of this science is the study of morphostructures, which have linear and circular elements of landscapes, controlled by tectonics and denudation. Morphostructures exhibit hierarchical relationships with geological time scales (Goudie, 2004). Morphostructural analysis describes the complex interaction of endogenous processes with surface relief. This is very useful for the identification of different dislocations of basement rocks, which are commonly hidden under sedimentary, volcanic, deformation and intrusion coverings (Goudie, 2004). It is said to be passive when dealing with the characteristics of the materials involved and their structural arrangement, and active when related to endogenous dynamics (volcanism, folding, faults).

In the area of influence of this EIA, two (2) main structural domains are presented: 1) The domain of NE-SW oriented faults and guidelines and 2) Faults or guidelines with NW-SE orientation. Associated with the first group are the geoforms resulting from volcanic activity (i.e volcanic boilers), which have a morphostructural influence, related to the Romeral Fault System, and its current layout is due to the tectonic influence of high angle. In contrast, the second group of structures is due to course faults, which produce a slight movement in linear elements such as channels; this fact is structurally important since it indicates neotectonic activity and evidences that the dynamic process between the major tectonic plates (South American Plate and Nazca Plate) has not ceased; however, none of these neotectonic evidences were observed in the field, because they are masked by the great thickness of the quaternary pyroclastic deposits, which represent the constant volcanic activity of the region.

5.1.2.2.4 Morphodynamics.

The morphodynamics correspond to a branch of geomorphology that is responsible for the study of active dynamic processes or those that can be activated in the future, on the surface of the terrain, processes that form the relief that can be aggradational or denudational. The aggradational surface processes are those that generate the elevation of the terrestrial surface and are associated, mainly, to processes of accumulation or sedimentation of material, as the case of alluvial deposits. The deggradational or denudational processes are those that contribute to the degradation and reduction of the initial reliefs, such processes are the erosion and the phenomena of mass removal. The recognition of the current processes of denudation and sedimentation is an important aspect for determining the susceptibility of a specific area, to be affected by natural phenomena or anthropic activities (Villota, 2005).

Rising, erosion and relief are fundamental components of a morphodynamic system and its operation has an inverse relationship (Goudie, 2004). When the rise of the relief prevails, the erosion rate increases, as erosion increases, creating eventually a balance in the orogenic process; in this case, the mountains do not change in elevation. When erosion exceeds the effects of lifting, the elevations become smaller and, consequently, the rate of erosion is progressively reduced until the process comes to an end (Goudie, 2004).

Erosion is a broad term, applied to the various ways in which mobile agents (water, wind and glaciers) dislodge and transport the products of weathering and sedimentation, resulting in loss of materials on the surface of the earth's crust. In turn, mass removal phenomena encompass the set of denudatory processes, related to the deformation of the terrain, and the more or less rapid and localized displacement and transposition of different soil volumes, complete weathering mantles, including soil material, debris, blocks and rock masses, downhill, by incidence of the forces of displacement (gravity and seismic movements), sometimes with greater or lesser participation of the ground water, ice and other agents (Villota, 2005).

In the area of influence of this EIA, the morphodynamic movements have been determined mainly by the slope of the terrain, the river dynamics, the climate regime and, in part, generated and / or accelerated by the anthropic activity. Both aggradational morphodynamic and deggradational or denudational morphodynamic processes take place (see **Cartographic Annex, Map No. 7. Morphodynamic Processes)**. The field visit made within the area of influence showed the presence of 35 morphodynamic processes in total (**Annex 3. Geomorphology**), where 11 were erosive processes (6 laminar erosive processes, 2 erosive processes generated by anthropic activity, 2 erosive processes in furrows and an erosive process by lateral undermining), and 24 mass removal processes (8 rotational landslides, 4 translational landslides, 7 rock falling, 5 debris flows). Of these, the relevant processes within the area of influence are described in **Table 5.18** below:

Table 5.18 Description of relevant processes within the area of influence.

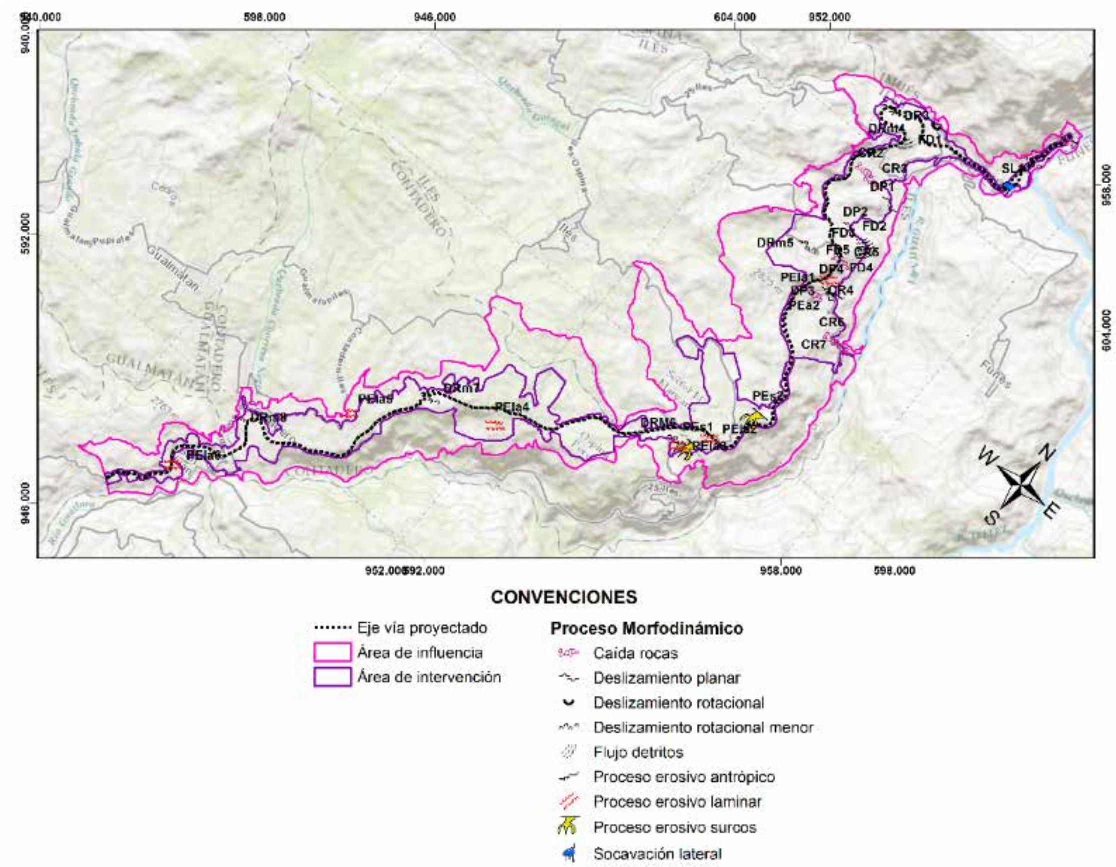
NUMBER	PROCESS TYPE	ID	X	Y	PROCESS DESCRIPTION
1	Rocks falling	CR1	957015	606514	At the height of the abscissa K44 + 80 of the road project, on the Ipiales - Pasto road, an intensely fractured rock massif can be observed of approximately 20 m in height, evidence of debris falling and potential wedge failure on the rocky massif is noticed, generating a high threat for the route. The rocky massif is made up of porphyritic igneous rocks of predominantly andesitic composition. The families of main discontinuities measured in this slope included: N64E / 78SE and N17W / 86NE.
2	Rotational Slip	DR3	954840	605081	At the height of the abscissa K42 + 000, an old rotational glide was identified, a soil mass in the dry state, advanced, without cracks and with a main escarpment of at least 20 m height, a width of 40 m, located at one of the left bank of the Sapuyes River; the materials involved in this morphodynamic process correspond to pyroclastic deposits and alluvial deposits associated with the dynamics of the Sapuyes river.
3	Minor rotational slip	DRm4	953964	604770	In the vicinity of the abscissa K40 + 100, a swarm of minor mass removal processes is evidenced by anthropic activity (construction of access roads and buildings). The topography of the area is abrupt and lithologically composed, deposits of lavas and pyroclasts and residual soils of little thickness.
4	Rocks falling	CR2	954332	603491	At the height of the K39 + 100 abscissa, a flow of debris of approximately 30 meters wide and 170 meters long was evidenced, due to the mining activity of the area; this mining operation generates threat in the tertiary road. The lithology of the area corresponds to sedimentary volcanic pyroclastic deposits of grain size coarse sand and thick tuff, in some areas there are blocks of more than 30 cm in diameter.
5	Rocks falling	CR5	955128	601807	At the height of the abscissa K35 + 600 of the road project, there is a laminar erosion and fallen blocks and debris proces on the Ipiales - Iles road, where the rock slope is severely fractured and potential wedge faults are present. The presence of subsurface water was identified, which contributes to the weathering of rocks; this process has an effect of at least 50 m on the road approximately.
6	Planar sliding	DP4	954924	601937	On the K35 + 900 abscissa, a mass removal process is located on a slope formed by pyroclastic deposits very meteorized and with fine granulometries; there is evidence of fallen block and debris; near this point, there is a series of minor landslides with Planar failure mechanism, which involve soft soils representing a high threat to the road affecting a length of approximately 300 meters.
7	Laminar erosive process	PEla2	955380	597447	At the height of the abscissa K30 + 200 of the projected road corridor, a process of laminar erosion on the Iles - Contadero segment and on maize crops is evidenced. Erosive processes present at the site do not pose a significant threat to the project. The lithology present in the area corresponds mainly to fine pyroclastic deposits such as volcanic, silt, clayish ashes and residual soils.
8	Minor rotational slip	Dm6	954906	597003	On the abscissa K29 + 300 there is a rotational sliding on a black clay soil, with a thickness of approximately 2 meters, that affects the route to the municipality of Contadero - Iles; in this zone, there is presence of a large amount of subsurface water acting as a detonating factor for the generation of the sliding producing an affectation on the road in a length of 5 m.

NUMBER	PROCESS TYPE	ID	X	Y	PROCESS DESCRIPTION
9	Minor rotational slip	DRm8	947908	591764	On the abscissa K19 + 600, an erosive process along the slope of the road that from San Juan leads to the municipality of Contadero is evidenced, specifically, minor mass removal processes are developed with rotational failure mechanism, volcanic ashes, highly weathered are noticed in the upper part of the slopes and residual soils, followed by a deposit of volcanic beige, clay - silty ashes with lithic and mafic fragments smaller than 1 mm.
10	Laminar erosive process	PEla6	947571	590214	At the height of the abscissa K17 + 300, a laminar erosion process is observed on an anthropic slope; in this section there is an occurrence of blocks and debris falling, the lithological composition of the slope corresponds to the ashes of Rumichaca formed mainly by fine sands and Limos, in the upper part of the slope there is presence of residual soils with vegetal cover.

Source: GEOCOL CONSULTORES S.A., 2017.

In **Figure 5.19** The main morphodynamic processes that were identified on the different geomorphological units are presented within the area of influence, where the recognition of the different processes was made from the field visit and the observation of satellite images available, with a resolution according to the scale of work.

Figure 5.19 Identified morphodynamic processes on the area of influence for the EIA, Rumichaca - Pasto divided highway project San Juan - Pedregal Segment.



Source: GEOCOL CONSULTORES S.A., 2017.

· **Aggradational processes.**

Aggradational processes within the area of influence are associated to the Guáitara river bed, represented by the sedimentation towards the lower energy zone of the meanders of the river in the form of lateral bars, in some areas where an incipient flood plain is developed and in the riverbanks that migrate from position therein. However, the river dynamics associated with the Guáitara river is determined by a rectilinear behavior that in some areas generates meanders, but that belongs to a young channel, with a deep and narrow valley, which has an erosive and non-depository character.

· **Denudatory processes.**

The denudatory processes are represented by processes of erosion, phenomena of mass removal and anthropic activities, described below:

o **Erosive processes.**

By erosion, the movement and detachment of soil or rock particles, by the effect of meteoric agents, their manifestation depends on factors, such as the type of rock or sediment constituent of the geoforms and slopes of the same, Climatic characteristics (mainly rainfall and temperature), and vegetation cover. The **Table 5.19** Presents the degree of erosion, which depends on the depth, spacing between the channels and coverage per unit area.

Table 5.19 Classification of erosive processes.

TYPE OF EROSION	SPACING BETWEEN CHANNELS (M)					
	<5	5 a 15	15 a 50	50 a 150	150 a 500	> 500
Laminar erosion	Severe	Moderate	Soft			
Furrows (<50 cm deep)	Severe	Severe	Moderate	Soft		
Ravines (51-150 cm deep)	Severe	Severe	Severe	Moderate	Soft	
Caves (> 150 cm deep)	Severe	Severe	Severe	Severe	Moderate	Soft

Source: Carvajal, 2012.

The erosive processes present within the area of influence are of three types: the erosion that occurs from the lateral undermining in the main rivers, the erosion laminar, which is a superficial erosion and that, in turn, can give origin To erosion in furrows or gullies.

§ **Laminar Erosion.**

Laminar erosion is a superficial wear of the soil, from which a uniform thin layer of soil is lost, mainly due to runoff; Is present on the slopes where the slope facilitates the loss of the topsoil. In this type of erosion two fundamental processes take place: The detachment of soil particles by rainfall and the removal of these particles from their original site by diffuse runoff (Villota, 2005).

In the area of influence, it presents as surface erosion, which mainly affects the first layer of residual soils, may involve loss of vegetation cover (**Picture 5.21**) Or differential erosion, according to the lithological changes that the section has; Is observed, in general, on the slopes of the existing road corridors, and areas intervened by crops in smaller proportion.

§ **Erosion in furrows.**

The furrows are the result of the entrainment of soil and sediment, generated by the flow of water, which is channeled. They are presented as erosion that has depths up to 50 cm, affecting vegetation and surface soils. From the furrows, as the channels deepen they give rise to the formation of gullies.

Within the area of influence of the present study, this type of processes are mainly related to the geoforms of hills and denudational slopes (**Picture 5.22**), Where there is presence of sub-surface water and a development of residual soils of considerable thickness, from pyroclastic deposits, with little competence and low consolidation.

Photography 5-21 Laminar erosion On cutting slopes.

Photography 5-22 Erosion in furrows On natural slopes.

Location X: 955191, Y: 601389. Municipality of Iles.

Source: GEOCOL CONSULTORES S.A., 2017.

Location X: 955200, Y: 596968. Municipality of Iles

Source: GEOCOL CONSULTORES S.A., 2017.

§ **Lateral scouring.**

It corresponds to a type of water erosion and refers to the excavation, caused by the water in the friction with the sinuous margins of the currents. The undermining causes the backslides that limit the channel, which, when weakened at the base, gradually collapse. The lateral undermining occurs, mainly, and in greater magnitude on the margins of the river Guáitara (**Picture 5.23**), Where the effects occur mainly during the winter, when the channel has more energy and rapidly erodes the margins, dragging considerable areas of land.

Photography 5-23 Lateral undercutting of the Guáitara river.

Location X: 956697 Y: 605508. Municipality of Funes.

Source: GEOCOL CONSULTORES S.A., 2017.

o **Mass Removal Processes.**

They cover the set of denudatory processes, related to the displacement of variable volumes of rock, weathered material and / or soil, downhill. The mass removal processes are generally the product of the geomechanical conditions of the geological units, outcrops in the area of influence, and the topography associated with the slopes of the same, generated according to the degree of instability the different processes . Within the area of influence of this EIA, three (3) types of mass removal processes were identified: Slips, rock fall and debris flow.

§ **Rotational and translational sliding.**

Rotational landslides occur along a curvilinear and concave break surface, where the terrain undergoes a movement along the same (Escobar and Duque-Escobar, 2016). From the field survey, localized rotational landslides were identified, with some reaching a considerable height of up to 15 m, associated with the pyroclastic, poorly consolidated deposits of fine granulometry in mountainous and hilly areas (**Picture 5.24**).

On the other hand, the translational landslides occur along a flat or undulating surface, so that they move on the surface of the original terrain and, if the inclination is sufficient, continue (Escobar and Duque-Escobar, 2016). Within the area of influence, localized translational landslides of no more than 7 m in height were associated with intensely fractured lava flows, as shown by **Photo 5.25**.

§ **Fall of rocks.**

They originate by the takeoff of rocks from a steep wall or cliff and subsequent descent by free fall, through the air, and rebound or final rolling. The main detonating factors are weathering, winds, rain or seismic activity, with the contribution of gravity (Escobar and Duque-Escobar, 2016). Due to the nature of the matrix and the poor selection and maturity of the sediments of the pyroclastic deposits of the region, in addition to the steep slope of the slopes of the tracks, this process is quite frequent throughout Of all retractable paths, as shown in **Picture 5.26** and the **Picture 5.27**.

Photography 5-24 Rotational Slip Old stabilized.

Location X: 954841, Y: 605081. Municipality of Iles

Source: GEOCOL CONSULTORES S.A., 2017.

Photography 5-25 Translational Slippage Along a discontinuity.

Location X: 955352, Y: 601161. Municipality of Iles

Source: GEOCOL CONSULTORES S.A., 2017.

Photography 5-26 Slope where there are falling blocks.

Location X: 955135 Y: 600975. Municipality of Iles

Source: GEOCOL CONSULTORES S.A, 2017.

Photography 5-27 Material dropped by falling blocks.

Location X: 955995, Y: 600503. Municipality of Iles

Source: GEOCOL CONSULTORES S.A, 2017.

§ **Debris flow.**

This type of process occurs due to the presence of fragments of rock of different sizes, embedded in a fine matrix matrix, which mobilize very quickly, depending on the terrain and the moisture content. Within the study area, as well as rock fall, this process is associated with the sediments of the pyroclastic deposits, which are erratically formed and are concentrated on the face of existing cutting slopes, as can be seen in **Picture 5.28** Y **Picture 5.29**.

Photography 5-28 Debris flow, fine matrix.

Location X: 950389, Y: 594537. Municipality of Contadero.

Source: GEOCOL CONSULTORES S.A., 2017.

Photography 5-29 Debris flow, variable size of clasts.

Location X: 955352, Y: 601161. Municipality of Iles

Source: GEOCOL CONSULTORES S.A., 2017.

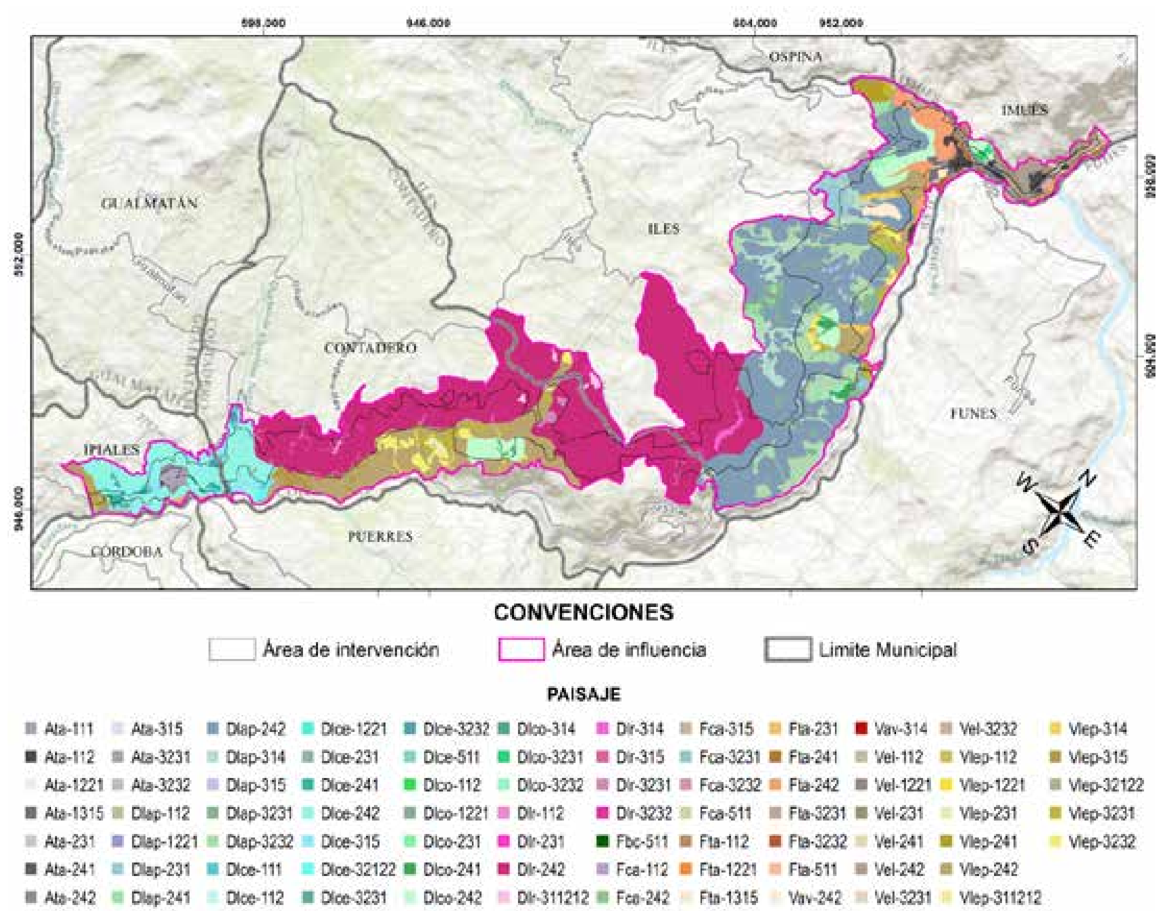
5.1.3 Landscape.

The analysis for the landscape component was performed for the area of influence of the project, and contemplated the description of the ecological landscape (expressed in the landscape units, and the analysis of fragility, visual quality and landscape integrity as a synthesis of visual analysis Of landscape. It also presents the description of the landscape component with respect to the characteristics of the project, the identification and description of sites of scenic interest, and cultural analysis regarding this component.

5.1.3.1 Ecological landscape units.

The ecological landscape is expressed spatially in the landscape units, which result from the crossing between geoforms and coverages identified within the area of indirect influence of the project. So well were identified 82 units of landscape, grouped in eleven (11) different geoforms: Antropical terrace, abrupt slope of pyroclasts, Denudational hillside in ashes, Coluvial denudacional hillside, Residual denudacional hillside, Runway bar, Active channel, Alluvial terrace, Volcanic plateau, Lava scarps and lava scarps. These units are represented spatially in the **Figure 5.20** And in the **Cartographic Annex, Map N ° 9. Local Landscape Units,** And are described accordingly.

Figure 5.20 Landscape units identified for the area of influence.



Source: GEOCOL CONSULTORES S.A., 2016.

- **Antropic Terrace.**

This geomorphological unit is one of the smallest in the area of influence (82.74 ha, or 2.05% of it), and it groups ten (10) landscape units, being those of greater dominance those associated to Tissue Continuous and discontinuous, with 21.41% and 47.31% of the geoform respectively (**Table 5.20**). As its name implies, these landscape units originate in modifications of anthropic type, which is why the coverages of artificialized territories (Road network, Exploitation of materials, Pastures, Crops and Forest plantations) are dominant.

Table 5.20 Landscape units in the anthropic terrace geoform.

# UP	NAME OF LANDSCAPE UNIT	UP CODE	AREA OF THE UP (HA)	% REPRESENTATIVENESS OF THE UP IN THE GEOFORM	% REPRESENTING OF THE UP IN THE AI
1	**Continuous urban fabric in anthropic terrace**	**Ata-111**	**17,71**	**21,41**	**0,44**
2	**Discontinuous urban fabric in anthropic terrace**	**Ata-112**	**39,15**	**47,31**	**0,97**
3	Road network and associated territories in anthropic terrace	Ata-1221	4,18	5,05	0,10
4	Exploitation of construction materials in anthropic terrace	Ata-1315	9,50	11,48	0,24
5	Clean pastures on anthropic terrace	Ata-231	0,16	0,19	0,00
6	Mosaic of crops in anthropic terrace	Ata-241	0,65	0,79	0,02
7	Mosaic of pastures and crops in anthropic terrace	Ata-242	8,46	10,23	0,21
8	Forest plantations in anthropic terrace	Ata-315	0,19	0,22	0,00
9	High secondary vegetation in anthropic terrace	Ata-3231	0,66	0,80	0,02
10	**Low secondary vegetation in anthropic terrace**	**Ata-3232**	**2,08**	**2,51**	**0,05**
Area of the geoform (ha)			82,74	% Representation of the geoform in the AI	2,05

Source: GEOCOL CONSULTORES S.A., 2017.

- **Abrupt denudational slope of pyroclasts.**

This geoform corresponds to one of the largest within the area of influence analyzed, grouping a total of nine (9) landscape units. Of these, the landscape unit associated to Mosaic of pastures and crops (Dlap-242) is the one of greater dominance, representing 65,34% of the area of the geoform, being besides one of the one of greater dominance in the area of Analyzed, occupying 21.09% of the area of the same, as can be seen in the **Table 5.21**. As for the units associated with natural hedges, the unit associated with Low secondary vegetation is the most representative, with 14% of the geoform area, evidencing a low representativeness of associated units or natural coverages.

Table 5.21 Landscape units in the abrupt denudational pyroclastic slope geoform.

# UP	NAME OF LANDSCAPE UNIT	UP CODE	AREA OF THE UP (HA)	% REPRESENTATIVENESS OF THE UP IN THE GEOFORM	% REPRESENTING OF THE UP IN THE AI
11	Discontinuous urban fabric on abrupt denudate pyroclastic slope	Dlap-112	1,75	0,13	0,04
12	Road network and associated territories on abrupt denudational slope of pyroclasts	Dlap-1221	3,91	0,30	0,10
13	Clean pastures on abrupt denudate slope of pyroclasts	Dlap-231	42,96	3,29	1,06

# UP	NAME OF LANDSCAPE UNIT	UP CODE	AREA OF THE UP (HA)	% REPRESENTATIVENESS OF THE UP IN THE GEOFORM	% REPRESENTING OF THE UP IN THE AI
14	Mosaic of crops in abrupt denudational slope of pyroclasts	Dlap-241	25,64	1,97	0,63
15	**Mosaic of grasses and crops in abrupt denudate hillside of pyroclasts**	**Dlap-242**	**852,30**	**65,34**	**21,09**
16	Riparian forest on abrupt denudate slope of pyroclasts	Dlap-314	102,89	7,89	2,55
17	Forest plantation on abrupt denudate pyroclastic slope	Dlap-315	13,95	1,07	0,35
18	High secondary vegetation in abrupt denudate hillside of pyroclasts	Dlap 3231	77,29	5,93	1,91
19	Low secondary vegetation in abrupt denudate hillside of pyroclasts	Dlap-3232	183,69	14,08	4,55
Area of the geoform (ha)			1.304,38	**% Representation of the geoform in the AI**	32,28

Source: GEOCOL CONSULTORES S.A., 2017.

- **Denudational hillside in ashes.**

This geoform represents 8.18% of the area of influence, grouping 11 units of landscape, of which the one of greater dominance corresponds is associated to the Mosaic coverage of pastures and crops (Dlce-242), with a representativity of 61, 74% of the area of the geoform, as can be detailed in the **Table 5.22**; Being the agricultural activities the main dynamic that has shaped the current landscape of the geoform. As for the landscape unit that follows in order of representativeness, this corresponds to the Forest Plantations, with a percentage of 24.12% of the geoform, so it also corresponds to a geoform where the landscape units originated to From anthropic modifications of the landscape.

Table 5.22 Landscape units in the denudacional hillside geoform in ashes.

# UP	NAME OF LANDSCAPE UNIT	UP CODE	AREA OF THE UP (HA)	% REPRESENTATIVENESS OF THE UP IN THE GEOFORM	% REPRESENTING OF THE UP IN THE AI
20	Continuous urban fabric in denudacional hillside in ashes	Dlce-111	5,55	1,68	0,14
21	Discontinuous urban fabric in denudacional hillside in ashes	Dlce-112	1,04	0,32	0,03
22	Road network and associated territories in denudacional hillside in ashes	Dlce-1221	5,32	1,61	0,13
23	Clean pastures in denudacional hillside in ashes	Dlce-231	3,40	1,03	0,08
24	Mosaic of cultivations in hillside denudacional in ashes	Dlce-241	14,01	4,24	0,35
25	**Mosaic of pastures and crops in denudacional slope in ashes**	**Dlce-242**	204,11	61,74	5,05
26	**Forest plantation in denudacional hillside in ashes**	**Dlce-315**	79,75	24,12	1,97

# UP	NAME OF LANDSCAPE UNIT	UP CODE	AREA OF THE UP (HA)	% REPRESENTATIVENESS OF THE UP IN THE GEOFORM	% REPRESENTING OF THE UP IN THE AI
27	Herbazal open rocky hillside denudacional in ashes	Dlce-32122	7,64	2,31	0,19
28	High secondary vegetation in denudacional hillside in ashes	Dlce-3231	0,15	0,05	0,00
29	Low secondary vegetation in denudacional hillside in ashes	Dlce-3232	8,32	2,52	0,21
30	Rivers in denudacional hillside in ashes	Dlce-511	1,31	0,40	0,03
Area of the geoform (ha)			330,60	**% Representation of the geoform in the AI**	8,18

Source: GEOCOL CONSULTORES S.A., 2017.

- **Coluvial denudacional hillside.**

In this geoform, which corresponds to one of the least representative in the area of influence analyzed (3.66% of the same), are grouped eight (8) landscape units of which, associated with Mosaics Of pastures and crops (Dlco-242) is the most representative with 78.62% of the geoform area; Followed by the landscape unit of Riparian Forest (Dlco-314) with 7.24% occupancy of the same. With the percentages of representativeness specified in the **Table 5.23**, It can be observed that the landscape units associated with natural coverings represent only about 16%, being a geoform where the landscape units have been modeled almost entirely by modifications of anthropic type.

Table 5.23 Landscape units in the Coluvial residual denudacional hillside geoform.

# UP	NAME OF LANDSCAPE UNIT	UP CODE	AREA OF THE UP (HA)	% REPRESENTATIVENESS OF THE UP IN THE GEOFORM	% REPRESENTING OF THE UP IN THE AI
31	Discontinuous urban fabric in Coluvial denudacional hillside	Dlco-112	0,62	0,42	0,02
32	Road network and associated territories in Coluvial denudacional hillside	Dlco-1221	0,20	0,14	0,01
33	Clean pastures in denudacional coluvial hillside	Dlco-231	0,42	0,29	0,01
34	Mosaic of crops in denudacional coluvial hillside	Dlco-241	6,27	4,25	0,16
35	**Mosaic of grasses and crops in denudacional coluvial hillside**	**Dlco-242**	**116,14**	**78,62**	**2,87**
36	**Riparian forest in denudacional coluvial hillside**	**Dlco-314**	**10,69**	**7,24**	**0,26**
37	High secondary vegetation in denudacional coluvial hillside	Dlco-3231	4,92	3,33	0,12
38	Low secondary vegetation in denudacional coluvial hillside	Dlco-3232	8,45	5,72	0,21
Area of the geoform (ha)			147,72	**% Representation of the geoform in the AI**	3,66

Source: GEOCOL CONSULTORES S.A., 2017.

- **Residual denudacional hillside.**

This geomorphological unit is the one of greater dominance in the area of influence defined for the project, occupying an area of 1,370.39 ha, that is to say 33.91% of the AI; And brings together altogether eight (8) landscape units. Of these, as with the previous described geoforms, the most representative landscape unit is the Mosaic of pastures and crops (Dlr-242) with almost the entire geoform area, representing 94.56% of the same (**Table 5.24**). In addition to the above, the DLr-242 unit is the one with the greatest dominance of the general landscape of the area of influence, occupying 32.07% of this (almost a third), which is an indicator of the dominance of agricultural activities as Main factors shaping the current landscape.

Table 5.24 Landscape units in the residual denudational hillside geoform.

# UP	NAME OF LANDSCAPE UNIT	UP CODE	AREA OF THE UP (HA)	% REPRESENTATIVENESS OF THE UP IN THE GEOFORM	% REPRESENTING OF THE UP IN THE AI
39	Discontinuous urban fabric in residual denudacional hillside	Dlr-112	3,10	0,23	0,08
40	Clean pastures in denudacional residual slope	Dlr-231	1,08	0,08	0,03
41	**Mosaic of pastures and crops in hillside denudacional residual**	**Dlr-242**	**1.295,80**	**94,56**	**32,07**
42	Dense high Andean forest in residual denudacional hillside	Dlr-311212	9,34	0,68	0,23
43	Riparian forest in residual denudacional hillside	Dlr-314	9,27	0,68	0,23
44	Forest plantation in hillside denudacional residual	Dlr-315	21,16	1,54	0,52
45	High secondary vegetation in residual denudacional hillside	Dlr-3231	13,51	0,99	0,33
46	Low secondary vegetation in residual denudacional hillside	Dlr-3232	17,14	1,25	0,42
Area of the geoform (ha)			1.370,39	**% Representation of the geoform in the AI**	33,91

Source: GEOCOL CONSULTORES S.A., 2017.

- **Runway bar.**

This geoform associated to the river bed is represented only by a landscape unit, corresponding to the river, with a representation of 0.003% of the area of influence (**Table 5.25**).

Table 5.25 Landscape units in the Barra de Cauce geoform.

# UP	NAME OF LANDSCAPE UNIT	UP CODE	AREA OF THE UP (HA)	% REPRESENTATIVENESS OF THE UP IN THE GEOFORM	% REPRESENTING OF THE UP IN THE AI
47	Rivers in Waterfront	Fbc-511	0,12	100,00	0,003
Area of the geoform (ha)			0,12	**% Representation of the geoform in the AI**	0,003

Source: GEOCOL CONSULTORES S.A., 2017.

· **Active channel.**

This geoform comprises six (6) landscape units, of which the river is the most representative (81.06% of the geoform), although there is also a presence of discontinuous urban tissue, heterogeneous agricultural areas, forest plantations and high secondary vegetation And low, although in a low proportion (**Table 5.26**).

Table 5.26 Landscape units in the active Cauce geoform.

# UP	NAME OF LANDSCAPE UNIT	UP CODE	AREA OF THE UP (HA)	% REPRESENTATIVENESS OF THE UP IN THE GEOFORM	% REPRESENTING OF THE UP IN THE AI
48	Discontinuous urban tissue in active channel	Fca-112	0,57	3,53	0,01
49	Mosaic of pastures and crops in active channel	Fca-242	0,67	4,15	0,02
50	Forest plantation in active stream	Fca-315	0,11	0,67	0,003
51	High secondary vegetation in active stream	Fca-3231	1,16	7,13	0,03
52	Low secondary vegetation in active stream	Fca-3232	0,56	3,46	0,01
53	**Rivers in active channel**	**Fca-511**	13,13	81,06	0,32
Area of the geoform (ha)			16,20	**% Representation of the geoform in the AI**	0,40

Source: GEOCOL CONSULTORES S.A., 2017.

· **Alluvial terrace.**

This geoform comprises nine (9) landscape units, of which the most representative is the Mosaic of pastures and crops, occupying 58.04% of the area of the geoform (**Table 5.27**). For the case of the units associated to natural cover, the one with the highest dominance corresponds to the low secondary vegetation with 14.89% of the total area of the geoform, and 9.53% for the high secondary vegetation, being one of the geoforms that

Conserves a moderate proportion of native vegetation, although it is still low with respect to the total analyzed.

Table 5.27 Landscape units in the Alluvial Terrace geoform.

# UP	NAME OF LANDSCAPE UNIT	UP CODE	AREA OF THE UP (HA)	% REPRESENTATIVENESS OF THE UP IN THE GEOFORM	% REPRESENTING OF THE UP IN THE AI
54	Discontinuous urban fabric in alluvial terrace	Fta-112	11,97	8,31	0,30
55	Road network and associated territories in Alluvial Terrace	Fta-1221	1,04	0,72	0,03
56	Exploitation of building materials in Alluvial Terrace	Fta-1315	3,83	2,66	0,09
57	Clean pastures in alluvial terrace	Fta-231	0,84	0,58	0,02
58	Mosaic of crops in Alluvial Terrace	Fta-241	3,43	2,38	0,08
59	**Mosaic of pastures and crops in Alluvial Terrace**	**Fta-242**	**83,61**	**58,04**	**2,07**
60	High secondary vegetation in Alluvial Terrace	Fta-3231	13,72	9,53	0,34
61	**Low secondary vegetation in Alluvial Terrace**	**Fta-3232**	**21,45**	**14,89**	**0,53**
62	Rivers in Alluvial Terrace	Fta-511	4,18	2,90	0,10
Area of the geoform (ha)			144,06	**% Representation of the geoform in the AI**	3,57

Source: GEOCOL CONSULTORES S.A., 2017.

· **Volcanic plateau.**

This geoform comprises two (2) landscape units, although it is occupied almost entirely by the Mosaic of pastures and crops (Vav-242), occupying 97.66% of the geoform area (**Table 5.28**). The remaining landscape unit is associated with Riparian Forest, occupying a 2.34% of the geoform, evidencing its high level of transformation due to anthropic activities.

Table 5.28 Landscape units in the volcanic upland geoform.

# UP	NAME OF LANDSCAPE UNIT	UP CODE	AREA OF THE UP (HA)	% REPRESENTATIVENESS OF THE UP IN THE GEOFORM	% REPRESENTING OF THE UP IN THE AI
63	**Mosaic of pastures and crops in volcanic plateau**	**Vav-242**	14,27	97,66	0,35
64	Riparian forest on volcanic plateau	Vav-314	0,34	2,34	0,01
Area of the geoform (ha)			14,61	**% Representation of the geoform in the AI**	0,36

Source: GEOCOL CONSULTORES S.A., 2017.

- **Escarps of lava.**

This geoform is one of the smallest in the area of influence (with 1.98% of it), and it groups seven (7) landscape units, of which the cleanest pastures are the most representative (30.46%), Followed by the Mosaic of pastures and crops (24.44%). On the other hand, the landscape units associated with natural coverages are represented by high and low secondary vegetations, which together represent a little less than 20% of the area of the geoform; Being the anthropic activities again the main modeling forces of the current landscape of the geoform.

Table 5.29 Landscape units in the La Escarpment geoform.

# UP	NAME OF LANDSCAPE UNIT	UP CODE	AREA OF THE UP (HA)	% REPRESENTATIVENESS OF THE UP IN THE GEOFORM	% REPRESENTING OF THE UP IN THE AI
65	Discontinuous urban fabric in La Escarpes	Vel-112	2,33	2,91	0,06
66	Road network and associated territories in La Escarpes	Vel-1221	1,48	1,85	0,04
67	**Clean pastures in lava rocks**	**Vel-231**	**30,46**	**38,05**	**0,75**
68	Mosaic of crops in lava scarps	Vel-241	1,50	1,87	0,04
69	**Mosaic of grasses and crops in La Escarpes**	**Vel-242**	**24,44**	**30,52**	**0,60**
70	High secondary vegetation in lava scarps	Vel-3231	3,94	4,92	0,10
71	Low secondary vegetation in lava scarps	Vel-3232	15,92	19,88	0,39
Area of the geoform (ha)			80,06	**% Representation of the geoform in the AI**	1,98

Source: GEOCOL CONSULTORES S.A., 2017.

- **Steep slopes of pyroclasts and lavas.**

This geoform, which represents 16.61% of the area of influence, comprises 11 landscape units, of which the one associated with the Mosaics of pastures and crops is the most representative, with 63.73% of the area of the geoform (**Table 5.30**). As for the landscape units associated with natural coverages, the units associated with high and low secondary vegetation represent a little less than 20% of the area of the geoform, again showing that anthropic activities have played the main role in the Modeling of the current landscape of the geoform.

Table 5.30 Landscape units in the geoform of Steep slopes of pyroclasts and lava.

# UP	NAME OF LANDSCAPE UNIT	UP CODE	AREA OF THE UP (HA)	% REPRESENTATIVENESS OF THE UP IN THE GEOFORM	% REPRESENTING OF THE UP IN THE AI
72	Discontinuous urban fabric on steep slopes of pyroclasts and lava	Vlep-112	4,18	0,76	0,10

# UP	NAME OF LANDSCAPE UNIT	UP CODE	AREA OF THE UP (HA)	% REPRESENTATIVENESS OF THE UP IN THE GEOFORM	% REPRESENTING OF THE UP IN THE AI
73	Road network and associated territories on steep slopes of pyroclasts and lavas	Vlep-1221	8,81	1,60	0,22
74	Clean pasture lands in Steep slopes of pyroclasts and lavas .	Vlep-231	6,26	1,14	0,16
75	Crop mosaic on steep slopes of pyroclasts and lava	Vlep-241	25,70	4,67	0,64
76	**Mosaic of grasses and crops on Steep slopes of pyroclasts and lava**	**Vlep-242**	**350,44**	**63,73**	**8,67**
77	Dense high-Andean forest in steep slopes of pyroclasts and lava	Vlep-311212	1,17	0,21	0,03
78	Riparian forest in Steep slopes of pyroclasts and lavas.	Vlep-314	21,23	3,86	0,53
79	Forest plantation on Steep slopes of pyroclasts and lavas	Vlep-315	24,70	4,49	0,61
80	Herbazal open rocky on steep slopes of pyroclasts and lava	Vlep-32122	3,60	0,65	0,09
81	**High secondary vegetation on steep slopes of pyroclasts and lava**	**Vlep-3231**	**53,14**	**9,67**	**1,32**
82	**Low secondary vegetation on steep slopes of pyroclasts and lava**	**Vlep-3232**	**50,61**	**9,20**	**1,25**
Area of the geoform (ha)			549,84	**% Representation of the geoform in the AI**	13,61

Source: GEOCOL CONSULTORES S.A., 2017.

5.1.3.2 Descriprion of the project within the landscaping component of the zone.

Under the scenario of the potential affected area, 68 of 82 landscape units, or 82.93% of them, would be affected in an area of 1629.29 ha (40.32% of the area of influence analyzed). From these units, once the different activities of the project are carried out, the greatest intervention would be the Anthropoptera (Ata) and denudational hillside (Dlce) geoforms, with 10 UPs intervened for each one (**Table 5.31**).

In line with the above, the most affected landscape unit would correspond to the Mosaics of pastures and crops located on the residual denudational hillside (Dlr-242) with 561.68 ha (34.48% of the intervention area), followed by Mosaics of pastures and crops located on the open denudational hillside (Dlap-242) with 338.28 ha (20.76% of the intervention area), and Mosaics of pastures and crops located on steep slopes of pyroclasts and lavas (Vlep-242) with 113.48 ha (6.97% of the intervention area). These three landscape units now account for 62.2% of the intervention area, and taking into account the other UPs associated with the Mosaic coverage of pastures and crops, an additional 265.53 ha of intervention (16.3%) is reached, . With the above, it is concluded that for the project scenario, 78.5% of the area is represented by landscape units associated with the Mosaics of pastures and crops (in an area of 1,278.97 ha, with a much smaller intervention on Other landscape units.

Table 5.31 Landscape units operated by the project.

UP CODE	AREA OF INTERVENTION (HA)		UP CODE	AREA OF INTERVENTION (HA)
Ata - 111	4,00		Dlco - 242	94,84
Ata - 112	22,06		Dlr-112	2,50
Ata - 1221	1,90		Dlr-231	0,11
Ata 1315	3,50		**Dlr-242**	**561,68**
Ata - 231	0,16		Dlr - 311212	2,02
Ata - 241	0,53		Dlr-314	9,27
Ata - 242	4,72		Dlr-315	12,48
Ata - 315	0,19		Dlr-3231	12,50
Ata - 3231	0,66		Dlr-3232	7,63
Ata - 3232	0,58		Fca-112	0,57
Dlap - 112	0,85		Fca-511	0,72
Dlap-1221	0,16		Fta-112	7,65
Dlap-231	9,52		Fta-1315	0,82
Dlap - 241	1,97		Fta-242	55,99
Dlap-242	**338,28**		Fta-3231	1,83
Dlap-314	**21,66**		Fta-3232	5,21
Dlap-315	8,43		Fta-511	0,70
Dlap-3231	**16,18**		Vav - 242	14,27
Dlap-3232	**74,30**		Vav - 314	0,34
Dlce - 111	0,92		Vel - 112	0,99
Dlce - 112	0,43		Vel-1221	1,38
Dlce - 1221	2,65		Vel-231	5,62
Dlce - 231	1,19		Vel - 241	0,56
Dlce - 241	7,52		Vel - 242	2,79
Dlce - 242	92,92		Vel-3231	0,32
Dlce - 315	25,35		Vel-3232	8,30
Dlce - 32122	0,73		Vlep - 241	0,45
Dlce - 3232	2,01		**Vlep - 242**	**113,48**
Dlce-511	0,77		Vlep - 311212	1,09
Dlco - 112	0,41		**Vlep - 314**	**11,96**
Dlco - 241	3,04		Vlep - 315	0,46
Dlco - 314	7,49		Vlep - 32122	0,10
Dlco - 3231	2,51		**Vlep - 3231**	**14,29**
Dlco - 3232	6,08		**Vlep - 3232**	**12,64**

Source: GEOCOL CONSULTORES S.A., 2017.

On the other hand, of the 68 landscape units potentially affected by the project, only 24 of these (29.41%) are associated with natural vegetation cover (excluding forest plantations), totaling an area of 219.7 ha. Of these the interventions of greater area would be presented on units associated to Secondary vegetation (green color in the **Table 5.31**), Of which the largest intervention will be associated with low secondary vegetation in the denudational hillside open in piroclasts (Dlap-3232) with 74.3 ha, followed by the riparian forest in the same geomorphological unit with 21.66 ha.

5.1.3.3 Analysis of the visual landscape.

Next, the results of the analysis of fragility, quality and integrity of the landscape made for the ecological landscape units identified for the area of influence of the project are presented.

5.1.3.3.1 Fragility of the landscape.

The fragility analysis of the landscape refers to the maintenance of natural elements and attributes of the landscape that conditions the responsiveness to visual and form disturbances, as the landscape assimilates such changes. In this sense, landscape units with greater degree of transformation have a high fragility related to a low presence of natural elements and attributes, while units with a higher degree of conservation maintain a less fragile landscape and a greater capacity to assimilate Changes generated in it.

Regarding the analysis, nine (9) landscape units were evaluated with low visual fragility (10.98%), which correspond to those that are better conserved, maintaining native vegetation, low contrasts between soil, rock and Vegetation, high potential for regeneration of vegetation, and good soil stability with low erosion processes. To this extent, the landscape units associated with mild sloping and sloping geoforms that maintain native vegetation, such as high and low secondary vegetation, riparian forest and dense high Andean, and some forest plantations, which have a high capacity Of visual absorption by acting as natural barriers that attribute high aesthetic values to the landscape.

Regarding the visual fragility Mean, 42 landscape units (51.22% of the total evaluated) were evaluated within this category, and are characterized by presenting some elements that maintain a moderate visual absorption capacity, such as slopes of little inclination , The maintenance of vegetation and the average regeneration potential of the same. These elements make a low contrast between the soil, the rocks and the vegetation, which translates into a landscape with harmony between its elements, which is made pleasant to the observer. Different units are associated with heterogeneous agricultural areas, successional vegetation, and some natural forests and artificialized territories.

Table 5.32 Analysis of fragility of the landscape for the UP of the area of influence.

LANDSCAPE UNIT		SLOPE	DIVERSITY OF VEGETATION	SOIL STABILITY AND EROSIONABILITY	CONTRAST BETWEEN SOIL AND VEGETATION	POTENTIAL REGENERATION OF VEGETATION	CONTRAST OF COLOR BETWEEN THE SOIL AND ROCK	ASSESSMENT	VISUAL FRAGILITY
1	Ata - 111	3	1	2	1	1	2	21	Medium
2	Ata - 112	3	1	2	1	1	1	18	Medium
3	Ata - 1221	3	1	2	1	1	1	18	Medium
4	Ata 1315	3	1	2	1	1	1	18	Medium
5	Ata - 231	3	1	2	1	1	2	21	Medium
6	Ata - 241	3	2	2	2	1	2	27	Medium
7	Ata - 242	3	2	2	2	1	2	27	Medium
8	Ata - 315	3	2	3	3	2	3	39	Write-off
9	Ata - 3231	3	3	3	3	3	3	45	Write-off
10	Ata - 3232	3	3	3	3	3	3	45	Write-off

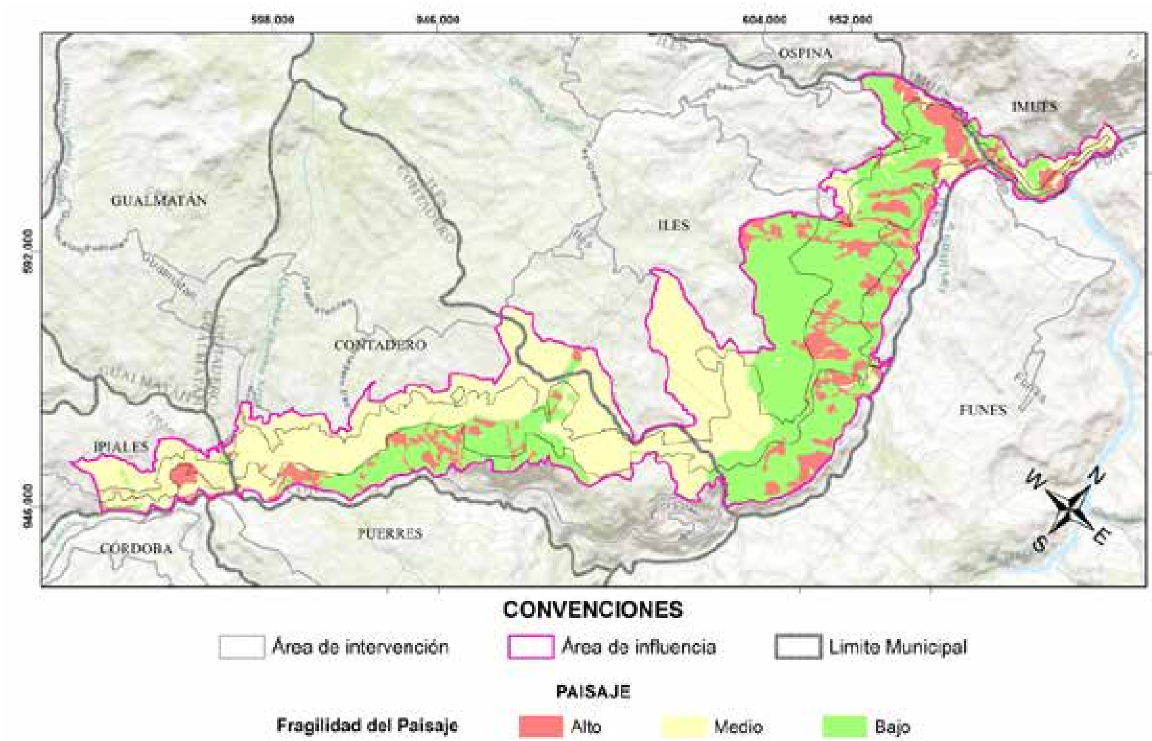
LANDSCAPE UNIT		SLOPE	DIVERSITY OF VEGETATION	SOIL STABILITY AND EROSIONABILITY	CONTRAST BETWEEN SOIL AND VEGETATION	POTENTIAL REGENERATION OF VEGETATION	CONTRAST OF COLOR BETWEEN THE SOIL AND ROCK	ASSESSMENT	VISUAL FRAGILITY
11	Dlap - 112	2	1	2	1	1	1	12	High
12	Dlap-1221	2	1	2	1	1	1	12	High
13	Dlap-231	2	1	2	2	1	1	14	High
14	Dlap - 241	2	2	2	2	1	2	18	Medium
15	Dlap-242	2	2	2	2	1	2	18	Medium
16	Dlap-314	2	3	3	3	3	3	30	Medium
17	Dlap-315	2	2	3	3	2	3	26	Medium
18	Dlap-3231	2	3	3	3	3	3	30	Medium
19	Dlap-3232	2	3	3	3	3	3	30	Medium
20	Dlce - 111	2	1	2	1	1	2	14	High
21	Dlce - 112	2	1	2	1	1	1	12	High
22	Dlce - 1221	2	1	2	1	1	1	12	High
23	Dlce - 231	2	1	2	1	1	1	12	High
24	Dlce - 241	2	2	2	2	1	2	18	Medium
25	Dlce - 242	2	2	2	2	1	2	18	Medium
26	Dlce - 315	2	2	3	3	2	2	24	Medium
27	Dlce - 32122	2	2	3	2	2	1	20	Medium
28	Dlce - 3231	2	3	3	3	2	2	26	Medium
29	Dlce - 3232	2	3	3	3	3	2	28	Medium
30	Dlce-511	2	1	2	2	1	1	14	High
31	Dlco - 112	2	1	2	1	1	2	14	High
32	Dlco - 1221	2	1	2	1	1	2	14	High
33	Dlco-231	2	1	2	1	1	2	14	High
34	Dlco - 241	2	2	2	2	1	2	18	Medium
35	Dlco - 242	2	2	2	2	1	2	18	Medium
36	Dlco - 314	2	3	3	3	3	3	30	Medium
37	Dlco - 3231	2	3	3	3	3	3	30	Medium
38	Dlco - 3232	2	3	3	3	3	3	30	Medium
39	Dlr-112	2	1	2	1	1	1	12	High
40	Dlr-231	2	1	2	1	1	1	12	High
41	Dlr-242	2	2	2	2	1	2	18	Medium
42	Dlr - 311212	2	3	3	3	3	3	30	Medium
43	Dlr-314	2	3	3	3	3	3	30	Medium
44	Dlr-315	2	2	3	3	2	3	26	Medium
45	Dlr-3231	2	3	3	3	3	3	30	Medium
46	Dlr-3232	2	3	3	3	3	3	30	Medium
47	Fbc-511	3	1	2	2	1	1	21	Medium
48	Fca-112	3	1	2	1	1	1	18	Medium
49	Fca-242	3	2	2	2	1	2	27	Medium
50	Fca-315	3	2	2	3	2	2	33	Write-off
51	Fca-3231	3	3	2	3	3	2	39	Write-off
52	Fca-3232	3	3	2	3	3	2	39	Write-off
53	Fca-511	3	1	2	2	1	1	21	Medium
54	Fta-112	3	1	2	1	1	2	21	Medium
55	Fta-1221	3	1	2	1	1	1	18	Medium

LANDSCAPE UNIT		SLOPE	DIVERSITY OF VEGETATION	SOIL STABILITY AND EROSIONABILITY	CONTRAST BETWEEN SOIL AND VEGETATION	POTENTIAL REGENERATION OF VEGETATION	CONTRAST OF COLOR BETWEEN THE SOIL AND ROCK	ASSESSMENT	VISUAL FRAGILITY
56	Fta-1315	3	1	2	1	1	1	18	Medium
57	Fta-231	3	1	2	1	1	2	21	Medium
58	Fta-241	3	2	2	2	1	3	30	Medium
59	Fta-242	3	2	2	2	1	3	30	Medium
60	Fta-3231	3	3	3	3	3	3	45	Write-off
61	Fta-3232	3	3	3	3	3	3	45	Write-off
62	Fta-511	3	1	2	2	1	1	21	Medium
63	Vav - 242	3	2	2	2	1	2	27	Medium
64	Vav - 314	3	3	2	3	3	3	42	Write-off
65	Vel - 112	1	1	2	1	1	1	6	High
66	Vel-1221	1	1	2	1	1	1	6	High
67	Vel-231	1	1	1	1	1	1	5	High
68	Vel - 241	1	2	1	2	1	2	8	High
69	Vel - 242	1	2	1	2	1	1	7	High
70	Vel-3231	1	3	2	3	3	3	14	High
71	Vel-3232	1	3	2	3	3	3	14	High
72	Vlep - 112	1	1	2	1	1	1	6	High
73	Vlep - 1221	1	1	2	1	1	1	6	High
74	Vlep - 231	1	1	1	1	1	1	5	High
75	Vlep - 241	1	2	1	2	1	2	8	High
76	Vlep - 242	1	2	1	2	1	1	7	High
77	Vlep- 311212	1	3	2	2	3	2	12	High
78	Vlep - 314	1	3	2	3	3	2	13	High
79	Vlep - 315	1	2	2	3	2	2	11	High
80	Vlep - 32122	1	2	2	2	2	2	10	High
81	Vlep - 3231	1	3	2	3	3	2	13	High
82	Vlep - 3232	1	3	2	3	3	2	13	High

Source: GEOCOL CONSULTORES S.A., 2017.

In the **Figure 5.21** We can observe the spatial representation of the evaluation performed for the landscape units of the area of influence as part of the fragility analysis of the landscape.

Figure 5.21 Spatial representation of the fragility analysis of the landscape for the UP of the area of influence.



Source: GEOCOL CONSULTORES S.A., 2016.

5.1.3.3.2 Visual quality of the landscape.

The visual quality refers to the presence of visible attributes that bring beauty and harmony to the landscape, such as vegetation and the bodies of water lotic and lentic; Where in addition must maintain characteristics like the scenic background, without abrupt changes in the perception of the same. To this extent, the existence of areas of exposed soil with degradation processes, or the dominance of transformed systems, translate into a low visual quality, while the conservation of the typical characteristics of the landscape express a high visual quality.

As for the evaluated landscape units, 21 of these (representing 25.61%) were evaluated with a high landscape quality (**Table 5.33**), Where there are some Mosaics of pastures and crops that configure the typical landscape of the region maintaining live fences that contribute to the harmony of the landscape, as well as those units associated with geoforms of smaller slope, which reduce the processes of removal in Mass and maintain visual attributes that bring quality to the system. As a whole these landscape units contribute to a scenic background that is pleasant to the observer, with pleasing colors and unique mosaics with which the communities have an important roots, because they represent their daily life there.

On the other hand, 44 landscape units representing 53.66% of the total evaluated, were evaluated with a quality of the Middle landscape, corresponding to different landscape units, both associated with transformed coverings and natural coverages, related in a narrow way With the relief conditions of the geoforms. Thus, units associated with forest plantations, clean pastures, heterogeneous agricultural areas, clean pastures, riparian forests and successional coverages are grouped into this category of visual quality, which maintains elements such as vegetation that lead to the maintenance of a pleasant scenic background.

Table 5.33 Analysis of visual quality of the landscape for the UP of the area of influence.

LANDSCAPE UNIT		MORPHOLOGY	VEGETATION	WATER	COLOR	SCENIC BACKGROUND	RARITY	HUMAN ACTION	ASSESSMENT	LANDSCAPE QUALITY
1	Ata - 111	3	3	0	5	3	1	1	16	Medium
2	Ata - 112	5	5	0	5	5	2	2	24	Medium
3	Ata - 1221	5	5	0	5	5	2	2	24	Medium
4	Ata 1315	3	1	0	1	3	1	0	9	Medium
5	Ata - 231	3	1	0	1	0	1	0	6	Medium
6	Ata - 241	3	1	0	3	3	1	0	11	Medium
7	Ata - 242	3	3	0	5	5	1	1	18	High
8	Ata - 315	3	3	0	5	5	1	1	18	High
9	Ata - 3231	3	5	3	5	5	2	2	25	High
10	Ata - 3232	3	3	0	5	3	1	1	16	High
11	Dlap - 112	3	5	0	5	5	2	2	22	High
12	Dlap-1221	3	5	0	5	5	2	2	22	Write-off
13	Dlap-231	3	1	0	1	3	1	0	9	Medium
14	Dlap - 241	3	1	0	1	3	1	0	9	Medium
15	Dlap-242	3	1	0	1	0	1	0	6	Write-off
16	Dlap-314	3	1	0	3	3	1	0	11	Write-off
17	Dlap-315	3	3	0	5	5	1	1	18	Medium
18	Dlap-3231	3	3	0	5	5	1	1	18	Medium
19	Dlap-3232	3	3	0	5	3	1	1	16	Medium
20	Dlce - 111	3	3	0	5	5	2	2	20	Medium
21	Dlce - 112	3	5	0	5	5	2	2	22	Medium
22	Dlce - 1221	3	5	0	5	5	2	2	22	Medium
23	Dlce - 231	3	1	5	5	5	1	2	22	Medium
24	Dlce - 241	3	1	0	1	3	1	0	9	Medium
25	Dlce - 242	3	1	0	1	0	1	0	6	High
26	Dlce - 315	3	1	0	3	3	1	0	11	High
27	Dlce - 32122	3	3	0	5	5	1	1	18	High
28	Dlce - 3231	3	3	0	5	5	1	1	18	High

LANDSCAPE UNIT		MORPHOLOGY	VEGETATION	WATER	COLOR	SCENIC BACKGROUND	RARITY	HUMAN ACTION	ASSESSMENT	LANDSCAPE QUALITY
29	Dlce - 3232	3	5	0	5	5	1	2	21	Write-off
30	Dlce-511	3	5	0	5	5	1	2	21	Write-off
31	Dlco - 112	3	5	0	5	5	1	2	21	Medium
32	Dlco - 1221	3	1	0	1	3	1	0	9	Medium
33	Dlco-231	3	1	0	3	3	1	0	11	Medium
34	Dlco - 241	3	3	0	5	5	1	1	18	Medium
35	Dlco - 242	3	5	0	5	5	6	2	26	Medium
36	Dlco - 314	3	5	3	5	5	2	2	25	Medium
37	Dlco - 3231	3	3	0	5	5	1	1	18	Medium
38	Dlco - 3232	3	5	0	5	5	2	2	22	Medium
39	Dlr-112	3	5	0	5	5	2	2	22	Medium
40	Dlr-231	1	1	5	5	5	1	2	20	High
41	Dlr-242	1	1	0	5	3	1	0	11	High
42	Dlr - 311212	1	3	0	5	5	1	1	16	High
43	Dlr-314	1	3	0	5	5	1	1	16	High
44	Dlr-315	1	5	0	5	5	2	2	20	High
45	Dlr-3231	1	5	0	5	5	2	2	20	Write-off
46	Dlr-3232	1	1	5	5	5	1	2	20	Write-off
47	Fbc-511	1	1	0	1	3	1	0	7	Medium
48	Fca-112	1	1	0	1	0	1	0	4	High
49	Fca-242	1	1	0	1	0	1	0	4	Medium
50	Fca-315	1	1	0	3	3	1	0	9	Medium
51	Fca-3231	1	3	0	5	5	1	1	16	Write-off
52	Fca-3232	1	3	0	5	5	1	1	16	Write-off
53	Fca-511	1	5	0	5	5	2	2	20	Medium
54	Fta-112	1	5	0	5	5	2	2	20	Medium
55	Fta-1221	1	1	5	5	5	1	2	20	Write-off
56	Fta-1315	1	3	0	5	5	1	1	16	Write-off
57	Fta-231	1	5	3	5	5	2	2	23	Write-off
58	Fta-241	5	1	0	1	3	1	0	11	Medium
59	Fta-242	5	1	0	1	0	1	0	8	Medium
60	Fta-3231	5	1	0	3	5	1	0	15	Medium
61	Fta-3232	5	3	0	5	5	1	1	20	Medium
62	Fta-511	5	3	0	5	5	1	1	20	Medium
63	Vav - 242	5	5	0	5	5	2	2	24	Medium
64	Vav - 314	5	5	0	5	5	2	2	24	Medium
65	Vel - 112	5	1	0	1	3	1	0	11	High
66	Vel-1221	5	1	0	1	0	1	0	8	High

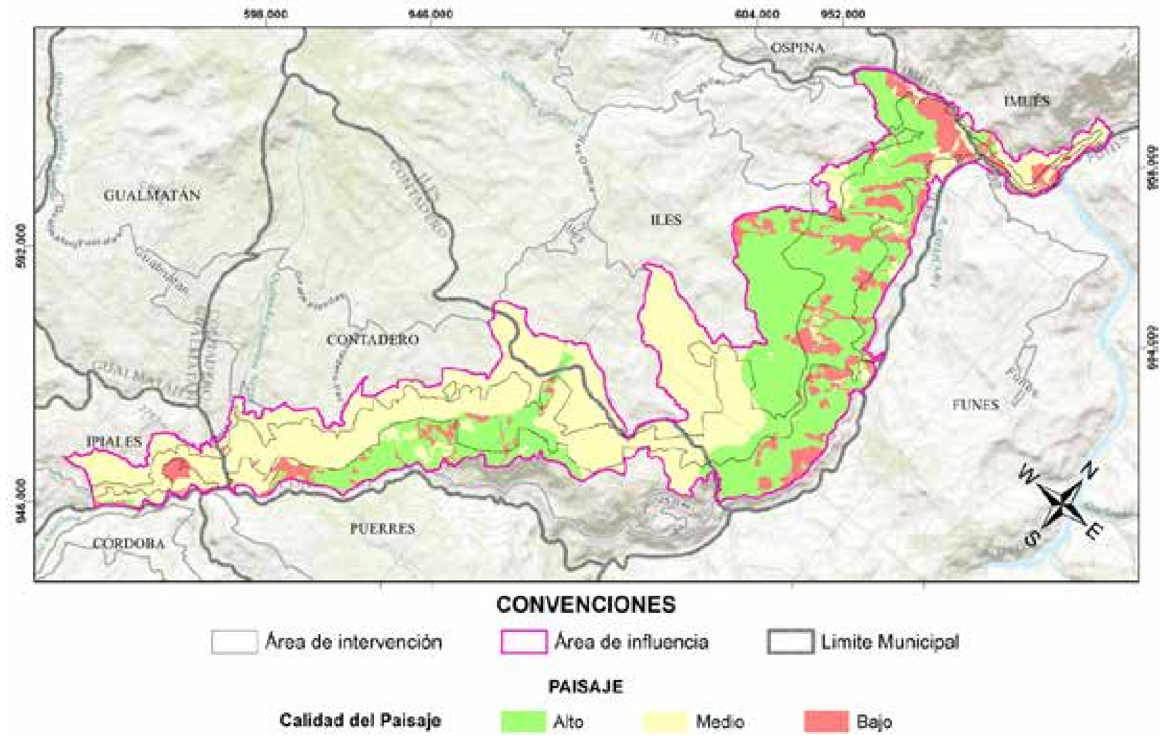
LANDSCAPE UNIT		MORPHOLOGY	VEGETATION	WATER	COLOR	SCENIC BACKGROUND	RARITY	HUMAN ACTION	ASSESSMENT	LANDSCAPE QUALITY
67	Vel-231	5	1	0	3	3	1	0	13	High
68	Vel - 241	5	3	0	5	5	1	1	20	High
69	Vel - 242	5	3	0	5	5	1	1	20	High
70	Vel-3231	5	5	0	5	5	6	2	28	Write-off
71	Vel-3232	5	5	3	5	5	2	2	27	Write-off
72	Vlep - 112	5	3	5	5	5	1	1	25	Write-off
73	Vlep - 1221	5	3	0	5	5	1	2	21	Write-off
74	Vlep - 231	5	5	0	5	5	2	2	24	Write-off
75	Vlep - 241	5	5	0	5	5	2	2	24	Medium
76	Vlep - 242	3	3	0	5	3	1	1	16	Medium
77	Vlep- 311212	5	5	0	5	5	2	2	24	Medium
78	Vlep - 314	5	5	0	5	5	2	2	24	Medium
79	Vlep - 315	3	1	0	1	3	1	0	9	Medium
80	Vlep - 32122	3	1	0	1	0	1	0	6	Medium
81	Vlep - 3231	3	1	0	3	3	1	0	11	Medium
82	Vlep - 3232	3	3	0	5	5	1	1	18	High

Source: GEOCOL CONSULTORES S.A., 2017.

Finally, 17 landscape units (20.73%) were evaluated with low visual quality, among which are those associated with the geoforms with the highest slope, such as the denudacional hillside open in pyroclasts, lava beds, among others, with coverings Transformed as the road network and associated territories, and Exploitation of construction materials, where there is a high presence of anthropic activities, and in which natural elements such as vegetation, have been replaced by artificial systems.

In the **Figure 5.22** We can observe the spatial representation of the evaluation performed for the landscape units of the area of influence as part of the visual quality analysis.

Figure 5.22 Spatial representation of the visual quality analysis for the UP of the area of influence.



Source: GEOCOL CONSULTORES S.A., 2016.

5.1.3.3.3 Integrity of the landscape.

The integrity of the landscape refers to the degree of correspondence that exists between landscape elements and color, as well as the level of anthropic intervention represented in the presence of discordant elements and their size. In this sense, the beauty of the landscape translates into a chromatic correspondence typical of the landscape, with low levels of anthropic intervention and elements that generate discordance, maintaining the typical form of the landscape. In this measure the presence of abrupt cuts or changes in the natural form of the landscape, and a dominance of artificial systems generates a low integrity of the landscape, while low levels of intervention and anthropic transformation express a high integrity of the landscape.

According to the above, 25.60% of landscape units (21 in total) (**Table 5.34**), Were evaluated with a very high scenic integrity, insofar as they conserve the natural elements with very low intervention, without presence of discordant elements and with a high chromatic correspondence. Among these are the landscape units associated with forest cover crops including forest plantations, since they correspond to the best preserved units of the area of influence analyzed. On the other hand, 24.39% (20 landscape units) were rated with scenic integrity High (**Table 5.34**), Since in spite of presenting small discordances, elements such as vegetation are maintained, being agreeable and in accordance with the observed environment. Thus, the units associated with crop and pasture mosaics and crops, rivers, forest plantations, some areas of clean pastures without the presence of discordant elements, and patches of native vegetation near intervened areas were grouped in this category.

As for the landscape units evaluated with moderate integrity, they represented 19.51% (16 landscape units), and correspond to areas with both discordant elements and some natural attributes of the landscape, which generate a medium visual impact To the size of the discordances. Thus well are grouped units associated with clean Pastures, discontinuous urban fabric and some areas of mosaics, especially those that are on the geostraphic anthropic Terrace (**Table 5.34**).

Table 5.34 Analysis of landscape integrity for UPs of the area of influence.

LANDSCAPE UNIT		DISCORDING ELEMENTS	SIZE OF DISCORDANCE	CHROMATIC CORRESPONDENCE	SCENIC INTEGRITY
1	Ata - 111	0	0	1	Very Low
2	Ata - 112	0	0	1	Very Low
3	Ata - 1221	0	0	1	Very Low
4	Ata 1315	0	2	0	Write-off
5	Ata - 231	1	2	2	Moderate
6	Ata - 241	2	2	2	High
7	Ata - 242	2	2	2	High
8	Ata - 315	3	2	2	High
9	Ata - 3231	3	2	3	Very High
10	Ata - 3232	3	2	3	Very High
11	Dlap - 112	0	2	1	Write-off
12	Dlap-1221	0	2	1	Write-off
13	Dlap-231	1	2	2	Moderate
14	Dlap - 241	2	3	2	High
15	Dlap-242	2	3	2	High
16	Dlap-314	3	3	3	Very High
17	Dlap-315	3	3	2	Very High
18	Dlap-3231	3	3	3	Very High
19	Dlap-3232	3	0	3	High
20	Dlce - 111	0	2	1	Write-off
21	Dlce - 112	0	2	1	Write-off
22	Dlce - 1221	0	0	1	Very Low
23	Dlce - 231	1	0	2	Write-off
24	Dlce - 241	2	2	2	High
25	Dlce - 242	2	2	2	High
26	Dlce - 315	2	2	2	High
27	Dlce - 32122	3	2	3	Very High
28	Dlce - 3231	3	2	3	Very High
29	Dlce - 3232	3	2	3	Very High
30	Dlce-511	2	2	3	High
31	Dlco - 112	0	2	1	Write-off
32	Dlco - 1221	0	3	1	Moderate
33	Dlco-231	1	3	2	High
34	Dlco - 241	2	3	2	High
35	Dlco - 242	2	3	2	High

LANDSCAPE UNIT		DISCORDING ELEMENTS	SIZE OF DISCORDANCE	CHROMATIC CORRESPONDENCE	SCENIC INTEGRITY
36	Dlco - 314	3	0	3	High
37	Dlco - 3231	3	0	3	High
38	Dlco - 3232	3	2	3	Very High
39	Dlr-112	0	2	1	Write-off
40	Dlr-231	1	2	2	Moderate
41	Dlr-242	2	2	2	High
42	Dlr - 311212	3	2	3	Very High
43	Dlr-314	3	2	3	Very High
44	Dlr-315	3	2	2	High
45	Dlr-3231	3	2	3	Very High
46	Dlr-3232	3	2	3	Very High
47	Fbc-511	2	3	3	Very High
48	Fca-112	0	3	1	Moderate
49	Fca-242	2	3	2	High
50	Fca-315	3	3	2	Very High
51	Fca-3231	3	3	3	Very High
52	Fca-3232	3	0	3	High
53	Fca-511	3	0	3	High
54	Fta-112	0	2	1	Write-off
55	Fta-1221	0	3	1	Moderate
56	Fta-1315	0	2	0	Write-off
57	Fta-231	1	2	2	Moderate
58	Fta-241	2	0	2	Moderate
59	Fta-242	2	0	2	Moderate
60	Fta-3231	3	2	3	Very High
61	Fta-3232	3	2	3	Very High
62	Fta-511	2	0	3	Moderate
63	Vav - 242	2	0	2	Moderate
64	Vav - 314	3	0	2	Moderate
65	Vel - 112	0	2	1	Write-off
66	Vel-1221	0	2	1	Write-off
67	Vel-231	0	2	2	Moderate
68	Vel - 241	2	2	2	High
69	Vel - 242	2	2	2	High
70	Vel-3231	3	2	3	Very High
71	Vel-3232	3	2	3	Very High
72	Vlep - 112	0	3	1	Moderate
73	Vlep - 1221	0	3	1	Moderate
74	Vlep - 231	1	3	2	High
75	Vlep - 241	2	3	2	High
76	Vlep - 242	2	3	2	High
77	Vlep- 311212	3	0	3	High
78	Vlep - 314	3	0	3	High
79	Vlep - 315	3	0	2	Moderate

LANDSCAPE UNIT		DISCORDING ELEMENTS	SIZE OF DISCORDANCE	CHROMATIC CORRESPONDENCE	SCENIC INTEGRITY
80	Vlep - 32122	3	0	3	High
81	Vlep - 3231	3	0	3	High
82	Vlep - 3232	3	2	3	Very High

Source: GEOCOL CONSULTORES S.A., 2017.

Of the remaining landscape units, 12 were evaluated with low integrity (ie, 14.63%), which are associated with landscape units related to discontinuous urban fabric, and some areas of clean pasture with size differences (Communication towers or power grids, for example). Finally four (4) landscape units were evaluated with very low scenic integrity (continuous and discontinuous urban fabric, and road network and associated territories in anthropic Terrace, and the areas of exploitation of construction materials), where, in addition to which numerous Discordant elements such as machinery, equipment and civil infrastructure, there is also a high degree of transformation of the natural coverings, being the artificial elements dominant.

Some examples of discordant elements identified within the project's areas of influence, which subtract scenic integrity from the landscape analyzed, can be observed from the **Photography 5.30** to **Photo 5.33**.

Photography 5-30 Communication Towers.

Photography 5-31 Electrical networks.

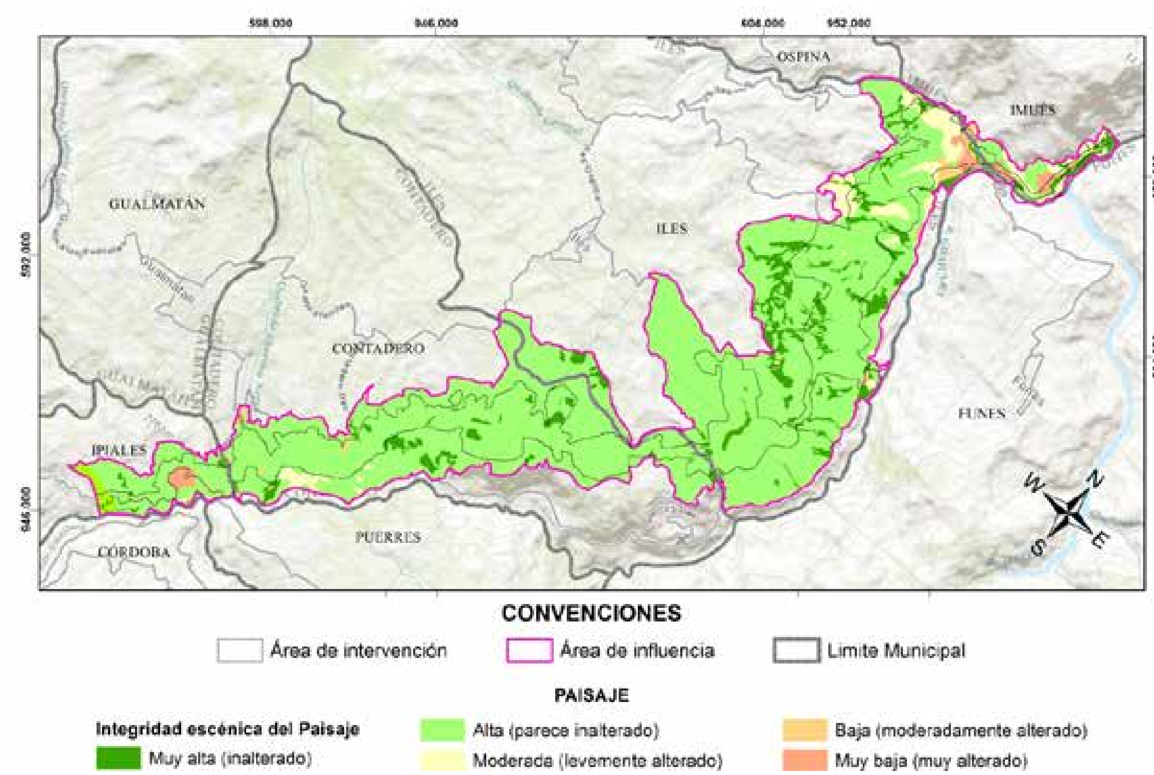
Photography 5-32 Zones of extraction of materials for construction.

Photography 5-33 Pan American Route.

Source: GEOCOL CONSULTORES S.A., 2016.

In the **Figure 5.23** We can observe the spatial representation of the evaluation performed for the landscape units of the area of influence as part of the integrity analysis.

Figure 5.23 Spatial representation of the landscape integrity analysis for the UP of the area of influence.



Source: GEOCOL CONSULTORES S.A., 2016.

5.1.3.4 Sites of scenic interest.

Sites of scenic interest refer to places of ecological, historical and cultural importance that are found within the areas of direct and indirect influence of the project, where they are developed among other activities such as tourism, recreation, recreation or contemplation, as well That areas that concentrate natural elements that harbor the native biodiversity, as areas of reserve or protection of natural resources.

Sites of scenic interest were identified using the field formats used (**Annex 4. Landscape**), Where the people interviewed were asked about important places nearby, representing geographical references, areas of historical or cultural importance, tourism and recreation sites, or environmentally relevant areas. In this way six (6) sites of scenic interest were identified; Three (3) within the area of influence and three (3) outside the area, but equally recognized as relevant by the communities (**Figure 5.24**).

Figure 5.24 Sites of landscaping interest identified.

Source: GEOCOL CONSULTORES S.A., 2016.

In the **Table 5.35** The coordinates of each of these are mentioned, and their general description is presented consecutively.

Table 5.35 Sites of landscaping interest identified.

	NAME	NORTH COORDINATES (X)	COORDINATES THIS (Y)
1	Aldea de María populated place	592988,612	949654,039
2	Downtown San Juan	590454,741	947653,371
3	Iles Town Center *	599010,392	950614,123
4	Pilcuan Town Center	605525,77	956782,235
5	Centro Poblado Pedregal *	608032,702	958396,196
6	Contadero Town Center	592204,523	947753,627
7	Grotto La Virgen *	593002,981	947120,642
8	Waterfall Quebrada Humeadora *	596486,419	955965,954
9	Cerro Iscuazán *	596152,058	949372,948
10	Stone of the Apes	594177,699	951069,478
11	The Stone of the Wolves	594792,175	951970,481
12	Guáitara River	590483,3	948291,072
** Outside the area of influence*			

Source: GEOCOL CONSULTORES S.A., 2017.

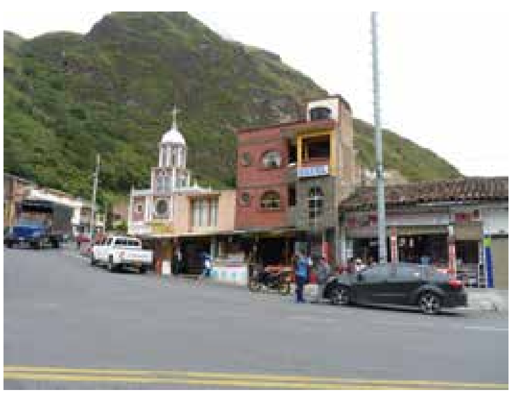
· **Populated areas.**

The populated centers represent strategic places for educational, cultural and recreational activities, the exchange, commerce and acquisition of goods and services, and as historical-cultural references of the inhabitants. Among the identified villages are the Aldea de María, San Juan, Contadero, Iles, Pedregal and Pilcuan. In general the populated centers have different tourist or recreational attractions like The Sanctuary of Our Lady of Iles (**Photography 5.34**), The swimming pools and recreational centers of Pilcuan near the river Guáitara (**Photo 5.35**), Or the sale of typical food and desserts in San Juan or the Village of María (**Photo 5.36** Y **Photo 5.37**).

Photography 5-34 Center of Iles

Photography 5-35 Populated center of Pilcuan

Photography 5-36 Populated area of Pedregal.



Photography 5-37 Village center of La Aldea de María.

Source: GEOCOL CONSULTORES S.A., 2017.

- **Cave La Virgen *.**

It corresponds to a place of pilgrimage of the municipality of Contadero, since there is an altar in the high part of the hill, where people take flowers and make prayers. Also from there you can also appreciate the typical landscape of this region. It is located on the road that leads from Contadero to Gualmatan, outside the area of influence of the project, and can be seen in the **Photo 5.38** Y **Picture 5.39**.

Photography 5-38 Grotto of La Virgen.

Photography 5-39 Panoramic landscape of the area of influence observed from the Grotto of La Virgen.

Source: GEOCOL CONSULTORES S.A., 2017.

- **Waterfall Quebrada Humeadora *.**

It is considered a site of scenic interest due to its scenic appeal and scenic beauty, since it corresponds to the fall of the Quebrada La Humeadora over the canyon of the Guáitara river, where it finally ends. It is also used as a geographical reference between San Juan and Pilcuan. It is within the area of influence on the Pan-American Highway, and can be seen in the **Photography 5.40** Y **Photo 5.41**.

Photography 5-40 Waterfall La Humeadora.

Photography 5-41 Waterfall La Humeadora.

Source: GEOCOL CONSULTORES S.A., 2017.

- **Cerro Iscuazán *.**

This site is important because it is a geographical reference for the communities, where the communications towers of the area are located (**Photo 5.42**), And from where it can also have an overview of both the area of influence of the project (**Photo 5.43**), As of other important places in the landscape like the páramo de Paja Blanca. Frequent visits of the inhabitants by the path of the hill Iscuazán, because it counts on a high scenic attractiveness by the landscape that is observed from there. Regarding its location, this is located outside the area of influence, in rural area of the municipality of Iles.

Photography 5-42 Cerro Iscuazán

Photography 5-43 Panoramic landscape of the area of influence observed from Cerro Iscuazán.

Source: GEOCOL CONSULTORES S.A., 2017.

- **Archaeological sites (Stone of the Monkeys and the Wolves).**

These two sites of scenic interest correspond to archaeological finds of rock carvings, which represent myths and legends of the creation of pastures, calendars and forms of social organization of indigenous communities. In total there are two points where there are several rocks with petroglyphs, which are visited by the people of the cabildos and by educational institutions, as part of the appropriation of the traditional systems of beliefs. Regarding their location, they are within the area of influence of the project, in the rural area of the municipality of Contadero. In the **Photo 5.44** Y **Photo 5.45** You can see some of these petroglyphs.

Photography 5-44 Petroglyphs of Los Lobos.

Photography 5-45 Petroglyphs of Los Monos.

Source: GEOCOL CONSULTORES S.A., 2017.

- **Guáitar River.**

This body of water is of great importance to the region because it corresponds to a relevant geographic and cultural referent, being associated to different important points such as the border between Ecuador and Colombia, the Guáitara river canyon near Ipiales, and the passage through Populated centers such as San Juan and Pilcuan (**Photography 5.46** Y **Photo 5.47**). On this river there are also activities of extraction of materials (rocks) for construction, car wash, and there are also areas near Pilcuan and San Juan with beach areas, which lend themselves to recreation and dispersal activities. However, during the interviews, it was mentioned that the environmental quality of the river had diminished since 2015 when a spill occurred on the body of water from the Trans-Andean Pipeline, so it was no longer a place to fish frequently, considering that Previously it was a typical activity on the river.

Photography 5-46 Guáitara River.

Photography 5-47 Guáitara River.

Source: GEOCOL CONSULTORES S.A., 2017.

5.1.3.5 Perception of the physical environment in cultural terms.

According to MADS (2012), the level of interest refers to the "degree of importance that both visitors and local actors assign to a landscape that is being observed from a track, path, viewpoints or any other infrastructure that allows to enjoy the landscape ". According to the above, the level of interest expresses the sOwnership and appropriation of the landscape units by the communities, while recognizing tangible or intangible values in the same, assigning different degrees of importance to the elements that constitute their environment, which expresses the cultural relationship with the same .

In relation to the above, the visual scale indicates the distance or plane of observation that the observers have of the different units of landscape and their main characteristics; What in cultural terms lends itself to identify those units with which there is a greater interaction and visual relation of what is typical, everyday and pleasant to observe in the landscape, from the perspective of the people who live there. Finally, the visual sensitivity is determined by the level of exposure and frequency of observation that the inhabitants have of the landscape, from where they can be observed changes in the number and presence of discordant elements, changes in the natural contrasts of color, in the harmony of The shape and texture of the landscape, and generally in the perception of permanent and floating observers of it. In this sense, these three attributes allow to describe in a general way the way in which the communities perceive their surroundings and express different cultural aspects in the same one, whereas that is where they are represented their ways of life, productive activities, activities of leisure and leisure , And cultural and historical references.

Regarding the analysis carried out for the landscape units of the project's area of influence, it was observed that 20.73% of the landscape units are valued with a High interest level and Visual scale of the foreground, associated with those units of Landscape related to productive activities, places for transport (roads), and the supply and exchange of goods and services are those that are closest to the communities (continuous and discontinuous urban fabric), on which there is a high degree of valuation , By representing the daily life of people living in the area of influence (**Table 5.36**). A similar percentage (23.17% of the analyzed units), has a high visual sensitivity, depending on the proximity of these units to roads and roads, populated centers and places with mountainous relief from where they can be appreciated in detail.

Table 5.36 Analysis of interest level, scale and visual sensitivity.

LANDSCAPE UNIT		INTEREST LEVEL	VISUAL SCALE	VISUAL SENSITIVITY
1	Ata - 111	Foreground	Close-up view with high interest	High
2	Ata - 112	Foreground	Close-up view with high interest	High
3	Ata - 1221	Foreground	Close-up view with high interest	High
4	Ata 1315	Foreground	Close-up view with low interest	High
5	Ata - 231	Foreground	Close-up view with high interest	High
6	Ata - 241	Foreground	Close-up view with high interest	High
7	Ata - 242	Foreground	Close-up view with high interest	High
8	Ata - 315	Distant plane	Distant view with medium interest	High
9	Ata - 3231	Foreground	Close-up view with medium interest	High
10	Ata - 3232	Foreground	Close-up view with medium interest	High
11	Dlap - 112	Foreground	Close-up view with high interest	High
12	Dlap-1221	Foreground	Close-up view with high interest	High

LANDSCAPE UNIT		INTEREST LEVEL	VISUAL SCALE	VISUAL SENSITIVITY
13	Dlap-231	Intermediate plane	Intermediate view with high interest	Medium
14	Dlap - 241	Intermediate plane	Intermediate view with high interest	Medium
15	Dlap-242	Intermediate plane	Intermediate view with high interest	Medium
16	Dlap-314	Intermediate plane	Intermediate view with high interest	Write-off
17	Dlap-315	Distant plane	Distant view with medium interest	Write-off
18	Dlap-3231	Distant plane	Distant view with medium interest	Write-off
19	Dlap-3232	Distant plane	Distant view with medium interest	Write-off
20	Dlce - 111	Foreground	Close-up view with high interest	High
21	Dlce - 112	Foreground	Close-up view with high interest	High
22	Dlce - 1221	Foreground	Close-up view with high interest	High
23	Dlce - 231	Foreground	Close-up view with high interest	High
24	Dlce - 241	Foreground	Close-up view with high interest	High
25	Dlce - 242	Foreground	Close-up view with high interest	High
26	Dlce - 315	Intermediate plane	Medium view with medium interest	Medium
27	Dlce - 32122	Intermediate plane	Medium view with medium interest	Medium
28	Dlce - 3231	Intermediate plane	Medium view with medium interest	Medium
29	Dlce - 3232	Intermediate plane	Medium view with medium interest	Medium
30	Dlce-511	Foreground	Close-up view with high interest	High
31	Dlco - 112	Foreground	Close-up view with high interest	High
32	Dlco - 1221	Foreground	Close-up view with high interest	High
33	Dlco-231	Intermediate plane	Intermediate view with high interest	Medium
34	Dlco - 241	Intermediate plane	Intermediate view with high interest	Medium
35	Dlco - 242	Intermediate plane	Intermediate view with high interest	Medium
36	Dlco - 314	Distant plane	Distant view with high interest	Medium
37	Dlco - 3231	Distant plane	Distant view with medium interest	Write-off
38	Dlco - 3232	Distant plane	Distant view with medium interest	Write-off
39	Dlr-112	Foreground	Close-up view with high interest	High
40	Dlr-231	Foreground	Close-up view with high interest	High
41	Dlr-242	Foreground	Close-up view with high interest	High
42	Dlr - 311212	Distant plane	Distant view with medium interest	Write-off
43	Dlr-314	Distant plane	Distant view with medium interest	Write-off
44	Dlr-315	Intermediate plane	Medium view with medium interest	Write-off
45	Dlr-3231	Intermediate plane	Medium view with medium interest	Write-off
46	Dlr-3232	Distant plane	Distant view with medium interest	Write-off
47	Fbc-511	Foreground	Close-up view with high interest	High
48	Fca-112	Foreground	Close-up view with high interest	High
49	Fca-242	Foreground	Close-up view with high interest	High
50	Fca-315	Foreground	Close-up view with high interest	High
51	Fca-3231	Foreground	Close-up view with low interest	High
52	Fca-3232	Foreground	Close-up view with low interest	High
53	Fca-511	Foreground	Close-up view with high interest	High
54	Fta-112	Foreground	Close-up view with high interest	High
55	Fta-1221	Foreground	Close-up view with high interest	High
56	Fta-1315	Foreground	Close-up view with medium interest	High

LANDSCAPE UNIT		INTEREST LEVEL	VISUAL SCALE	VISUAL SENSITIVITY
57	Fta-231	Intermediate plane	Intermediate view with high interest	Medium
58	Fta-241	Intermediate plane	Intermediate view with high interest	Medium
59	Fta-242	Intermediate plane	Intermediate view with high interest	Medium
60	Fta-3231	Intermediate plane	Medium view with medium interest	Medium
61	Fta-3232	Intermediate plane	Medium view with medium interest	Medium
62	Fta-511	Foreground	Close-up view with high interest	High
63	Vav - 242	Foreground	Close-up view with high interest	High
64	Vav - 314	Intermediate plane	Intermediate view with high interest	Write-off
65	Vel - 112	Foreground	Close-up view with high interest	High
66	Vel-1221	Foreground	Close-up view with high interest	High
67	Vel-231	Intermediate plane	Intermediate view with high interest	Medium
68	Vel - 241	Intermediate plane	Intermediate view with high interest	Medium
69	Vel - 242	Intermediate plane	Intermediate view with high interest	Medium
70	Vel-3231	Distant plane	Distant view with medium interest	Write-off
71	Vel-3232	Distant plane	Distant view with medium interest	Write-off
72	Vlep - 112	Foreground	Close-up view with high interest	High
73	Vlep - 1221	Foreground	Close-up view with high interest	High
74	Vlep - 231	Intermediate plane	Intermediate view with high interest	Medium
75	Vlep - 241	Intermediate plane	Intermediate view with high interest	Medium
76	Vlep - 242	Intermediate plane	Intermediate view with high interest	Medium
77	Vlep - 311212	Distant plane	Distant view with medium interest	Write-off
78	Vlep - 314	Distant plane	Distant view with medium interest	Write-off
79	Vlep - 315	Distant plane	Distant view with medium interest	Write-off
80	Vlep - 32122	Distant plane	Distant view with medium interest	Write-off
81	Vlep - 3231	Distant plane	Distant view with medium interest	Write-off
82	Vlep - 3232	Distant plane	Distant view with medium interest	Write-off

Source: GEOCOL CONSULTORES S.A., 2017.

As for the landscape units that are on an Intermediate visual scale with high interest (9.76%), there are those associated to heterogeneous agricultural areas located in Ladera (Dlap and Dlco) and Alluvial Terrace (Fta) geoforms, Since they lie outside the immediate visual basins, and it is necessary to move to other points of observation in order to be able to detail them, although they remain equally important for communities since they represent their economic activities (**Table 5.36**). With intermediate visual scale and medium level of interest are the landscape units associated with successional coverages (secondary vegetation high and low), other natural coverages such as open rocky Herbazales and some forest plantations located in Laderas (Dlce, Dlco and Dlr), Representing 7.72%, which do not have a relevant cultural value, although they are considered important for the environment because they are vegetation aggregations that provide different services to the communities. Likewise, a close percentage of landscape units was rated with an average visual sensitivity (14.63%), considering that being located in areas distant from access roads or observation sites in a large basin, sensitivity to changes in the area Decreases.

Regarding the Lejana visual scale, nine (6) landscape units (10.98%) were evaluated in this category, with a medium (8) and high (1) interest level. These correspond mainly to the units that are more distant to the settlements, access roads and viewpoints, and therefore of the observers, and whose visibility is restricted by diverse aspects as the relief, the presence of vegetation or the significant distance To roads and access roads. In this category are then the units associated with secondary vegetation high and low, Forest plantations, Riparian forests, and Dense high Andean forest, which also have a low visual sensitivity, Since they have a reduced level of exposure to the changes that have occurred on said landscape units, given the distance from the access roads and town centers. As for the cultural reference, these units are also associated with coverings with native vegetation, so they are recognized as important, although they are not identified as units of high interest because they do not provide a direct benefit to them, due to their location and difficult access.

5.1.4 Soils and land use.

The area of influence is characterized by variability in landscapes, climates, soils and parent material; In addition, due to the erosion, mass removal and contribution of alluvial, marine and pyroclastic materials, the latter arising from the repeated eruptions of the volcanoes Galeras, Cumbal and Azufral.

The soil is the product of the alteration of an original material, be it organic or mineral. Its formation and development depends on the joint action, which exerts on these materials the climate, organisms and topography, over time.

As a result of the interaction of pedogenetic factors, processes of losses, additions, transformations and translocations occur, which are responsible for producing the differentiation of horizons and determine the degree of evolution of soils. See **Photo 5.48**.

Photography 5-48 Differentiation of a soil profile, Río Guáitara, municipality of Imués, path Pilcuan La Recta, coordinates E: 957180 N: 604975

Source: GEOCOL CONSULTORES S.A., 2017.

The description of the soil units in the present study is based on the General Land Survey and Land Zoning of the Department of Nariño (IGAC, 2004), the Digital Elevation Model 15 meters and the methodology proposed by IGAC - Basic mechanism for gathering information in the field. During the field work, detailed observations of the soils were made, according to the pattern of distribution previously established in the area of influence.

The detailed observations correspond to the gauges made in the cartographic units of the area of influence. Each calicata was located strategically, in order to provide greater coverage to the units present. The analysis of the information in the field for the recognition of the soil was realized through the analysis of cuts of tracks and the accomplishment of 8 (eight) observations of characterization (calicatas); The soil samples for the physicochemical analysis were collected from the characterization observations (calicatas) made, taking into account the two (2) first horizons of the modal profile.

In each calicata, the internal and external characteristics of the soils were excavated at depths of 100 to 120 cm wide, 120 cm long and 100 cm deep, and even lower depths, when Found physical limitations such as rockiness or stony ground and water table. The characteristics that were evaluated were: environment or landscape, physical and chemical properties and the morphology of each of the horizons and / or soil layers.

Within the description of the soil units, mention is made of the Consociation and undifferentiated Group, these terms are described below:

Consociation: A cartographic unit consisting of at least 75% of a single taxon or miscellaneous areas and similar soils.

Undifferentiated group: Complex units, made up of more than one kind of soil, which are intimately associated and in which it is not possible to establish distribution patterns in the landscape.

Then, in the **Table 5.37** The main characteristics that are part of the area of influence, and in the **Figure 5.25** And in the **Cartographic Annex, Map Nº10. Floors** The spatial distribution of soil units.

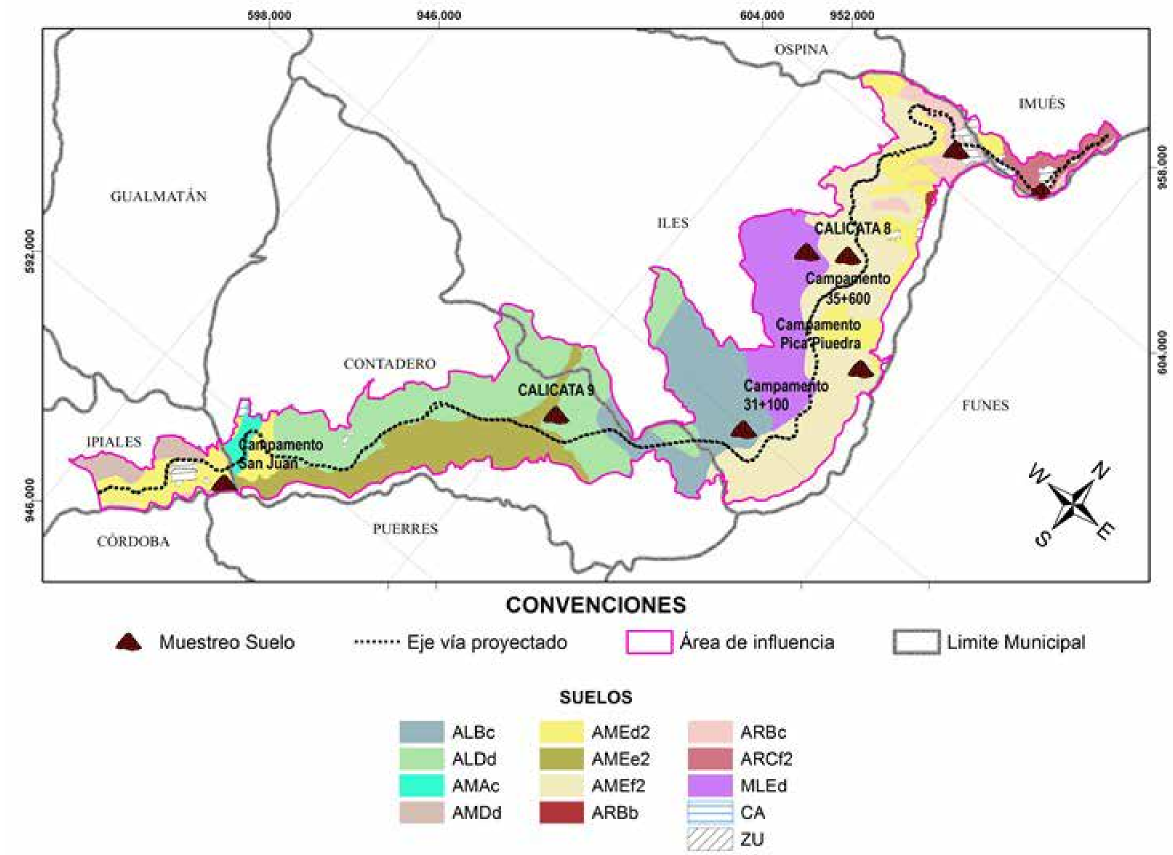
Table 5.37 Main characteristics of soils within the area Of influence.

ENVIRONMENTAL CLIMATE	Lithology	Main Characteristics	TAXONOMIC COMPONENT	SOIL UNIT	CARTOGRAPHIC PHASE	AREA (Ha)	%
Lomerío	Mantels of volcanic ash on ash and lapilli tufts or on andesites	Slightly sloping relief with slopes up to 12%, they are very deep to moderately deep, bordered by fragments of rock, well drained and moderately well drained	Pachic Melanudands, Pachic Fulvudands, Vitric Hapludands and Typic Paleudults.	ALB	ALBc	478,3	0,02
	Mantels of volcanic ash on ash and lapilli tufts and agglomerates	The unit corresponds to the landscape of hills, strongly undulating relief, very deep and moderately deep soils, bounded by a cemented layer, well drained, with a thick, sandy texture.	Pachic Melanudands, Typic Hapludands, Acrudoxic Placudands, Humic Dystrudepts and Histic Humaquepts.	ALD	ALDd	867,0	21,5
	Ashtrays of volcanic ash on ash and lapilli tufts	The relief varies from strongly wavy to strongly steep, very deep, well drained, very permeable.	Acrudoxic Fulvudands, Typic Fulvudands and Typic Palehumults.	MLE	MLEd	429,5	10,6

ENVIRONMENTAL CLIMATE	Lithology	Main Characteristics	TAXONOMIC COMPONENT	SOIL UNIT	CARTOGRAPHIC PHASE	AREA (Ha)	%
	Ash ashtrays and lapilli with sectoralized volcanic ash	They are very deep, well drained and of thick and sandy frank textural group	Andic Dystrustepts Consociation	AMA	AMAc	41,3	14,3
Valley	Lapilli ash and agglomerated ash slabs	Soils corresponding to the alluvial valley, slopes up to 12%, moderately deep, limited by rock fragment and / or compacted material, well drained, fine to heavy frank textural group	Typic Haplustolls, Cumulic Haplustolls and Typic Argiustolls.	ARB	ARBb, ARBc	154,8	3,8
Mountain	Ashes of ash, lapilli and agglomerates on andesites	Relief moderately steep to strongly steep, moderate erosion are very superficial and superficial, excessively drained from the coarse and thick textural group	Typic Ustorthents, Misc Rocky, Entic Haplustolls and Typic Argiustolls.	ARC	ARCf2	80,6	2,0
	Tobas, lapilli and agglomerates	Relief moderately steep to strongly steep, moderate erosion, are deep and superficial, excessively drained from the fine, clayey textural group.	Typic Haplustepts, Typic Ustorthents, Miscellaneous of Ashes and Vitrandic Dystrustepts.	AME	AMEd2, AMEf2 AMEg2	1795,7	44,4

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 5.25 Spatial distribution of soil units within the area of influence.



Source: GEOCOL CONSULTORES S.A., 2017.

In the area of influence are present the landscapes of: valley, hills and mountains; Occupying the greater part of the area the lomas landscape.

Next, the description of the landscape units is performed, with its corresponding soil unit.

5.1.4.1 Valley landscape.

The flat topography to slightly inclined, represented by small areas of elongated and narrow forms, located in some sectors. Soils developed in this area, are the product of sediment deposited by rivers; Presenting a highly saturated change complex, with irregular distribution of organic carbon, high fertility, low and moderate depth, limited by the presence of songs and gravels product of old alluvial contributions and in some cases by the presence of a horizon Bk, formed By accumulation of secondary carbonates; The latter case being constituted as a specific gain process known as calcification. See **Photo 5.49.**

Photography 5-49 Soils associated with the valley landscape within the area of influence, municipality Imués, path Pilcuan La Recta, coordinates E: 957180 N: 604975.

Source: GEOCOL CONSULTORES S.A., 2017.

Next, the soil unit corresponding to the valley landscape is described.

5.1.4.1.1 Consociation Typic Haplustolls - ARBb, ARBc.

This unit represents the type of terraces, moderately dissected, within the valley landscape. They comprise areas of small extension, it is located specifically in the path Pilcuán, in the municipality of Imúes, in sectors bordering the river Guáitara. The climate is dry, with temperatures of 14 ° C and rainfall of about 1000 mm annually.

The relief varies from slightly inclined to moderately inclined, with slopes between 3 and 12%, medium to long, rectilinear.

They are soils developed from ash tufts, lapilli and agglomerates and are characterized by being moderately deep, limited by fragments of rock and / or compacted material, well drained, fine to frank thick and high fertility textural group. See **Photo 5.50** and **Photo 5.51**.

The unit is composed of 50% Typic Haplustolls; 35% of the soils *Cumulic Haplustolls* And 15% of the soils *Typic Argiustolls*, With delimited phases in the following units.

ARBb: Slightly Inclined Phase

ARBc: Moderately Inclined Phase

The cartographic units ARBb and ARBc correspond to the subclass IIIsc by capacity of use.

Photography 5-50 Soil profile within the ARB unit, path Pilcuan the straight, municipality of Iles, coordinates E: 956746 N: 605041.

Photography 5-51 Soil profile within the ARB unit, sidewalk The future, municipality of Iles, coordinates E: 954992 N: 604592.

Source: GEOCOL CONSULTORES S.A., 2017.

- **Typic Haplustolls floors.**

These soils occur in the terraces, are moderately deep, limited by fragments of rock, well drained and fine textural group, have been developed from ash tuffs, lapilli and agglomerates.

Morphologically, they present ABC type profiles. The Ap horizon is thick, 47 cm thick, very dark gray and blackish grayish colors, loamy loamy and loamy textures and structure in angular and subangular blocks, thick, medium and thin, weak and moderate. Subsequently, a Bw of very dark gray and brown yellowish brown and dark brown, with an open texture and subangular structure, thin and medium, weak; Which rests on a C, of yellowish brown color and frank texture.

Chemically, they are moderately acidic soils on the surface and slightly acidic in depth, medium cation exchange capacity, high base saturation, medium organic carbon content, low phosphorus content and high fertility. The scarce and poorly distributed rains and the moderate effective depth are the limiting factors for the use and management of these lands.

- **Soils Cumulic Haplustolls.**

These soils occupy the position of terraces; Have been developed from ash tufts, lapilli and agglomerates, are moderately deep, limited by fragments of rock, well drained and of thick frank textural group on fine franc. Morphologically, they have AC type profiles. The horizon A, is very thick, 70 cm thick, made up of several layers of dark brown, very dark gray and deep black, frank textures and granular structure on the surface and in subangular blocks, thin and medium, deep in depth ; Which rests on a C, very dark grayish brown and stony sandy loam texture.

Chemically, they are soils strongly acidic in surface and moderately acid to neutral in depth, of high cationic capacity of change, saturation of bases, contents of calcium, magnesium, potassium and organic matter; High fertility and medium phosphorus content that can be used on the surface. The scarce rainfall is the main limitation for the use and management of soils.

- **Typic Argiustolls floors.**

They are soils that occupy the position of terraces, and represent the inclusion of the unit, are moderately deep, limited by compacted material, well drained and thick textural group frank, have originated from ash tuffs, lapilli and agglomerates.

The modal profile is ABC type. The Ap horizon has a thickness of 20 to 25 cm, very dark brown color, open texture and subangular structure, fine, weak; The argillic horizon Bt, of accumulation of iluvial clay, has very dark black and gray colors with grayish brown spots, development of cutanes, frank textures and frank sandy clay and structure in subangular blocks, thick, weak; The horizon C, is very pale brown with black spots and free texture, lying on a Cr, of compacted tuff material.

They are moderately acidic in the first horizon and slightly acid to moderately alkaline with depth, medium cation exchange capacity, high base saturation, high content of potassium, magnesium and calcium, high organic carbon content, low phosphorus content and Fertility. The main limitations to the use and management are the scarce and poorly distributed rains and the moderate effective depth of the soils.

5.1.4.2 Landscape of Lomerío.

They are areas of great extension. The geological material is composed of marine clays of tertiary age and sedimentary rocks arcillolites and sandstones. The action of climate over time, on the materials of the aforementioned origin, produces the rapid weathering of primary minerals, the loss of interchangeable bases, the accumulation of hydrated iron oxides and the formation of low activity clays (kaolinite and haloisite) . Under these conditions, low and very low fertility soils are generated, with high aluminum saturation and very strongly acids. See **Photo 5.52.**

Photography 5-52 Soils associated with the landscape of lomerío within the area of influence, municipality of Iles Nariño, urban path, Coordinates E: 955307 N: 597100.

Source: GEOCOL CONSULTORES S.A., 2017.

Next, the soil units corresponding to the land landscape are described.

5.1.4.2.1 Pachic Melanudands Consociation - ALBc.

Geographically, in the area of influence, the unit is located in the municipality of Iles in the department of Nariño, in cold humid and very humid climate, with temperatures between 12 ° C and 1050 mm annual precipitation.

Geomorphologically, they occupy sectors of the slopes and slightly inclined to moderately inclined, slopes up to 12%, short, sometimes medium and moderate dissection.

Soils developed from volcanic ash, lying on ash and lapilli tufts or on andesites, are very deep to moderately deep, bounded by fragments of rock, well drained, poorly drained, and high and moderate fertility. See **Photo 5.53**.

Photography 5-53 Soil profile within the unit ALB, municipality of Iles Nariño, urban path, Coordinates East: 955307 North: 597957

Source: GEOCOL CONSULTORES S.A., 2017.

The natural vegetation has been destroyed and replaced by grasses and crops such as corn, potatoes, onions, peas, vegetables and beans. However, there are some species such as pillo, white chilca, paico, hawthorn, borrachero, encaenillo and mora among others. See **Photo 5.54** and **Photo 5.55**.

Photography 5-54 Potato crops in the municipality of Iles, Urban Road, Coordinates East: 955307 North: 597957.

Photography 5-55 Livestock Use on clean pastures in the municipality of Iles, Urban Road, East Coordinates: 955307 North: 597957.

Source: GEOCOL CONSULTORES S.A., 2017.

Pachic Melanudands soils are composed of 50% of the soil, 30% of soils *Pachic Fulvudands*, 10% for the soils *Vitric Hapludands* And 10% for the soils *Typic Paleudults*.

The soil phase that is within the area of influence of this EIA corresponds to:

ALBc: Moderately Inclined Phase

The unit by capacity of use, corresponds to class IIIt. See **Photo 5.56**.

Photography 5-56 Agrological class III, in the municipality of Iles, Urban Way, Coordinates East: 955283 North: 5978036

Source: GEOCOL CONSULTORES S.A., 2017.

Next, the taxonomic components corresponding to the soil unit ALB are described.

Soils Pachic Melanudands: These soils occur on the slopes, within the landscape of lomerío; Comprises very deep soils, well drained and with a thick texture; Have been developed from volcanic ash on ash and lapilli tufts.

Morphologically, they present an ABC type profile. The horizon Ap, is 18 cm thick, black color, sandy loam texture and structure in subangular blocks, fine and medium, moderate; Then appears the A2, black color, sandy loam texture and structure in subangular blocks, medium, strong. The altering B horizon, dark brown, with black spots and sandy loam texture; Which lies on a C, of very dark grayish brown and yellowish brown, textures loamy clay (to the touch) and without structure, massive.

Chemically, they are strong to moderately acidic soils with high cation exchange capacity, high base saturation, high organic carbon content, medium to high calcium, magnesium, sodium and potassium contents, low in phosphorus and high fertility. The main limitations for use and handling are frequent frost and moderately thick textures.

- **Soils Pachic Fulvudands.**

They are soils that occupy the position of slopes of the tables, inside the landscape of lomerío, they are deep, well drained and of texture francs to fine; Have been developed from volcanic ash, which lie on tufts of ash and lapilli. The modal profile is ABC type. The surface horizon Ap thick, 33 cm thick, very dark grayish brown, sandy loam texture and granular structure, thick, moderate; Which lies on an A2 horizon, black, loamy texture and subangular, thick, moderate block structure; Later, the B horizon, dark yellowish brown, with black spots, clay loam texture and subangular, thick, weak structure is presented. The horizon C, of yellowish brown color with black spots; Loamy clay texture without structure, massive.

Soils are moderately acidic, high cation exchange capacity, high base saturation, high organic carbon content, medium calcium and magnesium content, high in potassium, low phosphorus and high fertility. Frequent frosts are the main limiting factors for the use and management of these soils.

- **Soils Vitric Hapludands.**

These soils represent the inclusion of the unit and occupy the position of slopes. It comprises moderately deep soils, bounded by rock fragments, well drained and of fine Frankish textural group; Are soils that have developed from volcanic ash deposited on andesites. Morphologically they present an ABC type profile. The Ap horizon, 18 cm thick, dark brown and loamy clay texture. The B horizon has dark yellowish brown, mixed with dark grayish brown, loamy and frank textures and subangular, medium and fine, strong and medium and thick, moderate structure. The transitional BC horizon shows dark yellowish brown color in mixture with dark grayish brown, frank texture and abundant saprolite material and stone of igneous origin.

They are extremely acidic at the surface and very strong to strongly acidic in depth, high cation exchange capacity, high organic carbon content, medium calcium and magnesium contents, high potassium contents, low phosphorus and high fertility.

5.1.4.2.2 Consociation Pachic Melanudands Symbol: ALDd.

This unit is located in the municipalities of Iles and Contadero; At altitudes between 2000 and 3100 meters above sea level, in humid and very humid cold, with temperatures of 12 to 18 ° C and rainfall of 1000 to 4000 mm per year. The unit corresponds to heavily undulating and strongly broken ridges, slopes between 12 and 50%, medium and long, rectilinear and moderate dissection. Volcanic ashes on ash, lapilli and agglomerate tufts have originated very deep and moderately deep soils, bounded by a cemented layer, well drained, with coarse texture on sandy and moderate and low fertility. See **Photo 5.57**.

Photography 5-57 Soil profile in the ALD unit, Contadero municipality, Ospina Perez road, E coordinates: 952410 N: 595885

Source: GEOCOL CONSULTORES S.A., 2017.

The natural vegetation is constituted by species such as black thorn, broom, abrojo, jundi, zarcillo, chilca, guanto, encenillo, hawthorn, mora, mayo and yellow. The soils of this unit are mostly dedicated to intensive agriculture with crops of potatoes, wheat, barley, corn, ollucos, geese, vegetables and some sectors with managed and natural pastures. See **Photo 5.58**.

Photography 5-58 Agricultural use (Potato - Maize) in ALD unit, Contadero Municipality, Ospina Pérez trail, E: 952410 N: 595895.

Source: GEOCOL CONSULTORES S.A., 2017.

They integrate the unit in 40% the floors *Pachic Melanudands*, By 30% the soils *Typic Hapludands*, 10% for the soils *Acrudoxic Placudands*, 10% for the soils *Humic Dystrudepts* And 10% by the soils *Histic Humaquepts.*

It presents phase by slope, delimited in the following unit:

ALDd: Strongly Inclined Phase

The unit by capacity of use, corresponds to class IIIt.

Next, the taxonomic components that make up the ALD soil unit are described.

- **Pachic Melanudands soils.**

These soils occupy the hillside position; Are very deep, well drained, of good permeability and moisture retention; Have been developed from volcanic ash, covering ash tufa, lapilli and agglomerates.

The soil profile is ABC type. The horizon A, is more than 100 cm thick, black color, sandy loam texture and granular structure, medium and fine, strong. The B horizon is yellowish-brown in color, sandy clay loam texture and subangular, coarse, weak block structure; Which lies on a C brownish yellow and sandy loam texture.

Chemically, they are strongly acidic soils with high cation exchange capacity, high organic carbon content, low base saturation, low calcium, magnesium and sodium contents, potassium median, high phosphate retention and moderate fertility.

The main constraints to the use and management are strong slopes, susceptibility to erosion and occasional frost.

- **Typic Hapludands floors.**

These soils appear on the shoulders of the hills. They are very deep, well drained and thick coarse texture. They are soils developed on volcanic rocks: ash tufa, lapilli and agglomerates. The modal profile presents a sequence of horizons of type AC. The horizon A, 80 cm thick, is made up of several horizons of dark yellowish brown and very dark grayish brown, sandy textures and subangular, medium strong structure. The C horizon has a dark yellowish brown color with black spots and layers of sand.

They are strong to moderately acidic soils with medium cation exchange capacity, high organic carbon content, low base saturation, low calcium, magnesium and phosphorus content, medium surface potassium contents and moderate fertility. Strong slopes and susceptibility to erosion are the main constraints to the use and management of soils.

· **Soils Acrudoxic Placudands.**

These soils constitute an inclusion within the unit, generally located in the tops of the hills. They are soils developed on deposits of ash and volcanic sand, are well drained, of thick textural group francaiso and moderately deep, limited by a cemented layer; Where a sandy horizon texture A has been developed; Later a Bw, of olive brown color and sandy loam texture; Which lies on a cemented B horizon (Bsm) formed by accumulation of iron and organic matter, reddish black. They are characterized by being very strong to strongly acid, high cation exchange capacity, low base saturation, moderate aluminum saturation, low calcium, potassium and phosphorus content, medium surface magnesium contents and low fertility.

5.1.4.2.3 Acrudoxic Fulvudands Consociation - MLEd.

This cartographic unit occupies the hills position; Within the area of influence is located in the municipality of Iles, at altitudes between 2000 and 3000 meters, corresponding to the humid and humid cold, with temperatures between 12 and 18 ° C and rainfall of 1000 mm annually, approximately . The relief varies from strongly wavy to slightly steep, with slopes between 12 and 50%, medium to very long, rectilinear. In some sectors, laminar water erosion occurs and in furrows to a moderate degree.

The soils have originated from volcanic ash on andesites or ash and lapilli tuffs, are very deep, well drained, very permeable and low to moderate fertility. See **Photo 5.59**.

Photography 5-59 Soil profile in the MLE soil unit, municipality of Iles Nariño, Tablón Alto, coordinates E: 953951 N: 601738.


Source: GEOCOL CONSULTORES S.A., 2017.

The natural vegetation consists of species such as sietecueros, tendrils, ferns, wild mora, encino, moridera, chicory, aurjuela, cress, verbena, espina, amarillo, cedrillo and cordoncillo among others.

Most of the vegetation has been replaced and replaced by crops such as potatoes, vegetables, legumes and mainly by natural and improved pastures. See **Photo 5.60**.

Photography 5-60 Development of transitional crops (Cebolla - Maíz), municipality of Iles Nariño, Tablón Alto, coordinates E: 954063 N: 601302.


Source: GEOCOL CONSULTORES S.A., 2017.

The cartographic unit is made up of 50% of the soils *Acrudoxic Fulvudands*; 30% for the soils *Typic Fulvudands* And by 20% by the soils *Typic Palehumults*.

It presents phase by slope, delimited in the following unit:

MLEd: Phase, slightly steep.

The unit by capacity of use, corresponds to class IVts.

Next, the taxonomic components that form the soil unit are described.

- **Soils Acrudoxic Fulvudands.**

They are located in the upper slope of the hills. They are soils developed from deposits of volcanic ash that rest on andesitas. They are characterized by being very deep, well drained and of textures frank sandy and frank sandy. Morphologically, an AB type profile is presented. The surface horizon Ap, is 18 cm thick, very dark gray to black, sandy loam texture and subangular and angular structure, thin and medium, weak. The Bw horizon of alteration presents two sub horizons of dark brown, yellowish brown and dark yellowish brown, frank sandy texture and subangular structure, thin and medium, weak.

Chemically, they are extremely strong and acidic soils, with high cation exchange capacity, low base saturation, high organic carbon and interchangeable aluminum content, low calcium, potassium, magnesium and phosphorus content and low fertility. The main limiting factors for the use and handling are high aluminum saturation, slopes strongly inclined to slightly steep and low fertility.

- **Typic Fulvudands floors.**

These soils occupy the position of average slope, within the landscape of the hills. They are soils developed from volcanic ash on ash tuffs and pumitas. They are very deep soils, well drained and of textures frank to clay loam. The modal profile presents a sequence of horizons of type A-AB-BC. The Ap horizon has a very dark grayish gray color, very dark gray, fair texture and subangular structure, fine and medium; Afterwards, a transitional horizon AB, dark yellowish brown, in mixture with very dark gray and frank texture, is presented. The Bw horizon of yellowish brown color, texture free to clay loam and structure in subangular blocks, medium, moderate, very weak; This horizon lies on a horizon C, of yellowish brown color and clay texture.

They are soils of strong reaction to very strongly acid, of high cationic capacity of change, medium to low saturation of bases, high contents of organic carbon, medium calcium and magnesium content, high in potassium, low in phosphorus and moderate fertility.

Highly inclined and steep slopes and susceptibility to erosion are the main constraints to the use and management of soils.

- **Typic Palehumults floors.**

These soils are found on the lower slope (skirts) of the hills, within the mountain landscape; Are deep, well drained and fine frank fine textural group on fine and very fine clay; Which have been developed on ash and lapilli tufts. The modal profile presents a sequence of horizons of type AB. The surface horizon Ap, is 20 cm thick, dark brown, frank texture, gravelly and gravelly and structure in subangular blocks, medium, weak; Follows a Bw horizon, dark reddish brown color, clay texture and subangular, medium, moderate block structure; Which rests on a Bt horizon, of accumulation of iluvial clay, of reddish brown and yellowish brown, clay texture and structure in subangular blocks, thick and medium, strong.

They are strongly acidic soils with high cation exchange capacity, low base saturation, calcium content media, high in magnesium and potassium, low in phosphorus, high organic carbon content and moderate fertility. Strong slopes and susceptibility to erosion are the main constraints to the use and management of soils.

5.1.4.2.4 Consociation Andic Dystrustepts Symbols - AMAb, AMAc.

They are located in sectors of the municipality of Ipiales. They occupy the position of tables within the landscape of hills denudacional of hydro-volcanic origin, slightly dissected and sometimes affected by erosive processes to a moderate degree.

The shape of the relief is flat to moderately inclined, with slopes between 0 and 12%, long to very long, rectilinear. The soils have originated from ash and lapilli tufts with sectoralized volcanic ash. They are very deep, well drained and of thick and sandy frank textural group. Natural vegetation has been replaced by crops such as wheat, barley, maize, potatoes and peas and in some sectors by pasture. The scarce natural vegetation that still remains is represented by some species such as chilco, blackberry, grass, gallinazo, hawthorn, encino and altamisa.

The unit is 100% composed of soils *Andic Dystrustepts*, With slope and erosion phases delimited in the following unit:

AMAc: Moderately Inclined Phase

The AMAc units correspond to the subclass IIIc by capacity of use.

Next, the taxonomic component that forms the soil unit is described.

- **Soils Andic Dystrustepts.**

These soils are presented on the benches of the tables within the landscape of hills, are very deep, of low retention of humidity and well drained; Have been developed from ash and volcanic sand on ash tufts. The modal profile shows a sequence of horizons of type ACA. The horizon A is thick, of very dark brown color, sandy loam texture and structure in subangular blocks, average, strong; The horizon C, constituted by several horizons of yellowish brown color with black spots and white color with black spots, sandy textures and without structure; (Ab), dark brown with red stripes, sandy loam texture and subangular, thick, weak block structure.

Soils present moderate and strongly acidic reaction, high cation exchange capacity, medium base saturation, high organic carbon content, medium calcium and magnesium contents, high potassium contents at the surface and low in depth, low phosphorus content at the surface And medium in depth and moderate fertility. The main limiting factors for use and management are the occasional rain and frost. See **Photo 5.61.**

Photography 5-61 Soil profile, Unit AMA, municipality of Ipiales, village of Las Cruces coordinates E: 943769 N: 586175.

Source: GEOCOL CONSULTORES S.A., 2017.

5.1.4.3 Mountain landscape.

Parental material from which most of the mountain soils have been formed, including some of the humid and very dry, wet weather cartographic units, correspond to volcanic ash deposits from volcanoes. The diverse types of vegetation of complex composition by the climatic variation, have provided organic materials necessary for the pedogenético development.

The relief that dominates is steep and very steep. In general, the most important training factors in the development of mountain soils are parental material, climate and organisms. The volcanic glass and the feldspars present in the ash, under suitable humidity conditions such as those that prevail in the area, are weathered and transformed into low crystallinity (amorphous) minerals that achieve a stability that allows them to persist with very Little advance in alteration over long periods of time. Organic matter, on the other hand, accumulates and tends to form highly stable organic compounds of the humus - allophane type; These processes allow to explain the presence of thick black upper horizons through which rainwater causes the leaching or loss of bases and the accumulation of interchangeable forms of aluminum, which determines the low and moderate fertility and very Strong to extreme acidity that characterizes most of the mountain soils. See **Photo 5.62.**

Photography 5-62 Soils of the landscape of Mountain, path San José de Qisnamuez, municipality of Contadero, Coordinates E: 954745 N: 597200.


Source: GEOCOL CONSULTORES S.A., 2017.

In general, they are soils of moderate evolution, product of physicochemical processes from abundant primary minerals, mainly amphiboles and feldspars and to a lesser extent altered materials rich in calcium and magnesium, on which there is high humification and development of minerals High activity clay, montmorillonite, vermiculite and metahaloisite.

On the other hand, as the conditions are drier, there are marked variations in both the landscape and the soil morphology. The low precipitation creates a confined environment that causes the evolution processes to be oriented towards the highly saturated soils, that is to say there is alteration but very low leaching, originating a means of accumulation of elements (bases and silicon, mainly).

As a result of the loss of bases by washing or leaching, as well as the rapid transformation and mineralization of the organic matter that does not allow it to accumulate, very strongly acid, desaturated soils with high aluminum saturation and low fertility are generated ; In these the quartz and the altered minerals predominate and are conformed by thin superficial horizons of yellowish brown color and strong brown to yellowish red in depth.

Next, the soil units corresponding to the mountain landscape are described.

5.1.4.3.1 Indifferent Group Typic Ustorthents, Rocky Miscellaneous, Entic Haplustolls and Typic Argiustolls, Steep, Eroded - ARCf2.

This cartographic unit represents the type of canyon relief, within the mountain landscape. They are the result of a process of erosion entrapment concentrated on the slopes or along fault lines that gave rise to V-shaped incisions formed by the rivers; With steep slopes, which present some secondary forms represented by small protrusions.

Photography 5-63 Miscellaneous Rocky, Path Pilcuan La Recta, municipality of Imúes Nariño, Coordinates AND: 956075 N: 605447.

Source: GEOCOL CONSULTORES S.A., 2017.

They are areas of small extension within the area of influence, located in the sidewalk of Pilcuán mainly. They are part of the moderately dissected canyons of the Guáitara river, at altitudes between 1000 and 2000 m, corresponding to the dry climate, with temperatures between 18 and 24 ° C and rainfall of 500 to 1000 mm annually. The relief varies from moderately steep to strongly steep, slopes of 50-75% and greater, very long and rectilinear. The unit is affected by erosion to a moderate degree, in addition there are frequently miscellaneous rock. In localized form mass removal phenomena such as landslides, cow legs are observed.

The relief varies from moderately steep to strongly steep, slopes of 50-75% and greater, very long and rectilinear. The unit is affected by erosion to a moderate degree, in addition there are frequently miscellaneous rock. In localized form mass removal phenomena such as landslides, cow legs and spoon strokes are observed.

They are soils developed from ash tufts, lapilli and agglomerates that lie on andesites, are very superficial and superficial, excessively drained, of thick and frank fine frank textural group, with or without gravel and high and moderate fertility.

The natural vegetation is constituted by the denominated straw and mosquerillo. The current use is land at rest. Only on hillside breaks, where the slopes are mild are mainly maize crops.

Soils are integrated in this unit *Typic Ustorthents*, Miscellaneous rocky, *Entic Haplustolls* And as inclusion soils *Typic Argiustolls.*

They present phases by slope and erosion delimited in the following units:

ARCf2: Phase, moderately steep, moderate erosion.

The cartographic unit ARCf2 corresponds to the subclass VIIItc by capacity of use.

Next, the taxonomic components that form the ARC soil unit are described.

- **Typic Ustorthents Floors.**

These soils are located on the slopes of the canyons, they are very superficial, bounded by a cemented layer, excessively drained, of fine textural group, have been developed from ash tufa, lapilli and agglomerates. The modal profile is AC type. The horizon A, is of 10 to 15 cm of thickness, brown to dark brown color, sandy clay loam texture and structure in subangular blocks, thick, strong; The horizon C, has yellowish-brown color and gravel sandy loam texture; In depth is the agglomerate with abundant pebbles, pebbles and stones of a pyroclastic nature.

Chemically, they are slightly acidic soils, with high cation exchange capacity and high base saturation, high calcium, magnesium and potassium contents, medium in organic carbon, low in use phosphorus and moderate fertility.

The main constraints to the use and management are steep slopes, susceptibility to erosion, low effective depth, low rainfall, current erosion and rock outcrops.

- **Entic Haplustolls floors.**

They occupy the hillside position; Are characterized by being very superficial, limited by a cemented layer, excessively drained and of fine frank textural group; Have been developed from ash tuffs, lapilli and agglomerates. Morphologically presents an A / C type profile. The horizon A presents, of 20 to 25 cm of thickness, very dark gray color, texture franco sandy clay and structure in subangular blocks, fine and average, moderate; Rests on the agglomerate (Cr). Soils are slightly acidic, with high cation exchange capacity, high base saturation, high organic carbon content, low phosphorus content and high fertility. Low effective depth, low rainfall, steep slopes, moderate erosion and rocky outcrops are the main constraints to the use and management of soils.

- **Typic Argiustolls Flooring**

These soils represent the inclusion of unity. They are characterized by being superficial, bounded by cemented layer, well drained and of thick frank textural group gravel on fine franc; Have a profile of soil with a horizon A, of 32 cm of thickness, black color, gravel sandy loam texture and granular structure, thick, moderate. Then appears a cemented horizon (Btm), of very dark gray and yellowish brown colors, loamy clay textures and structure in angular blocks, thick, strong; Which lies on a C, brownish-yellow color and loamy clay texture. They are slightly acidic, high cation exchange capacity, high base saturation, high calcium, magnesium and potassium content, low in usable phosphorus.

5.1.4.3.2 Group Indifferentiated Typic Haplustepts, Typic Ustorthents, Miscellaneous of Ashes and Vitrandic Dystrustepts, steep, eroded - AMEd2-AMEf2, AMEg2.

This unit is located in most of the area of influence, in cold dry climate, altitudes between 2300 and 2700 meters, rainfall up to 1000 mm annually and temperatures between 12 and 18 ° C. The unit corresponds to the canyons, with slopes greater than 50%, very long, rectilinear; Is affected by erosive processes in grooves and gullies of moderate degree. Soils have been developed on ash tufts, lapilli and agglomerates; Are excessive to well drained, deep and superficial; Belong to fine fine and fine clay loam textural group. Fertility is high to moderate. See **Photo 5.64.**

The unit is made up of 30% of the floors *Typic Haplustepts*, By 30% the soils *Typic Ustorthents*, 25% for Ash Miscellaneous and 15% for soils *Vitrandic Dystrustepts.*

They present phases by slopes and erosion delimited in the following units:

AMEd2: Phase Strongly sloping, moderate erosion.

AMEf2: Phase, moderately steep, moderate erosion.

AMEg2: Phase, strongly steep, moderate erosion. The cartographic units AMEf2 and AMEg2

They correspond to subclass VIIItc by capacity of use.

Photography 5-64 Soil profile Soil Typic Haplustepts, path La Esperanza, municipality of Iles AND: 955958 N: 600752.

Source: GEOCOL CONSULTORES S.A., 2017.

Next, the taxonomic components that form the soil unit are described.

Typic Haplustepts Flooring: These soils are located on the upper slope of the canyon. They are characterized by being deep, are excessively drained and of fine frank textural group; Have been formed from ash tufts, lapilli and agglomerates.

The modal profile is AC type. The surface horizon A is thin, with thicknesses between 12 and 20 cm, dark brown, free texture and structure in subangular blocks, thin and medium, moderate; Later it is a horizon C, of very pale brown color, white and yellowish brown with spots yellowish red and frank texture.

Chemically, they are strongly acidic in the first horizon and neutral in depth, with high cation exchange capacity, medium to high saturation of bases, medium and high content of calcium, magnesium and potassium, low phosphorus content, high organic carbon content And high fertility.

Strong slopes, susceptibility to erosion, the presence of miscellaneous ash and moderate erosion are the main limiting factors for the use and management of soils.

- **Typic Ustorthents Floors.**

These soils occupy the mid-slope position of the canyons. They are deep, excessively drained, belong to the fine, gravelly and gravelly Frankish textural group, have been developed from ash tufa, lapilli and agglomerates. Morphologically they present an AC type profile. The horizon A of 20 cm thick, is brown to dark brown, sandy clay texture and structure in subangular blocks, medium, weak; Which lies on a horizon C, light yellowish brown with yellowish brown spots, with gravel sandy loam texture and abundant fragments of rock. See **Photo 5.65**.

Photography 5-65 Soil profile Soils Typic Ustorthents, urban path, municipality of Iles, coordinates E: 955140 N: 596967.

Source: GEOCOL CONSULTORES S.A., 2017.

Chemically, they are slightly acidic, with high cation exchange capacity, high base saturation, high calcium, magnesium and potassium contents, low in phosphorus, high in organic carbon and high fertility. The main constraints to the use and management are steep slopes, susceptibility to erosion, the presence of miscellaneous ash and moderate erosion.

· **Soils Vitrandic Dystrustepts.**

These soils occupy the position of protruding hillside in the canyons; Are superficial, limited by rock fragments, well drained, belong to the fine frank textural group, have been developed on ash tufa, lapilli and agglomerates.

Morphologically, it presents an AC type profile. The Ap horizon is thick, 35 cm thick, black, sandy loam texture with gravel and pebble and fine, moderate subangular structure; Then Cr is presented as rock fragments of pebble and slab type, with an angular shape with an olive matrix and a sandy loam texture.

Soils are strongly acidic in surface and slightly acidic in depth, with high cation exchange capacity, medium saturation of bases, high total bases, high in organic carbon, low phosphorus content in the first horizon and medium in depth and high fertility. The main constraints to the use and management are strong slopes, susceptibility to erosion, shallow depth, rock outcrops and moderate erosion.

5.1.4.4 Agrological classification And suitability for land use.

Potential land use in the area of influence was determined according to the concept of the United States Soil Conservation Service manual 210 (Klingebiel and Montgomery, 1961), updated to 2010 by IGAC; Which determines that the classification is given by classes and subclasses, in which, as limitations increase, their numerical value increases. See **Table 5.38.**

Table 5.38 Diagram of agrological classification and potential use of soil.

CLASSES CAPACITY OF USE	INCREASE THE INTENSITY OF USE →							
	WILD LIFE	PASTORING THE FOREST			CROP			
		Limited	Moderate	Intensive	Limited	Moderate	Intensive	Very intensive
I								
II								
III								
IV								
V								
VI								
VII								
VIII								

They increase the limitations and risks in a vertical sense and decrease the adaptability and freedom for the choice of use in the same sense.

Source: IGAC, 2001.

The following describes each of the classes established in the system:

Class I: Soils with few limitations. Suitable for intensive agricultural use or with very high capacity of use. They are flat soils with no problems of erosion or very small. They are deep soils, generally well drained and easy to work, have good water retention capacity, are nutrient-filled and respond to fertilization.

Class II: Soils with some limitations that restrict plant choice or require moderate conservation practices. Suitable for continuous tillage. The main difference with Class I soils is that they have a gentle slope, are subject to moderate erosion, are medium in depth and may occasionally flood.

Class III: Soils with significant limitations that restrict plant choice or require special conservation practices or both. They are located on moderate slopes and, therefore, the risk of erosion is more severe in them. Its fertility is lower. They require cropping systems that provide adequate protection to defend the soil from erosion.

Class IV: Soils with very important limitations that restrict the choice of plants and require a very careful management. It is a transitional class, which only allows occasional tilling. In some cases, it has limitations due to the presence of steep slopes and, therefore, susceptible to severe erosion.

Class V: Soils with little or no risk of erosion, but with other limitations impossible to eliminate in practice, which limit the use to pastures or logging. They do not allow the cultivation by its character drenched, stony or by other causes. The slope is almost horizontal. Grazing must be regulated to avoid destruction of the vegetation cover.

Class VI: Soils with very important limitations that make them unfit for cultivation. Uses: pasture, forest. Its use involves moderate risks. They are subject to permanent but moderate limitations. Its slope is strong or very shallow.

Class VII: Soils with very important limitations, unfit for cultivation. Uses: pasture, forest. They are sloping, eroded, uneven, shallow, arid or flooded soils.

Class VIII: Soils not used, not even for agricultural, pasture or forestry use. They are soils with bare rocks, sandy, marshy areas, etc. They should be used for wildlife, for recreation or for hydrological uses.

Subclasses are formed by groups and land within each class, which have similar limitations and / or deficiencies in their use. In this way four types of constraints are recognized, which by themselves define the general subclasses, as follows:

Erosion: (and) It includes all lands with different degrees of erosion caused by either poor management (current erosion) or erosion risks caused by topographical constraints.

Humidity: (H) It integrates all those lands that have limitations caused by excess moisture, both superficial and subsoil.

Soils: (S) It refers to lands that have limitations or deficiencies in the root zone (effective depth, heavy or light textures, stoniness and / or rockiness, etc.)

Climate: (C) In this subclass are grouped those lands that present marked climatological limitations for agricultural purposes.

Note: These subclasses can be presented alone or in combination.

Then, in the **Table 5.39** We describe the agrological class and potential soil use corresponding to the area of influence.

Table 5.39 Agrological classification and potential land use In the area influence.

AGROLOGICAL CLASSIFICATION	SUBCLASS	CARTOGRAPHIC UNIT	LIMITATIONS OF USE	POTENTIAL USE	TYPE OF USE	Area (Ha)	%
III	sc	ARBb, ARBc	Scarce and poor distribution of rainfall, and moderate effective depth of soil	Crops of banana, maize, pineapple, fruit trees, citrus and drought resistant pastures	Intensive Transient Crops (ICS)	154,8	3,8
III	c	AMAc	They are limited by periodic frosts, some soils have low moisture retention and moderate effective depth.	Crops of wheat, barley, potatoes, peas, corn, carrots, barley and wheat. Likewise, they can be used with livestock with improved pastures.	Intensive Transient Crops (ICS)	41,3	14,3
III	t	ALBc, ALDd	Inclined slopes and susceptibility to arsenic are the main constraints to the use of these lands	Cultures of potatoes, vegetables, onions, beans, peas, curuba, blackberry and introduced pastures	Intensive Transient Crops (ICS)	1345,3	21,48
IV	ts	MLEd	Moderately broken relief, susceptibility to erosion, moderate effective depth of soils, high aluminum saturation and low fertility in soils	Cultures of potatoes, vegetables, onions, beans, peas, curuba, blackberry and introduced pastures	Semi-Intensive Transient Crops (CTS)	429,5	10,6
VIII	tc	ARCf2, , AMEd2, AMEf2, AMEg2	Relief strongly steep, shallow effective, high saturation of aluminum,	Preservation and conservation of natural	Areas for the conservation and / or recovery of	1877,9	46,4

AGROLOGICAL CLASSIFICATION	SUBCLASS	CARTOGRAPHIC UNIT	LIMITATIONS OF USE	POTENTIAL USE	TYPE OF USE	Area (Ha)	%
			high susceptibility to erosion and low fertility	forest protectors-producers and wildlife.	nature, recreation (CRE)		

Source: GEOCOL CONSULTORES S.A., 2017.

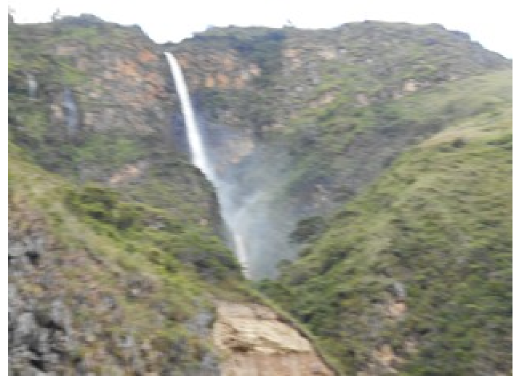
Then, from the **Photo 5.66** to **Photography** 5.69, The photographic record of the soils is presented, according to the described agrological classes.

Photography 5-66 Soils Class IIIsc, municipality of Imués, Vereda Pilcuan La Recta, Coordinates AND: 957180 N: 604975.

Photography 5-67 Soils Class IIIt, municipality of Iles Nariño, urban path, Coordinates E: 955307 N: 597100

Photography 5-68 Soils Class IVts, municipality of Iles Nariño, sidewalk Tablón Alto, Coordinates E: 954063 N: 601302.

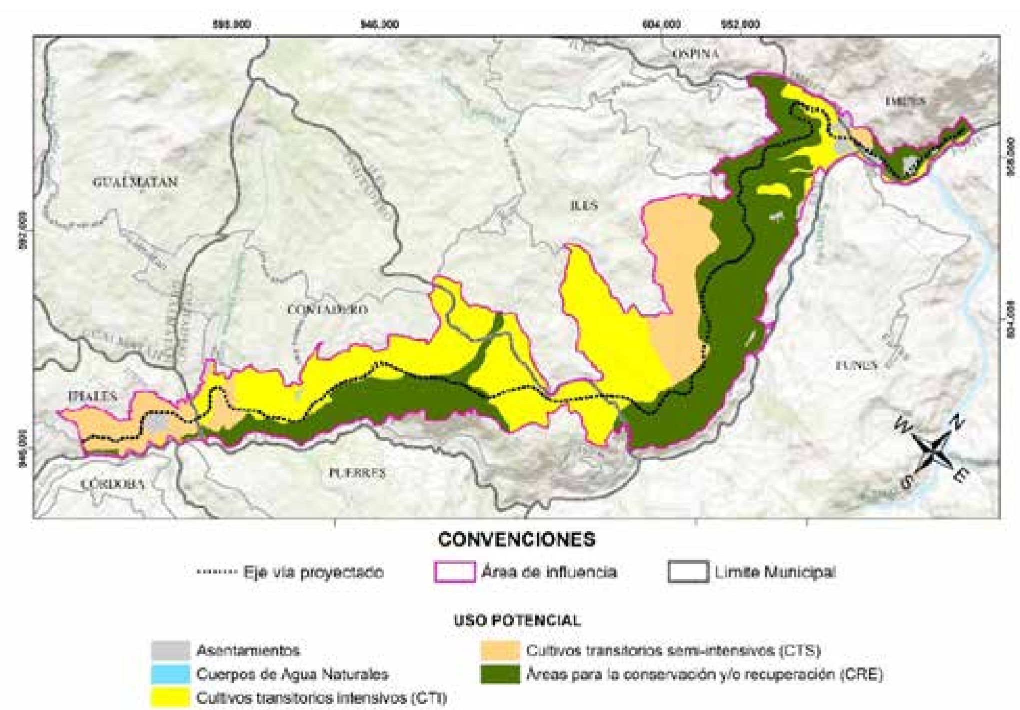
Photography 5-69 Class VIIItc Soils, San José de Qisnamuez Road, Contadero Municipality, E Coordinates: 954745 N: 597200.



Source: GEOCOL CONSULTORES S.A., 2017.

Then, in the **Figure 5.26 And in the Cartographic Annex, Map No. 12. Potential Use**, The distribution of potential land use within the area of influence is shown.

Figure 5.26 Agrological classification and potential land use in the area influence.



Source: GEOCOL CONSULTORES S.A., 2017.

5.1.4.5 Current land use.

The current use of the soil indicates the occupation of the same expressed in the form of cover, either by the different human activities or by the natural vegetation; This was determined according to the natural and anthropic activities observed in the field work; Taking into account the categories of group (land use) and subgroup (Type of use) defined in the IGAC methodology according to the Manual Soil Survey 2010. See **Table 5.40**.

Table 5.40 Distribution of land uses In the area influence.

VEGETABLE COVERAGE	CURRENT USE	CURRENT USE TYPE	AREA	%
Dense High Andean Forest	Conservation	Areas for the conservation and / or recovery of nature, recreation (CRE)	783	15,2
Riparian Forest	Conservation	Areas for the conservation and / or recovery of nature, recreation (CRE)		
Forest Plantation	Conservation	Protective Forest Systems (FPR)		
Open Rocky Grassland	Conservation	Areas for the conservation and / or recovery of nature, recreation (CRE)		
High secondary vegetation	Conservation	Areas for the conservation and / or recovery of nature, recreation (CRE)		
Low secondary vegetation	Conservation	Areas for the conservation and / or recovery of nature, recreation (CRE)		
Rivers	Natural Water Bodies	Natural Water Bodies	19	0,4
Exploitation of construction materials	Mining	Construction materials	13	0,3
Mosaic of Crops	Agricultural	Semi-Intensive Transient Crops (CTS)	3.027	58,8
• Mosaic of Pasture and Crops	Agricultural	Semi-Intensive Transient Crops (CTS)		
• Puse Pasture	Cattle-farming	Intensive grazing (PIN)	86	1,7
Road network and associated lands	Infrastructure	Transport	25	0,5
• Continuous Urban Fabric	Settlement	Residential	88	1,7
• Discontinuous Urban Fabric	Settlement	Residential		

Source: GEOCOL CONSULTORES S.A., 2017.

Taking into account the land uses exposed in the **Table 5.40,** It is possible to establish that the uses that occupy the largest area within the study area correspond to the use of livestock with 58.8%, followed by conservation use with 15.2%.

Next, each of the uses found within the area of influence is described.

5.1.4.5.1 Agricultural Use.

Within the area of influence, the agricultural use is represented by crops of short vegetative cycle (transitory), the predominant cultures are: Potato, Onion, Corn, Blackberry, Peas, Beans and Beans mainly; In addition, they are in association with grass mosaic. See **Photo 5.70** and **Photo 5.71**.

Photography 5-70 Cultivation of Beans within the area of influence, municipality of Ipiales Nariño, corregimiento of San Juan, coordinates AND: 948435 N: 590850.

Photography 5-71 Mosaic of crops with natural spaces, municipality of Iles Nariño, path El Tablón.

Source: GEOCOL CONSULTORES S.A., 2017.

5.1.4.5.2 Cattle Farmer.

They are the soils used for the reproduction and breeding of animals through the use of their vegetation as food, whether natural or induced. Within the area of influence, the livestock activity is practiced by families or small groups of people to produce milk or meat that will be consumed by them, not to be commercialized. This is usually practiced in natural spaces, with minimal interventions of the man. See **Photo 5.71** and **Photo 5.73**.

On the other hand, there are the activities associated with poultry production, porcicola and cunicola. See **Photo 5.74** and **Photo 5.75**.

Photography 5-72 Livestock on natural pastures within the area of influence, municipality of Iles, urban path, E coordinates: 955307 N: 597957

Photography 5-73 Livestock on natural pastures within the area of influence, municipality of Iles, sidewalk Tablón Alto, Coordinates E: 954070 N: 60170.

Source: GEOCOL CONSULTORES S.A., 2017.

Photography 5-74 Poultry farm El Naranjo, municipality of Ipiales Nariño, corregimiento of San Juan, coordinates E: 948248 N: 590982

Photography 5-75, Breeding and reproduction of Cuyes municipality of Ipiales Nariño, corregimiento of San Juan, Coordinates 948435 N: 590850

Source: GEOCOL CONSULTORES S.A., 2017.

5.1.4.5.3 Mining Use.

They correspond to the areas where materials are extracted or accumulated associated with mining activities of construction. See Photo 5.76.

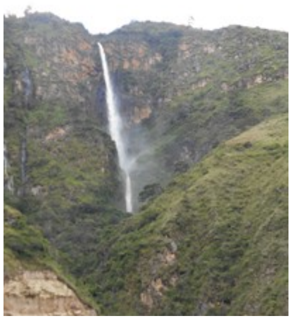
Photography 5-76 Mining activities in the municipality of Iles, Coordinates East: 955656 North: 595699

Source: GEOCOL CONSULTORES S.A., 2017.

5.1.4.5.4 Use of Conservation.

They correspond to those areas that can not be overexploited by their biophysical characteristics and ecological importance. In the area of influence are: High secondary vegetation, Low secondary vegetation, Rocky open Herbazal, High Andean dense forest, Riparian forest, Forest plantation (PROTECTORA) and River. See **Photo 5.77 and Photo 5.78.** The above mentioned coverages can be intervened during the development of the project taking into account the criteria established in the zoning of Environmental Management. On the other hand, there are forest plantations, which are based on the establishment of plantations that form a forest mass and that has a design, size and species defined to meet specific objectives such as productive planting, energy source, protection of agricultural areas, Protection of water mirrors, correction of erosion problems, silvopastoral plantations, among others. Eucalyptus plantations are mainly established in the area of influence. See **Photo 5.79.**

Photography 5-77 Quebrada la Humedeadora, path San José de Qisnamuez, municipality of Contadero, Coordinates E: 954745 N: 597200



Photography 5-78 Arroyo Papa Sicce Protective Area, El Porvenir Road, Iles Nariño Municipality, E Coordinates: 954626 N: 603417

Source: GEOCOL CONSULTORES S.A., 2017.

Photography 5-79 Plantation of Eucalyptus, municipality of Ipiales Nariño, path of San Juan, Coordinates E: 948248 N: 590982.

Source: GEOCOL CONSULTORES S.A., 2017.

5.1.4.5.5 Use infrastructure / settlement.

It includes urbanized areas, including territories covered by urban infrastructure and all those green spaces and communication networks associated with them. The use is made up of the following land cover: industrial areas, road network and associated land, continuous and discontinuous urban fabric formed by the municipalities of Imúes, Iles, Contadero and Ipiales, corresponding to the department of Nariño. See **Photo 5.80** and **Photo 5.81**.

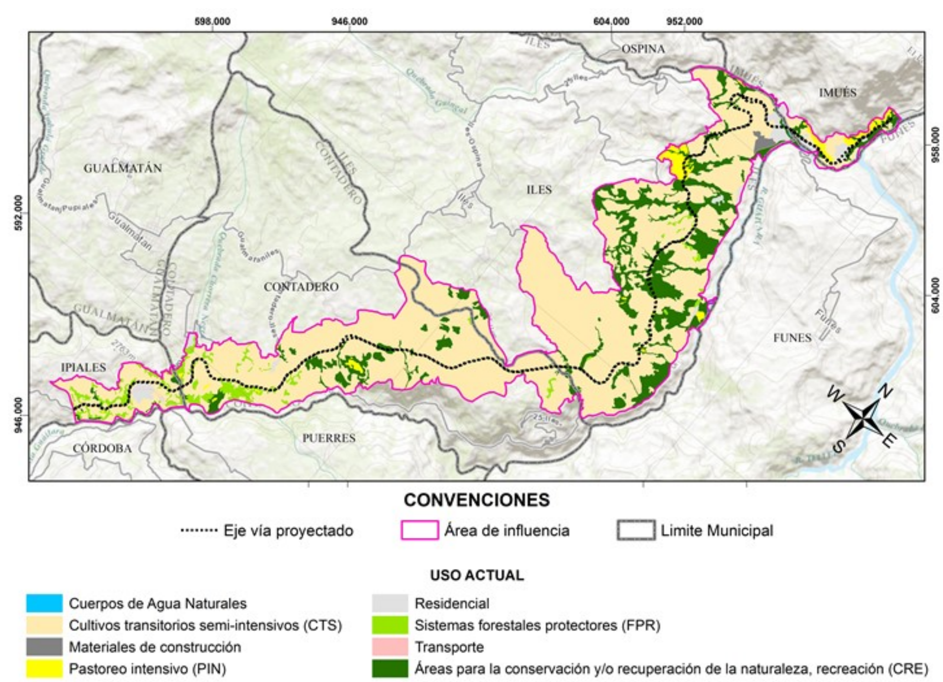
Photography 5-80 Urban center of the Municipality of Contadero Nariño.

Photography 5-81 Municipality of Imúes Nariño, corregimiento of Pilcuan La Recta, Coordinates AND: 955428 N: 606133.

Source: GEOCOL CONSULTORES S.A., 2017.

Then, in the **Figure 5.27 And in the Cartographic Annex, Map No. 11. Current usage**, The spatial distribution of land use within the area of influence is presented.

Figure 5.27 Spatial Distribution of Land Uses Within the Area of Influence Area.



Source: GEOCOL CONSULTORES S.A., 2017.

5.1.4.6 Conflicts of land use.

Conflicts in land use are manifested by crossing maps of potential land use, according to agrological classes, and land coverages. Through the two-dimensional matrix presented in the **Table 5.41**, Areas with adequate land use (areas without conflict) and areas in conflict (underutilization and overuse) were obtained. See **Table 5.41**, Distribution of conflicts in land use. The description of conflicts of land use is made taking into account the concepts of the study conducted by the Agustín Codazzi Geographic Institute "Zoning of Land Use Conflicts in Colombia - Year 2002".

Table 5.41 Two-dimensional matrix of land use conflicts.

VEGETABLE COVERAGE	CURRENT USE	AGROLOGICAL CLASSIFICATION AND POTENTIAL USE OF SOIL			
		IIIsc	IIIt	IVts	VIIItc
		Intensive Transient Crops (ICS)	Intensive Transient Crops (ICS)	Semi-Intensive Transient Crops (CTS)	Areas for the conservation and / or recovery of nature, recreation (CRE)
Dense High Andean Forest	Conservation		A		
Riparian Forest	Conservation	A	A	A	A
Exploitation of construction materials	Mining	O3			
Open Rocky Grassland	Conservation				A
Mosaic of Crops	Agricultural	A		A	O3
• Mosaic of Pasture and Crops	Agricultural	A	A	A	03
• Puse Pasture	Cattle-farming	S1		S1	O3
Forest Plantation	Conservation	A	A	A	A
High secondary vegetation	Conservation	A	A	A	A
Low secondary vegetation	Conservation	A	A	A	A

A: No Conflict; S1: Light underutilization; O3: Severe overuse.

Source: GEOCOL CONSULTORES. SA 2017.

Next, the analysis of land use conflicts within the area of influence is presented.

5.1.4.6.1 No conflict. Symbol A.

Under this title, lands are classified where the dominant agroecosystem, corresponds to the main use vocation or compatible use. The current use does not cause environmental deterioration, which allows to maintain adequate activities and concordant with the natural productive capacity of the lands.

In the area of influence areas are presented without conflict in the following cases:

For the establishment of dense Andean high forest, riparian forest, rocky grassland, high secondary vegetation, low secondary vegetation and forest plantation; It is considered that these coverages serve to give protection to the soil and bodies of water and conservation of the biodiversity of the flora and fauna.

On the other hand, zones are presented without conflicts by the establishment of mosaic of crops and mosaic of grasses and crops in soils that allow their development.

5.1.4.6.2 Conflicts due to underutilization.

Rating given to lands where the dominant agroecosystem corresponds to a lower level of intensity of use, when compared to the main use vocation or compatible uses.

Within the area of influence are areas with light underutilization, which is described below:

- **Light underutilization. Symbol S1.**

Lands whose current use is very close to the main use, therefore to the compatible uses, although it has been evaluated as of lower intensity to the recommended one.

In the area of influence it presents slight underutilization by the development of: clean pastures in soils that have potential for the development of agricultural systems.

5.1.4.6.3 Conflicts due to overuse. O symbol.

Rating given to land where the current dominant use is more intense, compared to the main vocation of natural use assigned to the land, according to its agroecological characteristics.

In these lands, current predominant uses make an intensive use of the natural resource base, surpassing their natural productive capacity, being incompatible with the main use vocation and compatible uses recommended for the zone, with serious ecological and social risks .

The conflicts of overuse in the area of influence of subdivide as follows:

- **Severe overuse. Symbol O3.**

Land in which current use exceeds the recommended main use vocation class by three or more levels, with evidence of advanced degradation of resources, such as severe erosive processes, marked decrease in land productivity, Salinization, among others.

Severe overuse is generated by the exploitation of building materials in soils that have potential for the development of agricultural systems.

In addition, for the development of clean pastures, mosaic of crops and mosaic of pastures and crops in soils that must be subjected to the protection and conservation of the soil and the native cover of the area.

As you can see in the **Figure 5.28, Figure 5.29 And in the Cartographic Annex, Map No. 13. Conflict of Use**, The non-conflict zones occupy up to 69% of the total area of influence, followed by severe overuse (30%), which is generated by the establishment of crops and exploitation of building materials, in soils that have potential for the conservation.

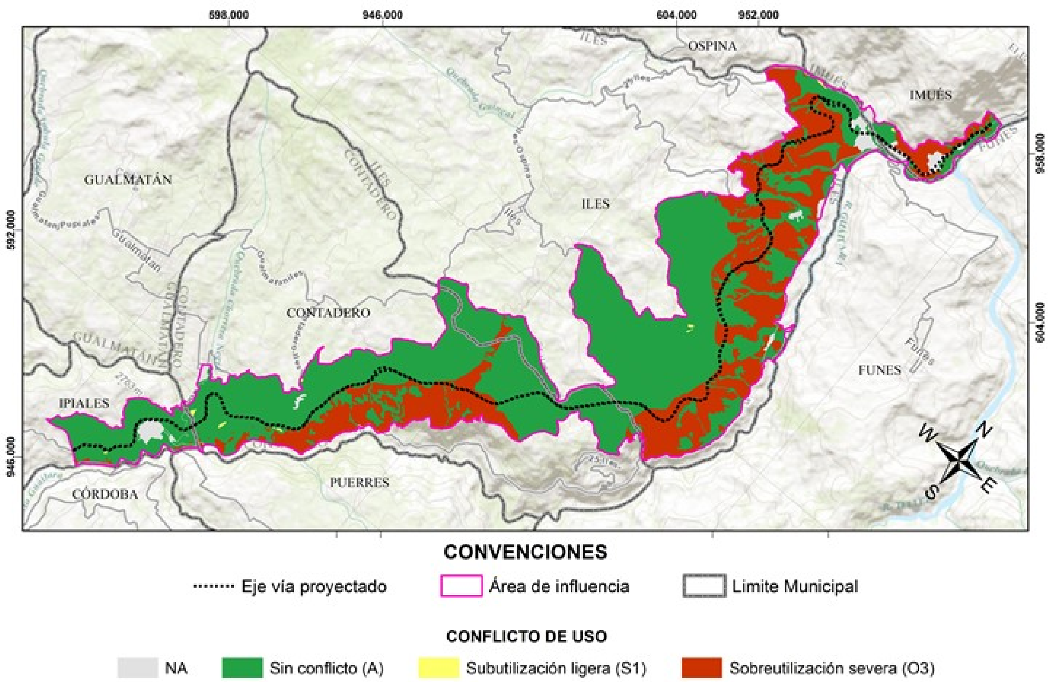
In conclusion it can be determined that the natural supply of the soil is being used in productive activities that correspond to its potentiality and therefore are not being over-exploited in the great majority.

Figure 5.28 Distribution of conflict types in area of influence.

TYPE OF CONFLICT	AREA (HA)	%
No conflict (A)	2710,38	69,34
Severe overuse (O3)	1193,17	30,52
Light underutilization (S1)	5,34	0,14
Total	3908,89	100,00

Source: GEOCOL CONSULTORES S.A 2017.

Figure 5.29 Distribution of the types of conflicts within the area of influence.



Source: GEOCOL CONSULTORES S.A 2017.

5.1.5 Hydrology.

5.1.5.1 Definition of units of hydrological analysis (UAH).

The study units are located in the binational watershed of the Carchi - Guáitara river, which is located to the southwest in the Department of Nariño and northwestern in the Province of Carchi in Ecuador. With the coordinate system Colombia West Zone and origin latitude 77 ° 34 '51.3' 'W, the river is born in the Republic of Ecuador located in the following geographical quadrant: 987,778 m E; 566.365 m N in the topographical divorce of the basin in Ecuador and in the south of the Department of Nariño, Republic of Colombia, on the slope of the Pacific Ocean, Colombia at 901,546 m E; 667.359 m N until its mouth in the river Patía to 400 msnm(CORPONARIÑO, 2011).

According to the IDEAM classification, the basin (at least in the Colombian part) belongs to the Pacific hydrographic area (AH 5), the hydrographic zone of the Patía River (ZH 52) and the sub-hydrographic basin of the Guáitara River basin (SZH 5205).

The hydrographic analysis units (hereinafter UAH) were extracted from the environmental impact study of the Rumichaca - Pasto road project, San Juan - Pedregal stretch.

The **Figure 5.30** and the **Cartographic Annex, Map N ° 14. Hydrology** (Encoding see **Table 5.42**) Show the location and unit of analysis Guáitara river; The Guáitara river basin is developed between Colombia and Ecuador; In the part of the neighboring country, the current is monitored in the upper part (Jativa River and Bobo River); While in Colombia the basin for the purposes of characterizing this stream in the area of influence of the project is only monitored before its confluence with the Sapuyes river at the Pilcuan station.

Figure 5.30 Location of the UAH for the study area AI-EIA-1B.

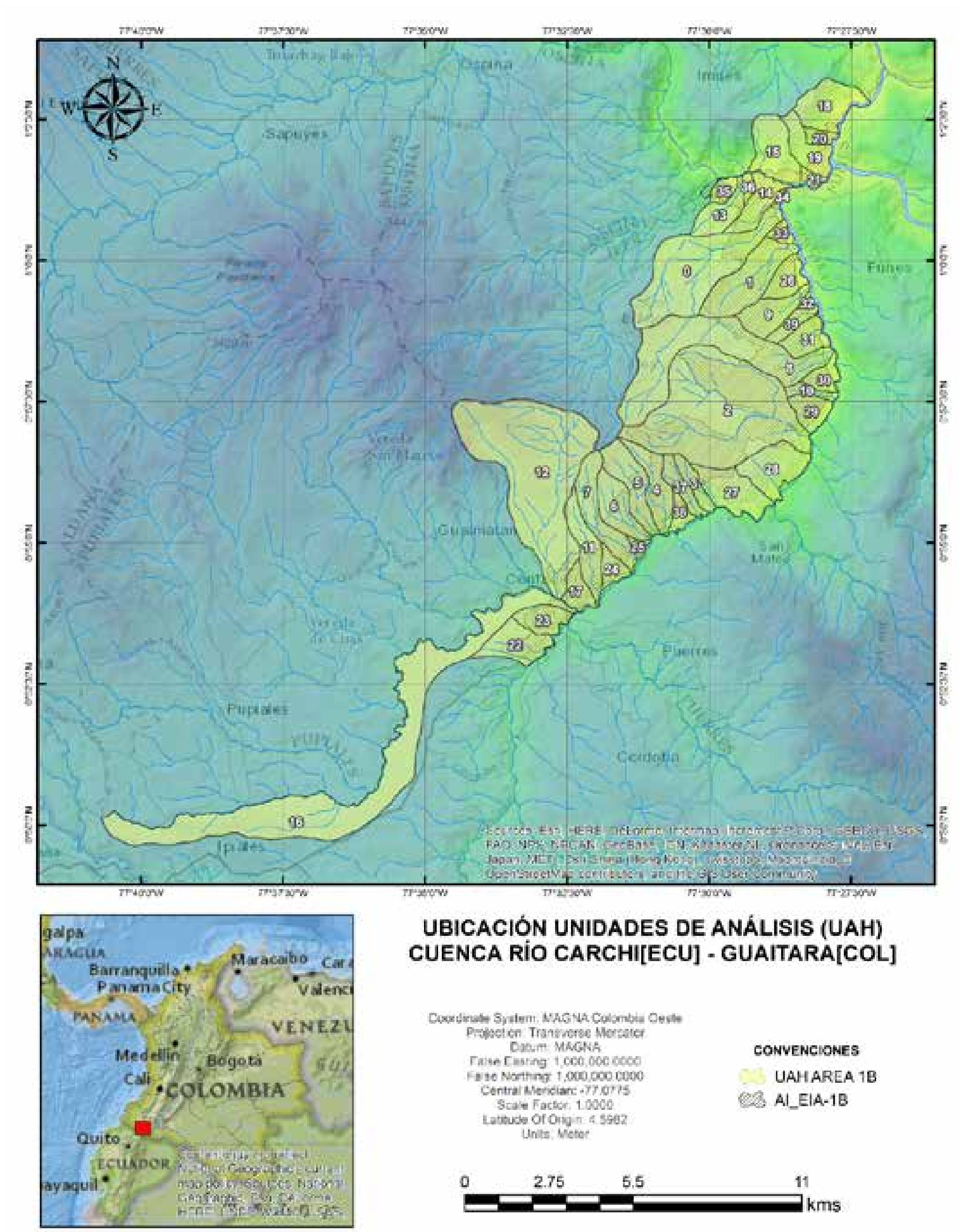


Figure 5.31 Location of the UAH Río Sapuyes and Quebrada Boquerón for the study area AI-EIA-1B.

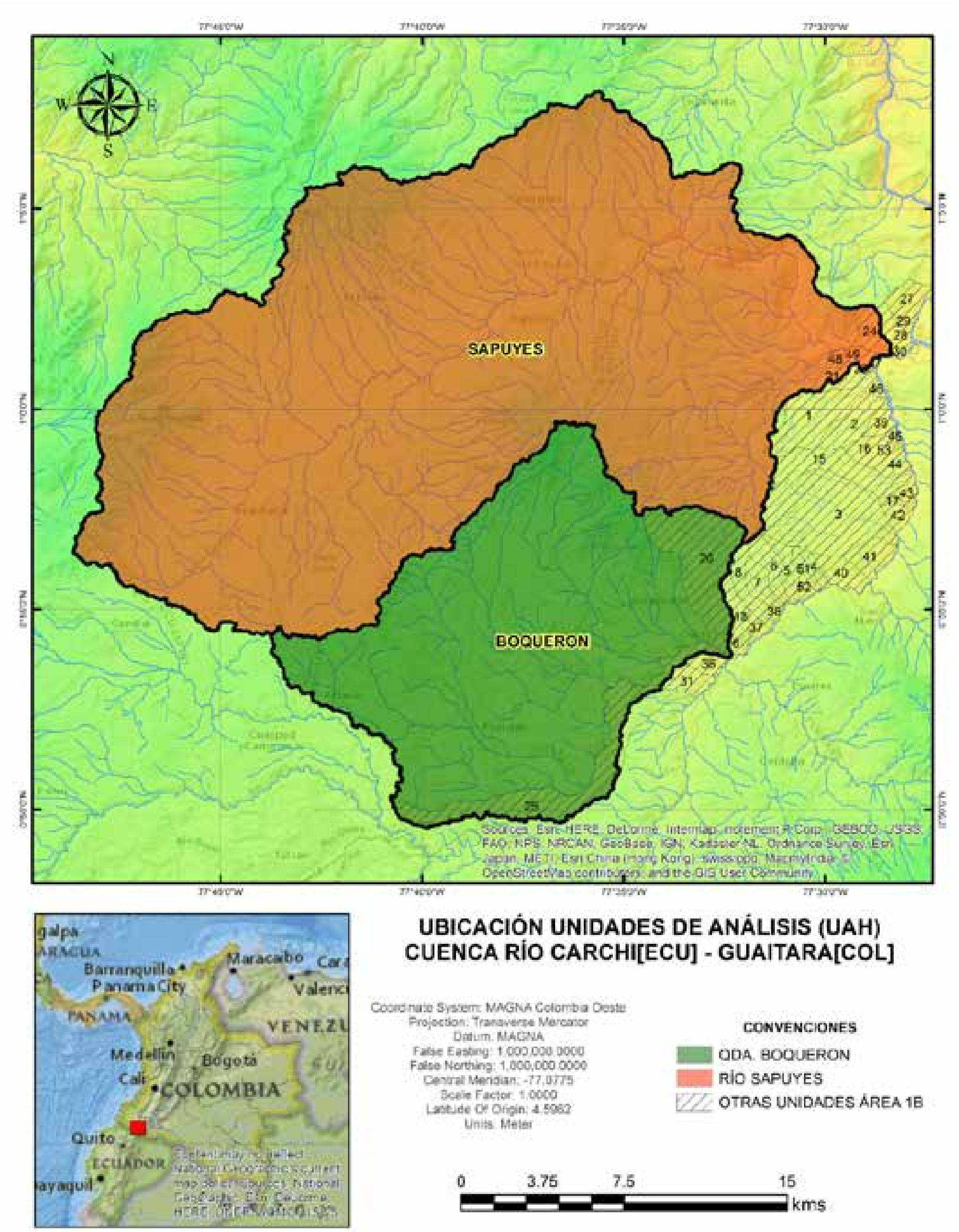


Table 5.42 Hydrographic Analysis Units for the area AI-EIA-1B.

ID	UAH	Area (km2)
1	Macal Stream	7,90
2	San Francisco Rural District	3,66
3	Home	14,80
4	Brigada Stream	0,87
5	La María Creek	2,04
6	The Culantro Gorge	2,35
7	Honda Breaks	2,03
8	San Francisco Stream	2,62
15	Moledores Stream	8,89
16	El Tablón Stream	1,88
17	Black Chorrera Ditch	0,49
18	Yamurayán Stream	2,04
20	Black Chorrera Gorge	15,10
21	Black Chorrera Gap	1,56
23	MD affluents - Sapuyes River 01	1,61
24	Influences MI - Sapuyes River	2,66
25	Direct tributaries MD - Rio Boquerón	16,04
26	Direct tributaries MI - Rio Guáitara 01	1,02
27	Direct tributaries MI - Rio Guáitara 17	2,59
28	Direct tributaries MI - Rio Guáitara 15	1,65
29	Direct tributaries MI - Rio Guáitara 16	0,47
30	Direct tributaries MI - Rio Guáitara 14	0,35
31	Direct tributaries Río Carchi - Río Guáitara 07	2,13
36	Direct tributaries Río Carchi - Río Guáitara 08	1,33
37	Direct tributaries MI - Rio Guáitara 02	0,76
38	Direct tributaries MI - Rio Guáitara 03	0,27
39	Direct tributaries MI - Rio Guáitara 11	1,26
40	Direct tributaries MI - Rio Guáitara 05	2,53
41	Direct tributaries MI - Rio Guáitara 06	2,61
42	Direct tributaries MI - Rio Guáitara 07	1,20
43	Direct tributaries MI - Rio Guáitara 08	0,84
44	Direct tributaries MI - Rio Guáitara 09	1,32
45	Direct tributaries MI - Rio Guáitara 10	0,15
46	Direct tributaries MI - Rio Guáitara 12	0,42
47	Direct tributaries MI - Rio Guáitara 13	0,12
48	MD - Río Sapuyes 03 tributaries	0,55
49	MD - Sapuyes River 02 tributaries	0,31
51	Manzano Stream	0,99
52	Direct tributaries MI - Rio Guáitara 04	0,63
53	Zanjón La Lechuza	0,77
54	Quebrada Boquerón (Watershed)	216,03
55	Sapuyes River (Watershed)	520,17

5.1.5.1.1 Morphometric characterization of the unit of analysis.

Next, some geomorphological characteristics of the Guáitara River Analysis Unit are presented. The characterization of the Guáitara River Hydrographic Analysis Unit (UAH) was carried out at a scale of 1: 25000 taking into account the national cartography of the Agustín Codazzi Geographic Institute (IGAC). This mapping was processed using the QGIS and GRASS GIS software. The referencing system used in the products of this chapter is Magna-Colombia-Oeste (Code EPSG 3115).

The characteristics of a basin and of the streams that form the hydrographic system can be quantitatively represented by indices of shape and relief of the basin and the connection with the river network. Many of the indices are mathematical reasons, so they can be used to characterize and compare basins of different sizes.

US engineer and hydrologist Robert E. Horton was the first to establish a quantitative method for analyzing drainage networks. This classification of the currents, developed in the early 1940s, establishes a hierarchical structure (Chow, 1994). Horton established in 1945 the statistical laws of the composition of the drainage networks in which he related the category, number, length and area of drainage of the currents. Horton's laws, as they have been termed, were subsequently modified and expanded, mainly by American researchers AN Strahler and RL Shreve.

- **Area of the basin - afferent area (A).**

This parameter proves to be one of the most important because it is directly related to the hydrological processes that occur within it (Reyes T., Barroso, & Carvajal E., 2010), The same author proposes a classification according to the area of the hydrographic unit (see **Table 5.43**).

Table 5.43 Classification of hydrographic units as a function of the geometric area.

AREA (KM2)	HYDROLOGICAL UNIT
<5	Unit
5-20	Sector
20-100	Microcuenca
100-300	Subwoofer
>3000	Basin

Source: (Reyes T. et al., 2010)

Additionally, the perimeter was determined for the areas of interest, since in conjunction with the area allow inferring on the shape of the basin. **(ii)Annex 1. Hydrology** Presents the results obtained for each component of the analysis unit. Under the criterion of classification by areas of Kings most of these are classified as units.

- **Length of main channel (Lt).**

It is the distance of the route that makes the main channel from its source to its mouth measured in kilometers. Usually L_T Presents a degree of sinuosity, which is represented by the coefficient of sinuosity K_S Which is the ratio of the total distance configured by the path of the current L_T, On the linear distance from birth to the mouth L_L (Domínguez, 2010):

$$K_s = \frac{L_t}{L_l}$$

Equation 1 Coefficient of Sinuosity

(ii)**Annex 1. Hydrology** Summarizes the results obtained for each index mentioned above and including the estimation of the sinuosity index.

Values of K_S Close to the unit characterize channels with straight alignment, while values above two describe channels with meanders and curves.

- **Average width of the basin (B).**

It is determined how the quotient between the area of the basin and the linear length of the main stream:

$$B = \frac{A}{L_l}$$

Equation 2 Average width of the basin

The results of the mean widths for each component of the study unit are presented in the **Annex 6. Hydrology**.

- **Elongation of the basin or coefficient of form (σ).**

It is calculated as the quotient between the linear length of the main current L_L And the mean width of basin B:

$$\sigma = \frac{L_l}{B} = \frac{{L_l}^2}{A}$$

Equation 3 Form factor

The results are presented in **Annex 6. Hydrology.**

- **Coefficient of compactness (Kc).**

It is the relationship between the length of the perimeter of the basin P_{cuenca} And the perimeter of a circle with an area equivalent to that of the basin $P_{circulo}$:

$$k_c = \frac{P_{cuenca}}{P_{circulo}} = \frac{P_{cuenca}}{2\sqrt{\pi A}} = 0.28\frac{P_{cuenca}}{\sqrt{A}}$$

Equation 4 Coefficient of compactness

The results of the units of analysis are presented in **Annex 6. Hydrology**.

Table 5.44 FAO basin classification based on compactness index.

TYPE	RANGE	DESCRIPTION
Kc	0.00 – 2.99	Round to round oval
Kc	26.58 – 38.66	Oval round to oblong oval
Kc	26.58 – 38.66	Oval oblong to rectangular oblong
Kc	1:18400	Rectangular oblong

Source: (FAO, 1985)

- **Longitudinal profile of main runway.**

This profile shows the evolution of the altitude levels of the main channel. The longitudinal section, can be built based on bathymetries made in the field or failing based on global digital elevation models. Field survey of the longitudinal profile can be performed for the entire current or, failing that, for characteristic stretches. The characteristic stretches can be delimited according to the sites of strong changes in the depths of the river, points of undercutting or accumulation, places with change in the upper width of the channel, etc. To construct the longitudinal profile, with a horizontal straight line, according to the selected scale, the length of the current is expressed. The vertical axis represents the river bottom or water level for each point in the current where information is available (Domínguez, 2010).

Annex 15. Hydrology The longitudinal profile for the component of the study unit extracted from the digital terrain model ASTER - GDEM and the main channel is shown.

- **Main channel height ($H_{channel}$).**

It is calculated as the average height of the characteristic stretches used in the construction of the longitudinal profile of the main channel. For currents with many changes in height in the course of the main course we calculate the weighted average slope based on the relative frequencies of the grouping in classes (usually between 8 and 12 classes) of the height values taken in the characteristic sections (Domínguez, 2010):

$$H_{cauce} = H_1 f_1 + H_2 f_2 + \cdots + H_n f_n$$

Equation 5 Weighted average height of the channel.

Here: H_i Is the height in the middle of the interval of each class and f_i Is the frequency that corresponds to that interval.

Annex 15. Hydrology The values for the estimation of the weighted height of the components of the unit of study are shown.

- **Slope of the main channel ($I_{channel}$).**

Slope refers to the ratio between height / height increments and the length increments of the current for a given section. The average slope and the weighted average slope are distinguished. The average slope I_{cauce} Is the quotient between the fall of heights / ΔH On the length of the section ΔL In which this fall occurs (Domínguez, 2010):

$$I_{cauce} = \frac{\Delta H}{\Delta L}$$

Equation 6 Average slope of the main channel.

For currents with many slope changes, the weighted average slope is calculated. It uses the relative frequencies of grouping into classes (usually between 8 and 12 classes) to weight the calculated slope values (Domínguez, 2010):

$$I_{cauce} = I_1 f_1 + I_2 f_2 + \cdots + I_n f_n$$

Equation 7 Average weighted slope of the main channel.

Here: I_i Is the slope in the middle of the interval of each class and f_i Is the frequency that corresponds to that interval.

The slope of the channel is one of the important factors that affect the capacity of the flow to transport sediment, because it is directly related to the velocity of the water. In sections with a strong slope, the channels have slopes higher than 5%, and flow velocities are so high that sediments with diameters larger than 5 centimeters can move as well as solids that roll because of the imbalance due to the effect of Lubrication produced by water (Reyes T. et al., 2010).

(ii)**Annex 1. Hydrology** Shows the values for the estimate of the weighted slope of the channel, for its construction were considered 12 classes.

- **Hypsometric curve.**

This curve gives a clear interpretation of the distribution of basin areas contained in different altitudinal zones. They are also indicative of the evolutionary patterns of watersheds (Strahler, 1952), So basins with a greater part of the area with elevation above the average values of the basin are considered basins with great erosive potential (immature basins), otherwise they are considered mature or sedimentary basins (Strahler, 1952). For basins where this relationship is in equilibrium (relative basin area - weighted elevation) are considered as basins in equilibrium.

To construct it, 8 to 12 altitudinal zones are determined and according to the information of the digital terrain model, the percentage of area contained in each one of them is calculated. On the horizontal axis, the percentage of area of the basin covered by each altitudinal zone is plotted and in the vertical the intervals of class of each altitudinal zone (Domínguez, 2010).

(ii)**Annex 1. Hydrology** Presents the hypsometric curve for each component of the study units, where it is observed that most of the distribution of heights (classes) with a greater part of the area of the basin distributed towards values above the average level, concentrating In the mountain area. Therefore, they are considered as basins of great erosive potential (immature).

- **Height of the basin (H_{basin}).**

It is calculated based on the frequency diagram of the hypsometric curve, homologous to the calculation of H_{cauce}, But using the 8 to 12 defined altitudinal zones (Domínguez, 2010):

$$H_{cuenca} = H_1 f_1 + H_2 f_2 + \cdots + H_n f_n$$

Equation 8 Weighted average height of the basin.

Here: H_i Is the height in the middle of the interval of each class and f_i Is the frequency that corresponds to that interval.

(ii)**Annex 1. Hydrology** Shows the values for the estimation of the weighted height for the subzone, for its construction were considered 12 classes.

- **Slope of the basin (I_{basin}).**

To obtain the average slope of the basin based on the DEM, the slope diagram is constructed with the local slopes of each cell calculated from the change of heights of the 8 neighboring cells (Up, Down, Right, Left, Up right , Up left, Down right, Down left). Similar to that applied to define the mean height, the weighted average slope of the basin is obtained by (Domínguez, 2010):

$$I_{cuenca} = I_1 f_1 + I_2 f_2 + \cdots + I_n f_n$$

Equation 9 Weighted average slope of the basin

Here: I_i Is the slope in the middle of the interval of each class and f_i Is the frequency that corresponds to that interval.

(ii)**Annex 1. Hydrology** Shows the values for the estimation of the weighted slope of the basin in the hydrographic unit, for its construction were considered 12 classes.

The depth of dissection of the basin H_{dis} Represents the difference between the average height of the basin H_{cuenca} And the average height of the longitudinal profile of the main river H_{cauce} (Domínguez, 2010):

$$H_{dis} = H_{cuenca} - H_{cauce}$$

Equation 10 Depth of dissection of the basin

Annex 15. Hydrology The results of this index are presented.

- **Level of relief dissection (N_{Dis})**

It results from the double product of the hydrographic density by the depth of dissection (Domínguez, 2010):

$$N_{dis} = 2DH_{dis}$$

Equation 11 Level of relief dissection

(ii)**Annex 1. Hydrology** Present the results of said index.

This indicator is related to the modeling of the terrain by water, that is, in the creation of streams and rivers, specifically with the erosive processes and accumulation of material. Also in context with other indicators such as relief, slope, drainage density, erosion and depth of the water table, are key factors in the geomorphological factors that control the underground flows and their accumulation in aquifers (Bhamare, Agone, Patil, & Science, 2012). Therefore, high values of these indices indicate greater geomorphological risk since these basins will be subject to more intense erosive processes.

- **Concentration Times (T_C).**

It is the time that elapses between the end of the hygrogram of excess and the end of the direct runoff, this being the definition that appears more frequently reviewed in the literature. However, other authors report the Tc as the time between the centroid of the excess plot and the point of inflection on the recession curve of the direct runoff hydrograph.

In addition, it can be defined as the time it takes to travel a particle of water from the most remote point to the point of interest. It corresponds to the lapse between the end of the rain and the time when surface runoff ceases. There are a series of formulas that allow the calculation of this time developed by various authors. Some of the formulas that are used for the calculation of this indicator are, Kirpich, Temez, Giandotti, Bransby-Williams, General Direction Roads (DGC). Their calculations are shown below:

$$T_c = 0.02 * L^{0.77} * S^{-0.385}$$

Equation 12 Concentration Time by Kirpich.

Source: (Wanielista, 1997)

Where:

Tc Concentration time (min)

L Length of main channel in (m)

S Slope of the main channel (m / m)

$$T_c = 0.3 * \left[\frac{L}{S^{0.25}}\right]^{0.75}$$

Equation 13 Concentration Time by Temez.

Source: (Chow, 1994)

Where:

Tc Concentration time (hours)

L Length of the main channel in (km)

S Slope of the main channel (m / m)

$$T_c = \left[\frac{4\sqrt{A} + 1.5L}{0.8\sqrt{H}}\right]^{0.75}$$

Equation 14 Concentration Time by Giandotti

Source: (Chow, 1994)

Where:

Tc Concentration Time (Hours)

L Length of the main channel in (Km)

TO Area of the basin (km^2)

H Difference of heights of the main channel (m)

$$T_c = \frac{L}{1.5D}\sqrt[5]{\frac{A^2}{S}}$$

Equation 15 Concentration Time by Bransby-Williams

Source: (Chow, 1994)

Where:

Tc Concentration Time (Hours)

L Length of the main channel in (Km)

TO Area of the basin (km^2)

S Average slope of the main channel (%)

D Diameter of the circle of area equivalent to the surface of the basin (km)

$$T_c = 0.3\left[\frac{L}{J^{0.25}}\right]^{0.76}$$

Equation 16 Concentration Time by General Direction of Roads

Source: (Chow, 1994)

Where:

Tc Concentration Time (Hours)

L Length of the main channel in (Km)

J Average slope of the main channel (H / L)

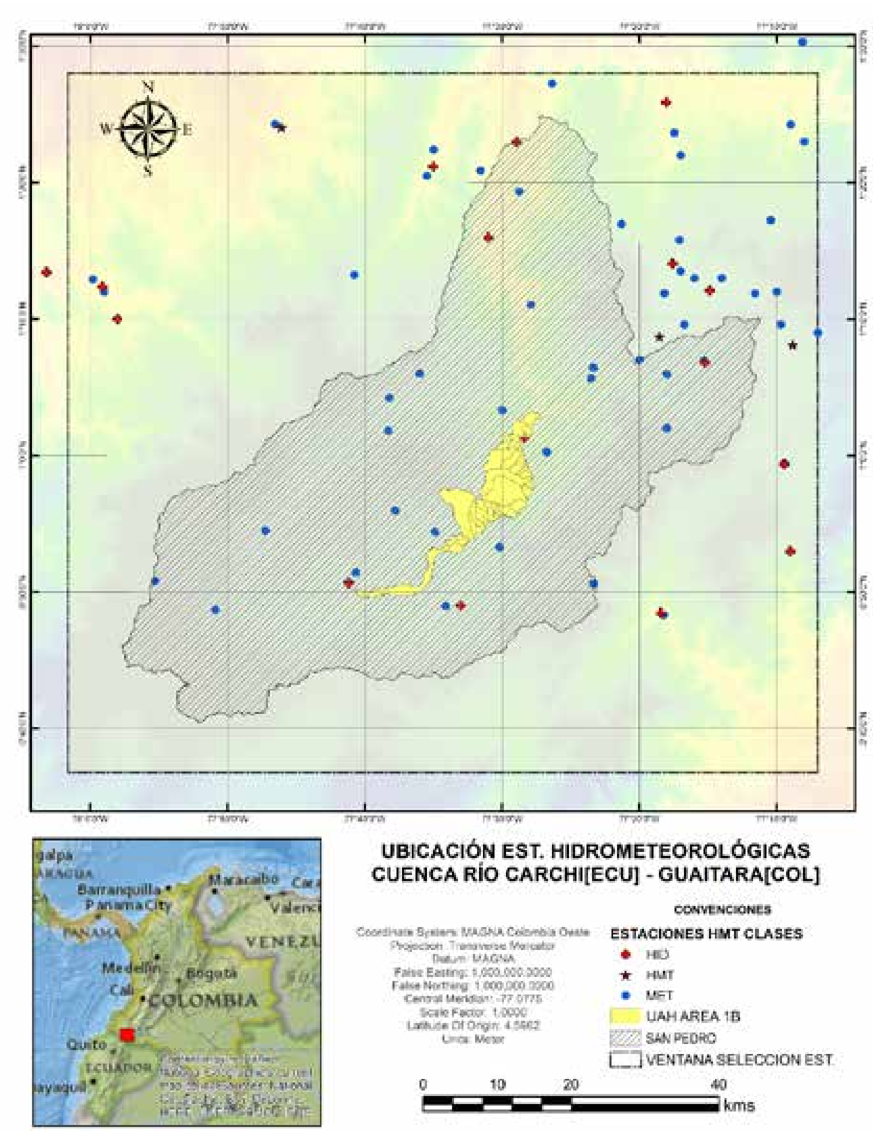
H Difference of level between the point of exit and the nearest hydrologically point (m)

The results obtained for the Guáitara River Basin for each of the methodologies explained above are presented in the **Annex 6. Hydrology**. As expected, the values differ widely according to the methodology used from a few hours to days.

5.1.5.2 Hydrometeorological information.

From the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) it was possible to consolidate the database with the hydrometeorological records for the area of interest to monthly resolution. In total, 137 meteorological stations and 3 flow stations were selected. The criterion considered for the selection of the stations corresponded to temporal extension and the continuity of registration in the same ones, being taken only those with registries older than 11 years and that also had at least 70% of completeness in their series of registry. In the **Figure 5.32** The spatial distribution of the hydrometeorological stations arranged in the Guáitara river basin until its closure point at the San Pedro station [52057050] is presented.

Figure 5.32 Spatial distribution of hydrometeorological stations arranged in the Guáitara river basin - San Pedro station closure [52057050].



In the **Table 5.45** Only the stations present the hydrometeorological stations present in the Guáitara River basin until its closure point at the Pilcuan station [52057010]. The description of the remaining stations is presented in the **Annex 8.** Climate:

Table 5.45 Hydroclimatological stations located in the study area.

CODE	NAME	CATEGORY	STATUS	DATE INSTALLATION	DATE SUSPENSION
52050070	TUQUERRES	PM	SUS	15/01/1958	15/02/1987
52050090	IMUES	PM	ACT	15/01/1957	-
52050100	GUALMATAN	PM	ACT	15/07/1972	-
52050110	CUMBAL	PM	ACT	15/01/1958	-
52050120	PUERRES	PM	ACT	15/08/1971	-
52050130	CHILIES	PM	ACT	15/07/1972	-
52050190	STA ROSA POTOSI	PM	ACT	15/06/1995	-
52055010	APTO SAN LUIS	SP	ACT	15/07/1941	-
52055020	THE PARADISE	CO	ACT	15/07/1968	-
52055100	VILLA ROSA	CO	SUS	15/04/1990	08/05/2006
52055200	FUNES	CO	ACT	01/09/2009	-
52057010	PILCUAN	LG	ACT	15/10/1979	-
52057040	CARLOSAMA	LG	ACT	15/12/1955	-
52057050	SAN PEDRO	LG	ACT	15/02/1980	-

5.1.5.2.1 Consistency of hydrometeorological information

The hydroclimatological data provided by the IDEAM, usually have a temporary discontinuity in their records, as well as certain inconsistencies in them. These may possibly be due to faults in measuring instruments, or to anthropic operating factors at monitoring stations, as well as many others. In this sense, to verify if the information is reliable, a preliminary analysis of the consistency of the information was carried out. For this, the box diagram methodology was implemented in the analysis of atypical or extreme data (this analysis was only carried out for the meteorological stations). The methodologies implemented are described below and the results are presented in the **Annex 8.** Climate:

- **Mean Absolute Deviation (MADS) (Rousseeuw & Croux, 1993).**

The mean absolute deviation (MADS) is a scatter measure that intends to give a summary idea of "distances to a central point" as it happens with the standard deviation.

Unlike these, the MADS considers the median as the center point of the distribution to calculate deviations (Left and Right), then estimates the absolute value of the deviations to eliminate the sign (instead of squaring as we do in calculating The standard deviation), to finally take the median of the distances (instead of averaging as we do with s). We define the MADS of a sample X1, X2, ..., Xn as:

$$X_i - \grave{X} \vee$$
$$MAD = mediana$$

Equation 17

Where:

X_i Observed variable

$\grave{X}$ Median of the observed variable

- **Mass Curve (Segerer & Villodas, 2006).**

It is defined as the accumulated precipitation curve in a given period, represented in a system of axes in which the values of the time in abscissa and the accumulated variable (mm) in ordinates are plotted.

This type of curves is generally used to represent the characteristics of the storms considered individually, obtaining the pertinent values based on the records of the rain gauges.

The slope of the line drawn between the extreme points of the mass curve allows the average intensity of the precipitation produced by the storm to be obtained in the time interval corresponding to its duration.

The mass curves produced are the most desirable information to have at each station in the basin or area under analysis.

LThe mass curves for each of the selected meteorological stations are presented in the **Annex 8.** Climate:

- **Box and Whisker Diagrams or Box Plot (Moros, 2010).**

This diagram, also known as box **-** whister, box and dot or box with pins, offers a representation created from seven numbers, in order that the data of the analyzed set does not lose its spatial distribution.

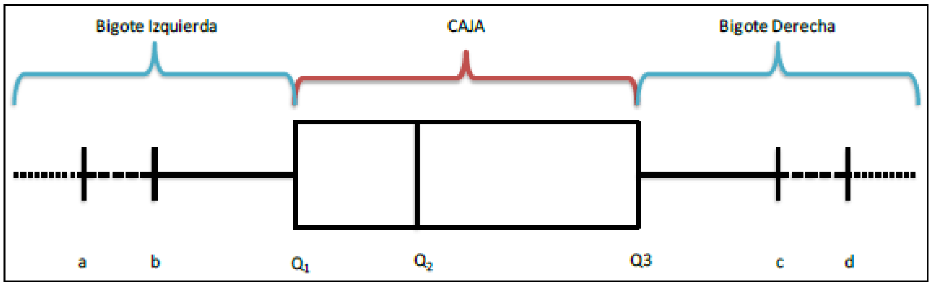
This exploratory analysis tool allows to study the symmetry of the data and to detect the outliers in the information being analyzed. The box and mustache diagram divides the data into four areas of equal frequency, with the following intervals:

- (I.e., Q1
- Q1, Q2
- Q2, Q3
- Q3, (I.e.

The box and whiskers diagram consists of a central box and two horizontal segments (whiskers) that start from the center of each side of the box as can be seen in the **Figure 5.33**. The central box encloses 50% of the data. The vertical line inside the box represents the median or 50th percentile. If this line is in the center of the box, there is no asymmetry in the data. The vertical sides of the box are located in the lower (25th percentile) and upper (75th percentile) quartiles of the data. Starting from the center of each vertical side of the box the mustaches are drawn, one towards the left and the other towards the right, taking into account the following:

- The left mustache has one end in the first quartile (Q1) and the other end in the corresponding "b" value in the **Figure 5.33** And calculated by Equation 17.
- The mustache on the right has one end in the third quartile (Q3) and the upper end corresponding to the value of "c" in the **Figure 5.33.**

Figure 5.33 Box and Mustache Diagram.



Source: (Moros, 2010)

$$b = Q1 - 1,5 * (R.I)$$

Equation 18 Coefficient b.

$$c = Q3 + 1,5 * (R.I)$$

Equation 19 Coefficient c.

Where the RI value: Interquartile Range, is defined by the following expression:

$$R.I = (75percentil) - (25percentil)$$

Equation 20 Interquartile range.

The data to the left of the left mustache and to the right of the right mustache are called moderate atypical values whenever there is between [a, b] and [c, d], (see **Figure 5.33**). Where "a" and "d" are calculated by the following equations:

$$a = Q1 - 3,0 * (R.I)$$

Equation 21 Coefficient a.

$$d = Q3 + 3,0 * (R.I)$$

Equation 22 Coefficient d.

The data to the left of the value "a" and to the right after the value "d" are called extreme outliers.

5.1.5.2.2 Complementation of hydrometeorological information.

As mentioned above in the consistency of the information, these factors also influence the discontinuity of the hydrometeorological information registered by the stations, reason why it is necessary to realize a complementation of the missing information. For this, the methodology of multiple linear regressions (See **Annex 6. Hydrology**_3. Consistency of hydrometeorological information Results of RLM) for the complementation of the hydrological series (Estación Carlosama, Pilcuan and San Pedro) and interpolation by surrounding stations for the meteorological series (137 selected stations). The methodologies implemented are described below. In **Annex 6. Hydrology_5. Flow series complemented,** The hydrological series are presented with no missing data for the periods of analysis.

- **Multiple Linear Regressions (Francisco, 2015).**

Multiple linear regression considers that there are p independent variables or repressors the RLM sets the following model:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_P X_P + \varepsilon$$

Equation 23

Accepting that you have *N* observations *Y, X_1, $X_2 X_P$*, The above expression in matrix notation will be

$$Y = X\beta + \varepsilon$$

Equation 24

Whose matrices are:

$$Y = \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix} X = \begin{bmatrix} 1 X_{11} X_{12} \dots Y_1 \\ 1 X_{21} X_{22} \dots Y_2 \\ \vdots \quad \vdots \quad \vdots \cdots \vdots \\ 1 X_{n1} X_{n2} \cdots Y_n \end{bmatrix} \beta = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_p \end{bmatrix} \varepsilon = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix}$$

Equation 25

In matrix X, X_{ij} Represents the i-th observation or datum in the j-th independent variable. The least squares method of the residuals establishes that the sum of the errors (ε_I) Squared must be minimized, ie:

$$\sum_{i=1}^{n} \varepsilon_i^2 = \sum_{i=1}^{n} \left(\gamma_i - \beta_0 - \beta_1 X_{i1} - \beta_2 X_{i2} - \cdots - \beta_p X_{ip} \right)^2$$

Equation 26

The difference of the right side of the above equation with respect to β_0, B_1, ..., β_P, Separately and equals zero, produces p equations with p unknown parameters, which are known as normal equations, their matrix notation is:

$$X^T \cdot X \cdot \beta = X^T \cdot Y$$

Equation 27

And whose solution is

$$\beta = (X^T \cdot X)^{-1} \cdot X^T \cdot Y$$

Equation 28

In the above equation, X^T Is the transposed matrix C and $(X^T * X)^{-1}$ Is the inverse matrix of $X^T * X$.

5.1.5.2.3 Generation of hydrometeorological information for modeling exercises.

The generation of hydrometeorological information for the modeling exercises in each of the hydrological units of analysis was performed from the selected meteorological stations (137) with which the monthly precipitation fields were generated for the period from January 1970 to December 2014 (528 Fields by variables) using Kriging interpolation methodology in the case of precipitation, and temperature - elevation regressions for the isotherms.

Subsequently, by means of zonal statistics and from the interpolated precipitation fields, the average monthly precipitation was estimated for each of the hydrological units of analysis, generating synthetic series of monthly precipitation throughout the registration period mentioned above (**Annex 6. Hydrology_5. Complementary flow series**).

- **Kriging Interpolation (Giraldo, 2011).**

Kriging interpolation is a local estimation technique that offers the best linear unbiased estimator. The limitation to the class of linear estimators is quite natural since this means that only the knowledge of the second-order moment of the random function (covariance or variogram)

- **Semivariogram.**

The semivariogram, also known as variogram, is the central tool of geostatistics. Given a regionalized variable *Z* (*X*) That fulfills the intrinsic hypothesis then there is the semivariate function and is defined as:

$$\boldsymbol{\gamma}_{(\boldsymbol{h})} = \frac{\sum\left(\boldsymbol{Z}(\boldsymbol{x}+\boldsymbol{h}) - \boldsymbol{Z}(\boldsymbol{x})\right)^2}{\boldsymbol{2n}}$$

Equation 29 Equation of the semivarigrama.

Where:

$Z(x)$	Variable in position x
$Z(x+h)$	Variable separated a distance h from x
Nyh	Number of couples that are separated by said distance.

The semivariogram is a function that relates the semivariance to the vector *H* Known as "lag", which denotes the separation in distance and direction of any Pair of values $Z(x) y Z(x+h)$.

- **General approach.**

Let Z (x) be a random function, which is defined in a point carrier and is stationary in the second order: The linear estimator Z_K Considered is a linear combination of n data values:

$$Z \quad (x_0) = \sum_{i=1}^{n} \lambda_i Z\,(x_i)$$

Equation 30

The **N** Coefficients of λi are calculated so that the estimator is unbiased and the variance of the estimate is minimal, then the estimator is said to be optimal. In order for the expected value of the error to equal zero, the following condition must be imposed:

$$E\left(\sum_{i=1}^{n} \lambda_i Z\,(x_i)\right) = m$$

Equation 31

That implies that:

$$\sum_{i=1}^{n} \lambda_i E\big(Z(x_i)\big) = m$$

Equation 32

The Kriging is equal to the expector of the estimator, the following condition guarantees that the variance of the estimate:

$$m \sum_{i=1}^{n} \lambda_i = m \Rightarrow \sum_{i=1}^{n} \lambda_i = 1$$

Equation 33

Therefore, the following function should be minimized:

$$\boldsymbol{F = \sigma_e^2 - 2\mu\left(\sum_{i=1}^{n} \lambda_i - 1\right)}$$

Equation 34

The first part of the equation represents the variance of the estimate, μ as Lagrange multiplier and the latter term guarantees the NO estimate bias. Solving the system of equations, the variance of the estimation error can be calculated in a simpler way if the value of μ is substituted, obtaining in this way:

$$\sigma_k^2 = \sum_{j=1}^{n} \lambda_j C_{1j} + \mu$$

Equation 35

In a matrix form, the Kriging system can replace the variances by the semi-weights:

$$\begin{bmatrix} 0 & \gamma_{12} \cdots \gamma_{1n} & 1 \\ \gamma_{21} & 0 \ \cdots \gamma_{2n} & 1 \\ \cdots & \cdots \ \cdots \ \cdots & \cdots \\ \gamma_{n1} & \gamma_{n2} \cdots \ 0 & 1 \\ 1 & 1 \ \cdots \ 1 & 0 \end{bmatrix} \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \cdots \\ \lambda_n \\ \mu \end{bmatrix} = \begin{bmatrix} \gamma_{k1} \\ \gamma_{k2} \\ \cdots \\ \gamma_{kn} \\ 1 \end{bmatrix}$$

Equation 36

The covariance matrix by the weights for each pair of points gives us the vector of semivariation. Finally, the variance of the estimate according to the matrix form is obtained as follows:

$$\sigma_k^2 = \sigma^2 - \sum_{i=1}^{n} \lambda_i C_{i0} - \mu$$

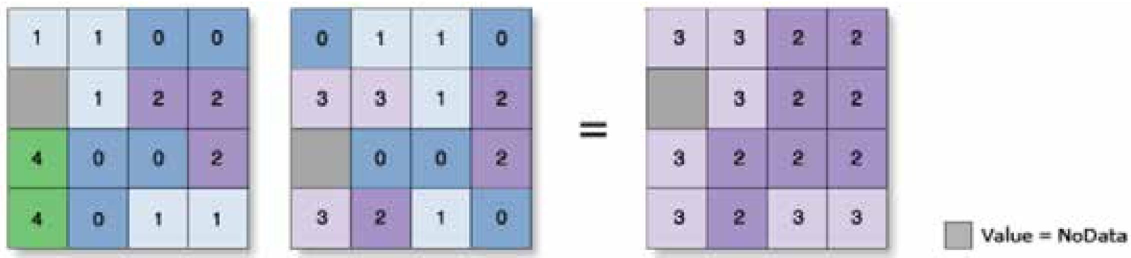
Equation 37

- **Zonal Statistics (Esri, 2017).**

The Zonal Statistics tool allows you to calculate the statistics for each zone defined by a zone dataset, based on the values of another dataset (a value raster). A simple output value is calculated for each zone in the input zone dataset.

An area is all cells in a raster that have the same value, whether or not they are contiguous. The input zone layer defines the shape, values, and locations of the zones. To define zones, you specify an integer field in the zone entry.

Figure 5.34 Scheme for the operation of zonal statistics in Arcgis software.



Source: (Esri, 2017)

The input value raster contains the input values that are used to calculate the output statistic for each zone. In the **Figure 5.34** Shows the layer Zone shows an input raster that defines the zones. The Value layer contains the entry for which the statistic is calculated per zone.

5.1.5.3 Estimation of hydrological series for UAH.

5.1.5.3.1 Modeling scheme.

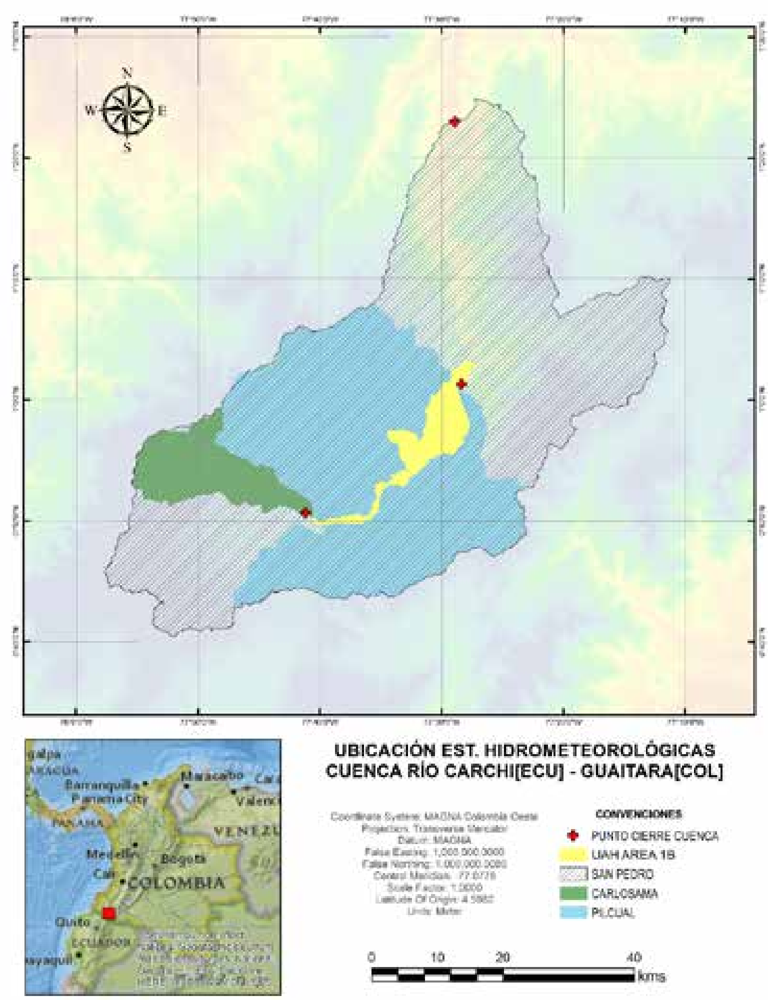
Due to the scarce hydrometric information in the study area that allowed to perform a characterization of the hydrological regime, for each of the units of analysis that compose the Guáitara River basin BN M, M, .-,, B, Parametric analysis.

As mentioned previously, the limited hydrometeorological information available makes it difficult to implement robust hydrological models, due to the input information required by them, such as multi-temporal coverage records, physical soil parameters, local climate characteristics, Many others; That although these variables can be estimated indirectly, the uncertainty associated with them is usually very high. In addition to this, the great majority of hydrological models present a considerable sum of parameterizations, which can have a physical interpretation or not, making it difficult to extrapolate the data to areas where there is no information (regionalization), without To forget also the associated uncertainty that this entails. On the other hand, there are hydrological models that meet the criteria of parsimony based on a simplification of the representation of the hydrological processes that occur in a basin at a certain scale, so that only a small number of parameters (Xu & Singh, 1996). In this way, hydrological information relevant to the management of water resources in watersheds with hydrometeorological information of low spatial and temporal resolution (Pande, Savenije, Bastidas, & Gosain, 2011) (Vargas, De la Fuente, & Arumí, 2012).

In this sense and in order to be able to characterize the hydrological regime of the best form in the units of analysis, it was chosen to construct models for those basins that have historical hydrological records (at least 11 years), these are the areas of drainage to The stations Carlosama, Pilcuan and San Pedro. The rainfall runoff model used obeys a uni-parametric simple agglutinated model in ordinary differential equations, whose only input variables are precipitation and runoff value as initial condition. In this way, parameters are obtained for the drainage areas containing the UAH of interest, and to carry out an analysis and regionalization of the parameters in the units of study (the model used is described later in more detail). In the **Figure 5.35** The hydrographic units included in the process of identifying the parameters of the rainfall runoff model are detailed.

Initially, hydrometric stations were identified with logging available along the Guáitara River (Carlosama Station, Pilcuan and San Pedro) and the afferent drainage area was delineated for each of them as presented in **Figure 5.35**.

Figure 5.35 Disposition of drainage areas selected for modeling and regionalization of parameters.



After the previous analysis of the meteorological information of the stations with available information (Supplementation of missing data and identification of atypical data), the precipitation fields were interpolated monthly with the 137 stations present in the study area and its surroundings , In the period from January 1970 to December 2014.

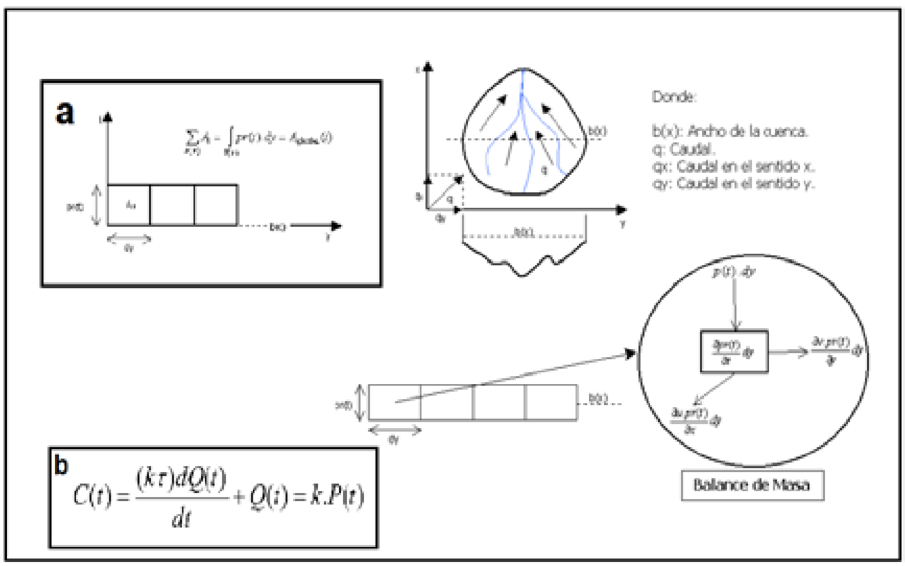
By means of zonal statistics and from the interpolated precipitation fields, the average monthly precipitation was estimated for each of the analysis units, thus generating monthly synthetic precipitation series throughout the interpolated record period mentioned above (**Annex 6. Hydrology_7. Synthetic precipitation series**).

Next, the evaluation of the simple agglutinated model for the Guáitara river basin was carried out at its three control points (Carlosama, Pilcuan and San Pedro stations). Calibrated and validated the model, we proceeded to perform the analysis for the regionalization of parameters and generation of synthetic flow series for the UAH present in the study area.

5.1.5.3.2 Model Rain - Runoff of Ordinary Differential Equations Simple Bonded.

The simple agglutinated model (**Figure 5.36**) Was proposed by Domínguez (2001) As an alternative for the construction of scenarios for the evaluation of susceptibility to climate change in areas where there is a low availability and quality of hydroclimatic information. The mathematical structure of this model is derived from the mass conservation equation in a two-dimensional flow through spatial weighting of the width of b (x) of the effective drainage area (**Figure 5.36**- to)

Figure 5.36 Descriptive scheme of the simple agglutinated model.



Source: (Domínguez, 2001).

The model is applied to each of the grid cells generated for the simulation domain. In each cell the parameters [t And k] and precipitation, from this information the runoff is estimated according to the mass balance.

The explicit structure of the simple agglutinated model proposed by Domínguez (2001) It is shown in **Equation 38.**

$$C(t) = \frac{(k\tau)dQ(t)}{dt} + Q(t) = k.P(t)$$

Equation 38 Explicit structure of the simple agglutinated model.

Where:

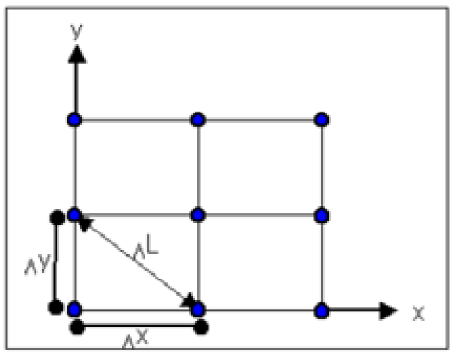
Q: Flow rate (m^3/ Sec)

P : Precipitation (m^3/ Sec)

T Concentration Time (Seconds)

K Coefficient of runoff (dimensionless)

Figure 5.37 Grid discretization specifications for modeling.



Source: (Domínguez, 2001)

The estimation of the concentration time (Parameter τ) Was performed using the methodology described in the number ☐For each of the grid cells.

The parameter identification κ Was determined by solving the model inversely for each of the grid points in which Precipitation, Runoff, Concentration Time and Time Interval are known, as shown below

$$k = \frac{E^{j+1}}{P^{j+1} - \frac{\tau}{\Delta t}(E^{j+1} - E^{j})}$$

Equation 39 Coefficient of runoff

Where:

K Coefficient of runoff. [Dimensional]

E j + 1 : Runoff in the time line j + 1. [Mm / month]

E j : Runoff in the time line j (initial condition). [Mm / month]

P j + 1 : Precipitation per unit of time in the time line j + 1. [Mm / month]

t : Concentration time. y

t Time interval . y

5.1.5.3.3 Performance metrics.

A performance metric is defined as a system of parameters, or quantitative evaluation methods, for something to be measured. The metrics define what is going to be measured, along with the processes that are used to carry out this measurement.(Teegavarapu & Elshorbagy, 2005).

The metrics implemented for the performance evaluation of the simple agglutinated model were RMSE, Pearson's coefficient and determination (R^2), The IRMSE and the SPHR which are described below.

- **Root Mean Square Error (RMSE).**

The root mean square error (RMSE) of an estimator measures the root mean square error, that is, the difference between the estimator and what is estimated. The RMSE is an error function, corresponding to the expected value of the error loss. The difference occurs because of the randomness or because the estimator does not take into account the information that could produce a more accurate estimate (Lehmann, EL, Casella, 1998).

$$\boldsymbol{RMSE} = \sqrt{\frac{\mathbf{1}}{\boldsymbol{n}}\sum_{\boldsymbol{i}=\mathbf{1}}^{\boldsymbol{n}}\left(\grave{\boldsymbol{X}}_{\boldsymbol{\iota}} - \boldsymbol{X}_{\boldsymbol{i}}\right)^{\mathbf{2}}}$$

Equation 40 Root of the mean square error.

Where:

$\grave{X}_\iota$ Observed value.

X_i Simulated value.

n Amount of data.

- **Inertia of the root mean square error.**

The inertia of the root mean square error (IRMSE) of an estimator measures the asymmetry of the average Of the root of the errors squared, that is to say, the centralization between difference between the estimator and what is estimated. The mathematical expression of this metric is presented below.

$$Si\grave{X} = \frac{1}{n}\sum_{i=1}^{n} X_i\, entonces \sigma_X = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(X_i - \grave{X}_\iota\right)^2}$$

Equation 41

$$IRMSE = \frac{RMSE}{\sigma_X}$$

Equation 42

· **Criteria for the Russian Hydrological Forecasting Service.**

The Russian Hydrological Forecasting Service (SPHR) criterion calculates the average forecast error for 70% of hits. This metric allows to evaluate the effectiveness of the forecast, there is no upper limit and its value, for a perfect model, is zero.

· **Coefficient of determination (R^2).**

The coefficient of determination makes an estimate of the quality of prediction that a model can present to best replicate the results of a simulation, and the proportion of variation generated, product of the results that can be explained by the model. (Teegavarapu & Elshorbagy, 2005).

$$r_{xy} = \left[\frac{\sigma_{xy}}{\sigma_x \sigma_y}\right]^2 = \left[\frac{E[(X-\mu_x)(Y-\mu_y)]}{\sigma_x \sigma_y}\right]^2$$

Equation 43 Coefficient of determination.

Where:

σ_{xy} Covariance of observed and simulated value.

σ_x Standard deviation of observed value.

σ_y Standard deviation of the simulated value.

5.1.5.3.4 Identification of Parameters (parameterization of the model).

The recording period of hydrometeorological information considered for calibration of the Río Guitara watershed in its three closing stations is presented in the **Table 5.46**.

Table 5.46 Parities of time considered for simple agglutinated model calibration.

Code	STATION	Initial Date	Final Date
52057050	PILCUAN	January 15	December 2014
52057010	Carlosama	January 15	December 2014
52057040	San Pedro	Enerp-1970	December 2014

The consideration of the entire hydrometeorological record for the calibration, without the exclusion of any fraction for the calibration of said model. It was mainly due to the fact that it is not intended to function in forecasting or operational mode, so that it is necessary to evaluate its performance with data different from those of calibration. If not, on the other hand, it would allow an estimation of the hydrological regime in the selected units of analysis, which did not have information available within them.

The calibration of the runoff coefficient was performed directly as presented in the model description above, so it was not necessary to implement any algorithm or optimization methodology to estimate the same. The three performance metrics described above whose results are presented in the **Table 5.47**.

Table 5.47 Results of the performance metrics evaluated by the calibration of the simple agglutinated model.

Code	STATION	RMSE [mm]	RMSE [%]	IRMSE	R2;	% Hit
52057010	PILCUAN	25,96	30,03	0,75	0,48	0,28
52057040	Carlosama	11,27	26,31	0,61	0,72	0,28
52057050	San Pedro	11,16	24,60	0,69	0,68	0,26

For the Río Guáitara drainage areas in the Carlosama and San Pedro closure stations, a better performance was obtained than for the closure at the Pilcuan station, however, in general, the calibrations performed were good, taking into account the parsimony of the model implemented the Which only presents a single parameterization. In this sense, the parameters estimated for the Rio Guáitara basin in its three seasons of closure, is presented in the **Table 5.48**.

Table 5.48 Calibrated parameters of the simple agglutinated model for the Guáitara river basin at its three closing points.

Code	STATION	K	TA	Area (km2)
52057010	PILCUAN	0,36	1,68	1040,97
52057040	Carlosama	0,22	2,14	210,33
52057050	San Pedro	0,19	3,12	3202,85

In the **Figure 5.38** to **Figure 5.40** We present the performance in the flow series observed and estimated by the simple agglutinated model for the three drainage areas evaluated, as well as the comparative dispersion diagram and the percentage of hits by the evaluated model.

Figure 5.38 Results of the calibration process of the model Agglutinated in Ordinary Differential Equations (EDO) at the Carlosama station [52057040]

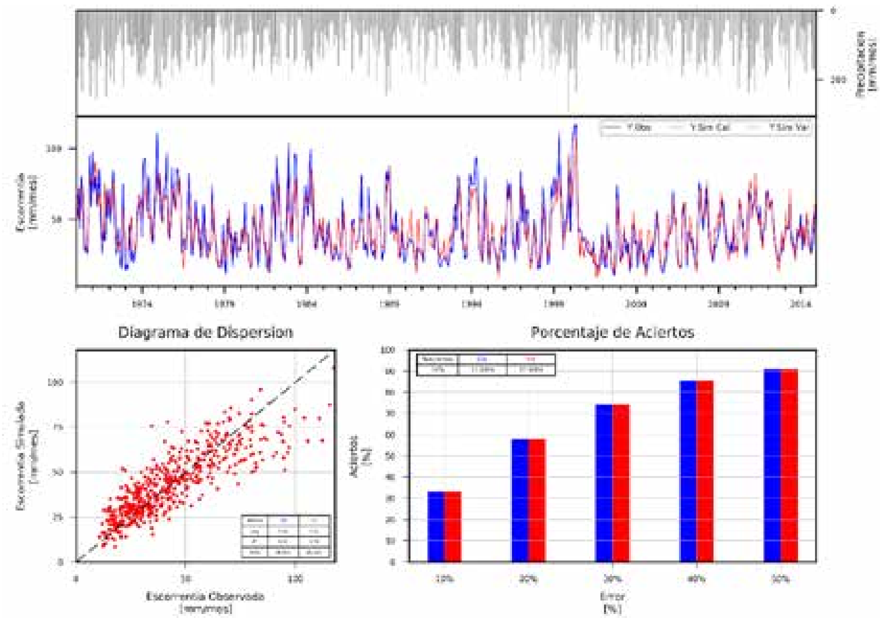


Figure 5.39 Results of the Calibration Process of the Bonded Model in Ordinary Differential Equations (ODE) at the Pilcuan Station [52057010].

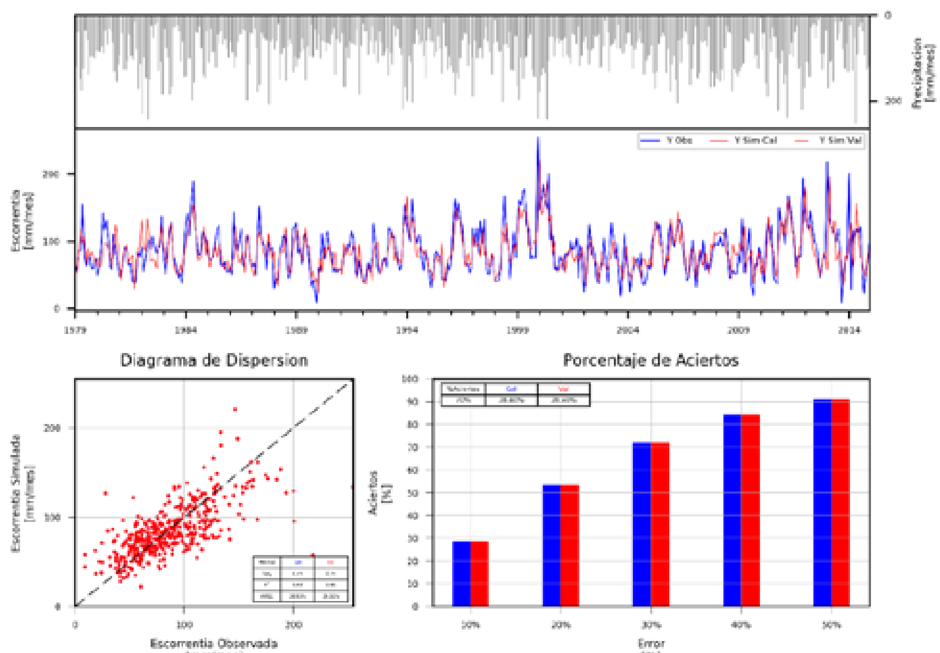
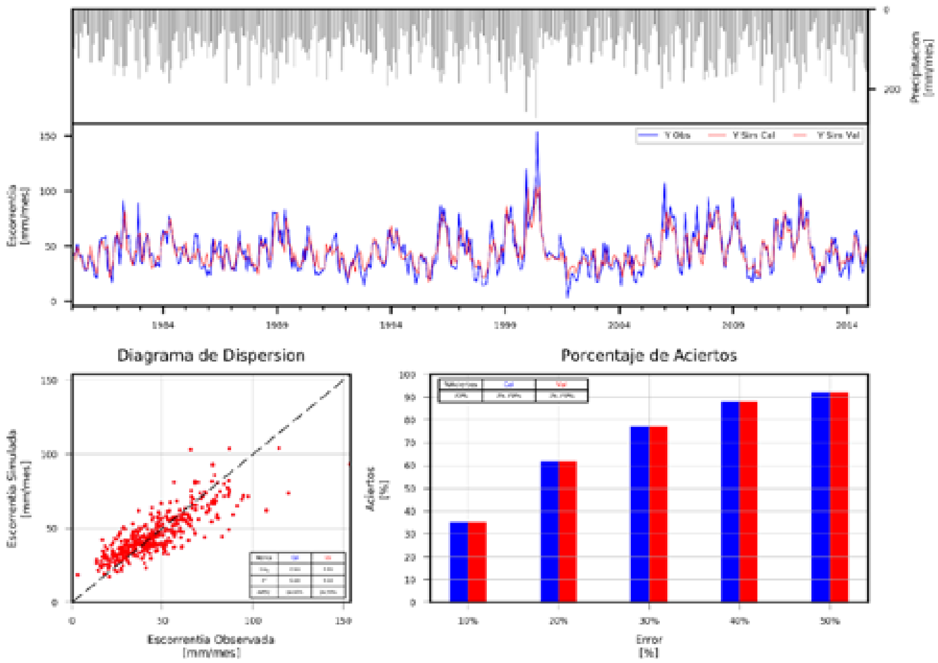


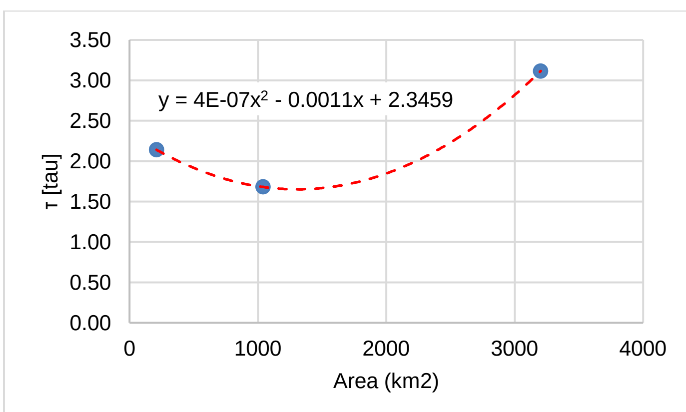
Figure 5.40 Results of the calibration process of the Agglutinated model in Ordinary Differential Equations (ODE) at San Pedro Station [52057050].



5.1.5.3.5 Regionalization of parameters.

Subsequent to the calibration of the simple agglutinated model for the three drainage areas, the parameters were distributed in each of the selected analysis units in order to estimate the synthetic flow series.

Figure 5. Tao parameter estimation curve as a function of area.



The tao parameter was distributed in relation to the afferent area of each of the analysis units. For this, an adjustment of the parameter tao obtained in the three basins evaluated was performed. In relation to the runoff coefficient the distribution was taken taking into account the hydrological condition (Precipitation) of each one. The parameters assigned to each unit of analysis are presented in the **Table 5.49**.

Table 5.49 Parameters of the simple agglutinated model for the stations Hydrographic Analysis Units for the area AI-EIA-1B.

UAH	K	TA	Area (km2)
Macal Stream	0,36	2,34	7,90
San Francisco Rural District	0,36	2,34	3,66
Home	0,36	2,33	14,80
Brigada Stream	0,36	2,34	0,87
La María Creek	0,36	2,34	2,04
The Culantro Gorge	0,36	2,34	2,35
Honda Breaks	0,36	2,34	2,03
San Francisco Stream	0,36	2,34	2,62
Moledores Stream	0,36	2,34	8,89
El Tablón Stream	0,36	2,34	1,88
Black Chorrera Ditch	0,36	2,35	0,49
Yamurayán Stream	0,36	2,34	2,04
Black Chorrera Gorge	0,36	2,33	15,10
Black Chorrera Gap	0,36	2,34	1,56
MD affluents - Sapuyes River 01	0,36	2,34	1,61
Influences MI - Sapuyes River	0,36	2,34	2,66
Direct tributaries MD - Rio Boquerón	0,36	2,33	16,04
Direct tributaries MI - Rio Guáitara 01	0,36	2,34	1,02
Direct tributaries MI - Rio Guáitara 17	0,36	2,34	2,59
Direct tributaries MI - Rio Guáitara 15	0,36	2,34	1,65
Direct tributaries MI - Rio Guáitara 16	0,36	2,35	0,47
Direct tributaries MI - Rio Guáitara 14	0,36	2,35	0,35
Direct tributaries Río Carchi - Río Guáitara 07	0,36	2,34	2,13
Direct tributaries Río Carchi - Río Guáitara 08	0,36	2,34	1,33
Direct tributaries MI - Rio Guáitara 02	0,36	2,35	0,76
Direct tributaries MI - Rio Guáitara 03	0,36	2,35	0,27
Direct tributaries MI - Rio Guáitara 11	0,36	2,34	1,26
Direct tributaries MI - Rio Guáitara 05	0,36	2,34	2,53
Direct tributaries MI - Rio Guáitara 06	0,36	2,34	2,61
Direct tributaries MI - Rio Guáitara 07	0,36	2,34	1,20
Direct tributaries MI - Rio Guáitara 08	0,36	2,34	0,84
Direct tributaries MI - Rio Guáitara 09	0,36	2,34	1,32
Direct tributaries MI - Rio Guáitara 10	0,36	2,35	0,15
Direct tributaries MI - Rio Guáitara 12	0,36	2,35	0,42
Direct tributaries MI - Rio Guáitara 13	0,36	2,35	0,12
MD - Río Sapuyes 03 tributaries	0,36	2,35	0,55
MD - Sapuyes River 02 tributaries	0,36	2,35	0,31
Manzano Stream	0,36	2,34	0,99
Direct tributaries MI - Rio Guáitara 04	0,36	2,35	0,63
Zanjón La Lechuza	0,36	2,35	0,77
Qda. Anchovy	0,36	2,13	216,03
Sapuyes River	0,36	1,88	520,17

5.1.5.3.6 SIMULATION

- **Determination of the initial condition by long-term balance approach.**

Once the parameters were identified in each of the analysis units, the estimation of the synthetic flow series for each of the units of analysis was carried out. As mentioned, there are no historical records of flows in these units, which allow to establish the initial condition for the operation of the model. Therefore, a long-term multi-annual monthly water balance was developed for all units of analysis using the mass conservation equation for estimating the initial runoff value in each UAH, as follows:

$$E = P - ET$$

Equation 44 Mass conservation equation.

Where:

E : Runoff (mm / month)

P : precipitation (mm/year)

TL) Potential evapotranspiration (mm / month)

The meteorological stations were identified with temperature registers inside the units of analysis, as well as their surroundings. Prior to the analysis of consistency of the information (complementation of missing data and identification of atypical data), temperature fields (isotherms) were generated and by means of zonal statistics the monthly average multi-annual temperature was obtained for each of the analyzed analyzes. However, for the present analysis the adjustment by solar brightness was not considered, since this only influences the estimation of the initial condition of the simulation process (see **Annex 6. Hydrology_8. Input Parameters and Variables**).

The methodology proposed by Thorthwaite (Thornthwaite, 1948) Was applied for the estimation of potential monthly evapotranspiration for each of the selected analysis units. From this and the estimated precipitation the long-term water balance was performed for all units of analysis. Finally, the runoff corresponding to the month of January was selected as the initial condition since the simulation period is between January 1970 and December 2014.

- *Potential Evapotranspiration*

It is an empirical temperature model which was developed based on temperature measurements and its correlation with lime meters and soil water balances in small basins in the United States. The method has restrictions in its use for arid zones, since it does not take into account the net radiation, an important factor in the phenomenon of evapotranspiration (Thornthwaite, 1948).

$$\boldsymbol{ET_m = 1.6\left[\frac{10 * T_i}{j}\right]^a}$$

Equation 45 Monthly Evapotranspiration Thorthwaite

Where,

ET_M Is the potential evapotranspiration in mm day^{-1}

T_I Is the average monthly air temperature in ° C

J Is the annual heat index $j_i = \sum_{i=1}^{12} \left(\frac{T_i}{5}\right)^{1.514}$

to Is the exponent in terms of J

$$a = 675x10^{-9} \cdot j^3 - 77x10^{-7} \cdot j^2 + 179x10^{-4} \cdot j + 0.492$$

Equation 46 Exponent based on j.

5.1.5.4 Characterization of the hydrological regime.

From the series generated by the simple agglutinated model for each of the hydrological units of analysis for the **Area AI-EIA-1B**. Characterization of the hydrological regime of the same. Similar to the precipitation series, the flow series generated were statistically described by the probability density functions as described above.

The characteristic flow rates for the hydrological regime in dry and wet periods were considered as corresponding to the 5 and 95% quantiles respectively for each month, whereas for a normal condition the mathematical expectation was taken. In all three cases the estimation was made from the probability density functions. The description of the monthly hydrological regime for each of the units of analysis is presented in the **Annex 6. Hidrología_ 9_10**. The methodologies used are presented below.

5.1.5.4.1 Probabilistic characterization.

For the present study a general statistical description was carried out using probability density functions and the estimation of their respective moments for the hydroclimatological flow series. The results are presented in the **Annex 6. Hidrología_ 9_10**.

- **Adjustment of probability density functions (PDF).**

A probability distribution is a function that represents the probability of occurrence of a random variable. By fitting a distribution of a hydrological dataset, a large amount of probabilistic information in the sample can be summarized in compact form in the function Y In its associated parameters (Ven Te Chow, Maidment, & Mays, 1994).

Each of the precipitation and flow signals were characterized by a monthly density probability function. It was done in this way, since when a variable is described with this dress, it must meet the hypotheses of a random quantity which states that:

A random magnitude is one that, when measured, always in the same conditions, with the same methods and instruments, yields values that differ from one another (Dominguez C, 2016a). Based on this principle, the proposed hypothesis considers that the energy, atmospheric and other conditions that govern the hydrological cycle at monthly level are similar in each month over the years.

Table 5.50 Probability density functions evaluated.

PD	EQUATION
Normal	$P(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-(x-\grave{x})}{2\sigma^2}}$
Normal Log	$P(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{x-\grave{x}}$
Exponential	$P(x) = \lambda e^{-\lambda x} \forall x \geq 0$
Gamma	$P(x) = \frac{\lambda^2 x^{(a-1)} e^{-\lambda x}}{\Gamma(a)}$
Loggamma	$P(x) = e^{\frac{-(cx-e^x)}{\Gamma(c)}} parax, c > 0$
Weibull min	$P(x) = CX^{(c-1)} e^{(-x^c)}$
Weibull max	$P(x) = C(-x)^{(c-1)} e^{(-(-x)^c)}$
Nakagami	$P(x) = \frac{2 * N^N}{\Gamma(N) x^{2*N-1} e^{-Nx^2}} parax > 0, N > 0$
Gumbel R	$P(x) = e^{-(x+e^{-x})}$
Genextreme	$P(x) = \frac{e^{(-e^{-x})}}{e^{-x}} parac = 0 P(x) = (1-cx)^{\frac{1}{(c-1)}} e^{-(1-cx)^{\frac{1}{c}}} parax \leq \frac{1}{c}, c > 0$
Power Law	$P(x) = a * x^{(a-1)} 0 \leq x \leq 1, a > 0$
Beta	$P(x) = \frac{\Gamma(a+b) * x^{(a-1)} (1-x)^{(b-1)}}{\Gamma(a)\Gamma(b)} 0 < x < 1, a > 0, b > 0$

Source: (Monsalve, 1995).

Some of the equations of the PDFs that were evaluated in the present study are presented in the Table 5.50, However if the reader wishes more information can refer to the reference of (Chow, 1994). The empirical frequency was performed by the equation proposed by Weibull as described Domínguez C (2016b)

The selection of the best fit was done using the mean squared error metrics where it was less than 20% and the Kolmogorov-Smirnov test was valid with a significance level of 95%.

- **Flow Regime (1st Moment).**

The statistical moments of a random magnitude are a set of quantitative characteristics that serve to describe it. This set is composed of statistical moments of order K | *k Eur-lex.europa.eu eur-lex.europa.eu {1, 2, ..., n}*. To have the collection of statistical moments up to the moment of order n with n → ∞ is equivalent to having the Probability Density Curve (CDP) p (x) or its equivalent distribution function F (x) (Dominguez C, 2016b). Next, the equation for its estimation is presented.

$$m_k = \sum_{i=i}^{n} x_i^k P_i$$

Equation 47 Moments to the origin

$$\mu_k = \sum_{i=i}^{n} (x_i - m_1)^k P_i$$

Equation 48 Central moments.

Where:

K Order of the moment $k \in 1,2, \dots, \infty$

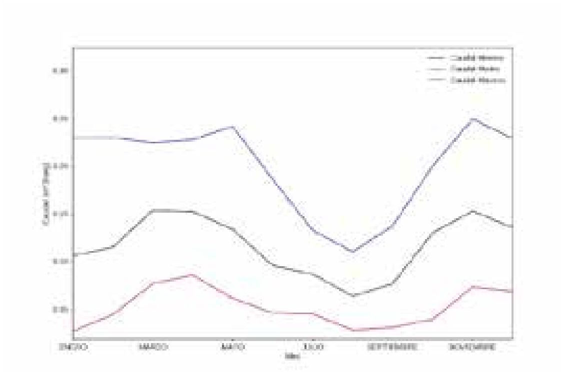
N Observed numbers of random magnitude

The analyzed hydroclimatological signals were characterized until the fourth moment, after their respective adjustment to a probability density function. The results of the adjustments are presented in the **Annex 6. Hidrología_ 9_10. Probability density functions for flow**.

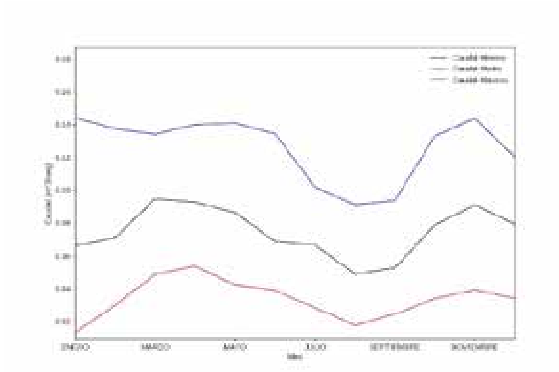
5.1.5.4.2 Minimum Flows, Means and Maxima from probabilistic characterization (probability density curves).

In all the monthly multi-year series of flow and precipitation, it is observed that they have a behavior of two maxima, between March and April for the first semester, and October and November for the second semester being greater than the first, as is Characteristics in the Colombian Andes as reported by Bedoya et al. (2010), In addition a period of drought between July and August is observed. In the **Figure 5.46** The distribution of the multi-annual monthly flow regime for the El chorro stream is presented. The regimes of the remaining units are presented below.

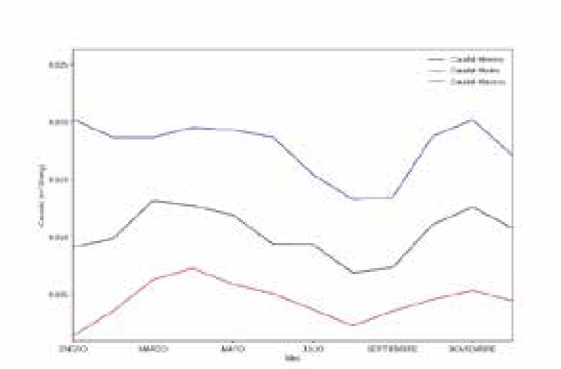
Figure 5.41 Characterization of hydrological regimes for minimum conditions [Q95], mathematical expectation (mean flow) and maximum [Q5].



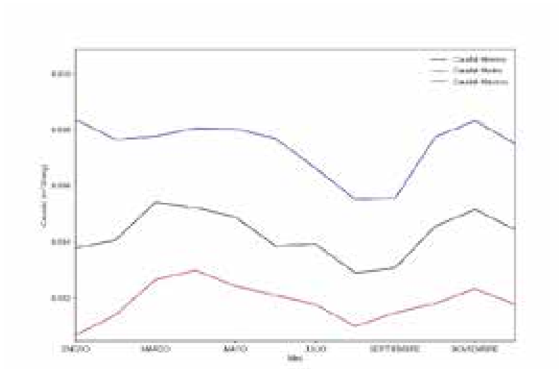
UAH Direct tributaries MI - Rio Guáitara 01



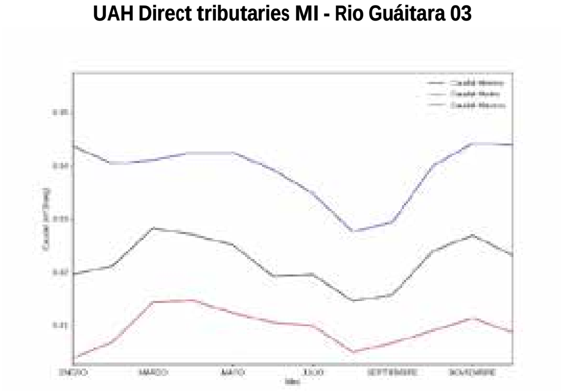
UAH Direct tributaries MI - Rio Guáitara 02



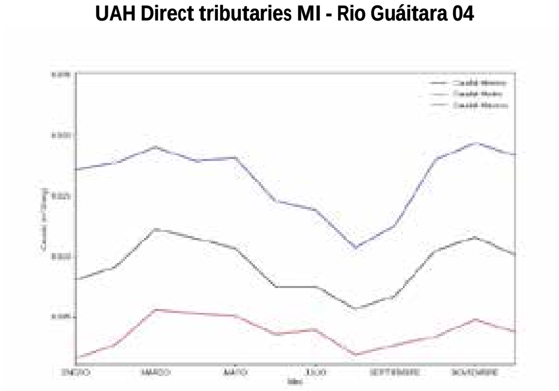
UAH Direct tributaries MI - Rio Guáitara 03



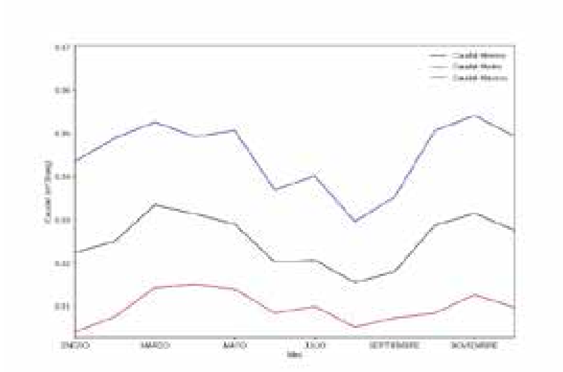
UAH Direct tributaries MI - Rio Guáitara 04



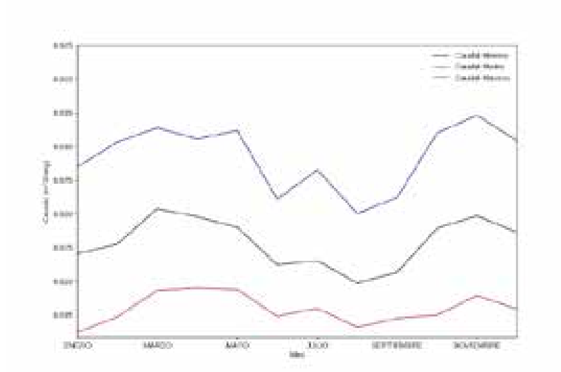
UAH Direct tributaries MI - Rio Guáitara 05



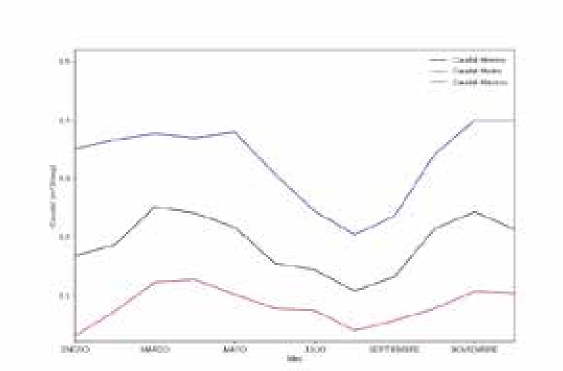
UAH Direct tributaries MI - Rio Guáitara 06



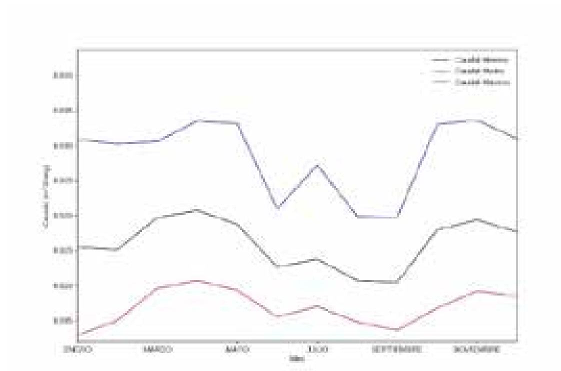
UAH Direct tributaries MI - Rio Guáitara 07



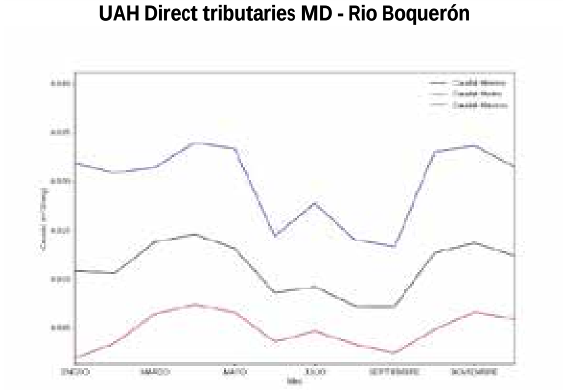
UAH Direct tributaries MI - Rio Guáitara 08



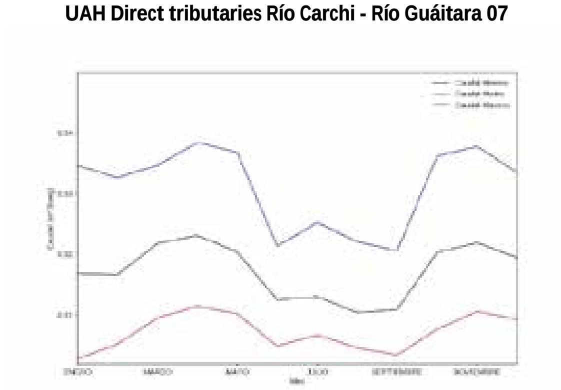
UAH Direct tributaries MD - Rio Boquerón



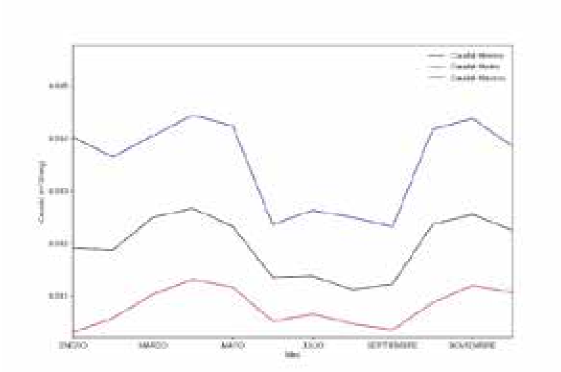
UAH Direct tributaries Río Carchi - Río Guáitara 07



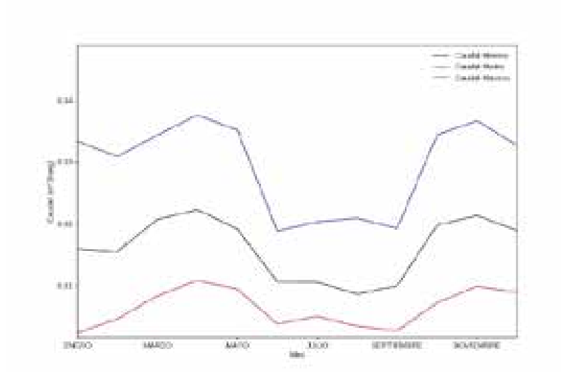
UAH Direct tributaries Río Carchi - Río Guáitara 08



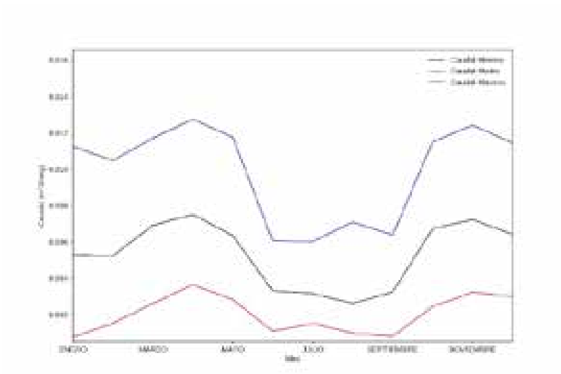
UAH Direct tributaries MI - Rio Guáitara 09



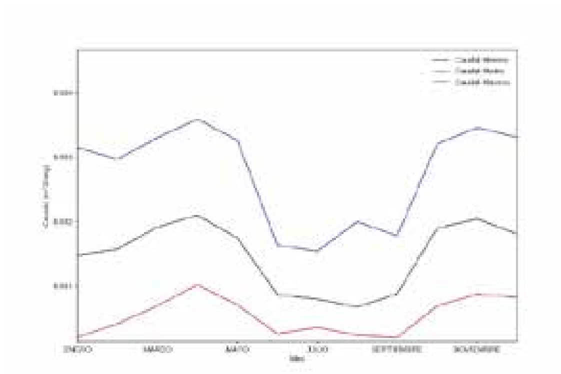
UAH Direct tributaries MI - Rio Guáitara 10



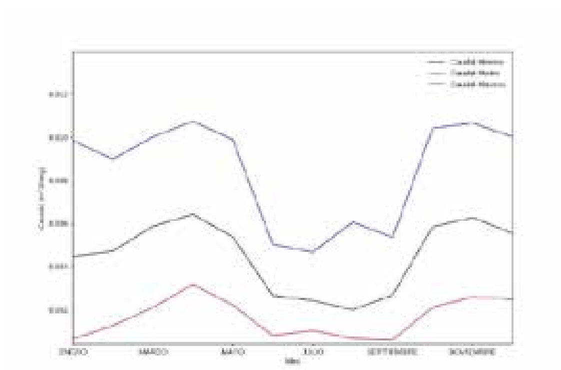
UAH Direct tributaries MI - Rio Guáitara 11



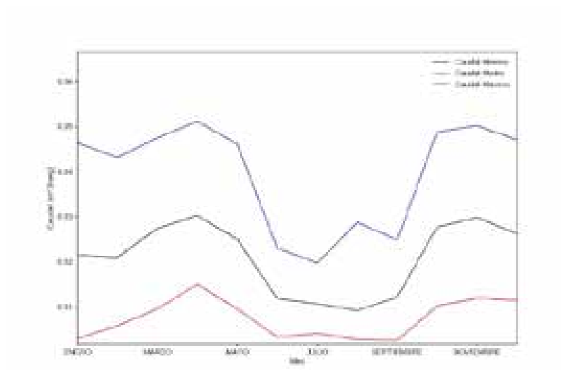
UAH Direct tributaries MI - Rio Guáitara 12



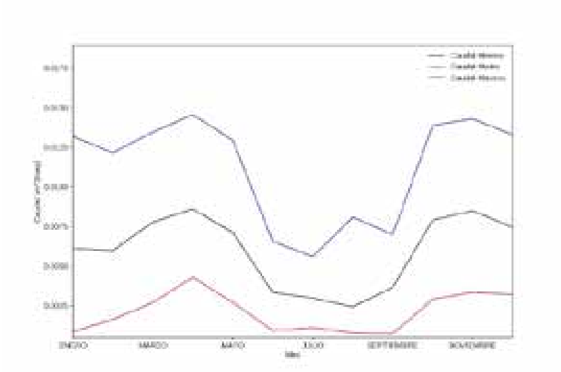
UAH Direct tributaries MI - Rio Guáitara 13



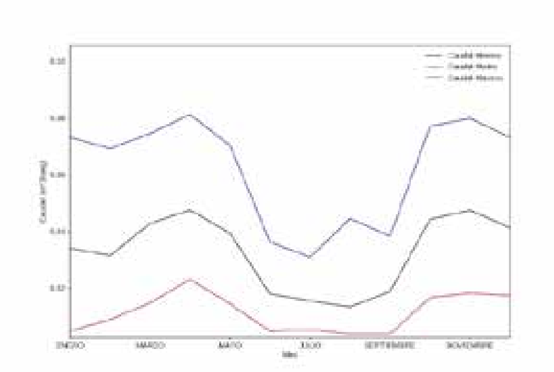
UAH Direct tributaries MI - Rio Guáitara 14



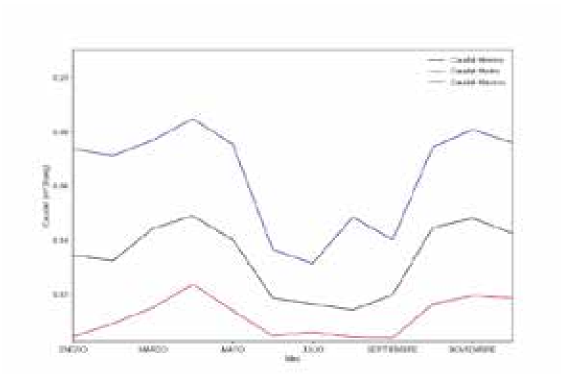
UAH Direct tributaries MI - Rio Guáitara 15



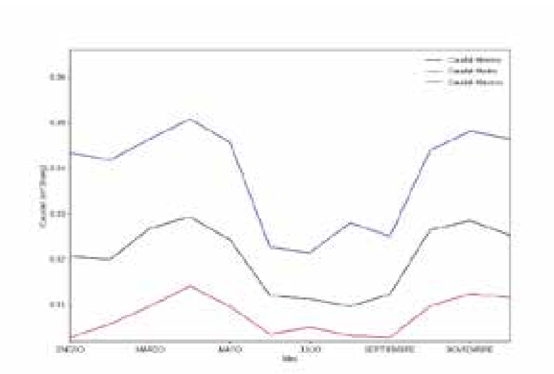
UAH Direct tributaries MI - Rio Guáitara 16



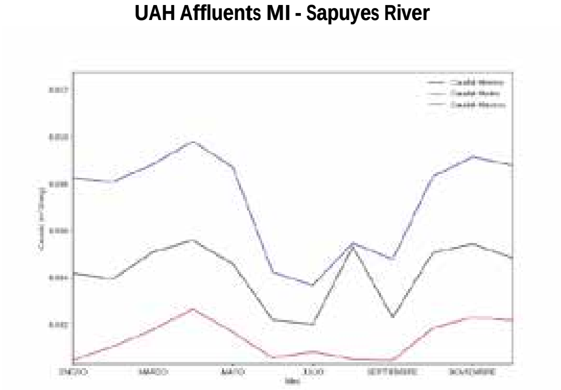
UAH Direct tributaries MI - Rio Guáitara 17



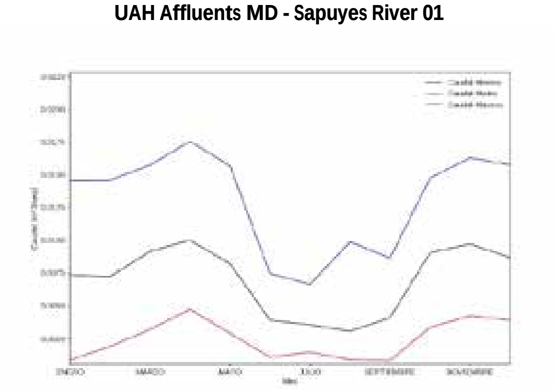
UAH Affluents MI - Sapuyes River



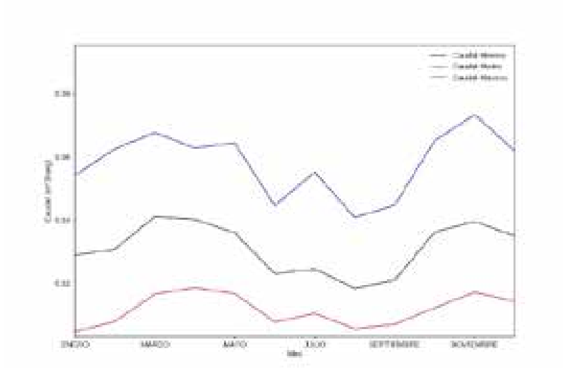
UAH Affluents MD - Sapuyes River 01



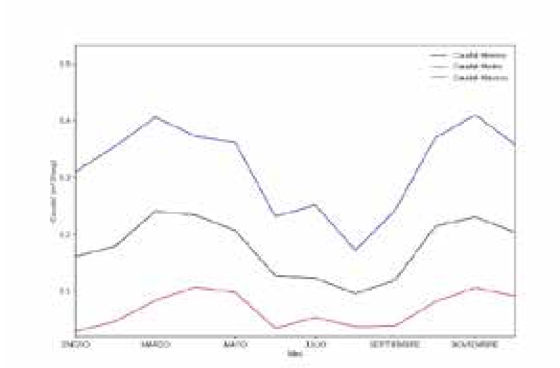
UAH Affluents MD - Sapuyes River 02



UAH Affluents MD - Sapuyes River 03



UAH Qda San Francisco



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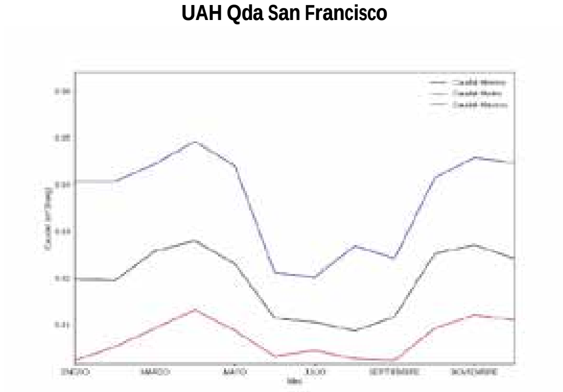

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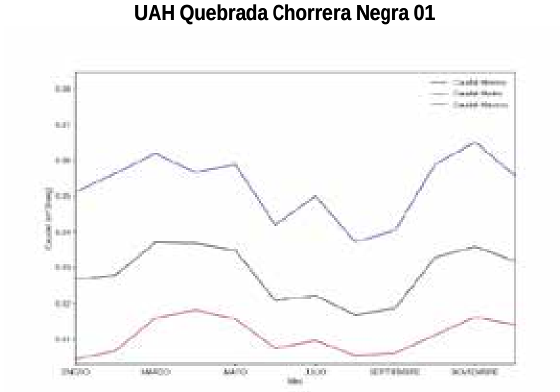

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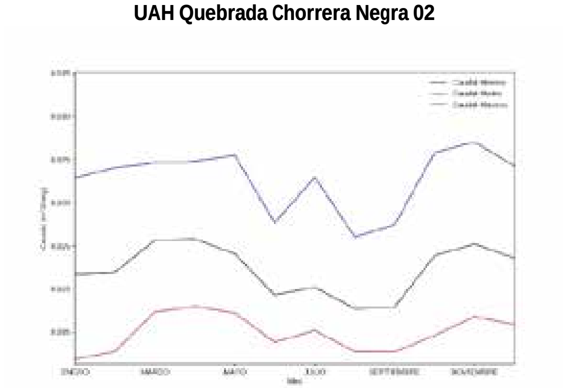
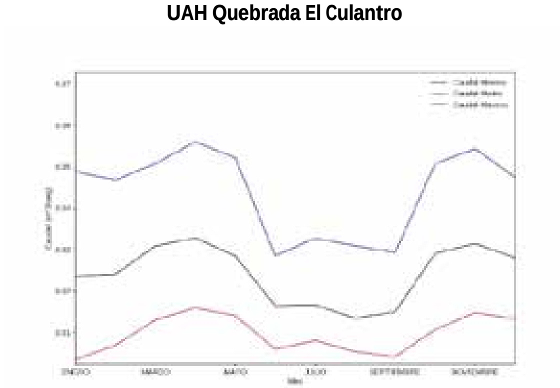
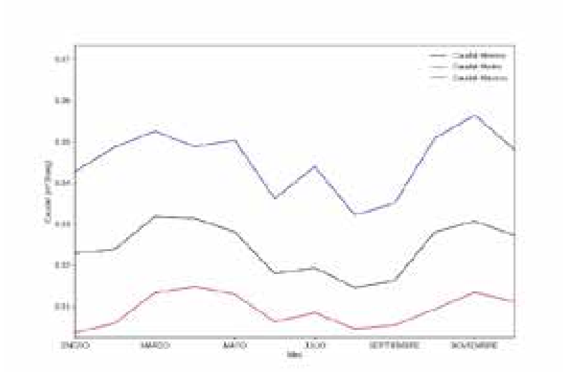


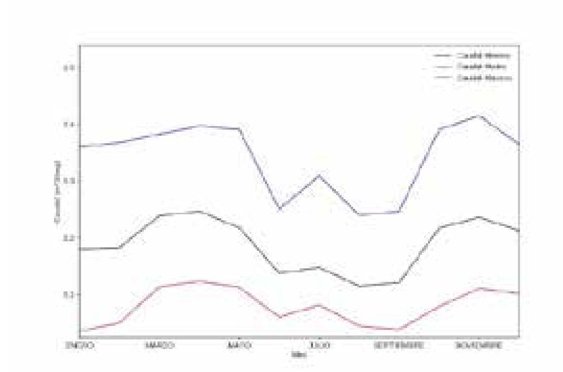
UAH Quebrada El Manzano



El Tablón Stream



UAH Quebradas Honda



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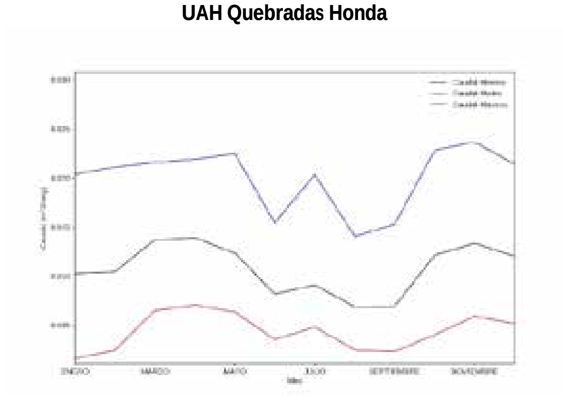
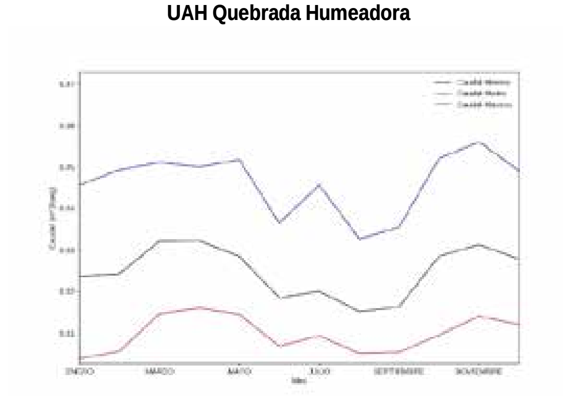


UAH Quebrada La Brigada



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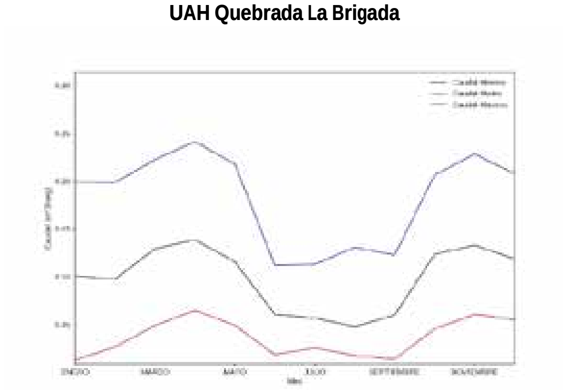
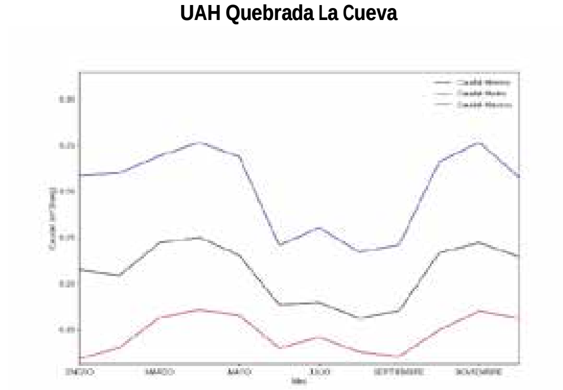
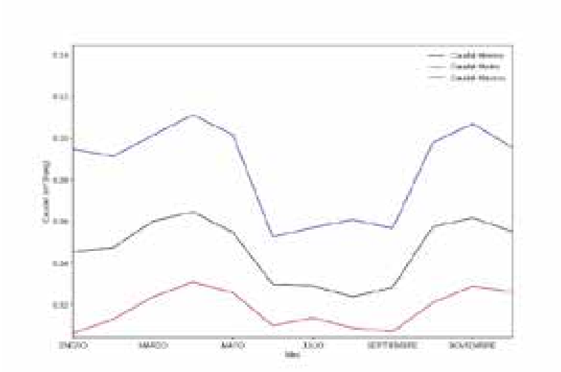


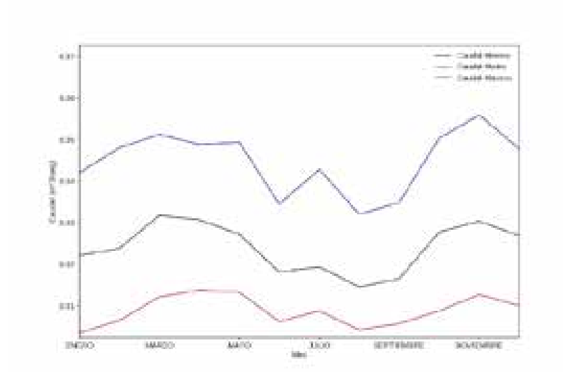
UAH Quebrada El Macal



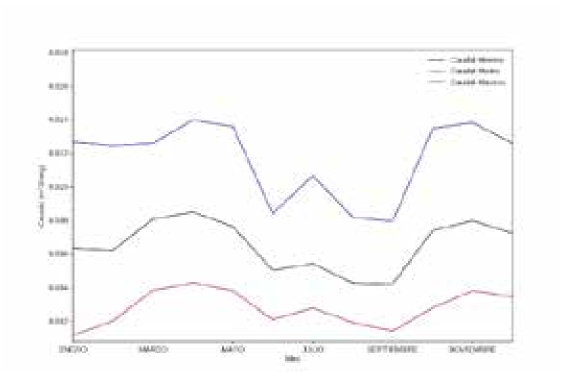
Moledores Stream



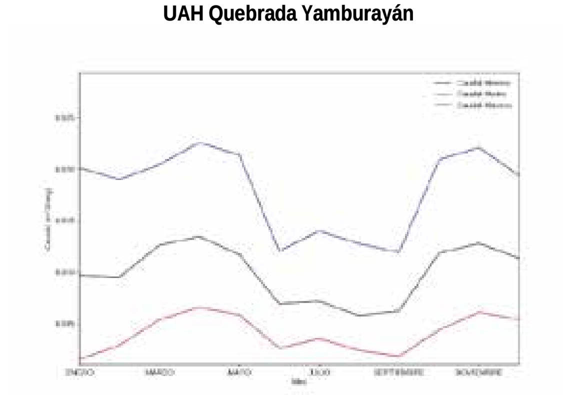
San Francisco Stream



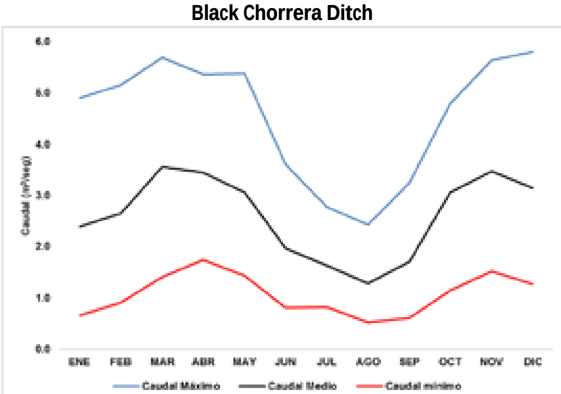
UAH Quebrada Yamburayán



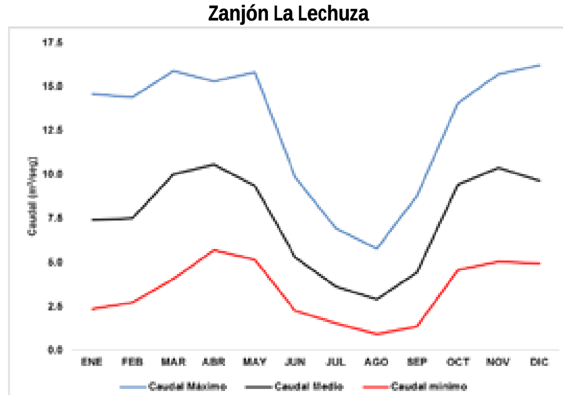
Black Chorrera Ditch



Zanjón La Lechuza



Quebrada Boquerón



Sapuyes River

This behavior of maxima is due to a greater extent to the southern migration of the Intertropical Convergence Zone (ITCZ), which is one of the preponderant mechanisms to explain the annual and semi-annual variability of precipitation in Colombia. The bi-modality or uni-modality of the distribution of precipitation and flow in the annual cycle is associated with the greater convective activity associated with the passage of the ITCZ by the Colombian geography, as well as its interaction with the circulations of the Oceans Pacific, Atlantic and the Amazon Basin. On the other hand, the spatial distribution of rainfall on Colombia is associated with the time of the year, when the ITCZ is more to the south (in the summer of the southern hemisphere), the zone of the caribbean coast presents a decrease in the rains and Vice versa for the southern zone during the summer of the northern hemisphere (July - August). Between these extremes of the calendar, the ITCT passes twice over Colombian territory, on its way south in the October-November period and to the north in the April-May period, producing the most rainy seasons in the Center of Colombia (Velez, Poveda, & Mesa, 2000). In relation to the flow rates, a behavior was also observed in the periods of dry season and of higher humidity with precipitation as observed in the signals.

In the **Table 5.51** to **Table 5.53** The monthly multi-annual characteristic flows for each unit of the AI-EIA-1B area of influence are presented.

Table 5.51 Consolidated of the minimum flow values for each unit of the AI-EIA-1B area of influence.

UAH	MINIMUM FLOWS [LPS]												
	JAN	FEB	MAR	APR	MAY	Jun	JUL	Aug	Sep	Oct	Nov	DEC	YEARLY
1	13,1	26,7	49,1	64,9	49,5	18,6	25,8	17,8	13,9	45,8	60,8	55,2	36,8
2	6,3	13,0	23,8	30,8	25,8	10,0	13,8	8,8	7,1	21,0	28,8	26,2	17,9
3	35,0	49,9	113,0	122,9	112,3	60,0	81,6	44,2	37,9	78,7	110,6	101,4	79,0
4	1,6	2,5	6,5	7,1	6,4	3,6	4,8	2,5	2,4	4,1	5,9	5,2	4,4
5	3,8	5,6	14,6	16,0	14,5	6,8	9,3	5,1	5,4	9,5	14,1	12,0	9,7
6	4,4	6,7	15,9	18,1	15,6	7,4	9,6	5,4	6,1	11,2	16,1	13,9	10,9
7	3,6	5,9	13,3	14,8	12,9	6,3	8,4	4,6	5,5	9,3	13,4	11,1	9,1
8	4,6	8,0	16,6	18,6	16,8	7,8	10,5	5,6	7,1	12,2	17,2	14,3	11,6
15	18,5	30,3	63,0	71,4	65,5	29,9	41,7	25,8	20,8	49,6	70,1	62,5	45,8
16	3,5	6,9	13,0	15,9	14,1	6,0	8,1	5,4	4,2	10,7	14,8	13,3	9,7
17	1,1	2,0	3,8	4,3	3,8	2,1	2,8	1,9	1,4	2,8	3,8	3,4	2,8
18	3,5	6,5	12,1	13,8	13,3	6,2	8,8	4,2	5,7	8,8	12,7	10,1	8,8
20	28,0	46,0	82,8	106,1	97,0	33,9	53,0	36,6	37,9	80,4	105,2	90,5	66,4
21	2,4	5,3	9,2	13,2	8,8	3,3	4,6	2,8	2,4	9,3	12,1	11,1	7,0
23	2,7	5,7	9,6	14,0	9,5	3,4	5,0	3,1	2,7	9,6	12,3	11,5	7,4
24	4,5	9,4	15,2	23,7	14,2	4,8	6,2	4,4	4,0	16,5	19,6	18,7	11,8
25	31,0	73,3	122,4	127,0	101,8	78,1	74,4	40,1	57,3	78,0	107,3	103,9	82,9
26	1,8	3,3	6,5	7,0	6,7	3,5	4,7	2,1	3,0	3,7	6,1	4,5	4,4
27	4,7	8,8	14,7	23,0	14,4	4,7	5,3	3,7	3,7	16,6	18,2	17,3	11,3
28	3,0	5,8	9,6	15,0	9,5	3,3	4,1	2,8	2,6	10,2	11,9	11,5	7,4
29	0,8	1,6	2,7	4,3	2,7	0,9	1,1	0,8	0,7	2,9	3,3	3,2	2,1
30	0,6	1,3	2,1	3,2	2,2	0,8	1,0	0,7	0,6	2,1	2,6	2,5	1,6
31	4,0	7,6	14,3	15,1	14,0	8,4	10,0	5,2	7,3	8,4	12,7	9,7	9,7
36	2,4	4,7	8,6	9,0	8,8	4,8	6,0	3,2	4,5	5,0	7,9	5,9	5,9
37	1,3	2,2	4,8	5,2	5,0	2,5	3,6	1,8	2,2	2,7	4,7	3,4	3,3
38	0,5	0,7	1,8	1,9	1,8	0,9	1,3	0,7	0,8	1,0	1,7	1,3	1,2
39	2,4	4,6	8,3	10,8	9,4	3,8	5,0	3,4	2,7	7,2	9,9	8,9	6,4
40	5,2	8,4	19,7	21,8	19,0	12,7	15,0	8,7	7,3	12,2	17,3	15,1	13,5
41	5,9	10,3	21,6	23,5	19,2	13,5	15,9	10,3	7,8	13,6	18,7	17,4	14,8
42	2,9	5,0	9,6	10,7	9,3	5,5	7,0	4,8	3,6	6,7	9,2	8,4	6,9
43	1,9	3,5	6,4	7,4	6,6	3,6	4,7	3,3	2,4	4,8	6,6	5,9	4,8
44	2,8	5,2	9,5	11,4	10,2	4,9	6,7	4,5	3,4	7,7	10,5	9,2	7,2
45	0,3	0,6	1,0	1,3	1,2	0,5	0,7	0,5	0,4	0,9	1,2	1,1	0,8
46	0,7	1,5	2,6	3,6	2,8	1,1	1,5	1,0	0,8	2,4	3,2	3,0	2,0
47	0,2	0,4	0,7	1,0	0,7	0,3	0,4	0,2	0,2	0,7	0,9	0,8	0,5
48	0,8	1,9	3,2	4,7	2,9	1,1	1,5	0,9	0,8	3,3	4,2	3,9	2,4

UAH	MINIMUM FLOWS [LPS]												
	JAN	FEB	MAR	APR	MAY	Jun	JUL	Aug	Sep	Oct	Nov	DEC	YEARLY
49	0,5	1,1	1,8	2,7	1,7	0,6	0,8	0,5	0,5	1,9	2,3	2,2	1,4
51	1,9	2,7	7,3	8,0	7,2	3,8	5,2	2,7	2,7	4,6	6,8	5,8	4,9
52	1,1	1,6	4,5	5,1	4,6	2,5	3,4	1,7	1,7	2,8	4,2	3,4	3,1
53	1,5	2,9	5,4	6,6	5,9	2,6	3,6	2,4	1,8	4,4	6,1	5,4	4,1
54%	0,7	0,9	1,4	1,7	1,4	0,8	0,8	0,5	0,6	1,1	1,5	1,3	1,1
55%	2,3	2,7	4,1	5,7	5,1	2,2	1,5	0,9	1,4	4,6	5,0	4,9	3,4

* For UAHs 54 and 55 the values are presented in m3 / sec.

Table 5.52. Consolidated average flow values for each unit of the area of influence AI-EIA-1B.

UAH	MEDIUM FLOWS [LPS]												
	JAN	FEB	MAR	APR	MAY	Jun	JUL	Aug	Sep	Oct	Nov	DEC	YEARLY
1	101,0	97,4	129,2	138,7	115,8	60,7	57,0	47,9	60,1	123,6	133,1	118,6	98,6
2	45,5	47,3	60,1	64,6	54,8	29,7	29,0	23,8	28,4	57,4	61,7	55,1	46,4
3	179,8	182,2	238,5	246,5	217,8	137,3	147,5	114,1	120,6	217,0	236,0	212,2	187,4
4	10,3	10,5	13,7	13,9	12,4	8,2	9,1	6,9	6,9	12,2	13,4	12,0	10,8
5	23,6	24,2	32,1	32,2	28,5	18,5	20,0	15,1	16,3	28,5	31,3	27,8	24,8
6	26,7	27,8	37,0	36,8	34,8	20,8	22,1	16,7	18,6	32,9	35,9	31,8	28,5
7	22,8	23,9	31,7	31,3	28,1	17,9	19,3	14,5	16,2	28,0	30,7	27,2	24,3
8	28,9	30,8	41,1	40,2	36,0	23,0	24,5	18,4	20,9	36,2	39,5	35,0	31,2
15	114,7	108,8	144,1	150,1	130,4	76,8	79,0	62,5	70,2	133,3	144,3	129,1	111,9
16	23,5	24,0	30,8	32,8	28,5	16,4	16,6	13,5	15,0	29,1	31,4	28,0	24,1
17	6,3	6,2	8,1	8,5	7,6	5,0	5,4	4,3	4,2	7,4	8,0	7,2	6,5
18	22,1	23,8	31,7	30,7	27,2	18,2	19,4	14,5	16,5	27,8	30,4	26,9	24,1
20	160,0	178,4	240,2	233,3	206,2	126,1	122,2	94,9	118,4	213,5	230,0	203,0	177,2
21	19,7	19,5	25,8	28,0	23,1	11,4	10,6	8,7	11,8	25,2	27,1	24,2	19,6
23	20,5	19,8	26,8	29,2	24,2	11,9	11,2	9,6	12,2	26,4	28,4	25,2	20,4
24	34,5	32,5	44,3	49,0	40,2	18,7	16,6	14,3	19,9	44,7	48,1	42,6	33,8
25	168,0	186,8	251,5	240,8	216,7	155,2	143,5	107,6	132,1	214,2	243,0	213,2	189,4
26	11,1	11,9	15,9	15,3	13,7	9,4	10,2	7,5	8,4	13,8	15,2	13,4	12,1
27	34,0	31,3	42,7	47,5	39,3	17,9	15,4	13,3	18,7	44,2	47,5	41,1	32,7
28	21,5	21,0	27,4	30,2	25,0	11,9	10,7	9,2	12,2	27,7	29,8	26,2	21,1
29	6,1	6,0	7,8	8,6	7,1	3,3	3,0	2,4	3,6	7,9	8,5	7,4	6,0
30	4,5	4,7	5,9	6,4	5,4	2,7	2,4	2,0	2,7	5,9	6,3	5,5	4,5
31	22,4	25,0	33,5	31,4	29,0	20,2	20,7	15,5	18,0	28,7	31,5	27,6	25,3
36	14,1	15,5	20,8	19,6	18,0	12,4	13,0	9,7	11,3	17,9	19,7	17,2	15,8
37	8,5	8,9	11,8	11,5	10,4	7,1	7,7	5,8	6,1	10,3	11,4	10,1	9,1
38	3,1	3,2	4,2	4,1	3,7	2,5	2,8	2,1	2,2	3,7	4,1	3,6	3,3
39	15,9	15,5	20,7	22,3	19,2	10,6	10,6	8,6	10,0	19,8	21,3	18,9	16,1
40	30,9	30,9	40,3	41,2	37,1	25,6	29,3	21,8	21,0	35,6	39,2	35,6	32,4
41	33,1	32,3	42,4	43,8	39,7	27,7	30,8	23,7	22,6	37,7	41,2	37,6	34,4
42	15,4	15,1	19,7	20,7	18,7	12,6	13,7	10,7	10,4	17,9	19,4	17,6	16,0
43	10,8	10,6	13,8	14,6	13,1	8,6	9,2	7,2	7,2	12,7	13,7	12,4	11,1
44	16,8	16,6	21,7	23,1	20,3	12,5	13,0	10,4	10,9	20,3	21,9	19,5	17,2
45	1,9	1,9	2,5	2,7	2,3	1,3	1,4	1,1	1,2	2,4	2,5	2,3	2,0
46	5,3	5,2	6,9	7,5	6,3	3,3	3,1	2,6	3,2	6,7	7,2	6,4	5,3
47	1,5	1,6	1,9	2,1	1,7	0,9	0,8	0,7	0,9	1,9	2,0	1,8	1,5
48	7,3	7,2	9,1	10,0	8,2	3,9	3,5	3,1	4,1	9,0	9,7	8,7	7,0
49	4,2	3,9	5,1	5,6	4,6	2,2	2,0	5,3	2,3	5,1	5,4	4,8	4,2

UAH	MEDIUM FLOWS [LPS]												
	JAN	FEB	MAR	APR	MAY	Jun	JUL	Aug	Sep	Oct	Nov	DEC	YEARLY
51	11,7	11,9	15,6	15,8	14,1	9,3	10,2	7,7	7,9	13,9	15,2	13,6	12,2
52	7,4	7,5	9,9	10,0	8,9	6,0	6,8	5,0	5,1	8,7	9,6	8,6	7,8
53	9,7	9,5	12,6	13,5	11,7	6,9	7,2	5,8	6,3	11,9	12,8	11,4	9,9
54%	2,4	2,7	3,6	3,5	3,1	2,0	1,6	1,3	1,7	3,1	3,5	3,2	2,6
55%	7,4	7,5	10,0	10,6	9,4	5,3	3,6	2,9	4,4	9,4	10,4	9,6	7,5

* For UAHs 54 and 55 the values are presented in m3 / sec.

Table 5.53 Consolidated of the maximum flow values for each unit of the area of influence AI-EIA-1B.

UAH	MAXIMUM FLOWS [LPS]												
	JAN	FEB	MAR	APR	MAY	Jun	JUL	Aug	Sep	Oct	Nov	DEC	YEARLY
1	198,6	198,3	222,3	241,2	217,8	112,1	113,1	130,8	122,7	206,4	228,1	207,6	183,3
2	94,8	91,1	101,3	111,2	101,7	52,6	57,0	60,9	56,7	97,8	106,9	95,4	85,6
3	359,8	367,6	382,3	396,7	390,5	250,2	308,8	239,5	246,3	390,6	414,5	364,6	342,6
4	20,4	21,1	21,6	21,9	22,5	15,4	20,3	14,1	15,3	22,8	23,7	21,4	20,0
5	45,6	49,3	51,1	50,1	51,8	36,5	45,7	32,7	35,5	52,1	56,0	49,1	46,3
6	51,1	56,3	61,8	56,6	58,8	41,9	50,0	37,2	40,3	58,9	65,0	55,7	52,8
7	42,7	48,7	52,5	48,8	50,3	36,1	43,9	32,2	35,0	50,8	56,4	48,0	45,4
8	54,1	62,5	67,7	62,8	64,4	44,6	55,2	40,8	44,8	65,1	73,3	61,9	58,1
15	217,0	219,9	238,4	253,1	237,6	141,4	160,6	134,1	142,0	232,1	253,2	215,3	203,7
16	48,8	46,8	50,7	56,0	52,2	28,5	32,7	30,9	29,3	50,8	54,3	47,4	44,0
17	12,7	12,4	12,6	14,0	13,6	8,4	10,7	8,2	7,9	13,5	13,8	12,6	11,7
18	42,0	48,0	51,3	48,9	49,3	34,5	42,8	32,0	34,8	50,4	55,9	47,8	44,8
20	309,4	354,9	405,5	372,4	361,4	230,7	251,2	171,3	241,9	369,5	409,6	357,9	319,6
21	40,8	40,7	44,4	49,2	44,1	21,2	20,2	26,9	24,2	41,5	45,8	44,6	37,0
23	43,4	41,7	46,4	50,8	45,6	22,5	21,3	28,0	25,0	43,9	48,0	46,4	38,6
24	73,6	71,2	76,9	84,7	75,4	36,6	31,5	48,6	40,2	74,3	80,7	75,9	64,1
25	350,8	366,1	376,5	369,3	379,0	307,6	243,9	204,1	236,2	341,6	399,3	399,9	331,2
26	21,6	23,9	25,1	24,4	25,5	18,0	21,9	16,1	17,7	25,2	27,6	24,0	22,6
27	73,2	69,1	74,4	81,2	70,2	36,2	30,8	44,5	38,2	77,0	79,8	73,0	62,3
28	46,3	43,2	47,4	51,2	46,0	23,1	19,7	28,8	24,8	48,8	50,2	47,0	39,7
29	13,2	12,2	13,4	14,6	12,9	6,6	5,6	8,1	7,0	13,9	14,3	13,3	11,2
30	9,8	9,0	10,0	10,7	9,9	5,0	4,7	6,1	5,4	10,4	10,6	10,0	8,5
31	43,5	49,0	52,7	49,3	50,7	36,9	40,2	29,6	35,3	50,7	54,2	49,4	45,1
36	27,0	30,7	32,8	31,1	32,4	22,2	26,5	20,1	22,5	32,0	34,6	30,8	28,5
37	16,7	18,2	19,0	18,2	18,8	14,5	17,4	12,2	13,7	19,1	21,1	18,2	17,3
38	6,0	6,5	6,8	6,6	6,8	5,0	6,3	4,4	4,9	6,9	7,4	6,5	6,2
39	33,4	30,9	34,4	37,6	35,2	18,8	20,3	20,9	19,3	34,4	36,7	32,7	29,5
40	61,4	62,3	63,2	65,0	67,0	45,7	61,9	41,8	44,9	68,2	68,9	64,2	59,5
41	65,2	64,8	65,8	68,6	70,6	47,2	63,5	43,3	46,0	71,5	72,0	67,6	62,2
42	30,9	30,2	30,6	33,4	33,1	20,9	27,2	19,9	19,7	33,0	33,6	30,9	28,6
43	21,8	20,8	21,4	23,9	23,3	14,4	17,7	14,0	13,3	23,0	23,6	21,5	19,9
44	34,6	32,6	34,6	38,4	36,8	21,3	25,2	22,0	20,5	36,1	37,7	33,5	31,1
45	4,0	3,6	4,0	4,4	4,2	2,4	2,6	2,5	2,3	4,2	4,4	3,8	3,5
46	11,3	10,5	11,7	12,8	11,8	6,1	6,0	7,1	6,4	11,5	12,4	11,4	9,9
47	3,2	3,0	3,3	3,6	3,3	1,6	1,5	2,0	1,8	3,2	3,5	3,3	2,8
48	14,6	14,6	15,7	17,5	15,7	7,5	6,6	9,9	8,6	14,7	16,3	15,7	13,1

UAH	MAXIMUM FLOWS [LPS]												
	JAN	FEB	MAR	APR	MAY	Jun	JUL	Aug	Sep	Oct	Nov	DEC	YEARLY
49	8,3	8,1	8,8	9,8	8,7	4,2	3,7	5,5	4,8	8,3	9,1	8,8	7,3
51	22,9	24,0	24,6	24,8	25,5	17,6	22,9	16,0	17,4	25,8	27,0	24,2	22,7
52	14,3	15,5	15,6	15,8	16,2	11,4	15,1	10,3	11,3	16,6	17,1	15,6	14,6
53	20,1	19,0	20,4	22,6	21,4	12,0	14,0	12,8	11,9	20,9	22,1	19,4	18,1
54*	4,9	5,2	5,7	5,4	5,4	3,6	2,8	2,4	3,3	4,8	5,6	5,8	4,6
55*	14,6	14,4	15,9	15,3	15,8	9,9	6,9	5,8	8,8	14,1	15,7	16,2	12,8

* For UAHs 54 and 55 the values are presented in m3 / sec.

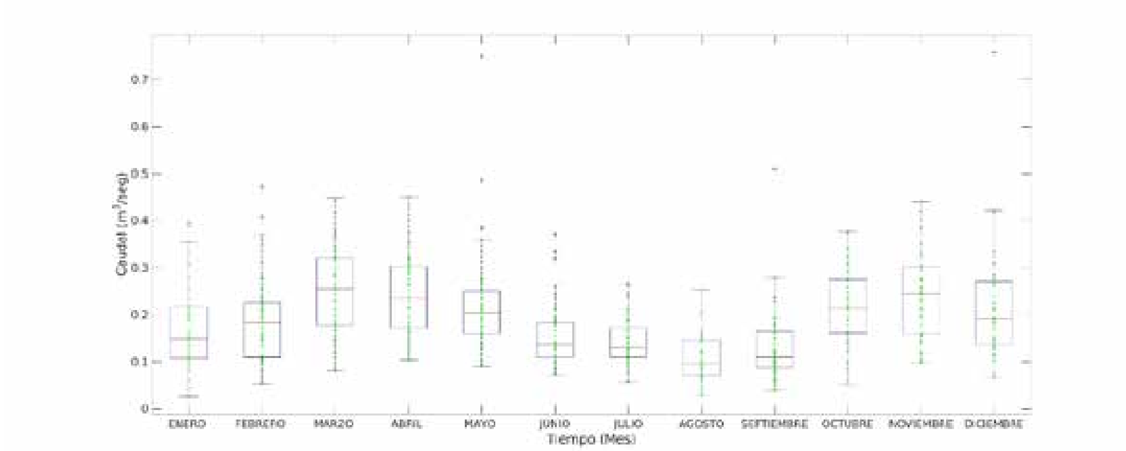
It is worth emphasizing from the results presented above that most of the maximum flows do not exceed 300 lps (liters per second) and that there are also minima lower than 1 lps (with the exception of UAH Sapuyes and Boquerón that present values In 4 orders of magnitude higher). These characteristics take place thanks to diverse physical and methodological factors. Firstly, the UAH are drainage areas of less than 10 km2 located mainly on the left bank of the Guáitara river, with morphometric characteristics that favor runoff (especially the high slopes in the basin and the riverbeds), which helps the smaller Capacity of regulation of the hydrographic areas analyzed. The above added to the regime of precipitation consolidate the hydrological characteristics of the zone and exposed in the present chapter.

Another important aspect is that the magnitudes reported here are due to long characteristics, that is, it is very possible that most streams present intermittent flow during periods of drought, since the results of the characterization of minimums showed very close values To zero. The above is possible given the context of hydroclimatic variability.

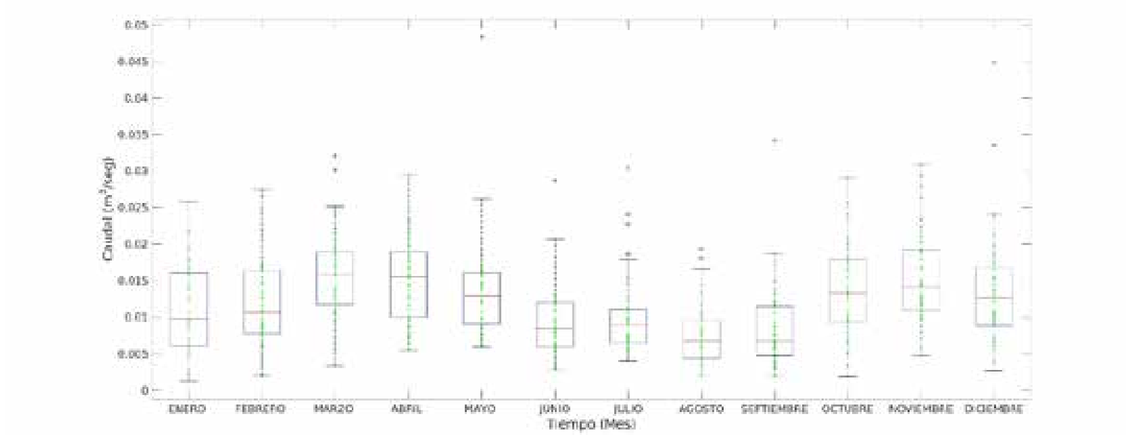
5.1.5.4.3 Characteristic Flows through dispersion diagrams (Box Plots).

Next, the characteristic flows are presented by means of scatter diagrams, in which the distribution of the data and the arrangement of the ranges of the regimes for each of the units of analysis can be observed monthly.

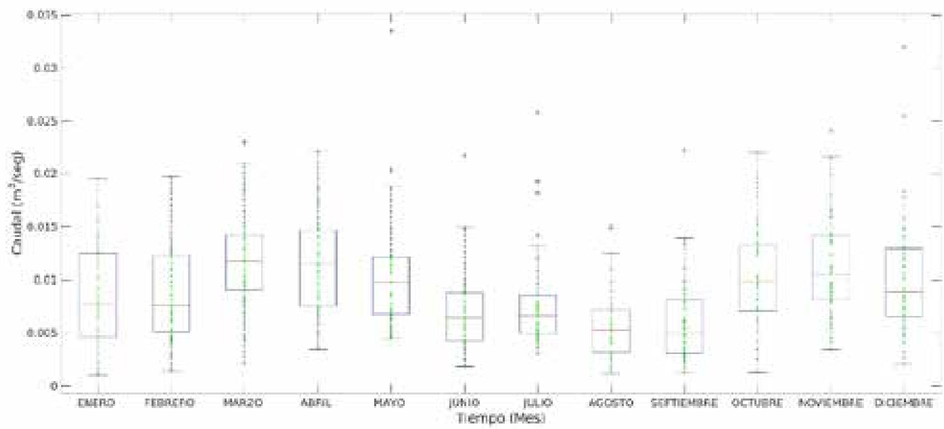
Figure 5.42 Scatter plots (Box Plots).



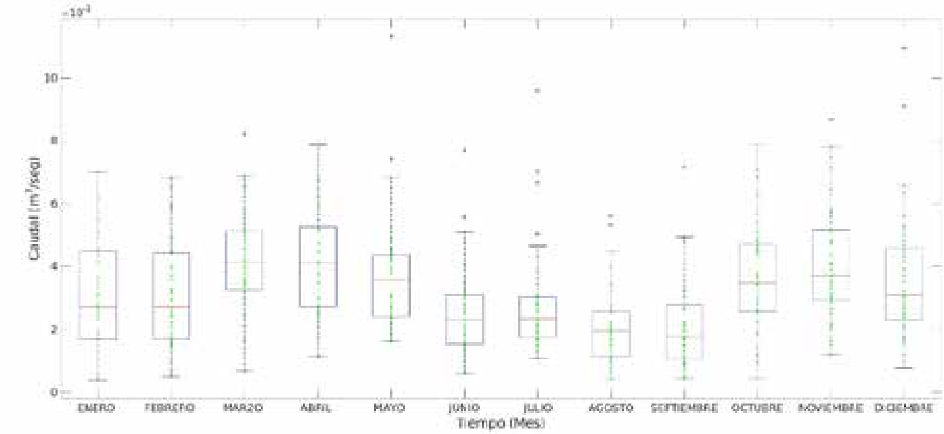
UAH Direct tributaries MD - Rio Boquerón



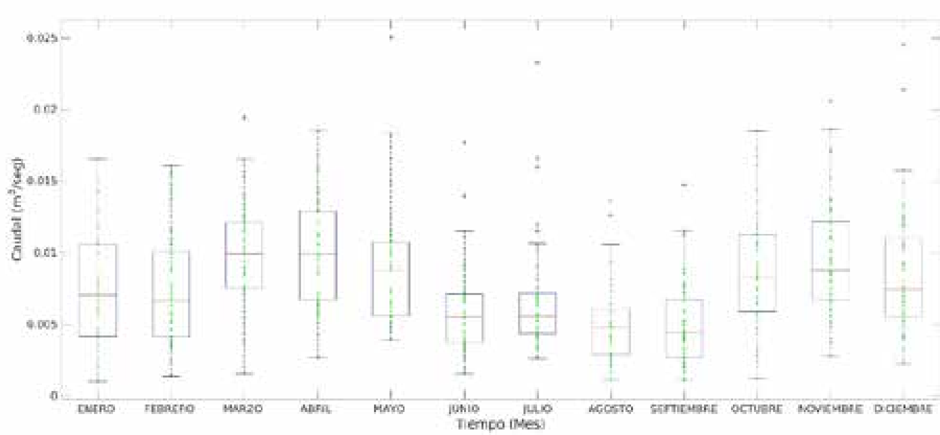
UAH Direct tributaries MI - Rio Guáitara 01



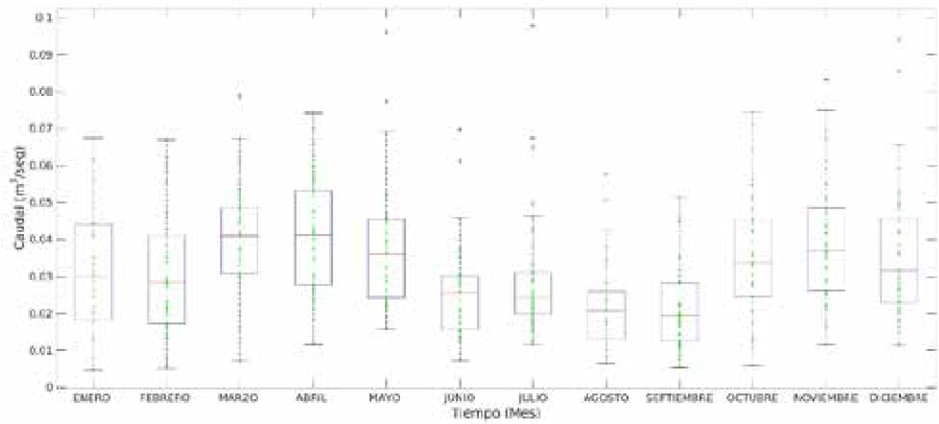
UAH Direct tributaries MI - Rio Guáitara 02



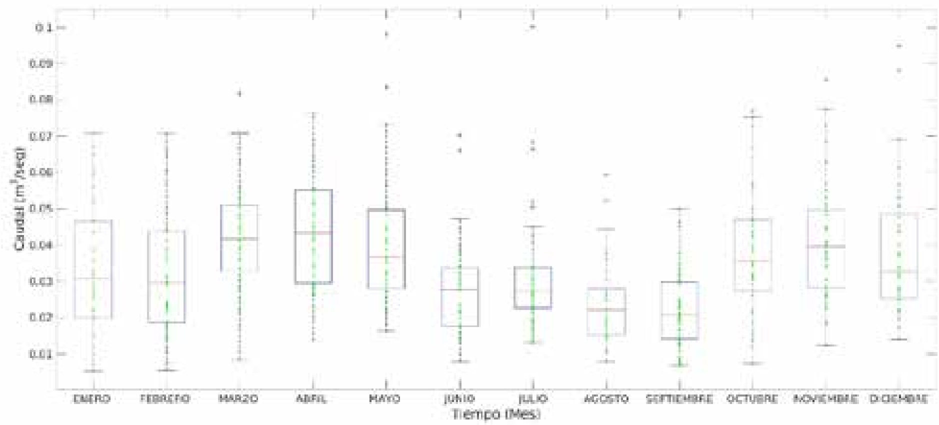
UAH Direct tributaries MI - Rio Guáitara 03



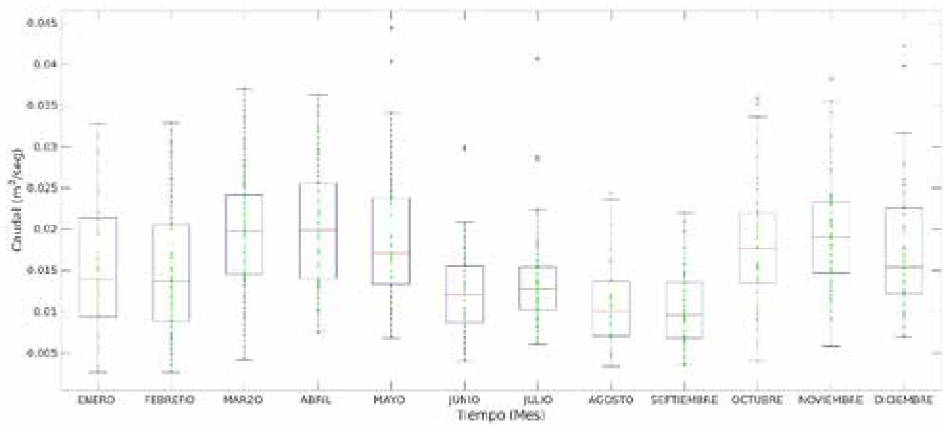
UAH Direct tributaries MI - Rio Guáitara 04



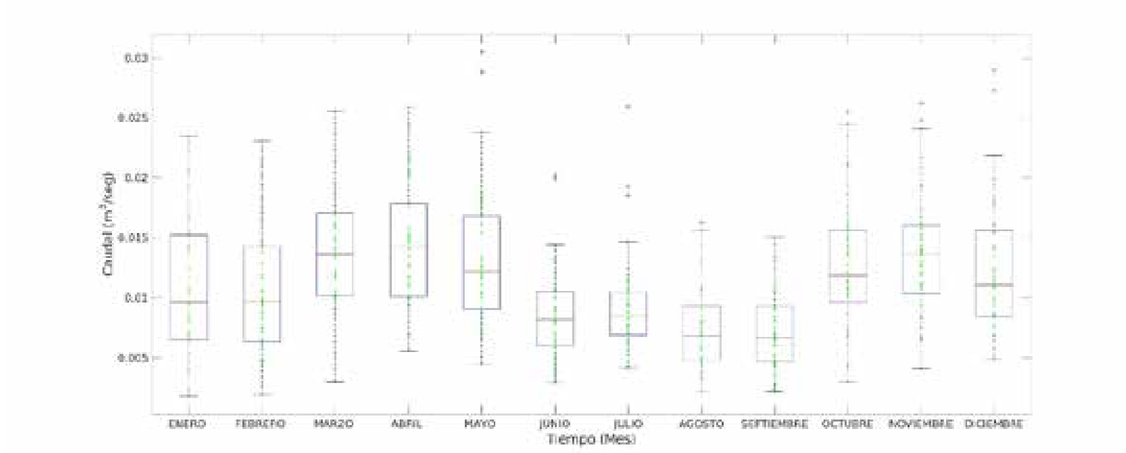
UAH Direct tributaries MI - Rio Guáitara 05



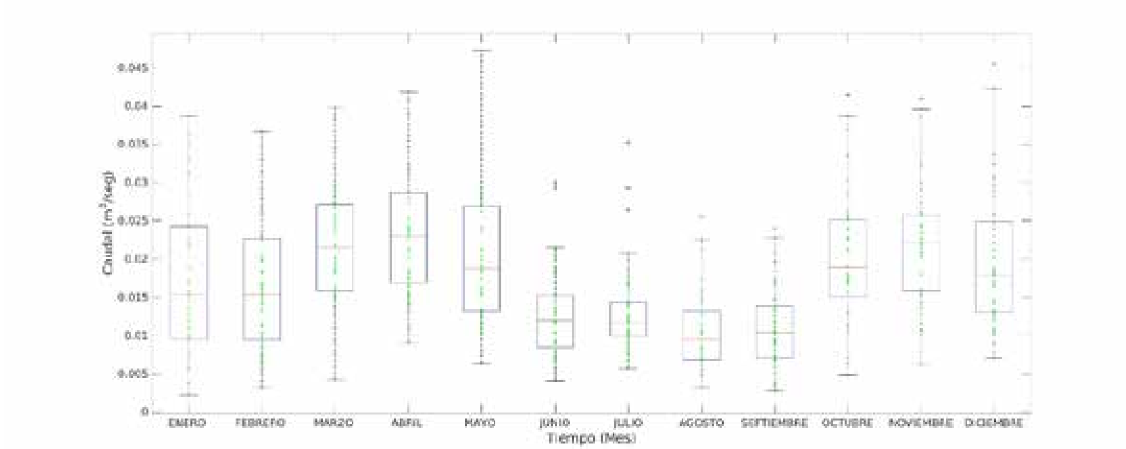
UAH Direct tributaries MI - Rio Guáitara 06



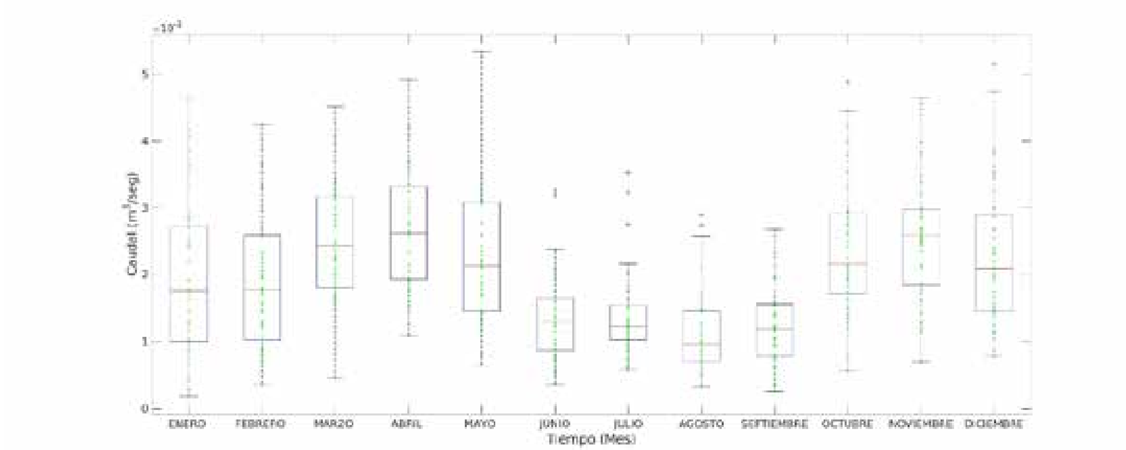
UAH Direct tributaries MI - Rio Guáitara 07



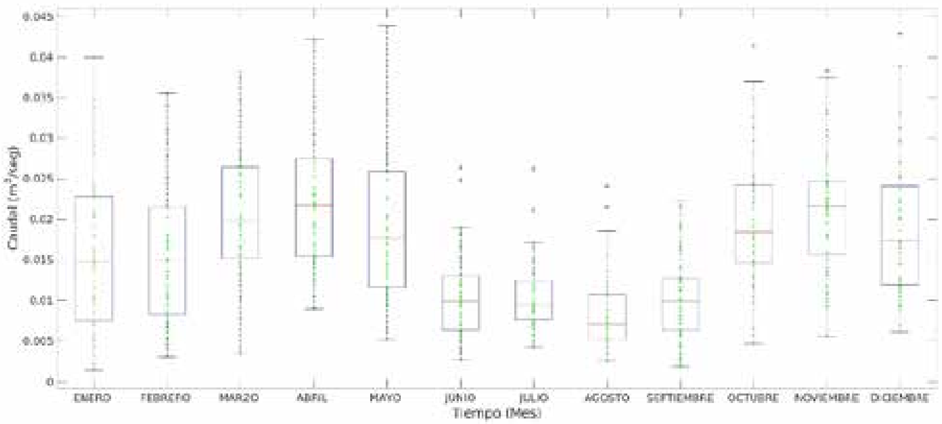
UAH Direct tributaries MI - Rio Guáitara 08



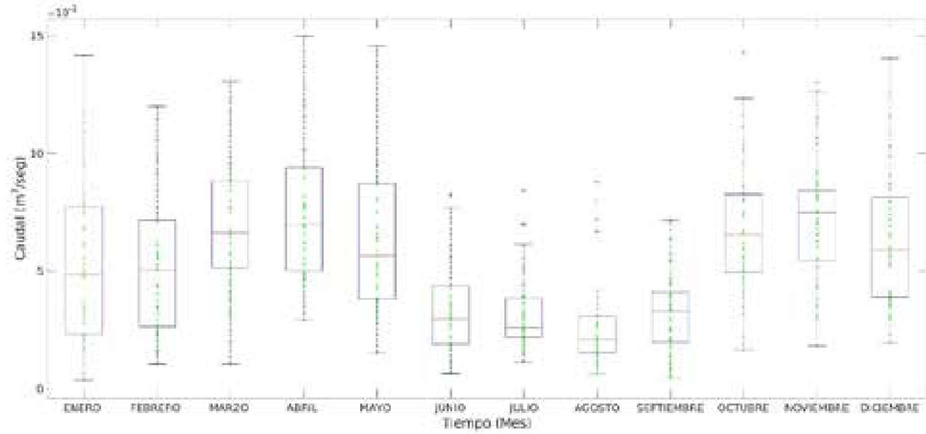
UAH Direct tributaries MI - Rio Guáitara 09



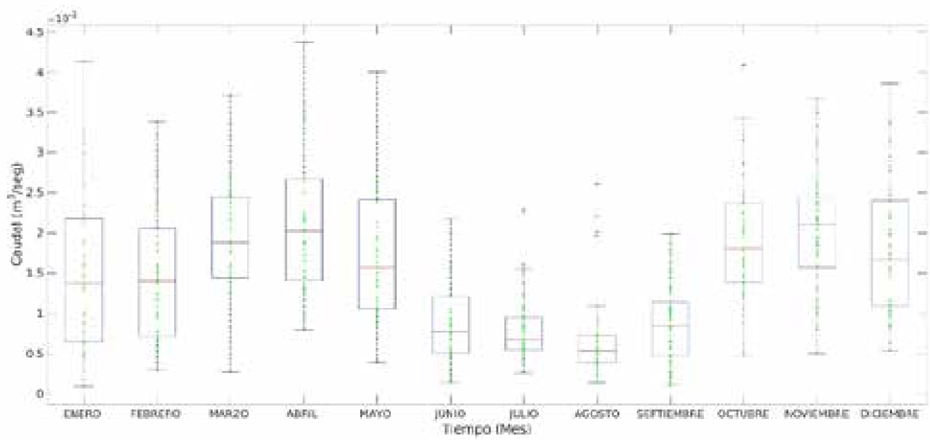
UAH Direct tributaries MI - Rio Guáitara 10



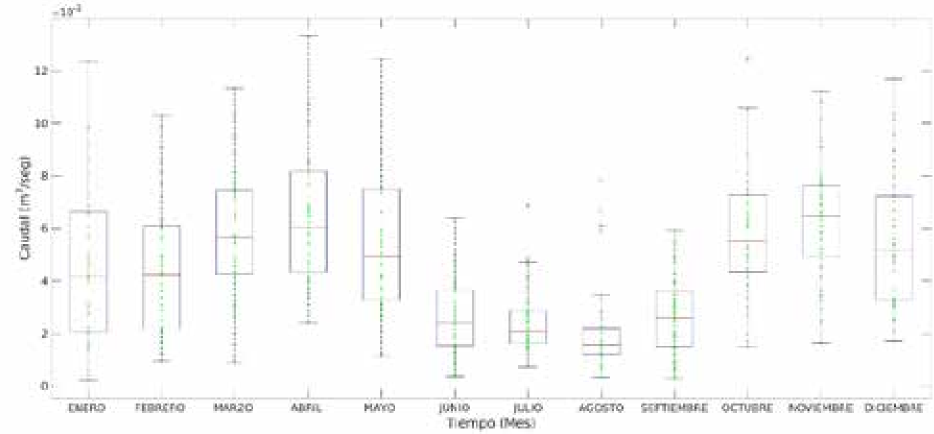
UAH Direct tributaries MI - Rio Guáitara 11



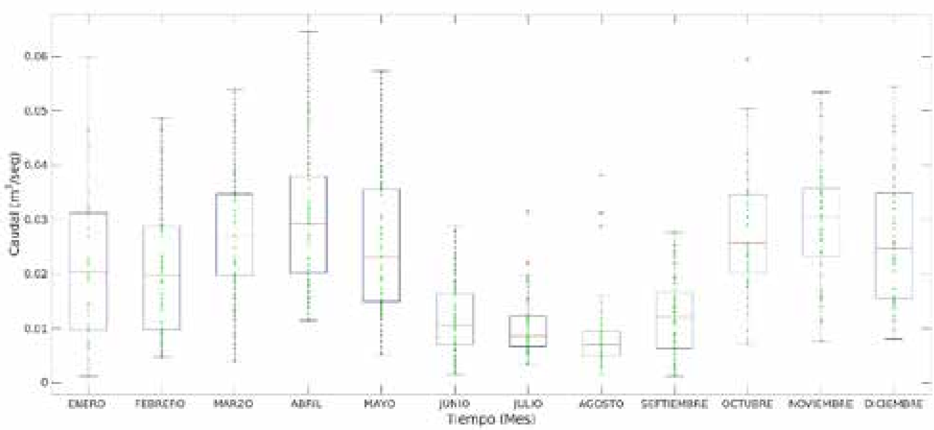
UAH Direct tributaries MI - Rio Guáitara 12



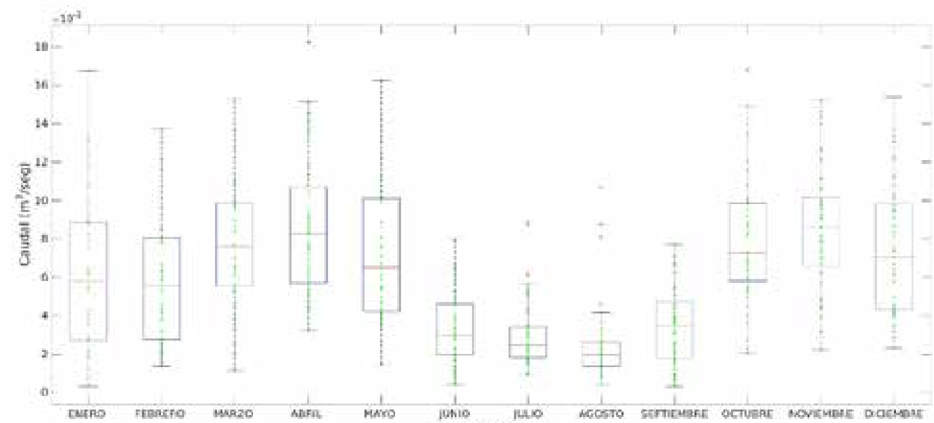
UAH Direct tributaries MI - Rio Guáitara 13



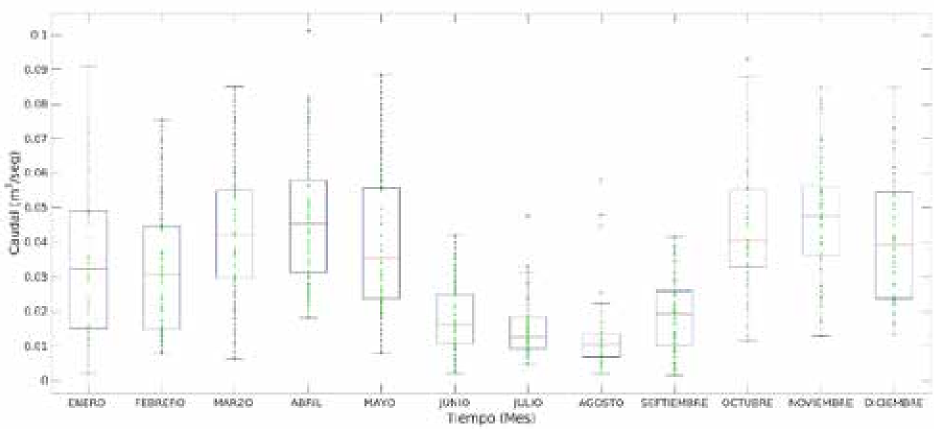
UAH Direct tributaries MI - Rio Guáitara 14



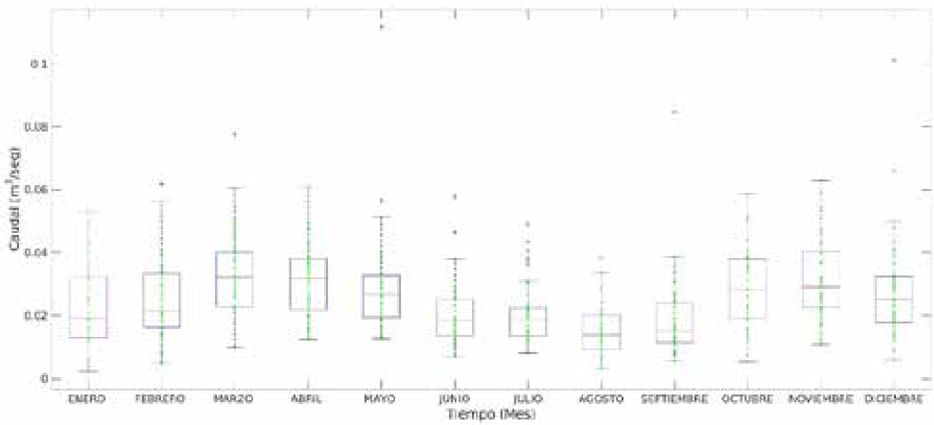
UAH Direct tributaries MI - Rio Guáitara 15



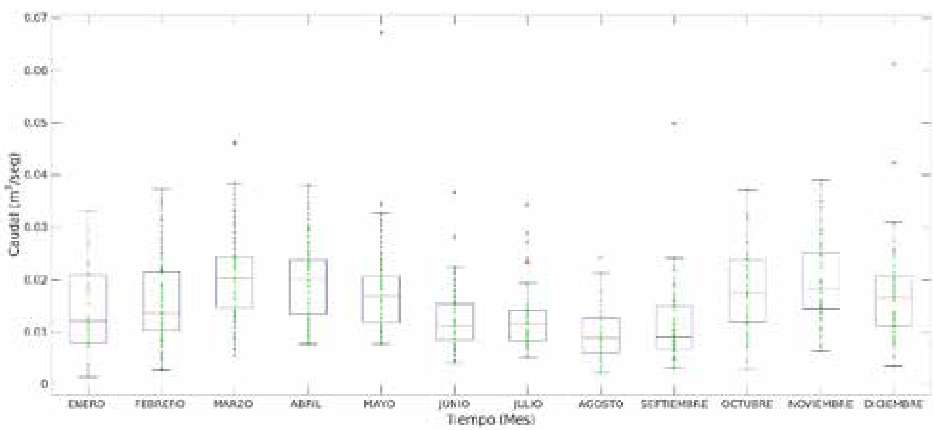
UAH Direct tributaries MI - Rio Guáitara 16



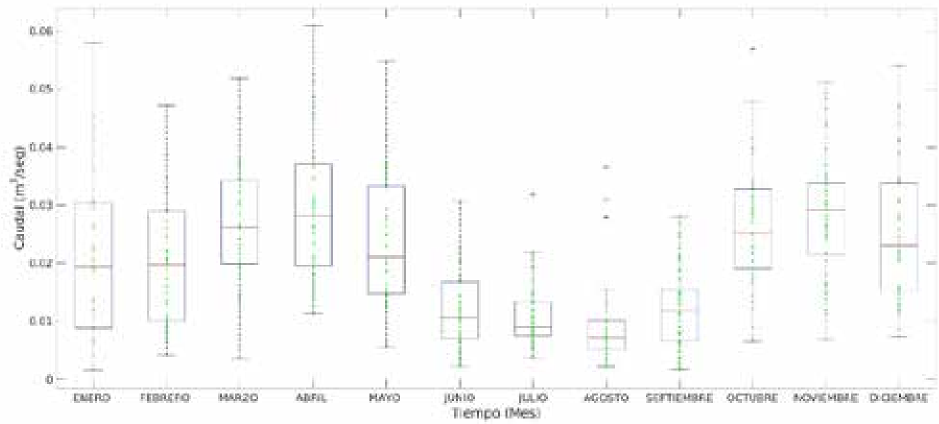
UAH Direct tributaries MI - Rio Guáitara 17



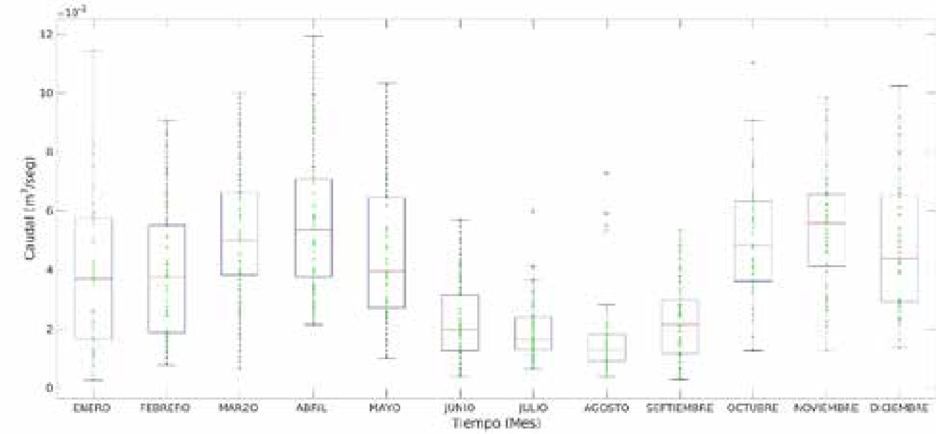
UAH Direct tributaries Río Carchi - Río Guáitara 07



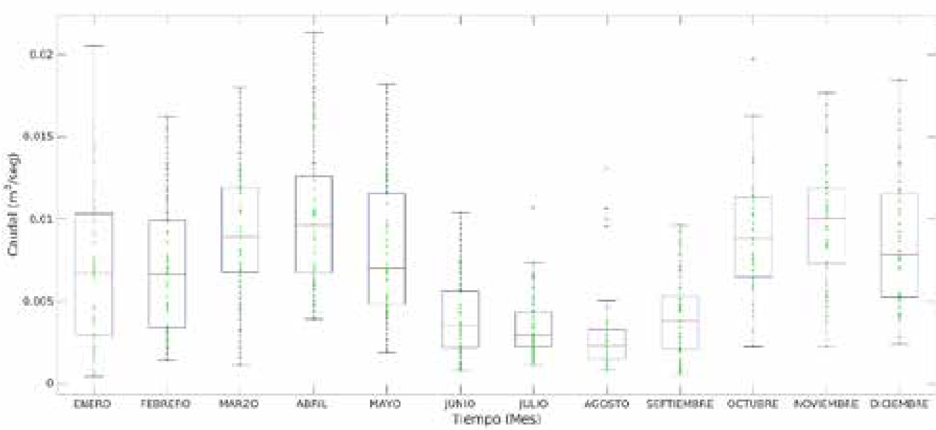
UAH Direct tributaries Rio Carchi - Río Guáitara 08



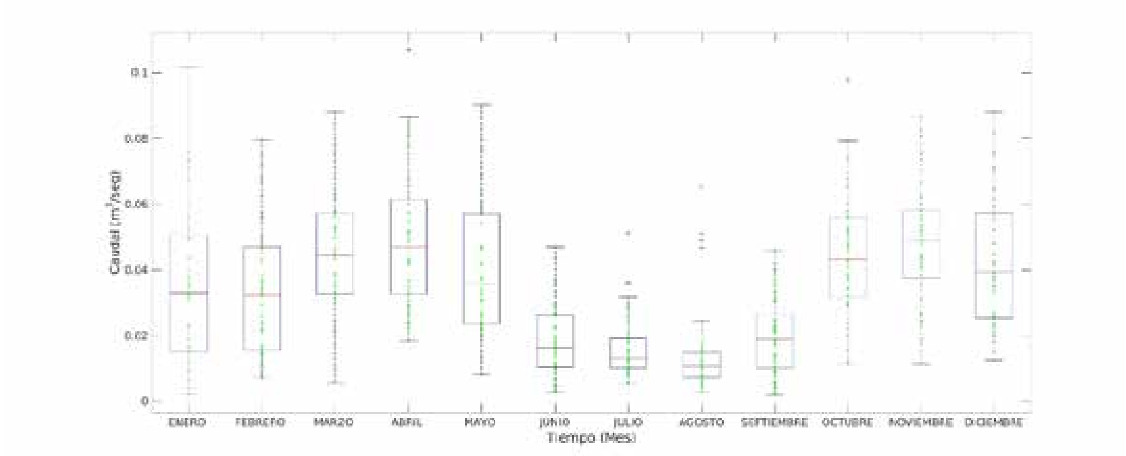
UAH Affluents MD - Sapuyes River 01



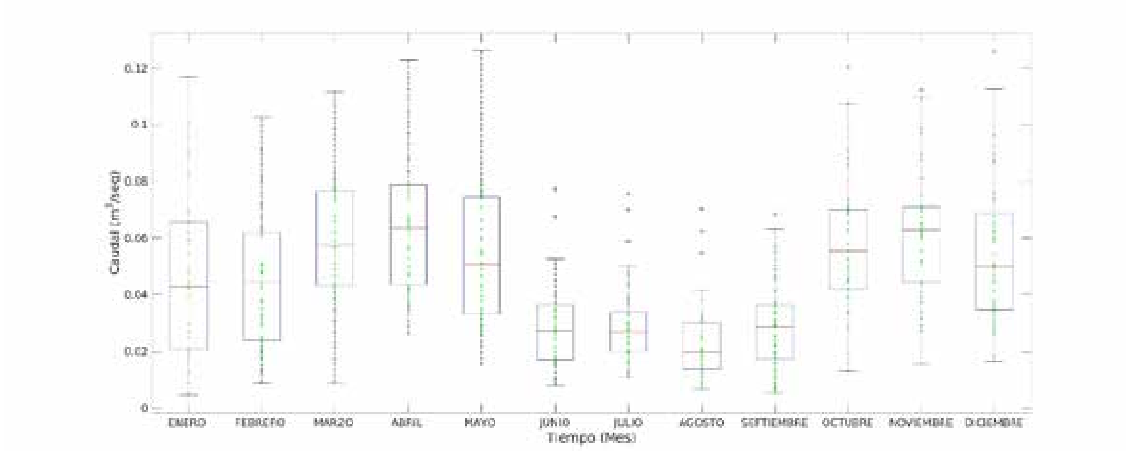
UAH Affluents MD - Sapuyes River 02



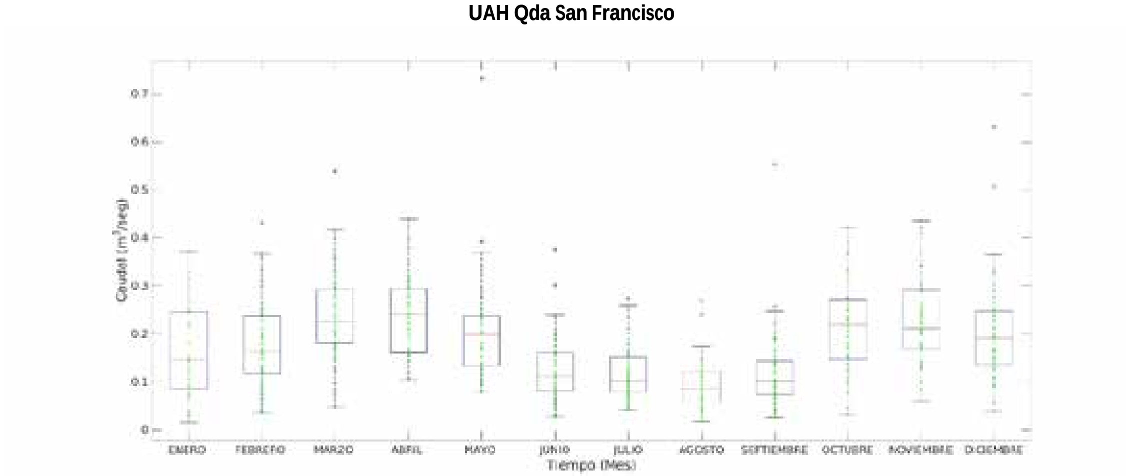
UAH Affluents MD - Sapuyes River 03



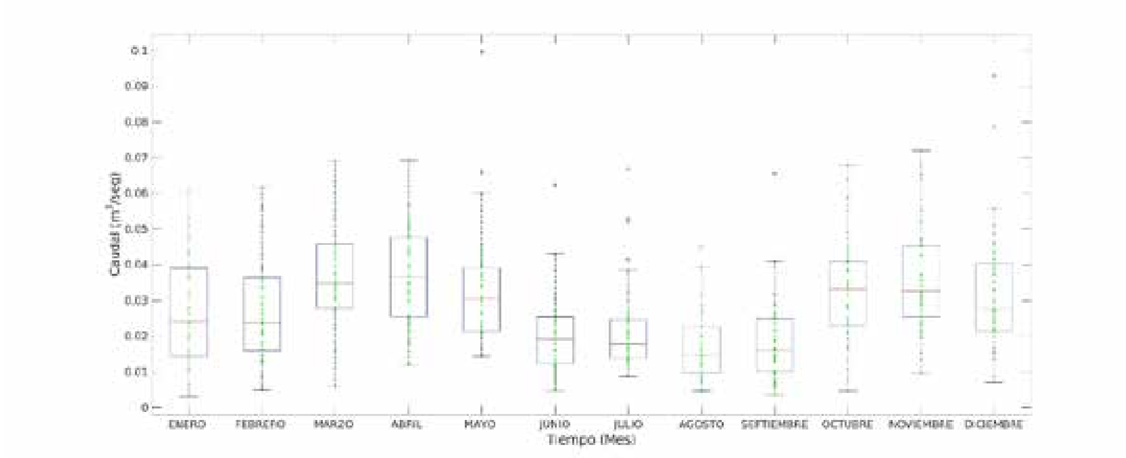
UAH Affluents MI - Sapuyes River



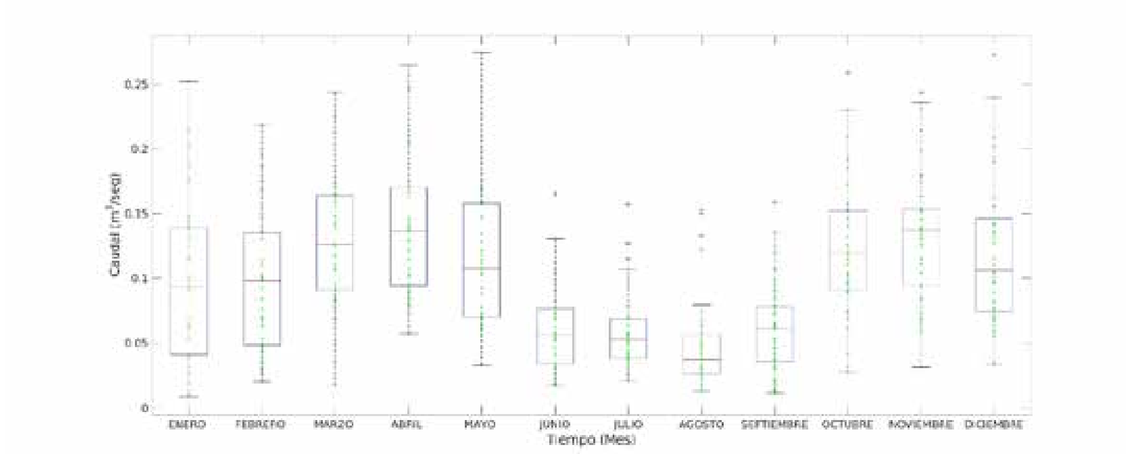
UAH Qda San Francisco



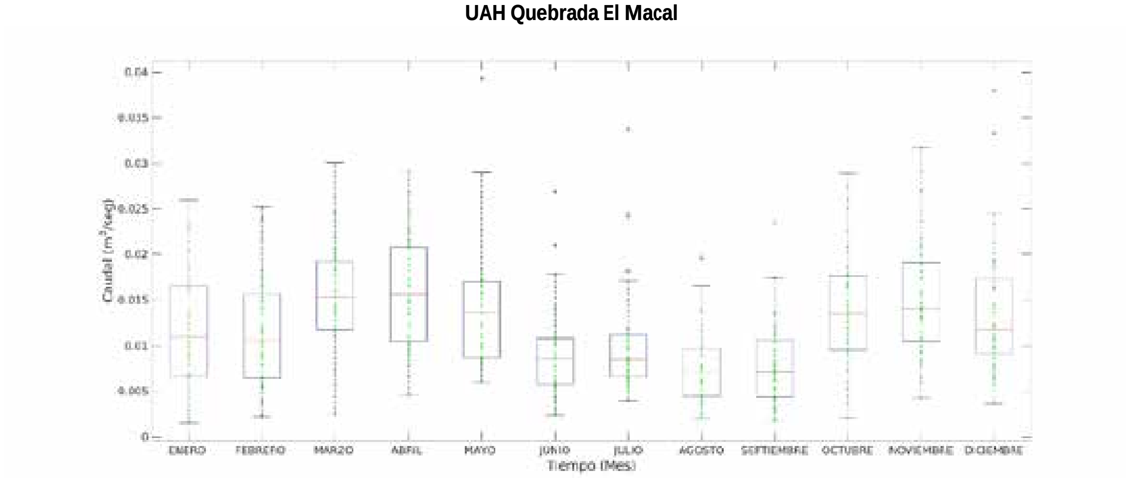
UAH Quebrada Chorrera Negra



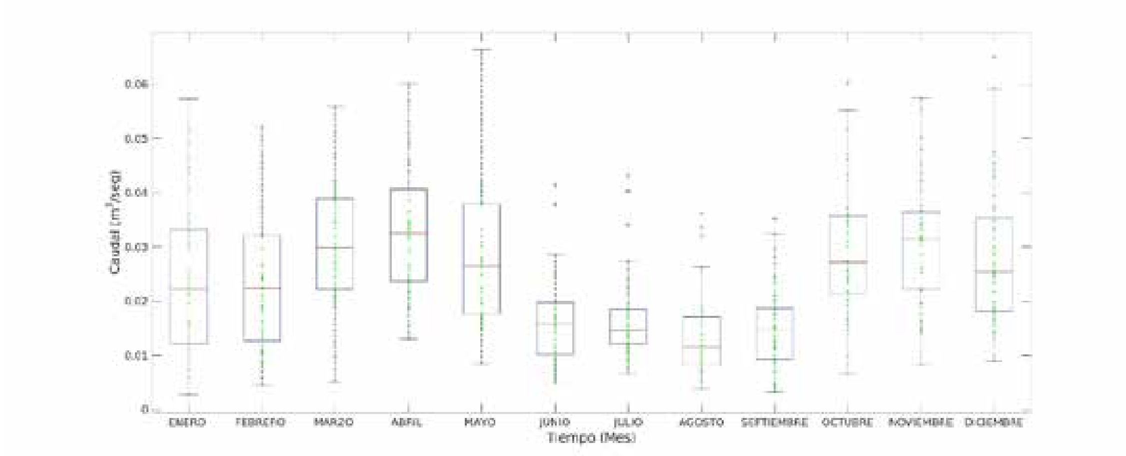
UAH Quebrada El Culantro



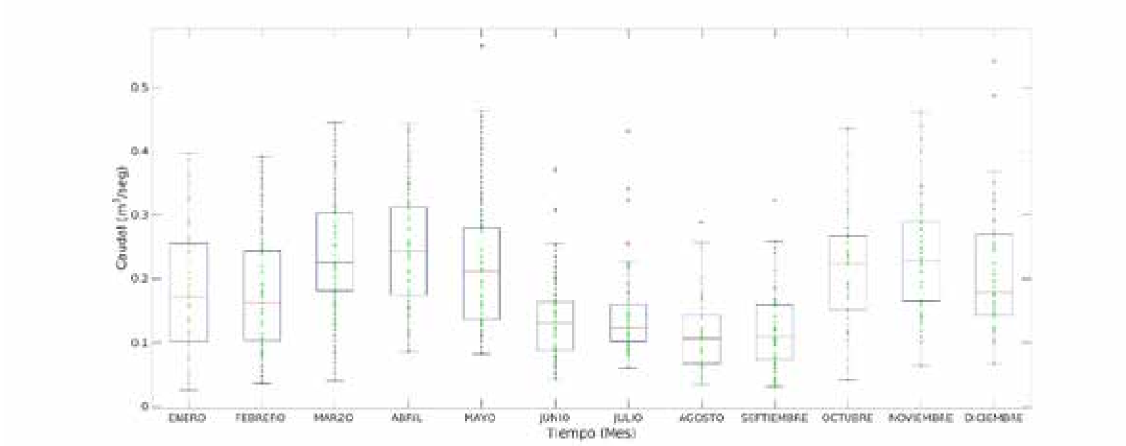
UAH Quebrada El Macal



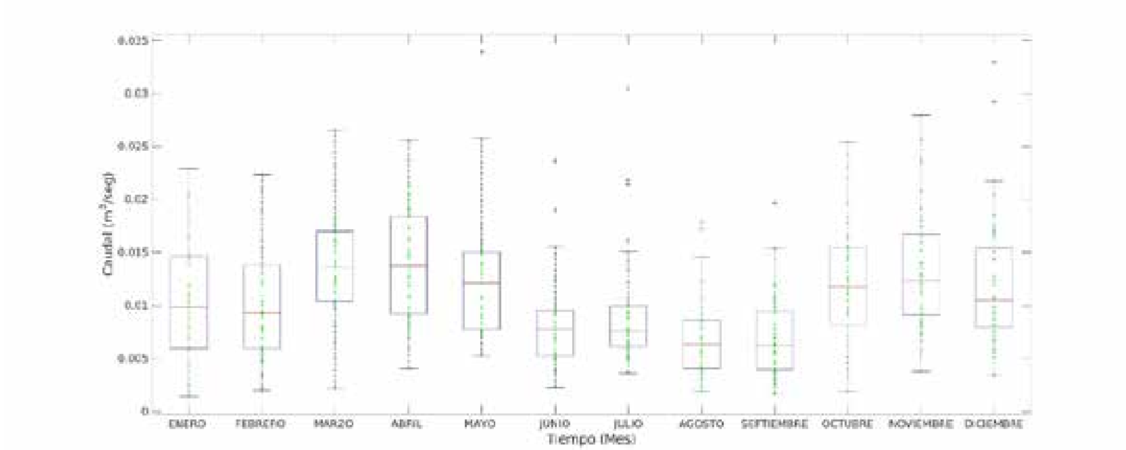
UAH Quebrada El Manzano



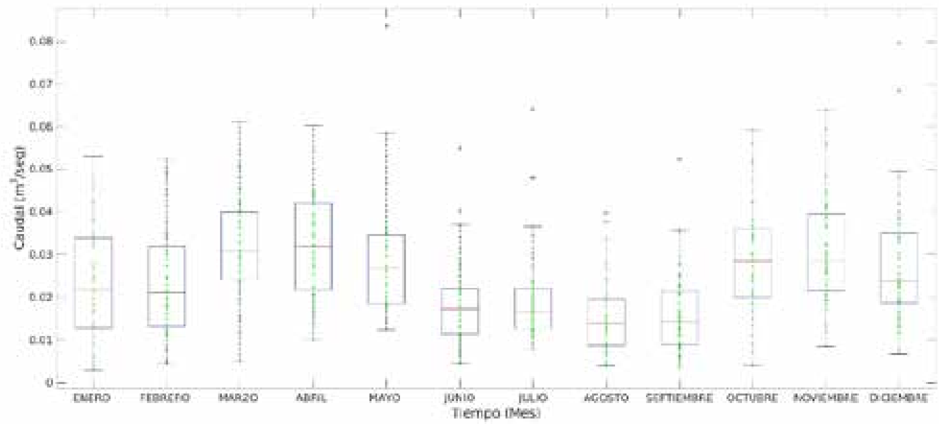
El Tablón Stream



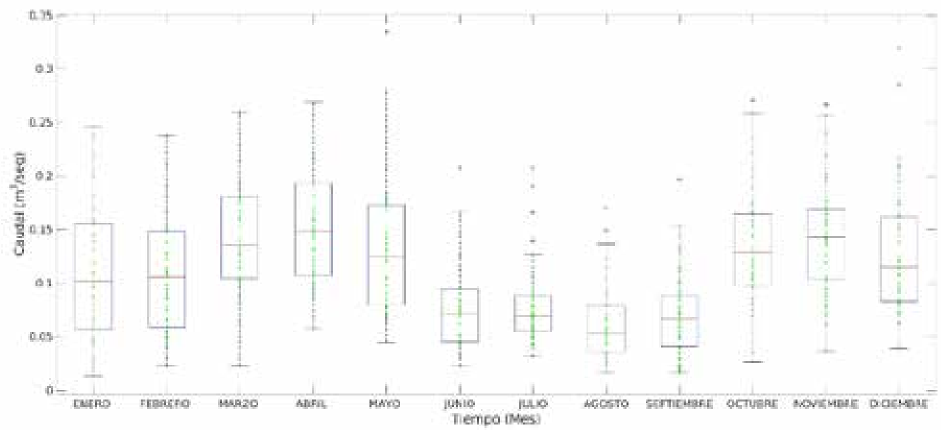
UAH Quebrada Humeadora



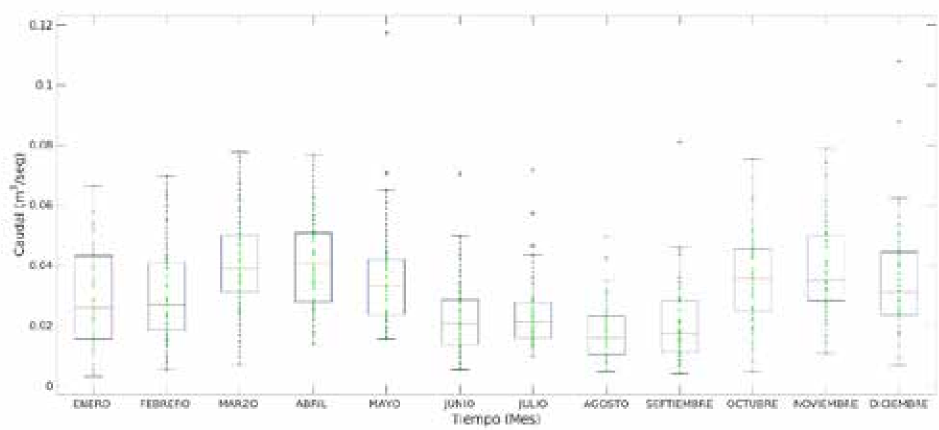
UAH Quebrada La Brigada



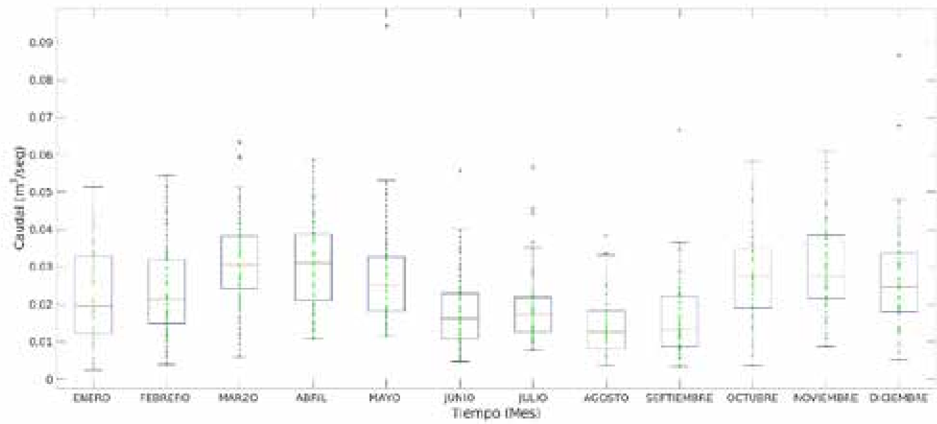
UAH Quebrada La Cueva



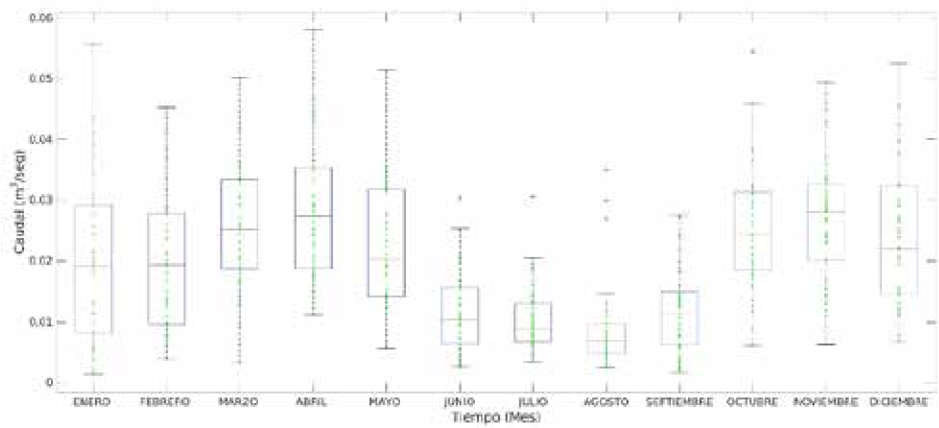
Moledores Stream



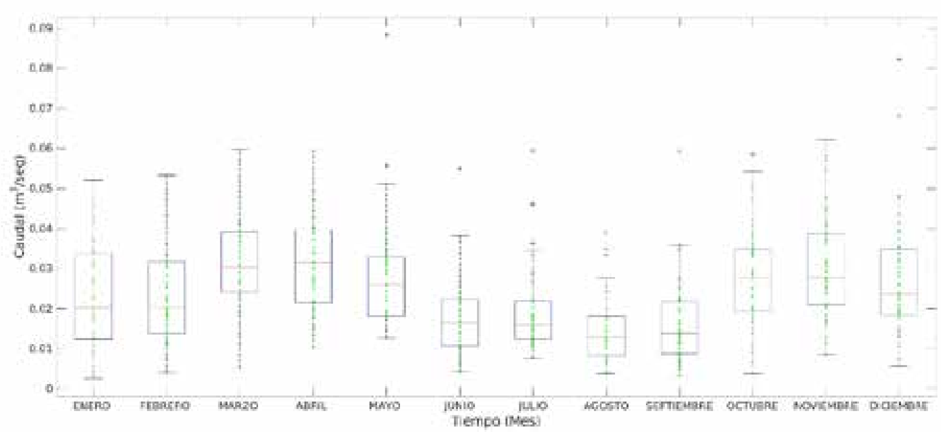
San Francisco Stream



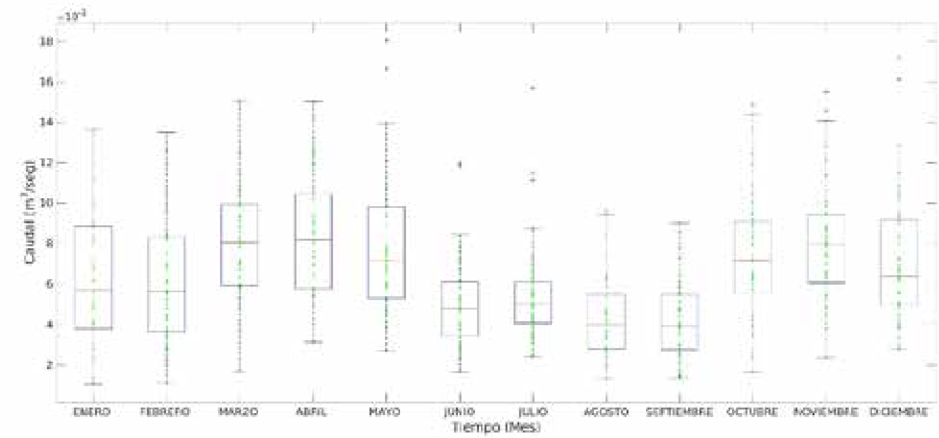
UAH Quebrada Yamburayán



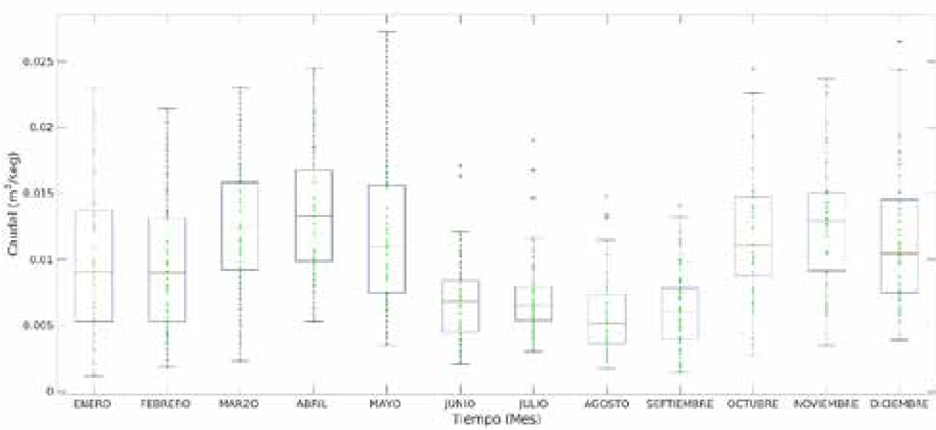
UAH Quebradas Chorrera Negra



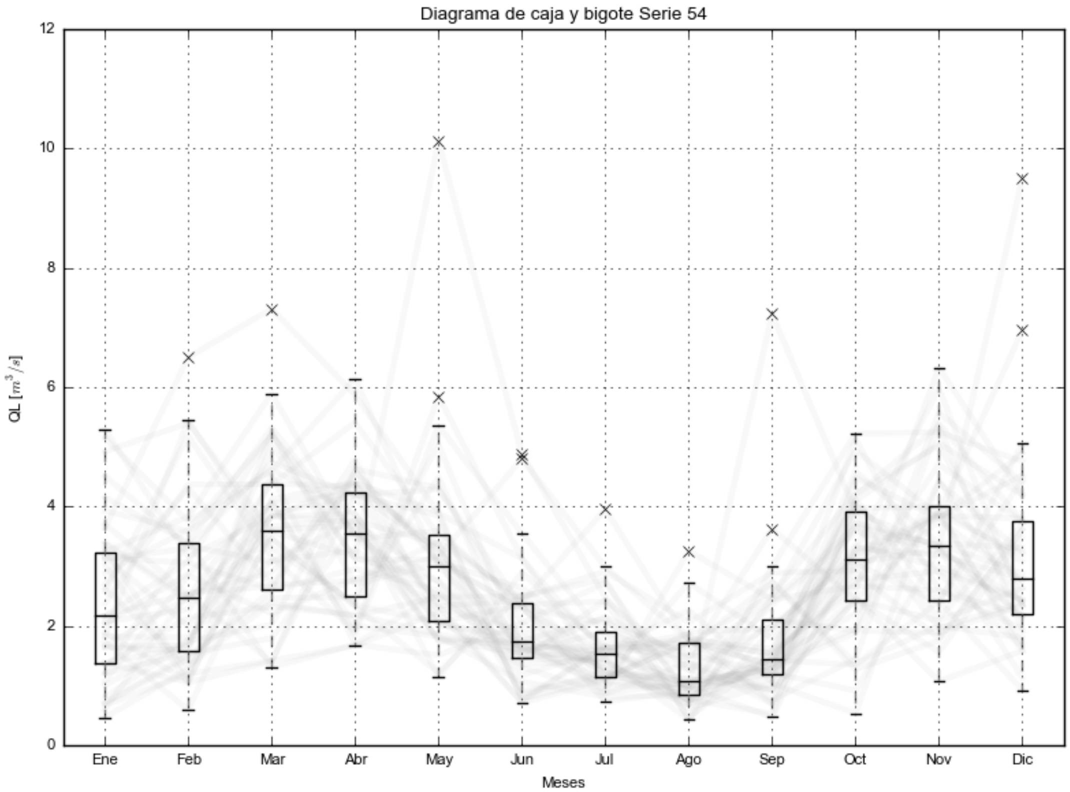
UAH Quebradas Honda



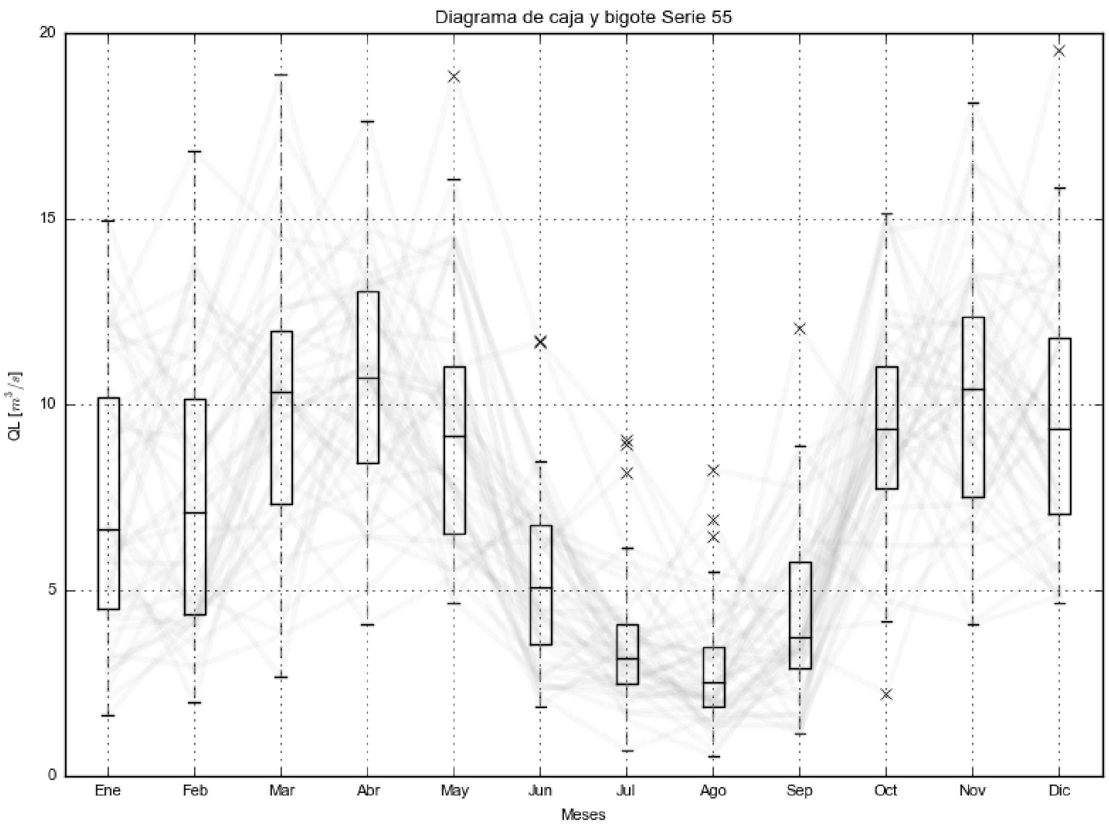
UAH Black Chorrera Ditch



UAH Zanjón La Lechuza



Quebrada Boquerón



Sapuyes River

5.1.6 Quality of water

Water quality is understood as the physicochemical composition of water as it is altered by the concentration of different substances generated by natural processes and anthropic activities. It is determined according to the use for which the water is intended.

Based on the above, the criteria that are established according to water quality standards represent a series of variations depending on their application, whether it is water for human consumption (potable water), for agricultural or industrial use, for recreation, To maintain environmental quality, etc.

To determine the current quality of the water, in the area of influence of the Rumichaca - Pasto dual carriageway project, San Juan - Pedregal stretch, the laboratory MCS Consulting and Environmental Monitoring, Carried out the monitoring (laboratory accredited by IDEAM, Resolution 2892 of December 30, 2016 and Resolution 0049 of January 16, 2017), by means of which the physicochemical, bacteriological and hydrobiological attributes of water bodies and based In these, their suitability for the different potential uses of the resource in the study area is determined, according to the quality standards established in the single Decree 1076 of 2015.

In the same way, we calculated: The Water Quality Index (ICA), Index of Alteration of Water Quality Potential (IACAL)[1], Langelier Index, Buffer Capability Index and Pollution Indices (ICOs), to evaluate the conditions of each of the water sources considered for different types of contamination.

In addition, a multitemporal water analysis is presented, with data from previous studies in the main water bodies of the study area, which allows analyzing their behavior in time, for this analysis were taken the monitoring of the years 2016 and 2017 .

5.1.6.1 Inland water bodies.

The project presents continental-type water bodies, which are part of the Guáitara River hydrographic subzone system.

5.1.6.1.1 Physicochemical and bacteriological characterization.

This numeral shows the physicochemical and bacteriological characterization of the surface water bodies located within the area of influence of the Rumichaca - Pasto dual carriageway project, San Juan - Pedregal stretch.

This characterization was carried out during the days of February 26 to March 21, 2017 in rainy season, according to the climatic analysis, specifically to the precipitation regime.

The monitoring plan was developed with the objective of characterizing the physicochemical and bacteriological conditions of the water bodies that would intervene in the road project. For this, the sub-basins and micro-basins that are part of the area of influence of the project were identified, once their main channels Monitoring points were located upstream and downstream of these (River and / or ravines) taking as a central point the axis of the road. Likewise were characterized water bodies where capture and dumping, it is clear that due to the strong topographic variations, some water bodies were lined by which the monitoring points were determined based on access to them.

In the selection of the points to be sampled, those identified in previous studies in the area were taken into account in order to carry out a multitemporal analysis of the water quality that allows the monitoring of the water ecosystem.

The monitored plan contemplated 44 points (see **Table 5.54)**. The location and description of the monitoring sites is shown in the **Table 5.55** and in the **Figure 5.44** The spatial location is presented.

[1]IDEAM. 2010. National Water Study.

Table 5.54 Point of intersection for the Rumichaca - Pasto Divided Highway Project, San Juan - Pedregal segment.

NUMBER	NAME	BOGOTA PLANE COORDINATES DATUM MAGNA SIRGAS		MONITORING DATE
		EAST	NORTH	
1	Stream NN 3 upstream	947096	589672	26-February-2017
2	Guáitara River	948503	590762	26-February-2017
3	Upstream Boquerón River	947873	591368	26-February-2017
4	Boquerón River downstream	948589	590972	26-February-2017
5	Yamurayán Quebrada upstream	949114	592110	27-February-2017
6	Quebrada Yamurayán downstream	949327	591577	28-February-2017
7	Quebrada San Francisco upstream	949980	593156	27-February-2017
8	Quebrada San Francisco downstream	950086	593036	27-February-2017
9	Quebrada Cuayarín (Honda) upstream	950179	593808	28-February-2017
10	Quebrada Honda upstream	950297	594011	28-February-2017
11	Quebrada Honda downstream	950982	593341	09-March-2017
12	Quebrada tributary to the Corrientes ravine upstream	950591	594688	06-March-2017
13	Culantro Stream	950823	594809	02-March-2017
14	Quebrada Corantro downstream	950603	594509	06- March -2017
15	Quebrada La Cueva upstream	951107	595359	03- March -2017
16	Quebrada La Cueva downstream	950979	594734	03- March -2017
17	Quebrada tributary to the creek Manzano upstream	951604	595195	04- March -2017
18	Quebrada El Manzano upstream	951875	595341	05- March -2017
19	Quebrada El Manzano downstream	952102	594886	05- March -2017
20	Quebrada Brigada upstream	952234	595503	04- March -2017
21	Quebrada Brigada downstream	952271	595345	04- March -2017
22	Affluent to the ravine	954168	596477	05- March -2017
23	Quebrada Los Arayanes (Huneadora) upstream	954623	597220	07- March -2017
24	Quebrada El Manzano (Humidor) upstream	954840	597388	06- March -2017
25	Upstream Gorge (Smoker) upstream	955161	597523	06- March -2017
26	Downstream Humidifier Gully	955074	597201	06- March -2017
27	Zanja Chorrera Chiquita upstream	955908	598687	07- March -2017
28	Zanja Chorrera Chiquita downstream	956740	599033	09- March -2017
29	Quebrada Moledores upstream	955872	598885	08- March -2017
30	Quebrada Moledores downstream	956019	598991	08- March -2017
31	Quebrada The plank downstream	955333	600464	12- March -2017
32	Quebrada The plank downstream	955135	600723	12- March -2017
33	Affluent to the ravine San Francisco 2 upstream	954815	601862	12- March -2017
34	Affluent to the ravine San Francisco 2 upstream	954467	601562	12- March -2017
35	Quebrada San Francisco 2 upstream	953962	601557	13- March -2017
36	Quebrada San Francisco 2 downstream	955044	602720	13- March -2017
37	Quebrada El Macal upstream	951530	602195	14- March -2017
38	Quebrada El Macal downstream	954870	603721	13- March -2017
39	Quebrada Saraconcha upstream	953962	604651	14- March -2017
40	Quebrada Saraconcha downstream	953970	604830	14- March -2017

NUMBER	NAME	BOGOTA PLANE COORDINATES DATUM MAGNA SIRGAS		MONITORING DATE
		EAST	NORTH	
41	RÍO SAPUYES AGUAS ARRIBA	954977	605045	15- March -2017
42	RÍO SAPUYES AGUAS ABAJO	955466	604839	15- March -2017
43	Guáitara River 2	957634	607421	16- March -2017
44	Guáitara River 3	956508	600552	27- March -2017

Source: GEOCOL CONSULTORES S.A., 2017.

Table 5.55 Description of surface water monitoring points.

ID	BODY OF WATER	LOCATION	DESCRIPTION	PHOTOGRAPHIC RECORD / COORDINATES MAGNA SIRGAS ORIGEN WEST
1	Stream NN 3 upstream	**Rural District:** San Juan **Municipality: Ipiales**	Body of water lotic, straight channel with a very low water level, bed with stability low deposition, composed of sand, silt and rocks, clear water. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes No characteristic odors or presence of oils on the body of water.	 E: 955428 N: 5800463300144095
2	Guáitara River	**Rural District:** San Juan **Municipality: Ipiales**	Body of water lotic, straight channel with a medium-high water level, bed with stability moderate deposition, composed of sand, silt and rocks, cloudy water. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. No characteristic odor or presence of oils on the body of water.	 E: 948503 N: 590762

ID	BODY OF WATER	LOCATION	DESCRIPTION	PHOTOGRAPHIC RECORD / COORDINATES MAGNA SIRGAS ORIGEN WEST
3	Upstream Boquerón River	**Rural District:** Anchovy **Municipality: Ipiales**	Body of lotic water, meandering channel with a medium-high water level, bed with stability moderate deposition, composed of sand and rocks, water with moderate turbidity and high speed. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. No characteristic odor or presence of oils on the body of water.	 E: 947873 N: 591368
4	Boquerón River downstream	**Rural District:** San Juan **Municipality: Ipiales**	Body of lotic water, meandering channel with a medium-high water level, bed with stability moderate deposition, composed of sand and rocks, water with moderate turbidity and high speed. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. No characteristic odor or presence of oils on the body of water.	 E: 948589 N: 590972
5	Yamurayán Quebrada upstream	**Rural District:** Aldea de María **Municipality: Contadero**	Body of lotic water, with a low-medium water level, straight channel, bed with stability moderate deposition, composed of clay and sand, cloudy water. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of emerging macrophytes. There are no characteristic odors or presence of oils on the body of water.	 E: 949114 N: 592110

ID	BODY OF WATER	LOCATION	DESCRIPTION	PHOTOGRAPHIC RECORD / COORDINATES MAGNA SIRGAS ORIGEN WEST
6	Quebrada Yamurayán downstream	**Rural District:** La Providencia **Municipality: Contadero**	Body of lotic water, with a low water level, straight channel covered with vegetation, bed with stability low deposition, composed of silt, clay and litter, clear water. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. There are no characteristic odors or presence of oils on the body of water.	 **E:** 949114 N: 592110
7	Quebrada San Francisco upstream	**Rural District:** Las Delicias **Municipality: Contadero**	Body of lotic water, with a low-medium water level, meandering canal, bed with stability low deposition, composed of sand and rocks, water with slight turbidity. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of emerging macrophytes. There are no characteristic odors or presence of oils on the body of water.	 E: 949114 N: 592110
8	Quebrada San Francisco downstream	**Rural District:** Aldea de María **Municipality: Contadero**	Body of lotic water, with a low-medium water level, meandering canal, bed with stability low deposition, composed of sand and rocks, water with slight turbidity. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of emerging macrophytes. There are no characteristic odors or presence of oils on the body of water.	 E: 949114 N: 592110

ID	BODY OF WATER	LOCATION	DESCRIPTION	PHOTOGRAPHIC RECORD / COORDINATES MAGNA SIRGAS ORIGEN WEST
9	Quebrada Cuayarín (Honda) upstream	**Rural District:** El Capulí **Municipality: Contadero**	Body of lotic water, with a low water level, straight channel, bed with low deposition stability, composed of silt and clay, clear water. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. There are no characteristic odors or presence of oils on the body of water.	 E: 949114 N: 592110
10	Quebrada Honda upstream	**Rural District:** El Culantro **Municipality: Contadero**	Body of lotic water, with a low water level, expanded canal straight covered with vegetation and litter, bed with stability low deposition, composed of silt, clay and litter, slightly cloudy water. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes There are no characteristic odors or presence of oils on the body of water.	 E: 949114 N: 592110
11	Quebrada Honda downstream	**Rural District:** Las Delicias **Municipality: Contadero**	Body of lotic water, with a low-medium water level, bed with stability moderate deposition, composed of sand and rocks, clear water. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes. No characteristic odor or presence of oils on the body of water.	 **E:** 949114 N: 592110

ID	BODY OF WATER	LOCATION	DESCRIPTION	PHOTOGRAPHIC RECORD / COORDINATES MAGNA SIRGAS ORIGEN WEST
12	Quebrada tributary to the Corrientes ravine upstream	**Rural District:** El Culantro **Municipality: Contadero**	Body of lotic water, with a low water level, meandering and inclined canal, bed with stability high deposition, composed of clay, sand and rocks, cloudy water. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation riparia composed of a cover of shrubs and grasses. There are no characteristic odors or presence of oils on the body of water.	 E: 949114 N: 592110
13	Culantro Stream	**Rural District:** El Culantro **Municipality: Contadero**	Body of lotic water, with a low water level and pitted, bed with stability moderate deposition, composed of silt, clay and litter, slightly cloudy water. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. No characteristic odor or presence of oils on the body of water.	 E: 949114 N: 592110
14	Quebrada Corantro downstream	**Rural District:** El Culantro **Municipality: Contadero**	Body of lotic water, with a low water level, meandering and inclined canal, bed with stability high deposition, composed of clay, sand and rocks, cloudy water. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation riparia composed of a cover of shrubs and grasses. There are no characteristic odors or presence of oils on the body of water.	 E: 949114 N: 592110

ID	BODY OF WATER	LOCATION	DESCRIPTION	PHOTOGRAPHIC RECORD / COORDINATES MAGNA SIRGAS ORIGEN WEST
15	Quebrada La Cueva upstream	**Rural District:** Iscuazan **Municipality: Contadero**	Body of water lotic, with a low water level, straight channel, bed with stability moderate deposition, composed of silt and clay, slightly cloudy water. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. No characteristic odor or presence of oils on the body of water.	 E: 949114 N: 592110
16	Quebrada La Cueva downstream	**Rural District:** El Culantro **Municipality: Contadero**	Body of lotic water, with a low water level, straight channel, bed with stability low deposition, composed of sand, litter and rocks, clear water. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation riparia composed of a cover of shrubs and grasses. There are no characteristic odors or presence of oils on the body of water.	 E: 949114 N: 592110
17	Quebrada tributary to the creek Manzano upstream	**Rural District:** Las Cuevas **Municipality: Contadero**	Body of lotic water, with a low water level, meandering and inclined canal, bed with stability low deposition, composed of rocks, clear water. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes. There are no characteristic odors or presence of oils on the body of water.	 E: 949114 N: 592110

ID	BODY OF WATER	LOCATION	DESCRIPTION	PHOTOGRAPHIC RECORD / COORDINATES MAGNA SIRGAS ORIGEN WEST
18	Quebrada El Manzano upstream	**Rural District:** Ospina Perez **Municipality: Contadero**	Body of lotic water, with a low water level, inclined cascade type, bed with stability low deposition, composed of rocks, clear water. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes. There are no characteristic odors or presence of oils on the body of water.	 E: 949114 N: 592110
19	Quebrada El Manzano downstream	**Rural District:** Las Cuevas **Municipality: Contadero**	Body of lotic water, with a low water level, meandering and inclined canal, bed with stability low deposition, composed of rocks, clear water. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes. There are no characteristic odors or presence of oils on the body of water.	 **E:** 949114 N: 592110
20	Quebrada Brigada upstream	**Rural District:** Ospina Perez **Municipality: Contadero**	Body of lotic water, with a low water level, straight channel, bed with stability low deposition, composed of silt and clay, water with slight turbidity. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes. There are no characteristic odors or presence of oils on the body of water.	 E: 949114 N: 592110

ID	BODY OF WATER	LOCATION	DESCRIPTION	PHOTOGRAPHIC RECORD / COORDINATES MAGNA SIRGAS ORIGEN WEST
21	Quebrada Brigada downstream	**Rural District:** Ospina Perez **Municipality: Contadero**	Body of lotic water, with a low water level, straight channel covered with vegetation, bed with stability low deposition, composed of silt and clay, water with slight turbidity. Perturbation of very low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes. There are no characteristic odors or presence of oils on the body of water.	 E: 949114 N: 592110
22	Affluent to the ravine	**Rural District:** San José de Quisnamuez **Municipality: Contadero**	Body of water lotic, with a low water level, straight channel, bed with stability low deposition, composed of rocks and sand, clear water. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes. There are no characteristic odors or presence of oils on the body of water.	 E: 949114 N: 592110
23	Quebrada Los Arayanes (Hummingbird) upstream	**Rural District:** High King **Municipality: Iles**	Body of lotic water, with a low-medium water level, bed with stability moderate deposition, composed of sand, silt and clay, water with light turbidity. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes. No characteristic odor or presence of oils on the body of water.	 E: 949114 N: 592110

ID	BODY OF WATER	LOCATION	DESCRIPTION	PHOTOGRAPHIC RECORD / COORDINATES MAGNA SIRGAS ORIGEN WEST
24	Quebrada El Manzano (Humidor) upstream	**Rural District:** Ilés, urban center **Municipality:** ILES	Body of lotic water, with a low water level, straight channel, bed with stability moderate deposition, composed of sand and rocks, slightly cloudy water. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation ripiara composed of a cover of shrubs and herbs, emergent macrophytes, without characteristic odors or presence of oils on the body of water.	 E: 949114 N: 592110
25	Upstream Gorge (Smoker) upstream	**Rural District:** Ilés, urban center **Municipality:** ILES	Body of water lotic, with a low water level, straight channel, bed with stability low deposition, composed of sand and rocks, clear water. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of emergent macrophytes There are no characteristic odors or presence of oils on the body of water.	 **E:** 949114 N: 592110
26	Downstream Humidifier Gully	**Sidewalk**: Casco Urbano Iles **Municipality**: Iles	Body of lotic water, with a medium water level, straight channel, bed with stability moderate deposition, composed of clay and sand, moderately cloudy water. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation riparia composed of a cover of shrubs and grasses. There are no characteristic odors or presence of oils on the body of water.	 AND: 955074 N: 597201

ID	BODY OF WATER	LOCATION	DESCRIPTION	PHOTOGRAPHIC RECORD / COORDINATES MAGNA SIRGAS ORIGEN WEST
27	Zanja Chorrera Chiquita upstream	**Sidewalk**: High Plank **Municipality**: Iles	Body of lotic water, with a low water level, bed with stability moderate deposition covered with vegetation, composed of sand, silt and clay, water with light turbidity. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes. No characteristic odor or presence of oils on the body of water.	 AND: 955908 N: 598687
28	Zanja Chorrera Chiquita downstream	**Sidewalk**: The hope **Municipality**: Iles	Body of lotic water, with a medium water level, bed with stability moderate deposition, composed of sand and rocks, water with light turbidity. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes. No characteristic odor or presence of oils on the body of water.	 **AND:** 956740 N: 599033
29	Quebrada Moledores upstream	**Sidewalk**: High Plank **Municipality**: Iles	Body of lotic water, with a low-medium water level, straight channel, bed with stability low deposition, composed of silt and clay, slightly cloudy water. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. No characteristic odor or presence of oils on the body of water.	 AND: 955872 N: 598885

ID	BODY OF WATER	LOCATION	DESCRIPTION	PHOTOGRAPHIC RECORD / COORDINATES MAGNA SIRGAS ORIGEN WEST
30	Quebrada Moledores downstream	**Sidewalk**: High Plank **Municipality**: Iles	Body of lotic water, with a medium-high water level, meandering channel, bed with stability low deposition, composed of sand and rocks, slightly cloudy water. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. No characteristic odor or presence of oils on the body of water.	 AND: 956019 N: 598991
31	Quebrada The plank downstream	**Sidewalk**: Low Plank **Municipality**: Iles	Body of water lotic, small, with a low water level, bed with stability, low deposition, composed of sand and silt, cloudy water. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes No characteristic odors or presence of oils on the body of water.	 AND: 955333 N: 600464
32	Broken tributary The Plank Downstream	**Sidewalk**: Low Plank **Municipality**: Iles	Body of lotic water, meandering channel, with a low-medium water level, bed with stability, low deposition, composed of sand, silt and rocks, cloudy water. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes No characteristic odors or presence of oils on the body of water.	 AND: 955135 N: 600723

ID	BODY OF WATER	LOCATION	DESCRIPTION	PHOTOGRAPHIC RECORD / COORDINATES MAGNA SIRGAS ORIGEN WEST
33	Affluent to the ravine San Francisco 2 upstream	**Sidewalk**: High Plank **Municipality**: Iles	Body of water lotic, straight channel with a low water level, bed with stability low deposition, composed of sand, silt and rocks, cloudy water. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes No characteristic odors or presence of oils on the body of water.	 AND: 954815 N: 601862
34	Affluent to the ravine San Francisco 2 upstream	**Sidewalk**: High Plank **Municipality**: Iles	Body of lotic water, with waterfall type cascade, with a low-medium water level, bed with stability low deposition, composed of sand, silt and rocks, cloudy water. Disturbance of the low vegetation, it is observed that the local use of the soil is native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes No characteristic odors or presence of oils on the body of water.	 AND: 954467 N: 601562
35	Quebrada San Francisco 2 upstream	**Sidewalk**: High Plank **Municipality**: Iles	Body of lotic water, with a low-medium water level, bed with stability, low deposition, composed of sand and rocks, cloudy water. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation riparia composed of a cover of shrubs and grasses. No characteristic odor or presence of oils on the body of water.	 AND: 953962 N: 601557

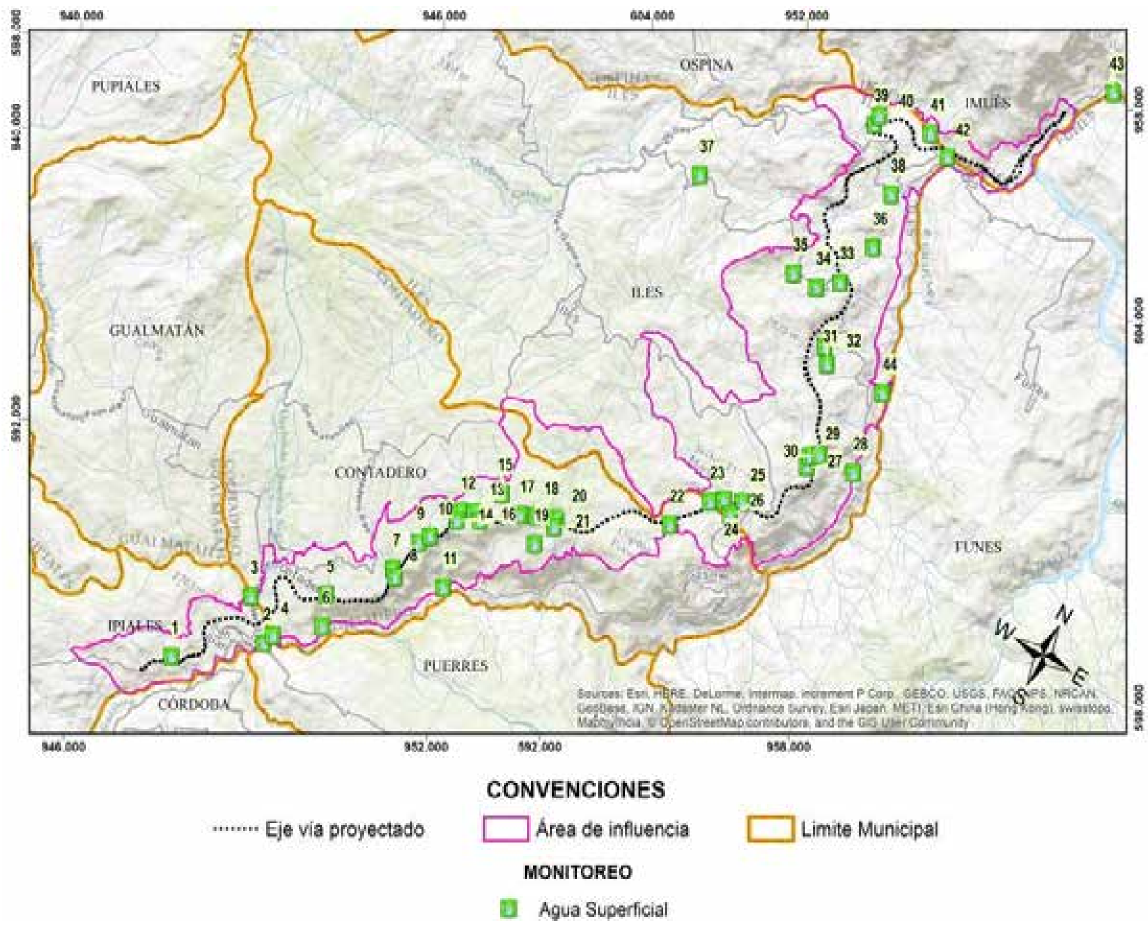
ID	BODY OF WATER	LOCATION	DESCRIPTION	PHOTOGRAPHIC RECORD / COORDINATES MAGNA SIRGAS ORIGEN WEST
36	Quebrada San Francisco 2 downstream	**Sidewalk**: Capuli **Municipality**: Iles	Body of lotic water, with a medium water level, bed with stability, low deposition, composed of sand and rocks, cloudy water. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation riparia composed of a cover of shrubs and grasses. No characteristic odor or presence of oils on the body of water.	 AND: 955044 N: 602720
37	Quebrada El Macal upstream	**Sidewalk**: The rosary **Municipality**: Iles	Body of lotic water, with a low-medium water level, bed with stability, low deposition, composed of sand and rocks, cloudy water. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes No characteristic odors or presence of oils on the body of water.	 AND: 953397 N: 602713
38	Quebrada El Macal downstream	**Sidewalk**: Future **Municipality**: Iles	Body of lotic water, with a medium-high water level, bed with stability, low deposition, composed of sand and rocks, cloudy water and with high speed. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation riparia composed of a cover of shrubs and grasses. No characteristic odor or presence of oils on the body of water.	 AND: 954870 N: 603721

ID	BODY OF WATER	LOCATION	DESCRIPTION	PHOTOGRAPHIC RECORD / COORDINATES MAGNA SIRGAS ORIGEN WEST
39	Quebrada Saraconcha upstream	**Sidewalk**: Future **Municipality**: Iles	Body of lotic water, with a low-medium water level, bed with stability, low deposition, composed of sand and rocks, cloudy water. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes No characteristic odors or presence of oils on the body of water.	 AND: 953962 N: 604651
40	Quebrada Saraconcha downstream	**Sidewalk**: Future **Municipality**: Iles	Body of lotic water, with a low-medium water level, bed with stability, low deposition, composed of sand and rocks, cloudy water. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation riparia composed of a cover of shrubs and grasses. Presence of macrophytes No characteristic odors or presence of oils on the body of water.	 AND: 953970 N: 604830
41	Sapuyes River upstream	**Sidewalk**: Silamag **Municipality**: Imués	Body of lotic water, with a medium-high water level, bed with stability, low deposition, composed of sand and rocks, large dimensions, cloudy water and with high speed. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation riparia composed of a cover of shrubs and grasses. No characteristic odor or presence of oils on the body of water.	 **AND:** 954977 N: 605045

ID	BODY OF WATER	LOCATION	DESCRIPTION	PHOTOGRAPHIC RECORD / COORDINATES MAGNA SIRGAS ORIGEN WEST
42	Sapuyes River downstream	**Sidewalk**: Future **Municipality**: Iles	Body of lotic water, with a medium-high water level, bed with stability, low deposition, composed of sand and rocks, large dimensions, cloudy water and with high speed. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation riparia composed of a cover of shrubs and grasses. No characteristic odor or presence of oils on the body of water.	 AND: 955466 N: 604839
43	Guáitara River 2	**Sidewalk**: The Pedregal **Municipality**: Imues	Body of lotic water, with a medium-high water level, bed with stability, low deposition, composed of sand and rocks, large dimensions, cloudy water and with high speed. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation riparia composed of a cover of shrubs and grasses. No characteristic odor or presence of oils on the body of water.	 AND: 957634 N: 607421
44	Río Guáitara 3	**Sidewalk**: The hope **Municipality**: Iles	Body of lotic water, with a medium-high water level, bed with stability, low deposition, composed of sand and rocks, large dimensions, cloudy water and with high speed. Perturbation of moderate vegetation, local use of the soil is observed to be native forest. Vegetation riparia composed of a cover of shrubs and grasses. No characteristic odor or presence of oils on the body of water.	 AND: 956508 N: 600552

Source: GEOCOL CONSULTORES SA, 2017.

Figure 5.43 Location of the monitoring points of bodies of surface water Rumichaca dual carriageway road project - Pasto, San Juan - Pedregal stretch.



Source: GEOCOL CONSULTORES SA, 2017.

The parameters analyzed are those established in the Terms of Reference for the Elaboration of environmental impact studies - Road construction projects and / or tunnels, as well as those required to determine the calculated pollution rates. Their characterization was carried out following the methodology described in **Annex 15. Monitoring**, Which contains the report presented by the laboratory MCS Consultoria y Monitoreo Ambiental SAS, which is accredited by IDEAM, Resolution 2892 of December 30, 2016 and Resolution 0049 of January 16, 2017, as the laboratory competent to carry out the analyzes Physicochemical properties in the water matrix. This annex presents the description of the points monitored.

In the **Table 5.56** The analyzed parameters are presented, referencing the sampling method and the analytical technique used for each of them, as well as the units in which the obtained results are reported. It should be noted that, of all the parameters taken into account, five (5) of them were recorded *In situ* (Temperature, pH, dissolved solids, conductivity and dissolved oxygen), while the samples of the remaining variables were sent to the laboratories MCS Consultoria y Monitoreo Ambiental SAS and CIAN Ltda., For their corresponding analysis. The time elapsed between taking the samples and receiving them in the laboratories did not exceed 48 hours.

Table 5.56 List of the methods and analytical techniques used for the analysis of physicochemical and bacteriological parameters of the monitored stations.

SETTINGS	UNITS	ANALYTICAL TECHNIQUE	METHOD
TEMPERATURE SAMPLE	° C	THERMOMETRIC	SM 2550 B
PH	UNITS	ELECTROMETRIC	SM 4500H + B
ELECTRIC CONDUCTIVITY	µS/cm	ELECTROMETRIC	SM 2510 B
DISSOLVED OXYGEN	Mg / L O2	LUMINESCENCE	ISO 17289: 2014
FLOW	M3 / s	AREA - SPEED WITH MICROMOLINET OR FLOW METER	PROTOCOL FOR WATER MONITORING AND MONITORING. EPISODE 2. IDEAM. 2007
TURBIDITY	NTU	NEPHELOMETRIC	SM 2130 B
REAL COLOR	CPU	SPECTROPHOTOMETRIC - SIMPLE WAVE LENGTH	SM 2120 C
TOTAL ORGANIC CARBON	Mg / L	HIGH COMBUSTION	EPA 5310 B
BICARBONATES	Mg / l CaCO3	VOLUMETRIC	SM 2320 B
TOTAL ACIDITY	Mg / l CaCO3	VOLUMETRIC	SM 2310 B
TOTAL ALKALINITY	Mg / l CaCO3	VOLUMETRIC	SM 2320 B
TOTAL HARDNESS	Mg / l CaCO3	VOLUMETRIC - EDTA	SM 2340 C
CALCULIC HARDNESS	Mg / l CaCO3	VOLUMETRIC - EDTA	SM 3500-Ca B
CHLORIDE	Mg / L Cl-	ARGENTOMETRIC	SM 4500-Cl B
SULFATES	Mg / L S04-2	TURBIDIMÉTRICO	SM 4500-SO4 E
PHOSPHATES	Mg / L P-PO4-3	ASCORBIC ACID	SM 4500-PO4 E
NITRATES	Mg / L N-NO3	COLORIMETRIC	SM 4500-NO3-B
NITRITES	Mg / L N-NO2	COLORIMETRIC	SM 4500-NO2 B
AMMONIACAL NITROGEN	Mg / L	DISTILLATION - VOLUMETRIC	SM 4500-NH3 B-F
TOTAL NITROGEN	Mg / LN	KJELDAHL - TITULOMETRIC	SM 4500-Norg C, SM 4500-NH3 C
TOTAL PHOSPHORUS	Mg / L	ASCORBIC ACID	SM 4500 PE
INORGANIC PHOSPHORUS	Mg / LP	DIGESTION - COLORIMETRIC	SM 4500-PB, SM 4500-PE
ORGANIC PHOSPHORUS	Mg / L	DIGESTION - COLORIMETRIC	SM 4500-PB, SM 4500-PE
TOTAL PHENOLS	Mg / L	DISTILLATION - DIRECT PHOTOMETRIC	SM 5530 B, SM 5530 D
TOTAL DISSOLVED SOLIDS	Mg / L	ELECTROMETRIC	SM 2510 B
SEDIMENTABLE SOLIDS	ML / Lh	VOLUMETRIC (CONO IMHOFF)	SM 2540 F
TOTAL SUSPENDED SOLIDS	Mg / L	DRYING AT 103-105 ° C	SM 2540 D
TOTAL SOLIDS	Mg / L	DRYING AT 103 - 105 ° C	SM 2540 B
BOD_5	Mg / L O2	INCUBATION 5 DAYS - MEMBRANE ELECTRODE	SM 5210 B, SM 4500-OG
COD	Mg / L O2	CLOSED REFLUX - VOLUMETRIC	SM 5220 C
TOTAL IRON	Mg / L	EAA	SM 3030 E, SM 3111 B
MAGNESIUM	Mg / L	EAA	SM 3030 E, SM 3111 B
NICKEL	Mg / L	EAA	SM 3030 E, SM 3111 B
LEAD	Mg / L	EAA	SM 3030 E, SM 3111 B
POTASSIUM	Mg / L	EAA	SM 3030 E, SM 3111 B
SELENIUM	Mg / L	EAA GENERATOR OF HYDROS	SM 3114 C
BARIUM	Mg / L	EAA	SM 3030 E, SM 3111 D

SETTINGS	UNITS	ANALYTICAL TECHNIQUE	METHOD
CADMIUM	Mg / L	EAA	SM 3030 E, SM 3111 B
CALCIUM	Mg / L	EAA	SM 3030 E, SM 3111 B
TOTAL CHROME	Mg / L	EAA	SM 3030 E, SM 3111 B
SODIUM	Mg / L	EAA	SM 3111 B
ARSENIC	Mg / L	EAA - HYDRIDE GENERATOR	SM 3114 C
COPPER	Mg / L	EAA	SM 3030 E, SM 3111 B
MANGANESE	Mg / L	EAA	SM 3030 E, SM 3111 B
MERCURY	Mg / L	EAA / VF	SM 3114 C
SILVER	Mg / L	EAA	SM 3030 E, SM 3111 B
ZINC	Mg / L	EAA	SM 3030 E, SM 3111 B
TENSOACTIVES (SAAM)	Mg / L LAS	COLORIMETRIC	SM 5540 C
FATS AND OILS	Mg / L	PARTITION - INFRARED	SM 5520 C
TOTAL HYDROCARBONS	Mg / L	PARTITION - INFRARED	SM 5520 C, SM 5520 F
TOTAL COLIFORMS	NMP / 100 mL	ENZYMATIC SUBSTRATE TEST	SM 9223 B
THERMOTOLERANT COLIFORMES (FECALES)	NMP / 100mL	ENZYMATIC SUBSTRATE TEST	SM 9223 B

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5.1.6.1.2 Results of the physicochemical and bacteriological characterization of surface water bodies.

The comparison limits included in this document correspond to those established in the transitional provisions of the single Decree 1076/2015 (articles 2.2.3.3.9.2 to 2.2.3.3.9.10), which compile articles 37 to 45 of Decree 1594 of 1984, for some probable uses, such as the criteria for the destination of the resource for human and domestic consumption that indicate that for its purification only conventional treatment or disinfection is required, as well as the conditions for agricultural and livestock use, since to date The quality criteria for the use of water are not defined in Decree 3930 of 2010 (Chapter V, Article 20).

The analysis of the physicochemical and bacteriological parameters, includes the presentation of the results and the comparison with the quality criteria according to the current regulations. Subsequently, a description of the main parameters evaluated is made and the indexes and indicators mentioned above are calculated.

The results of the physicochemical and bacteriological characterization of the surface water sources of the area of influence of the Rumichaca - Pasto dual carriageway project, San Juan - Pedregal section, are presented below (**Table 5.57** to **Table 5.65**). See **Annex 15. Monitoring.**

Table 5.57 Results of physicochemical and bacteriological parameters obtained at the monitoring points evaluated and their comparison with the permissible quality criteria.

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		BROKEN THE SMOOTHING APPLE WATER ABOVE	WET BLEEDING WATER DOWN	MOISTURIZING URBAN BREAK	SAN FRANCISCO AGUAS ARRIBA BROKEN	SAN FRANCISCO WATER BOW DOWN	Article 38 Limit Human Consumption	Article 39 Limit Human consumption	Article 40 Agricultural use limit
No. MCS		5358	5356	5357	5273	5274			
DATE	A-M-D	6-3-2017	6-3-2017	6-3-2017	27-2-2017	27-2-2017			
HOUR	h:min	3:45 p.m.	8:20	12:15	9:30 a.m.	12:00			
TEMPERATURE SAMPLE	° C	15,35	15,15	16,75	14,75	16,7	NE	NE	NE
PH	UNITS	8,05	7,35	7,75	6,31	6,42	5 - 9	6,5 - 8,5	4,5 - 9,0
ELECTRIC CONDUCTIVITY	µS/cm	118	120	105	180	220	NE	NE	NE
TOTAL DISSOLVED SOLIDS	Mg / L	60	64	54,2	90	105	NE	NE	NE
SEDIMENTABLE SOLIDS	ML / Lh	<0.1	<0.1	<0.1	<0.1	<0.1	NE	NE	NE
DISSOLVED OXYGEN	Mg / L O2	6	5	6	1,2	1	NE	NE	NE
FLOW	M3 / s	0,082	0,27	0,179	0,002	0,002	NE	NE	NE
TOTAL ACIDITY	Mg / l CaCO3	5,53	6,03	6,03	4,52	7,54	NE	NE	NE
TOTAL ALKALINITY	Mg / l CaCO3	27	28,7	26,5	43,2	42,8	NE	NE	NE
ARSENIC	Mg / L	<0.01	<0.01	<0.01	<0.01	<0.01	0,05	0,05	0,1
BARIUM	Mg / L	<0.6	<0.6	<0.6	<0.6	<0.6	1	1	NE
BICARBONATES	Mg / l CaCO3	27	28,7	26,5	43,2	42,8	NE	NE	NE
CADMIUM	Mg / L	<0.01	<0.01	<0.01	<0.01	<0.01	0,01	0,01	0,01
CALCIUM	Mg / L	9,21	10,2	9,62	14,8	15,7	NE	NE	NE
TOTAL ORGANIC CARBON	Mg / L	<3	<3	<3	<3	<3	NE	NE	NE
CHLORIDE	Mg / L Cl-	12,8	12,7	15,8	19,98	24,11	250	250	NE
COPPER	Mg / L	<0.15	<0.15	<0.15	<0.15	<0.15	1	1	0,2
THERMOTOLERANT COLIFORMES (FECALES)	NMP / 100mL	288	156	189	265	230	2000	NE	1000
TOTAL COLIFORMS	NMP / 100 mL	2640	2160	1500	1480	1730	20000	1000	5000
REAL COLOR	CPU	25,48	32,22	32,47	52,49	56,4272	75	20	NE
TOTAL CHROME	Mg / L	<0.11	<0.11	<0.11	<0.11	<0.11	0,05	0,05	0,1
BOD5	Mg / L O2	<5	<5	<5	<5	<5	NE	NE	NE
COD	Mg / L O2	<20	<20	<20	<20	<20	NE	NE	NE
CALCULIC HARDNESS	Mg / l CaCO3	24,4	26,9	24,6	38,4	40,3	NE	NE	NE
TOTAL HARDNESS	Mg / l CaCO3	34,8	38,4	35,2	54,8	57,6	NE	NE	NE
TOTAL PHENOLS	Mg / L	<0.002	<0.002	<0.002	<0.002	<0.002	0,002	0,002	NE
PHOSPHATES	Mg / L P-PO4-3	<0.03	<0.03	<0.03	<0.1	0,1181	NE	NE	NE

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		BROKEN THE SMOOTHING APPLE WATER ABOVE	WET BLEEDING WATER DOWN	MOISTURIZING URBAN BREAK	SAN FRANCISCO AGUAS ARRIBA BROKEN	SAN FRANCISCO WATER BOW DOWN	Article 38 Limit Human Consumption	Article 39 Limit Human consumption	Article 40 Agricultural use limit
No. MCS		5358	5356	5357	5273	5274			
DATE	A-M-D	6-3-2017	6-3-2017	6-3-2017	27-2-2017	27-2-2017			
HOUR	h:min	3:45 p.m.	8:20	12:15	9:30 a.m.	12:00			
INORGANIC PHOSPHORUS	Mg / LP	<0.1	<0.1	<0.1	0,188	0,253	NE	NE	NE
ORGANIC PHOSPHORUS	Mg / L	<0.1	<0.1	<0.1	<0.1	<0.1	NE	NE	NE
TOTAL PHOSPHORUS	Mg / L	<0.1	<0.1	<0.1	0,222	0,305	NE	NE	NE
FATS AND OILS	Mg / L	<1.4	<1.4	<1.4	<1.4	<1.4	SPV	SPV	NE
TOTAL HYDROCARBONS	Mg / L	<1.4	<1.4	<1.4	<1.4	<1.4	NE	NE	NE
TOTAL IRON	Mg / L	0,178	0,199	0,183	0,211	0,321	NE	NE	5
MAGNESIUM	Mg / L	2,12	2,3	2,22	3,71	3,81	NE	NE	NE
MANGANESE	Mg / L	<0.12	<0.12	<0.12	<0.12	<0.12	NE	NE	0,2
MERCURY	Mg / L	<0.002	<0.002	<0.002	<0.05	<0.05	0,002	0,002	NE
NICKEL	Mg / L	<0.15	<0.15	<0.15	<0.15	<0.15	NE	NE	0,2
NITRATES	Mg / L N-NO3	0,803	0,752	0,856	5	5,75	10	10	NE
NITRITES	Mg / L N-NO2	0,0095	0,0075	0,0087	0,0089	0,0074	1	1	NE
AMMONIACAL NITROGEN	Mg / L	<1	<1	<1	<1	<1	NE	NE	N.E.
TOTAL NITROGEN	mg/L N	<3	<3	<3	<3	<3	N.E.	N.E.	N.E.
SILVER	mg/L	<0,05	<0,05	<0,05	<0,05	<0,05	0,05	0,05	N.E.
LEAD	mg/L	<0,05	<0,05	<0,05	<0,05	<0,05	0,05	0,05	5
POTASSIUM	mg/L	0,322	0,302	0,301	0,854	0,932	N.E.	N.E.	N.E.
SELENIUM	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,01	0,01	0,02
SODIUM	mg/L	10,6	5,8	10,8	16,4	19,9	N.E.	N.E.	N.E.
TOTAL SUSPENDED SOLIDS	mg/L	18	22	10	69	46	N.E.	N.E.	N.E.
TOTAL SOLIDS	mg/L	82	90	74	168	162	N.E.	N.E.	N.E.
SULFATES	mg/L S04-2	6,13	<5	<5	<5	<5	400	400	N.E.
TENSOACTIVES (SAAM)	mg/L LAS	<0,24	<0,24	<0,24	<0,24	<0,24	0,5	0,5	N.E.
TURBIDITY	NTU	15,9	19,3	11,5	68,7	48,9	N.E.	190	N.E.
ZINC	mg/L	<0,12	<0,12	<0,12	<0,12	<0,12	15	15	2

Source: Results of physicochemical and bacteriological analyzes carried out by the Laboratorios MCS Consultoría y Monitoreo Ambiental SAS y CIAN Ltda., 2017.

Table 5.58 Results of physicochemical and bacteriological parameters obtained at the monitoring points evaluated and their comparison with the permissible quality criteria.

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		BROKEN YAMURAYAN AGUAS TOP	AFFLUENT BROKEN CULANTRO WATER ABOVE	BREAK CULANTRO WATERS DOWN	BROKEN DOWN THE CAVE WATERS	BROKEN THE MANZANO WATERS ABOVE	Article 38 Limit Human Consumption Treatment	Article 39 Limit Human consumption Disinfection	Article 40 Agricultural use limit
No. MCS		5275	5355	5353	5354	5350			
DATE	A-M-D	27-2-2017	2-3-2017	2-3-2017	2-3-2017	5-3-2017			
HOUR	h:min	15:30	15:15	8:00	11:30	8:30			
TEMPERATURE SAMPLE	°C	14,5	15,65	14,5	15,6	15,65	N.E.	N.E.	N.E.
pH	UNITS	6,46	7,2	7,15	7,4	7,75	5 - 9	6,5 - 8,5	4,5 - 9,0
ELECTRIC CONDUCTIVITY	µS/cm	190	140	95	90	90	N.E.	N.E.	N.E.
TOTAL DISSOLVED SOLIDS	mg/L	85	45	40	60	39,5	N.E.	N.E.	N.E.
SEDIMENTABLE SOLIDS	mL/L-h	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
DISSOLVED OXYGEN	mg/L O2	1,01	5,3	5,2	5	6	N.E.	N.E.	N.E.
FLOW	m3/s	0,001	0,005	0,008	0,04	0,006	N.E.	N.E.	N.E.
TOTAL ACIDITY	mg/L CaCO3	6,53	5,03	6,03	6,53	5,03	N.E.	N.E.	N.E.
TOTAL ALKALINITY	mg/L CaCO3	42,8	22,5	22,6	21,3	22,8	N.E.	N.E.	N.E.
ARSENIC	Mg / L	<0,01	<0,01	<0,01	<0,01	<0,01	0,05	0,05	0,1
BARIO	mg/L	<0,6	<0,6	<0,6	<0,6	<0,6	1	1	N.E.
BICARBONATES	mg/L CaCO3	42,8	22,5	22,6	21,3	22,8	N.E.	N.E.	N.E.
CADMIUM	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,01	0,01	0,01
CALCIUM	mg/L	16,8	6,11	9,09	7,82	4,97	N.E.	N.E.	N.E.
TOTAL ORGANIC CARBON	mg/L	<3	<3	<3	<3	<3	N.E.	N.E.	N.E.
CHLORIDE	mg/L Cl-	24,26	6,54	8,76	8,76	5,08	250	250	N.E.
COPPER	mg/L	<0,15	<0,15	<0,15	<0,15	<0,15	1	1	0,2
THERMOTOLERANT COLIFORMES (FECALES)	NMP/100mL	166	310	167	110	210	2000	N.E.	1000
TOTAL COLIFORMS	NMP/100 mL	1300	1780	1260	1056	2200	20000	1000	5000
REAL COLOR	UPC	50,68	29,36	48,78	34,68	47,93	75	20	N.E.
TOTAL CHROME	mg/L	<0,11	<0,11	<0,11	<0,11	<0,11	0,05	0,05	0,1
DBO5	mg/L O2	<5	<5	<5	<5	<5	N.E.	N.E.	N.E.
DQO	mg/L O2	<20	<20	<20	<20	<20	N.E.	N.E.	N.E.
CALCULIC HARDNESS	mg/L CaCO3	43,9	15,9	23,2	20,4	13,3	N.E.	N.E.	N.E.
TOTAL HARDNESS	mg/L CaCO3	62,8	22,8	33,2	29,2	19	N.E.	N.E.	N.E.
TOTAL PHENOLS	mg/L	<0,002	<0,002	<0,002	<0,002	<0,002	0,002	0,002	N.E.

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		BROKEN YAMURAYAN AGUAS TOP	AFFLUENT BROKEN CULANTRO WATER ABOVE	BREAK CULANTRO WATERS DOWN	BROKEN DOWN THE CAVE WATERS	BROKEN THE MANZANO WATERS ABOVE	Article 38 Limit Human Consumption Treatment	Article 39 Limit Human consumption Disinfection	Article 40 Agricultural use limit
No. MCS		5275	5355	5353	5354	5350			
DATE	A-M-D	27-2-2017	2-3-2017	2-3-2017	2-3-2017	5-3-2017			
HOUR	h:min	15:30	15:15	8:00	11:30	8:30			
PHOSPHATES	mg/L P-PO4-3	0,1106	<0,03	<0,03	<0,03	<0,03	N.E.	N.E.	N.E.
INORGANIC PHOSPHORUS	mg/L P	0,259	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
ORGANIC PHOSPHORUS	mg/L	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
TOTAL PHOSPHORUS	mg/L	0,286	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
FATS AND OILS	mg/L	<1,4	<1,4	<1,4	<1,4	<1,4	S.P.V	S.P.V	N.E.
TOTAL HYDROCARBONS	mg/L	<1,4	<1,4	<1,4	<1,4	<1,4	N.E.	N.E.	N.E.
TOTAL IRON	mg/L	0,198	0,178	0,193	0,204	<0,15	N.E.	N.E.	5
MAGNESIUM	mg/L	4,32	1,28	2,05	1,95	1,1	N.E.	N.E.	N.E.
MANGANESE	mg/L	<0,12	<0,12	<0,12	<0,12	<0,12	N.E.	N.E.	0,2
MERCURY	mg/L	<0,002	<0,002	<0,002	<0,002	<0,002	0,002	0,002	N.E.
NICKEL	mg/L	<0,15	<0,15	<0,15	<0,15	<0,15	N.E.	N.E.	0,2
NITRATES	mg/L N-NO3	5,877	0,941	0,929	0,856	0,91	10	10	N.E.
NITRITES	mg/L N-NO2	0,0089	0,0076	0,0071	0,0084	0,009	1	1	N.E.
AMMONIACAL NITROGEN	mg/L	<1	<1	<1	<1	<1	N.E.	N.E.	NE
TOTAL NITROGEN	mg/L N	<3	SC	SC	<3	<3	N.E.	N.E.	N.E.
SILVER	mg/L	<0,05	<0,05	<0,05	<0,05	<0,05	0,05	0,05	N.E.
LEAD	mg/L	<0,05	<0,05	<0,05	<0,05	<0,05	0,05	0,05	5
POTASSIUM	mg/L	0,528	0,305	<0,27	<0,27	0,322	N.E.	N.E.	N.E.
SELENIUM	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,01	0,01	0,02
SODIUM	mg/L	17,2	7,01	4,18	4,64	7,81	N.E.	N.E.	N.E.
TOTAL SUSPENDED SOLIDS	mg/L	34	8	16	14	8	N.E.	N.E.	N.E.
TOTAL SOLIDS	mg/L	130	54	76	72	54	N.E.	N.E.	N.E.
SULFATES	mg/L S04-2	<5	<5	<5	<5	<5	400	400	N.E.
TENSOACTIVES (SAAM)	mg/L LAS	<0,24	<0,24	<0,24	<0,24	<0,24	0,5	0,5	N.E.
TURBIDITY	NTU	44,7	12,9	16,6	18,5	11,6	N.E.	190	N.E.
ZINC	mg/L	<0,12	<0,12	<0,12	<0,12	<0,12	15	15	2

Source: Results of physicochemical and bacteriological analyzes performed by the Laboratorios MCS Consultoria y Monitoreo Ambiental SAS y CIAN Ltda., 2017

Table 5.59 Results of physicochemical and bacteriological parameters obtained at the monitoring points evaluated and their comparison with the permissible quality criteria.

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		BROWN MANZANO WATERS DOWN	HYGIENE HYGIENE UPSTREAM	BROKEN BRIGADE UPSTREAM	BROKEN BRIGADE DOWNSTREAM	BROWN MANZANO UPSTREAM	Article 38 Limit Human Consumption Treatment	Article 39 Limit Human consumption Disinfection	Article 40 Agricultural use limit
No. MCS		5351	5352	5347	5348	5349			
DATE	A-M-D	5-3-2017	5-3-2017	4-3-2017	4-3-2017	4-3-2017			
HOUR	h:min	12:00	15:20	8:30	12:35	14:00			
TEMPERATURE SAMPLE	°C	13,95	16,3	15	14,2	16,8	N.E.	N.E.	N.E.
pH	UNITS	7,55	7,1	7,25	7,45	7,95	5 - 9	6,5 - 8,5	4,5 - 9,0
ELECTRIC CONDUCTIVITY	µS/cm	75	200	110	75	80	N.E.	N.E.	N.E.
TOTAL DISSOLVED SOLIDS	mg/L	30	90	40	30	40	N.E.	N.E.	N.E.
SEDIMENTABLE SOLIDS	mL/L-h	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
DISSOLVED OXYGEN	mg/L O2	5,9	5	4,5	4,4	5	N.E.	N.E.	N.E.
FLOW	m3/s	0,082	0,004	0,003	0,005	0,018	N.E.	N.E.	N.E.
TOTAL ACIDITY	mg/L CaCO3	4,52	5,53	7,04	7,54	5,03	N.E.	N.E.	N.E.
TOTAL ALKALINITY	mg/L CaCO3	21,9	26,7	17,8	18,2	22,3	N.E.	N.E.	N.E.
ARSENIC	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,05	0,05	0,1
BARIUM	mg/L	<0,6	<0,6	<0,6	<0,6	<0,6	1	1	N.E.
BICARBONATES	mg/L CaCO3	21,9	26,7	17,8	18,2	22,3	N.E.	N.E.	N.E.
CADMIUM	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,01	0,01	0,01
CALCIUM	mg/L	5,32	14,4	6,32	8,32	5,07	N.E.	N.E.	N.E.
TOTAL ORGANIC CARBON	mg/L	<3	<3	<3	<3	<3	N.E.	N.E.	N.E.
CHLORIDE	mg/L Cl-	5,29	17,1	7,45	7,6	5,44	250	250	N.E.
COPPER	mg/L	<0,15	<0,15	<0,15	<0,15	<0,15	1	1	0,2
THERMOTOLERANT COLIFORMES (FECALES)	NMP/100mL	130	207	200	256	165	2000	N.E.	1000
TOTAL COLIFORMS	NMP / 100 mL	1300	1250	1390	1140	1600	20000	1000	5000
REAL COLOR	UPC	49,75	33,15	<5	<5	40,35	75	20	N.E.
TOTAL CHROME	mg/L	<0,11	<0,11	<0,11	<0,11	<0,11	0,05	0,05	0,1
DBO5	mg/L O2	<5	<5	<5	<5	<5	N.E.	N.E.	N.E.
DQO	mg/L O2	<20	<20	<20	<20	<20	N.E.	N.E.	N.E.
CALCULIC HARDNESS	mg/L CaCO3	14,2	37,2	17,1	21,8	13,4	N.E.	N.E.	N.E.
TOTAL HARDNESS	mg/L CaCO3	20,3	53,2	24,4	31,2	19,2	N.E.	N.E.	N.E.
TOTAL PHENOLS	mg/L	<0,002	<0,002	<0,002	<0,002	<0,002	0,002	0,002	N.E.

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		BROWN MANZANO WATERS DOWN	HYGIENE HYGIENE UPSTREAM	BROKEN BRIGADE UPSTREAM	BROKEN BRIGADE DOWNSTREAM	BROWN MANZANO UPSTREAM	Article 38 Limit Human Consumption Treatment	Article 39 Limit Human consumption Disinfection	Article 40 Agricultural use limit
No. MCS		5351	5352	5347	5348	5349			
DATE	A-M-D	5-3-2017	5-3-2017	4-3-2017	4-3-2017	4-3-2017			
HOUR	h:min	12:00	15:20	8:30	12:35	14:00			
PHOSPHATES	mg/L P-PO4-3	<0,03	<0,03	<0,03	<0,03	<0,03	N.E.	N.E.	N.E.
INORGANIC PHOSPHORUS	mg/L P	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
ORGANIC PHOSPHORUS	mg/L	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
TOTAL PHOSPHORUS	mg/L	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	NE
FATS AND OILS	mg/L	<1,4	<1,4	<1,4	<1,4	<1,4	S.P.V	S.P.V	N.E.
TOTAL HYDROCARBONS	mg/L	<1,4	<1,4	<1,4	<1,4	<1,4	N.E.	N.E.	N.E.
TOTAL IRON	mg/L	<0,15	<0,15	0,307	0,225	0,211	N.E.	N.E.	5
MAGNESIUM	mg/L	1,09	3,25	1,21	2,01	1,11	N.E.	N.E.	N.E.
MANGANESE	mg/L	<0,12	<0,12	<0,12	<0,12	<0,12	N.E.	N.E.	0,2
MERCURY	mg/L	<0,002	<0,002	<0,002	<0,002	<0,002	0,002	0,002	N.E.
NICKEL	mg/L	<0,15	<0,15	<0,15	<0,15	<0,15	N.E.	N.E.	0,2
NITRATES	mg/L N-NO3	0,951	0,825	0,711	0,84	0,97	10	10	N.E.
NITRITES	mg/L N-NO2	0,0108	0,0082	<0,003	<0,003	<0,003	1	1	N.E.
AMMONIACAL NITROGEN	mg/L	<1	<1	<1	<1	<1	N.E.	N.E.	N.E.
TOTAL NITROGEN	mg/L N	<3	<3	<3	<3	<3	N.E.	N.E.	N.E.
SILVER	mg/L	<0,05	<0,05	<0,05	<0,05	<0,05	0,05	0,05	N.E.
LEAD	mg/L	<0,05	<0,05	<0,05	<0,05	<0,05	0,05	0,05	5
POTASSIUM	mg/L	0,322	<0,27	<0,27	<0,27	<0,27	N.E.	N.E.	N.E.
SELENIUM	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,01	0,01	0,02
SODIO	mg/L	6,32	5,04	5,32	4,12	7,82	N.E.	N.E.	N.E.
TOTAL SUSPENDED SOLIDS	mg/L	8	16	11	20	53	N.E.	N.E.	N.E.
TOTAL SOLIDS	mg/L	52	118	64	64	94	N.E.	N.E.	N.E.
SULFATES	mg/L S04-2	<5	<5	<5	<5	<5	400	400	N.E.
TENSOACTIVES (SAAM)	mg/L LAS	<0,24	<0,24	<0,24	<0,24	<0,24	0,5	0,5	N.E.
TURBIDITY	NTU	13,9	32,2	9,6	18,2	40,8	N.E.	190	N.E.
ZINC	mg/L	<0,12	<0,12	<0,12	<0,12	<0,12	15	15	2

Source: Results of physicochemical and bacteriological analyzes carried out by the Laboratorios MCS Consultoría y Monitoreo Ambiental SAS y CIAN Ltda., 2017.

Table 5.60 Results of physicochemical and bacteriological parameters obtained at the monitoring points evaluated and their comparison with the permissible quality criteria

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		CUAYARIN WATER	BROKEN YAMURAYAN DOWNSTREAM	BROKEN LA HONDA UPSTREAM	BROKEN WATER UPSTREAM	BROKERS GROUNDS DOWNSTREAM	Article 38 Limit Human Consumption	Article 39 Limit Human consumption Disinfection	Article 40 Agricultural use
No. MCS		5271	5270	5272	5345	5346			
DATE	A-M-D	28-2-2017	28-2-2017	28-2-2017	8-3-2017	8-3-2017			
HOUR	h:min	12:15	8:00	16:30	9:20	12:47			
TEMPERATURE SAMPLE	°C	16,9	16,5	15,3	16,6	16,4	N.E.	N.E.	N.E.
pH	UNITS	7,85	7,6	7,4	7,3	7,25	5 - 9	6,5 - 8,5	4,5 - 9,0
ELECTRIC CONDUCTIVITY	µS/cm	205	190	150	110	135	N.E.	N.E.	N.E.
TOTAL DISSOLVED SOLIDS	mg/L	81,6	85	70	40	60	N.E.	N.E.	N.E.
SEDIMENTABLE SOLIDS	mL/L-h	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
DISSOLVED OXYGEN	mg/L O2	4,5	4,7	4,2	5,3	5,2	N.E.	N.E.	N.E.
FLOW	m3/s	0,003	0,001	0,004	0,531	0,572	N.E.	N.E.	N.E.
TOTAL ACIDITY	mg/L CaCO3	7,54	10,05	7,04	7,04	5,03	N.E.	N.E.	N.E.
TOTAL ALKALINITY	mg/L CaCO3	49,6	48,7	41,1	32,8	31,3	N.E.	N.E.	N.E.
ARSENIC	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,05	0,05	0,1
BARIUM	mg/L	<0,6	<0,6	<0,6	<0,6	<0,6	1	1	N.E.
BICARBONATES	mg/L CaCO3	49,6	48,7	41,1	32,8	31,3	N.E.	N.E.	N.E.
CADMIUM	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,01	0,01	0,01
CALCIUM	mg/L	15,2	16,9	11,8	7,19	7,81	N.E.	N.E.	N.E.
TOTAL ORGANIC CARBON	mg/L	<3	<3	<3	<3	<3	N.E.	N.E.	N.E.
CHLORIDE	mg/L Cl-	12,64	23,71	12,99	8,81	8,26	250	250	N.E.
COPPER	mg/L	<0,15	<0,15	<0,15	<0,15	<0,15	1	1	0,2
THERMOTOLERANT COLIFORMES (FECALES)	NMP/100mL	420	330	310	467	580	2000	N.E.	1000
TOTAL COLIFORMS	NMP/100 mL	2390	2100	2370	1890	2450	20000	1000	5000
REAL COLOR	UPC	40,69	60,24	45,63	50,96	57,56	75	20	N.E.
TOTAL CHROME	mg/L	<0,11	<0,11	<0,11	<0,11	<0,11	0,05	0,05	0,1
DBO5	mg/L O2	<5	<5	<5	<5	<5	N.E.	N.E.	N.E.
DQO	mg/L O2	<20	<20	<20	<20	<20	N.E.	N.E.	N.E.
CALCULIC HARDNESS	mg/L CaCO3	39,5	43,9	31,9	19	19,9	N.E.	N.E.	N.E.
TOTAL HARDNESS	mg/L CaCO3	56,4	62,8	45,6	27,2	28,4	N.E.	N.E.	N.E.
TOTAL PHENOLS	mg/L	<0,002	<0,002	<0,002	<0,002	<0,002	0,002	0,002	N.E.
PHOSPHATES	mg/L P-PO4-3	<0,03	<0,03	<0,03	<0,24	<0,24	N.E.	N.E.	N.E.
INORGANIC PHOSPHORUS	mg/L P	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		CUAYARIN WATER	BROKEN YAMURAYAN DOWNSTREAM	BROKEN LA HONDA UPSTREAM	BROKEN WATER UPSTREAM	BROKERS GROUNDS DOWNSTREAM	Article 38 Limit Human Consumption	Article 39 Limit Human consumption Disinfection	Article 40 Agricultural use
No. MCS		5271	5270	5272	5345	5346			
DATE	A-M-D	28-2-2017	28-2-2017	28-2-2017	8-3-2017	8-3-2017			
HOUR	h:min	12:15	8:00	16:30	9:20	12:47			
ORGANIC PHOSPHORUS	mg/L	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
TOTAL PHOSPHORUS	mg/L	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
FATS AND OILS	mg/L	<1,4	<1,4	<1,4	<1,4	<1,4	S.P.V	S.P.V	N.E.
TOTAL HYDROCARBONS	mg/L	<1,4	<1,4	<1,4	<1,4	<1,4	N.E.	N.E.	N.E.
TOTAL IRON	mg/L	0,181	0,208	0,194	0,324	0,303	N.E.	N.E.	5
MAGNESIUM	mg/L	3,87	4,2	3,04	1,98	1,92	N.E.	N.E.	N.E.
MANGANESE	mg/L	<0,12	<0,12	<0,12	<0,12	<0,12	N.E.	N.E.	0,2
MERCURY	mg/L	<0,002	<0,002	<0,002	<0,002	<0,002	0,002	0,002	N.E.
NICKEL	Mg / L	<0,15	<0,15	<0,15	<0,15	<0,15	N.E.	N.E.	0,2
NITRATES	mg/L N-NO3	0,97	1,26	0,84	0,909	0,825	10	10	N.E.
NITRITES	mg/L N-NO2	0,0099	0,0112	0,0081	0,0094	0,0076	1	1	N.E.
AMMONIACAL NITROGEN	mg/L	<1	<1	<1	<1	<1	N.E.	N.E.	N.E.
TOTAL NITROGEN	mg/L N	<3	<3	<3	<3	<3	N.E.	N.E.	N.E.
SILVER	mg/L	<0,05	<0,05	<0,05	<0,05	<0,05	0,05	0,05	N.E.
LEAD	mg/L	<0,05	<0,05	<0,5	<0,05	<0,05	0,05	0,05	5
POTASSIUM	mg/L	0,722	0,632	0,709	0,512	0,428	N.E.	N.E.	N.E.
SELENIUM	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,01	0,01	0,02
SODIUM	mg/L	8,11	12,3	7,25	10,1	9,03	N.E.	N.E.	N.E.
TOTAL SUSPENDED SOLIDS	mg/L	12	39	6	24	22	N.E.	N.E.	N.E.
TOTAL SOLIDS	mg/L	94	154	96	80	96	N.E.	N.E.	N.E.
SULFATES	mg/L S04-2	<5	<5	<5	<5	<5	400	400	N.E.
TENSOACTIVES (SAAM)	mg/L LAS	<0,24	<0,24	<0,24	<0,24	<0.24	0,5	0,5	NE
TURBIDITY	NTU	9,08	44,1	4,77	21,5	25,7	N.E.	190	N.E.
ZINC	mg/L	<0,12	<0,12	<0,12	<0,12	<0,12	15	15	2

Source: Results of physicochemical and bacteriological analyzes performed by the Laboratorios MCS Consultoria y Monitoreo Ambiental SAS y CIAN Ltda., 2017

Table 5.61 Results of physicochemical and bacteriological parameters obtained at the monitoring points evaluated and their comparison with the permissible quality criteria.

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		BREAKING THE CAVE AGUAS ABOVE	CULANTRO BREAK WATER UP	BROKEN HONDA WATERS DOWN	ZANJA CHORRERA WATERS DOWN	ARRAYANES WATER BROOK TOP	Article 38 Limit Human Consumption Treatment	Article 39 Limit Human consumption Disinfection	Article 40 Agricultural use limit
No. MCS		5343	5344	5341	5342	5339			
DATE	A-M-D	3-3-2017	3-3-2017	9-3-2017	9-3-2017	7-3-2017			
HORA	h:min	8:00	14:20	8:25	12:30	8:40			
TEMPERATURE SAMPLE	°C	14,8	14	17,05	20,6	16,85	N.E.	N.E.	N.E.
pH	UNITS	7,25	7,85	7,85	8,2	7,3	5 - 9	6,5 - 8,5	4,5 - 9,0
ELECTRIC CONDUCTIVITY	µS/cm	100	115	185	225	170	N.E.	N.E.	N.E.
TOTAL DISSOLVED SOLIDS	mg/L	40	50	90	105	65	N.E.	N.E.	N.E.
SEDIMENTABLE SOLIDS	mL/L-h	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
DISSOLVED OXYGEN	mg/L O2	4,2	4,4	4,7	6,5	4,5	N.E.	N.E.	N.E.
FLOW	m3/s	0,00115	0,007	0,005	0,004	0,033	N.E.	N.E.	N.E.
TOTAL ACIDITY	mg/L CaCO3	4,02	6,03	6,53	6,03	3,02	N.E.	N.E.	N.E.
TOTAL ALKALINITY	mg/L CaCO3	23,9	23,1	67,4	53,9	24,4	N.E.	N.E.	N.E.
ARSENIC	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,05	0,05	0,1
BARIUM	mg/L	<0,6	<0,6	<0,6	<0,6	<0,6	1	1	N.E.
BICARBONATES	mg/L CaCO3	23,9	23,1	67,4	53,9	24,4	N.E.	N.E.	N.E.
CADMIUM	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,01	0,01	0,01
CALCIUM	mg/L	6,94	8,07	16,9	22,4	9,69	N.E.	N.E.	N.E.
TOTAL ORGANIC CARBON	mg/L	<3	<3	<3	<3	<3	N.E.	N.E.	N.E.
CHLORIDE	mg/L Cl-	5,59	6,64	6,7	27,1	9,77	250	250	N.E.
COPPER	mg/L	<0,15	<0,15	<0,15	<0,15	<0,15	1	1	0,2
THERMOTOLERANT COLIFORMES (FECALES)	NMP/100mL	500	370	400	650	345	2000	N.E.	1000
TOTAL COLIFORMS	NMP/100 mL	1540	1280	1670	1430	1600	20000	1000	5000
REAL COLOR	UPC	59,32	16,22	21,53	66,27	25,39	75	20	N.E.
TOTAL CHROME	mg/L	<0,11	<0,11	<0,11	<0,11	<0,11	0,05	0,05	0,1
DBO5	mg/L O2	<5	<5	<5	<5	<5	N.E.	N.E.	N.E.
DQO	mg/L O2	<20	<20	<20	<20	<20	N.E.	N.E.	N.E.
CALCULIC HARDNESS	mg/L CaCO3	17,9	20,7	43,4	56,8	24,7	N.E.	N.E.	N.E.
TOTAL HARDNESS	mg/L CaCO3	25,6	29,6	61,2	80	34,8	N.E.	N.E.	N.E.
TOTAL PHENOLS	mg/L	<0,002	<0,002	<0,002	<0,002	<0,002	0,002	0,002	N.E.
PHOSPHATES	mg/L P-PO4-3	<0,03	<0,03	<0,03	<0,03	<0,03	N.E.	N.E.	N.E.
INORGANIC PHOSPHORUS	mg/L P	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
ORGANIC PHOSPHORUS	mg/L	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
TOTAL PHOSPHORUS	mg/L	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
FATS AND OILS	mg/L	<1,4	<1,4	<1,4	<1,4	<1,4	S.P.V	S.P.V	N.E.
TOTAL HYDROCARBONS	mg/L	<1,4	<1,4	<1,4	<1,4	<1,4	N.E.	N.E.	N.E.

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		BREAKING THE CAVE AGUAS ABOVE	CULANTRO BREAK WATER UP	BROKEN HONDA WATERS DOWN	ZANJA CHORRERA WATERS DOWN	ARRAYANES WATER BROOK TOP	Article 38 Limit Human Consumption Treatment	Article 39 Limit Human consumption Disinfection	Article 40 Agricultural use limit
No. MCS		5343	5344	5341	5342	5339			
DATE	A-M-D	3-3-2017	3-3-2017	9-3-2017	9-3-2017	7-3-2017			
HORA	h:min	8:00	14:20	8:25	12:30	8:40			
TOTAL IRON	mg/L	0,178	<0,15	0,168	0,187	0,184	N.E.	N.E.	5
MAGNESIUM	mg/L	1,67	1,95	4,07	5,01	2,29	N.E.	N.E.	N.E.
MANGANESE	mg/L	<0,12	<0,12	<0,12	<0,12	<0,12	N.E.	N.E.	0,2
MERCURY	mg/L	<0,002	<0,002	<0,002	<0,002	<0,002	0,002	0,002	N.E.
NICKEL	mg/L	<0,15	<0,15	<0,15	<0,15	<0,15	N.E.	N.E.	0,2
NITRATES	mg/L N-NO3	1,07	0,789	0,941	1,11	0,814	10	10	N.E.
NITRITES	mg/L N-NO2	0,0109	0,0082	0,0091	0,0121	0,0101	1	1	N.E.
AMMONIACAL NITROGEN	mg/L	<1	<1	<1	<1	<1	N.E.	N.E.	N.E.
TOTAL NITROGEN	mg/L N	<3	<3	<3	<3	SC	N.E.	N.E.	N.E.
SILVER	mg/L	<0,05	<0,05	<0,05	<0,05	<0,05	0,05	0,05	N.E.
LEAD	mg/L	<0,05	<0,05	<0,05	<0,05	<0,05	0,05	0,05	5
POTASSIUM	mg/L	0,291	<0,27	0,492	0,723	<0,27	N.E.	N.E.	N.E.
SELENIUM	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,01	0,01	0,02
SODIUM	mg/L	5,12	3,98	9,72	9,81	5,12	N.E.	N.E.	N.E.
TOTAL SUSPENDED SOLIDS	mg/L	17	9	12	18	8	N.E.	N.E.	NE
TOTAL SOLIDS	mg/L	64	68	110	152	66	N.E.	N.E.	N.E.
SULFATES	mg/L S04-2	<5	<5	<5	<5	<5	400	400	N.E.
TENSOACTIVES (SAAM)	mg/L LAS	<0,24	<0,24	<0,24	<0,24	<0,24	0,5	0,5	N.E.
TURBIDITY	NTU	12,3	4,2	9,73	20,3	16,5	N.E.	190	N.E.
ZINC	mg/L	<0,12	<0,12	<0,12	<0,12	<0,12	15	15	2

Source: Results of physicochemical and bacteriological analyzes performed by the Laboratorios MCS Consultoria y Monitoreo Ambiental SAS y CIAN Ltda., 2017

Table 5.62 Results of physicochemical and bacteriological parameters obtained at the monitoring points evaluated and their comparison with the permissible quality criteria.

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		ZANJA CHORRERA CHIQUITO AGUAS ARRIBA	RIO BOQUERON AGUAS ARRIBA	RIO BOQUERON WATERS DOWN	RIO GUAITARA	BROKEN NN3	Article 38 Limit Human Consumption Treatment	Article 39 Limit Human consumption Disinfection	Article 40 Agricultural use limit
Do not. MCS		5340	5277	5278	5276	5279			
DATE	A-M-D	7-3-2017	26-2-2017	26-2-2017	26-2-2017	26-2-2017			
HORA	h:min	13:40	16:06	13:12	11:00	17:20			
TEMPERATURE SAMPLE	°C	16,85	14,65	15,55	14,65	15,1	N.E.	N.E.	N.E.
pH	UNITS	7,1	7,85	7,85	8,05	7,2	5 - 9	6,5 - 8,5	4,5 - 9,0

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		ZANJA CHORRERA CHIQUITO AGUAS ARRIBA	RIO BOQUERON AGUAS ARRIBA	RIO BOQUERON WATERS DOWN	RIO GUAITARA	BROKEN NN3	Article 38 Limit Human Consumption Treatment	Article 39 Limit Human consumption Disinfection	Article 40 Agricultural use limit
Do not. MCS		5340	5277	5278	5276	5279			
DATE	A-M-D	7-3-2017	26-2-2017	26-2-2017	26-2-2017	26-2-2017			
HORA	h:min	13:40	16:06	13:12	11:00	17:20			
ELECTRIC CONDUCTIVITY	µS/cm	445	165	195	155	285	N.E.	N.E.	N.E.
TOTAL DISSOLVED SOLIDS	mg/L	220	75	90	75	130	N.E.	N.E.	N.E.
SEDIMENTABLE SOLIDS	mL/L-h	<0,1	0,2	0,4	<0,1	0,6	N.E.	N.E.	N.E.
DISSOLVED OXYGEN	mg/L O2	4,3	7	7	6,5	4,5	N.E.	N.E.	N.E.
FLOW	m3/s	0,008	8,965	13,076	27,533	0,002	N.E.	N.E.	N.E.
TOTAL ACIDITY	mg/L CaCO3	7,54	12,06	14,57	8,04	13,07	N.E.	N.E.	N.E.
TOTAL ALKALINITY	mg/L CaCO3	38,2	81,4	93,8	57	104	N.E.	N.E.	N.E.
ARSENIC	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,05	0,05	0,1
BARIUM	mg/L	<0,6	<0,6	<0,6	<0,6	<0,6	1	1	N.E.
BICARBONATES	mg/L CaCO3	38,2	81,4	93,8	57	104	N.E.	N.E.	N.E.
CADMIUM	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,01	0,01	0,01
CALCIUM	mg/L	32,1	13,8	13,8	15,3	24,2	N.E.	N.E.	N.E.
TOTAL ORGANIC CARBON	mg/L	<3	<3	<3	<3	<3	N.E.	N.E.	N.E.
CHLORIDE	mg/L Cl-	49,1	12,58	14,95	8,15	27,94	250	250	N.E.
COPPER	mg/L	<0,15	<0,15	<0,15	<0,15	<0,15	1	1	0,2
THERMOTOLERANT COLIFORMES (FECALES)	NMP/100mL	267	1 300	1 100	890	990	2000	N.E.	1000
TOTAL COLIFORMS	NMP/100 mL	1450	3800	3690	2890	3270	20000	1000	5000
REAL COLOR	UPC	49,53	29,2	26,9	35,8	131,2	75	20	N.E.
TOTAL CHROME	mg/L	<0,11	<0,11	<0,11	<0,11	<0,11	0,05	0,05	0,1
DBO5	mg/L O2	<5	<5	<5	<5	12	N.E.	N.E.	N.E.
DQO	mg/L O2	<20	<20	<20	<20	22	N.E.	N.E.	N.E.
CALCULIC HARDNESS	mg/L CaCO3	88,9	37,2	35	39,5	62,1	N.E.	N.E.	N.E.
TOTAL HARDNESS	mg/L CaCO3	125,2	53,2	50	56,4	88,8	N.E.	N.E.	N.E.
TOTAL PHENOLS	mg/L	<0,002	<0,002	<0,002	<0,002	<0,002	0,002	0,002	N.E.
PHOSPHATES	mg/L P-PO4-3	<0,03	<0,03	<0,03	<0,03	<0,03	N.E.	N.E.	N.E.
INORGANIC PHOSPHORUS	mg/L P	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
ORGANIC PHOSPHORUS	mg/L	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
TOTAL PHOSPHORUS	mg/L	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
FATS AND OILS	mg/L	<1,4	<1,4	<1,4	<1,4	<1,4	S.P.V	S.P.V	N.E.
TOTAL HYDROCARBONS	mg/L	<1,4	<1,4	<1,4	<1,4	<1,4	N.E.	N.E.	N.E.
TOTAL IRON	mg/L	0,918	<0,15	<0,15	<0,15	<0,15	N.E.	N.E.	5
MAGNESIUM	mg/L	7,92	3,6	3,2	3,92	6	N.E.	N.E.	N.E.

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		ZANJA CHORRERA CHIQUITO AGUAS ARRIBA	RIO BOQUERON AGUAS ARRIBA	RIO BOQUERON WATERS DOWN	RIO GUAITARA	BROKEN NN3	Article 38 Limit Human Consumption Treatment	Article 39 Limit Human consumption Disinfection	Article 40 Agricultural use limit
Do not. MCS		5340	5277	5278	5276	5279			
DATE	A-M-D	7-3-2017	26-2-2017	26-2-2017	26-2-2017	26-2-2017			
HORA	h:min	13:40	16:06	13:12	11:00	17:20			
MANGANESE	mg/L	<0,12	<0,12	<0,12	<0,12	<0,12	N.E.	N.E.	0,2
MERCURY	mg/L	<0,002	<0,002	<0,002	<0,002	<0,002	0,002	0,002	N.E.
NICKEL	mg/L	<0,15	<0,15	<0,15	<0,15	<0,15	N.E.	N.E.	0,2
NITRATES	mg/L N-NO3	1	1,12	0,808	1,01	1,48	10	10	N.E.
NITRITES	mg/L N-NO2	0,0154	<0,003	<0,003	<0,003	<0,003	1	1	N.E.
AMMONIACAL NITROGEN	mg/L	<1	<1	<1	<1	<1	N.E.	N.E.	N.E.
TOTAL NITROGEN	mg/L N	SC	<3	<3	<3	<3	N.E.	N.E.	N.E.
SILVER	mg/L	<0,05	<0,05	<0,05	<0,05	<0,05	0,05	0,05	N.E.
LEAD	mg/L	<0,05	<0,05	<0,05	<0,05	<0,05	0,05	0,05	5
POTASSIUM	mg/L	<0,27	1,61	1,08	0,327	1,18	N.E.	N.E.	N.E.
SELENIUM	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,01	0,01	0,02
SODIUM	mg/L	5,37	16,4	27,2	10,3	28,4	N.E.	N.E.	N.E.
TOTAL SUSPENDED SOLIDS	mg/L	43	273	305	46	500	N.E.	N.E.	N.E.
TOTAL SOLIDS	mg/L	248	310	316	94	532	N.E.	N.E.	N.E.
SULFATES	mg/L S04-2	<5	<5	5,26	6,13	<5	400	400	N.E.
TENSOACTIVES (SAAM)	mg/L LAS	<0,24	<0,24	<0,24	<0,24	<0,24	0,5	0,5	N.E.
TURBIDITY	NTU	28,4	87,7	135	42,9	348	N.E.	190	N.E.
ZINC	mg/L	<0,12	<0,12	<0,12	<0,12	<0,12	15	15	2

Source: Results of physicochemical and bacteriological analyzes carried out by the Laboratorios MCS Consultoría y Monitoreo Ambiental SAS y CIAN Ltda., 2017.

Table 5.63 Results of physicochemical and bacteriological parameters obtained at the monitoring points evaluated and their comparison with the permissible quality criteria.

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		SAN FRANCISC O 2A WATCHED UP ARA	SAN FRANCISC O 2B WATCHED UP AGUAS ARRIBA	AF BROKEN THE TABLON WATERS DOWN	BROKEN DOWN THE TABLON WATERS	SARACON CHA BROOKES AGUAS ARRIBA	Article 38 Limit Human Consumption Treatment	Article 39 Limit Human consumption Disinfection	Article 40 Agricultural use limit
Do not. MCS		6341	6342	6340	6343	6345			
DATE	A-M-D	12-3-2017	12-3-2017	12-3-2017	12-3-2017	14-3-2017			
HOUR	h:min	10:00	12:30	8:30	15:40	12:50			
TEMPERATURE SAMPLE	°C	16,85	17,85	17,2	17,6	20,75	N.E.	N.E.	N.E.

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		SAN FRANCISCO 2A WATCHED UP ARA	SAN FRANCISCO 2B WATCHED UP AGUAS ARRIBA	AF BROKEN THE TABLON WATERS DOWN	BROKEN DOWN THE TABLON WATERS	SARACONCHA BROOKES AGUAS ARRIBA	Article 38 Limit Human Consumption Treatment	Article 39 Limit Human consumption Disinfection	Article 40 Agricultural use limit
Do not. MCS		6341	6342	6340	6343	6345			
DATE	A-M-D	12-3-2017	12-3-2017	12-3-2017	12-3-2017	14-3-2017			
HOUR	h:min	10:00	12:30	8:30	15:40	12:50			
pH	UNITS	7,65	7,5	7,1	7,5	7,9	5 - 9	6,5 - 8,5	4,5 - 9,0
ELECTRIC CONDUCTIVITY	µS/cm	175	145	165	155	130	N.E.	N.E.	N.E.
TOTAL DISSOLVED SOLIDS	mg/L	85	60	70	70	60	N.E.	N.E.	N.E.
SEDIMENTABLE SOLIDS	mL/L-h	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
DISSOLVED OXYGEN	mg/L O2	4,7	4,5	5,1	5,3	7,75	N.E.	N.E.	N.E.
FLOW	m3/s	7,91	0,41	5,14	0,2	0,045	N.E.	N.E.	N.E.
TOTAL ACIDITY	mg/L CaCO3	5,03	6,03	6,53	4,52	6,53	N.E.	N.E.	N.E.
TOTAL ALKALINITY	mg/L CaCO3	37,1	53,3	48,5	41,4	50,7	N.E.	N.E.	N.E.
ARSENIC	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,05	0,05	0,1
BARIUM	mg/L	<0,6	<0,6	<0,6	<0,6	<0,6	1	1	N.E.
BICARBONATES	mg/L CaCO3	37,1	53,3	48,5	41,4	50,7	N.E.	N.E.	N.E.
CADMIUM	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,01	0,01	0,01
CALCIUM	mg/L	9,07	11,7	12,4	9,74	12,8	N.E.	N.E.	N.E.
TOTAL ORGANIC CARBON	mg/L	<3	<3	<3	<3	<3	N.E.	N.E.	N.E.
CHLORIDE	mg/L Cl-	6,44	10	13,2	8,71	6,14	250	250	N.E.
COPPER	mg/L	<0,15	<0,15	<0,15	<0,15	<0,15	1	1	0,2
THERMOTOLERANT COLIFORMES (FECALES)	NMP/100mL	300	379	230	178	450	2000	N.E.	1000
TOTAL COLIFORMS	NMP/100 mL	2670	2890	2430	2700	2890	20000	1000	5000
REAL COLOR	UPC	81,71	90,53	107,51	272,29	196,81	75	20	N.E.
TOTAL CHROME	mg/L	<0,11	<0,11	<0,11	<0,11	<0,11	0,05	0,05	0,1
DBO5	mg/L O2	<5	<5	<5	<5	<5	N.E.	N.E.	N.E.
DQO	mg/L O2	<20	<20	<20	<20	<20	N.E.	N.E.	N.E.
CALCULIC HARDNESS	mg/L CaCO3	23,8	31,1	89,6	24,6	33	N.E.	N.E.	N.E.

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		SAN FRANCISCO 2A WATCHED UP ARA	SAN FRANCISCO 2B WATCHED UP AGUAS ARRIBA	AF BROKEN THE TABLON WATERS DOWN	BROKEN DOWN THE TABLON WATERS	SARACONCHA BROOKES AGUAS ARRIBA	Article 38 Limit Human Consumption Treatment	Article 39 Limit Human consumption Disinfection	Article 40 Agricultural use limit
Do not. MCS		6341	6342	6340	6343	6345			
DATE	A-M-D	12-3-2017	12-3-2017	12-3-2017	12-3-2017	14-3-2017			
HOUR	h:min	10:00	12:30	8:30	15:40	12:50			
TOTAL HARDNESS	mg/L CaCO3	34	44,4	128	35,2	47,2	N.E.	N.E.	N.E.
TOTAL PHENOLS	mg/L	<0,002	<0,002	<0,002	<0,002	<0,002	0,002	0,002	N.E.
PHOSPHATES	mg/L P-PO4-3	<0,03	<0,03	<0,03	<0,03	<0,03	N.E.	N.E.	N.E.
INORGANIC PHOSPHORUS	mg/L P	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
ORGANIC PHOSPHORUS	mg/L	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
TOTAL PHOSPHORUS	mg/L	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
FATS AND OILS	mg/L	<1,4	<1,4	<1,4	<1,4	<1,4	S.P.V	S.P.V	N.E.
TOTAL HYDROCARBONS	mg/L	<1,4	<1,4	<1,4	<1,4	<1,4	N.E.	N.E.	N.E.
TOTAL IRON	mg/L	0,372	0,389	0,399	0,411	0,725	N.E.	N.E.	5
MAGNESIUM	mg/L	2,31	2,97	3,25	2,2	3,15	N.E.	N.E.	N.E.
MANGANESE	mg/L	<0,12	<0,12	<0,12	<0,12	<0,12	N.E.	N.E.	0,2
MERCURY	mg/L	<0,002	<0,002	<0,002	<0,002	<0,002	0,002	0,002	N.E.
NICKEL	mg/L	<0,15	<0,15	<0,15	<0,15	<0,15	N.E.	N.E.	0,2
NITRATES	mg/L N-NO3	0,97	0,99	1,1	1,3	1,43	10	10	N.E.
NITRITES	mg/L N-NO2	0,0097	0,0138	0,0139	0,0281	0,0212	1	1	N.E.
AMMONIACAL NITROGEN	mg/L	<1	<1	<1	<1	<1	N.E.	N.E.	N.E.
TOTAL NITROGEN	mg/L N	<3	<3	<3	<3	<3	N.E.	N.E.	N.E.
SILVER	mg/L	<0,05	<0,05	<0,05	<0,05	<0,05	0,05	0,05	N.E.
LEAD	mg/L	<0,05	<0,05	<0,05	<0,05	<0,05	0,05	0,05	5
POTASSIUM	mg/L	0,738	<0,27	0,957	0,957	1,32	N.E.	N.E.	N.E.
SELENIUM	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,01	0,01	0,02
SODIUM	mg/L	10,4	14,1	14,1	7,59	9,13	N.E.	N.E.	N.E.
TOTAL SUSPENDED SOLIDS	mg/L	41	59	76	92	98	N.E.	N.E.	N.E.
TOTAL SOLIDS	mg/L	94	136	152	153	166	N.E.	N.E.	N.E.
SULFATES	mg/L S04-2	<5	<5	<5	<5	<5	400	400	N.E.

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		SAN FRANCISCO 2A WATCHED UP ARA	SAN FRANCISCO 2B WATCHED UP AGUAS ARRIBA	AF BROKEN THE TABLON WATERS DOWN	BROKEN DOWN THE TABLON WATERS	SARACONCHA BROOKES AGUAS ARRIBA	Article 38 Limit Human Consumption Treatment	Article 39 Limit Human consumption Disinfection	Article 40 Agricultural use limit
Do not. MCS		6341	6342	6340	6343	6345			
DATE	A-M-D	12-3-2017	12-3-2017	12-3-2017	12-3-2017	14-3-2017			
HOUR	h:min	10:00	12:30	8:30	15:40	12:50			
TENSOACTIVES (SAAM)	mg/L LAS	<0,24	<0,24	<0,24	<0,24	<0,24	0,5	0,5	N.E.
TURBIDITY	NTU	35,9	67,7	45,9	109	111	N.E.	190	N.E.
ZINC	mg/L	<0,12	<0,12	<0,12	<0,12	<0,12	15	15	2

Source: Results of physicochemical and bacteriological analyzes carried out by the Laboratorios MCS Consultoría y Monitoreo Ambiental SAS y CIAN Ltda., 2017.

Table 5.64 Results of physicochemical and bacteriological parameters obtained at the monitoring points evaluated and their comparison with the permissible quality criteria.

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		BROKEN SARACONCHA WATERS DOWN	BROKEN THE MACAL WATERS ABOVE	BROKEN SAN FRANCISCO 2 AGUAS ARRIBA	SAN FRANCISCO BROKEN 2 WATERS DOWN	BROKEN THE MACAL WATERS DOWN	Article 38 Limit Human Consumption	Article 39 Limit Human consumption	Article 40 Agricultural use limit
Do not. MCS		6344	6346	6348	6349	6347			
DATE	A-M-D	14-3-2017	14-3-2017	13-3-2017	13-3-2017	13-3-2017			
HOUR	Hr	10:20	3:30 p.m.	14:20	16:15	9:35			
TEMPERATURE SAMPLE	°C	22	16,9	18,75	19,2	18,65	N.E.	N.E.	N.E.
pH	UNITS	7,7	7,1	7,7	7,8	7,6	5 - 9	6,5 - 8,5	4,5 - 9,0
ELECTRIC CONDUCTIVITY	µS/cm	140	64	125	145	100	N.E.	N.E.	N.E.
TOTAL DISSOLVED SOLIDS	mg/L	65	31,5	60	70	40	N.E.	N.E.	N.E.
SEDIMENTABLE SOLIDS	mL/L-h	<0,1	0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
DISSOLVED OXYGEN	mg/L O2	7,4	7,25	6,65	6,85	6,45	N.E.	N.E.	N.E.
FLOW	m3/s	0,051	0,968	0,312	0,472	2,14	N.E.	N.E.	N.E.
TOTAL ACIDITY	mg/L CaCO3	5,03	6,03	6,53	5,53	6,03	N.E.	N.E.	N.E.
TOTAL ALKALINITY	mg/L CaCO3	55,6	26,9	39,8	45,9	38,4	N.E.	N.E.	N.E.
ARSENIC	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,05	0,05	0,1
BARIUM	mg/L	<0,6	<0,6	<0,6	<0,6	<0,6	1	1	N.E.
BICARBONATES	mg/L CaCO3	55,6	26,9	39,8	45,9	38,4	N.E.	N.E.	N.E.
CADMIUM	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,01	0,01	0,01
CALCIUM	mg/L	13,3	5,2	11,2	12,3	9,12	N.E.	N.E.	N.E.

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		BROKEN SARACONCHA WATERS DOWN	BROKEN THE MACAL WATERS ABOVE	BROKEN SAN FRANCISCO 2 AGUAS ARRIBA	SAN FRANCISCO BROKEN 2 WATERS DOWN	BROKEN THE MACAL WATERS DOWN	Article 38 Limit Human Consumption	Article 39 Limit Human consumption	Article 40 Agricultural use limit
Do not. MCS		6344	6346	6348	6349	6347			
DATE	A-M-D	14-3-2017	14-3-2017	13-3-2017	13-3-2017	13-3-2017			
HOUR	Hr	10:20	3:30 p.m.	14:20	16:15	9:35			
TOTAL ORGANIC CARBON	mg/L	<3	<3	3,45	3,12	3,15	N.E.	N.E.	N.E.
CHLORIDE	mg/L Cl-	6,95	<4	21,8	30,1	6,75	250	250	N.E.
COPPER	mg/L	<0,15	<0,15	<0,15	<0,15	<0,15	1	1	0,2
THERMOTOLERANT COLIFORMES (FECALES)	NMP/100mL	289	600	320	254	264	2000	N.E.	1000
TOTAL COLIFORMS	NMP/100 mL	3400	2560	2890	2650	2200	20000	1000	5000
REAL COLOR	UPC	185,39	160,94	101,6	237,19	67,709	75	20	N.E.
TOTAL CHROME	mg/L	<0,11	<0,11	<0,11	<0,11	<0,11	0,05	0,05	0,1
DBO5	mg/L O2	<5	<5	15	13	13	N.E.	N.E.	N.E.
DQO	mg/L O2	<20	<20	25	22	23	N.E.	N.E.	N.E.
CALCULIC HARDNESS	mg/L CaCO3	34,9	14	34,3	38,3	24,9	N.E.	N.E.	N.E.
TOTAL HARDNESS	mg/L CaCO3	49,2	20,1	48,4	54	35,2	N.E.	N.E.	N.E.
TOTAL PHENOLS	mg/L	<0,002	<0,002	<0,002	<0,002	<0,002	0,002	0,002	N.E.
PHOSPHATES	mg/L P-PO4-3	<0,03	<0,03	0,051	0,0412	0,0426	N.E.	N.E.	N.E.
INORGANIC PHOSPHORUS	mg/L P	<0,1	<0,1	<0,1	<0,1	<0,1	N.E.	N.E.	N.E.
ORGANIC PHOSPHORUS	mg/L	<0,1	<0,1	0,102	<0,1	<0,1	N.E.	N.E.	N.E.
TOTAL PHOSPHORUS	mg/L	<0,1	<0,1	0,127	0,103	0,1065	N.E.	N.E.	N.E.
FATS AND OILS	mg/L	<1,4	<1,4	<1,4	<1,4	<1,4	S.P.V	S.P.V	N.E.
TOTAL HYDROCARBONS	mg/L	<1,4	<1,4	<1,4	<1,4	<1,4	N.E.	N.E.	N.E.
TOTAL IRON	mg/L	0,532	0,851	1,08	0,192	0,169	N.E.	N.E.	5
MAGNESIUM	mg/L	3,21	1,28	3,1	3,5	2,27	N.E.	N.E.	N.E.
MANGANESE	mg/L	<0,12	<0,12	<0,12	<0,12	<0,12	N.E.	N.E.	0,2
MERCURY	mg/L	<0,002	<0,002	<0,002	<0,002	<0,002	0,002	0,002	N.E.
NICKEL	mg/L	<0,15	<0,15	<0,15	<0,15	<0,15	N.E.	N.E.	0,2
NITRATES	mg/L N-NO3	1,39	1,48	1,74	1,62	1,68	10	10	N.E.
NITRITES	mg/L N-NO2	0,0189	0,0294	0,0279	0,0184	0,0246	1	1	N.E.
AMMONIACAL NITROGEN	mg/L	<1	<1	<1	<1	<1	N.E.	N.E.	N.E.
TOTAL NITROGEN	mg/L N	<3	<3	<3	<3	<3	N.E.	N.E.	N.E.
SILVER	mg/L	<0,05	<0,05	<0,05	<0,05	<0,05	0,05	0,05	N.E.
LEAD	mg/L	<0,05	<0,05	<0,05	<0,05	<0,05	0,05	0,05	5
POTASSIUM	mg/L	1,51	<0,27	1,74	1,24	1,12	N.E.	N.E.	N.E.
SELENIUM	mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,01	0,01	0,02

PARAMETER	UNITS	RESULTS					NORMA, DEC. 1594/84		
		BROKEN SARACONCHA WATERS DOWN	BROKEN THE MACAL WATERS ABOVE	BROKEN SAN FRANCISCO 2 AGUAS ARRIBA	SAN FRANCISCO BROKEN 2 WATERS DOWN	BROKEN THE MACAL WATERS DOWN	Article 38 Limit Human Consumption	Article 39 Limit Human consumption	Article 40 Agricultural use limit
Do not. MCS		6344	6346	6348	6349	6347			
DATE	A-M-D	14-3-2017	14-3-2017	13-3-2017	13-3-2017	13-3-2017			
HOUR	Hr	10:20	3:30 p.m.	14:20	16:15	9:35			
SODIUM	mg/L	9,71	6,11	13,5	15	11,2	N.E.	N.E.	N.E.
TOTAL SUSPENDED SOLIDS	mg/L	81	106	48	36	36	N.E.	N.E.	N.E.
TOTAL SOLIDS	mg/L	156	142	136	146	96	N.E.	N.E.	N.E.
SULFATES	mg/L S04-2	<5	<5	<5	<5	<5	400	400	N.E.
TENSOACTIVES (SAAM)	mg/L LAS	<0,24	<0,24	<0,24	<0,24	<0,24	0,5	0,5	N.E.
TURBIDITY	NTU	81,6	144	50,8	46,8	46,9	N.E.	190	N.E.
ZINC	mg/L	<0,12	<0,12	<0,12	<0,12	<0,12	15	15	2

Source: Results of physicochemical and bacteriological analyzes performed by the Laboratorios MCS Consultoria y Monitoreo Ambiental SAS y CIAN Ltda., 2017

Table 5.65 Results of physicochemical and bacteriological parameters obtained at the monitoring points evaluated and their comparison with the permissible quality criteria.

PARAMETER	UNITS	RESULTS				NORMA, DEC. 1594/84		
		RIO GUAITAR A 2	RIO SAPUYES AGUAS ARIBA	RIO SAPUYES AGUAS ABAJO	GUAITAR A 3	Article 38 Limit Human Consumption Treatment	Article 39 Limit Human consumption Disinfection	Article 40 Agricultural use limit
Do not. MCS		6350	6351	6352	6742			
DATE	A-M-D	16-3-2017	15-3-2017	15-3-2017	27-3-2017			
HOUR	Hr	9:30 a.m.	10:30 a.m.	14:45	9:00			
TEMPERATURE SAMPLE	°C	17,15	18,25	15,75	18,85	N.E.	N.E.	N.E.
pH	UNITS	7,5	7,25	7,7	8,5	5 - 9	6,5 - 8,5	4,5 - 9,0
ELECTRIC CONDUCTIVITY	µS/cm	180	180	140	80	N.E.	N.E.	N.E.
TOTAL DISSOLVED SOLIDS	mg/L	63	80	70	40	N.E.	N.E.	N.E.

PARAMETER	UNITS	RESULTS				NORMA, DEC. 1594/84		
		RIO GUAITAR A 2	RIO SAPUYES AGUAS ARIBA	RIO SAPUYES AGUAS ABAJO	GUAITAR A 3	Article 38 Limit Human Consumption Treatment	Article 39 Limit Human consumption Disinfection	Article 40 Agricultural use limit
Do not. MCS		6350	6351	6352	6742			
DATE	A-M-D	16-3-2017	15-3-2017	15-3-2017	27-3-2017			
HOUR	Hr	9:30 a.m.	10:30 a.m.	14:45	9:00			
SEDIMENTABLE SOLIDS	mL/L-h	0,3	0,6	0,3	0,3	N.E.	N.E.	N.E.
DISSOLVED OXYGEN	mg/L O2	6,4	6,5	7,25	6,15	N.E.	N.E.	N.E.
FLOW	m3/s	26,192	11,07	12,59	26,142	N.E.	N.E.	N.E.
TOTAL ACIDITY	mg/L CaCO3	4,52	10	20,1	<2	N.E.	N.E.	N.E.
TOTAL ALKALINITY	mg/L CaCO3	32,9	31,5	23,9	26	N.E.	N.E.	N.E.
ARSENIC	mg/L	<0,01	<0,01	<0,01	<0,01	0,05	0,05	0,1
BARIUM	mg/L	<0,06	<0,06	<0,06	<0,06	1	1	N.E.
BICARBONATES	mg/L CaCO3	32,9	31,5	23,9	26	N.E.	N.E.	N.E.
CADMIUM	mg/L	<0,01	<0,01	<0,01	<0,01	0,01	0,01	0,01
CALCIUM	mg/L	8,12	11,8	10,4	7,12	N.E.	N.E.	N.E.
TOTAL ORGANIC CARBON	mg/L	4,2	5,42	4,72	5,07	N.E.	N.E.	N.E.
CHLORIDE	mg/L Cl-	5,03	8,71	8,51	<4	250	250	N.E.
COPPER	mg/L	<0,15	<0,15	<0,15	<0,15	1	1	0,2
THERMOTOLERANT COLIFORMES (FECALES)	NMP/100mL	780	680	800	980	2000	N.E.	1000
TOTAL COLIFORMS	NMP/100 mL	3670	2200	1700	4150	20000	1000	5000
REAL COLOR	UPC	12,1	49,12	70,18	16,1	75	20	N.E.
TOTAL CHROME	mg/L	<0,11	<0,11	<0,11	<0,11	0,05	0,05	0,1
DBO5	mg/L O2	15	20	17	17	N.E.	N.E.	N.E.
DQO	mg/L O2	24	31	27	29	N.E.	N.E.	N.E.
CALCULIC HARDNESS	mg/L CaCO3	21,6	31,6	27,7	19,2	N.E.	N.E.	N.E.
TOTAL HARDNESS	mg/L CaCO3	30,8	45,2	39,6	28,8	N.E.	N.E.	N.E.
TOTAL PHENOLS	mg/L	<0,002	0,037	<0,002	<0,002	0,002	0,002	N.E.
PHOSPHATES	mg/L P-PO4-3	0,342	1,321	0,8424	<0,03	N.E.	N.E.	N.E.
INORGANIC PHOSPHORUS	mg/L P	0,514	3,1	1,85	<0,1	N.E.	N.E.	N.E.
ORGANIC PHOSPHORUS	mg/L	0,732	3,25	1,95	<0,1	N.E.	N.E.	N.E.
TOTAL PHOSPHORUS	mg/L	0,855	3,3	2,1	<0,1	N.E.	N.E.	N.E.
FATS AND OILS	mg/L	<1,4	10,9	3,45	<1,4	S.P.V	S.P.V	N.E.

PARAMETER	UNITS	RESULTS				NORMA, DEC. 1594/84		
		RIO GUAITARA 2	RIO SAPUYES AGUAS ARIBA	RIO SAPUYES AGUAS ABAJO	GUAITARA 3	Article 38 Limit Human Consumption Treatment	Article 39 Limit Human consumption Disinfection	Article 40 Agricultural use limit
Do not. MCS		6350	6351	6352	6742			
DATE	A-M-D	16-3-2017	15-3-2017	15-3-2017	27-3-2017			
HOUR	Hr	9:30 a.m.	10:30 a.m.	14:45	9:00			
TOTAL HYDROCARBONS	mg/L	<1,4	1,6	<1,4	<1,4	N.E.	N.E.	N.E.
TOTAL IRON	mg/L	0,567	0,722	0,512	0,845	N.E.	N.E.	5
MAGNESIUM	mg/L	1,93	2,97	2,4	2	N.E.	N.E.	N.E.
MANGANESE	mg/L	<0,12	<0,12	<0,12	<0,12	N.E.	N.E.	0,2
MERCURY	mg/L	<0,002	<0,002	<0,002	<0,002	0,002	0,002	N.E.
NICKEL	mg/L	<0,15	<0,15	<0,15	<0,15	N.E.	N.E.	0,2
NITRATES	mg/L N-NO3	3,24	5,42	8,411	2,77	10	10	N.E.
NITRITES	mg/L N-NO2	0,019	0,0394	0,0487	0,083	1	1	N.E.
AMMONIACAL NITROGEN	mg/L	<1	1,28	1,25	<1	N.E.	N.E.	N.E.
TOTAL NITROGEN	mg/L N	<3	<3	<3	<3	N.E.	N.E.	N.E.
SILVER	mg/L	<0,05	<0,05	<0,05	<0,05	0,05	0,05	N.E.
LEAD	mg/L	<0,05	<0,05	<0,05	<0,05	0,05	0,05	5
POTASSIUM	mg/L	0,757	0,711	0,604	2,67	N.E.	N.E.	N.E.
SELENIUM	mg/L	<0,01	<0,01	<0,01	<0,01	0,01	0,01	0,02
SODIUM	mg/L	11,8	12,1	12,7	6,15	N.E.	N.E.	N.E.
TOTAL SUSPENDED SOLIDS	mg/L	282	478	264	218	N.E.	N.E.	N.E.
TOTAL SOLIDS	mg/L	354	580	362	270	N.E.	N.E.	N.E.
SULFATES	mg/L S04-2	<5	<5	<5	<5	400	400	N.E.
TENSOACTIVES (SAAM)	mg/L LAS	<0,24	0,32	1,04	<0,24	0,5	0,5	N.E.
TURBIDITY	NTU	56,4	111	130	140	N.E.	190	N.E.
ZINC	mg/L	<0,12	<0,12	<0,12	<0,12	15	15	2

Source: Results of physicochemical and bacteriological analyzes performed by the Laboratorios MCS Consultoria y Monitoreo Ambiental SAS y CIAN Ltda., 2017

5.1.6.1.3 Analysis of results.

- **Temperature.**

As can be seen in the **Figure 5.45**, The temperature presented a moderate variation, from 14 ° C to 22 ° C, however this variation is attributed to the time of sampling since, in general, the stations that presented a higher temperature were monitored at noon between 11: 00 and 14:00; While those of lower temperature were measured in the morning or afternoon. This allows us to state that changes in temperature, although important, can not be attributed to anthropogenic causes. These data can be considered normal with respect to the characteristics of the zone. In addition, with no significant increase in temperatures, some type of industrial disturbance is ruled out in any of the monitored bodies of water.

· **Dissolved oxygen.**

Dissolved oxygen had differences between stations ranging from 1 mg / L to 7.75 mg / L (**Figure 5.46**). In general, high oxygen, except for the upstream and downstream San Francisco gullies and the upstream Yamurayan gully, presented 1.2 mg / L, 1 mg / L and 1.01 mg / L, respectively. The other monitoring points had higher oxygen, mainly due to the magnitude of the flow, which allows considerable mechanical aeration.

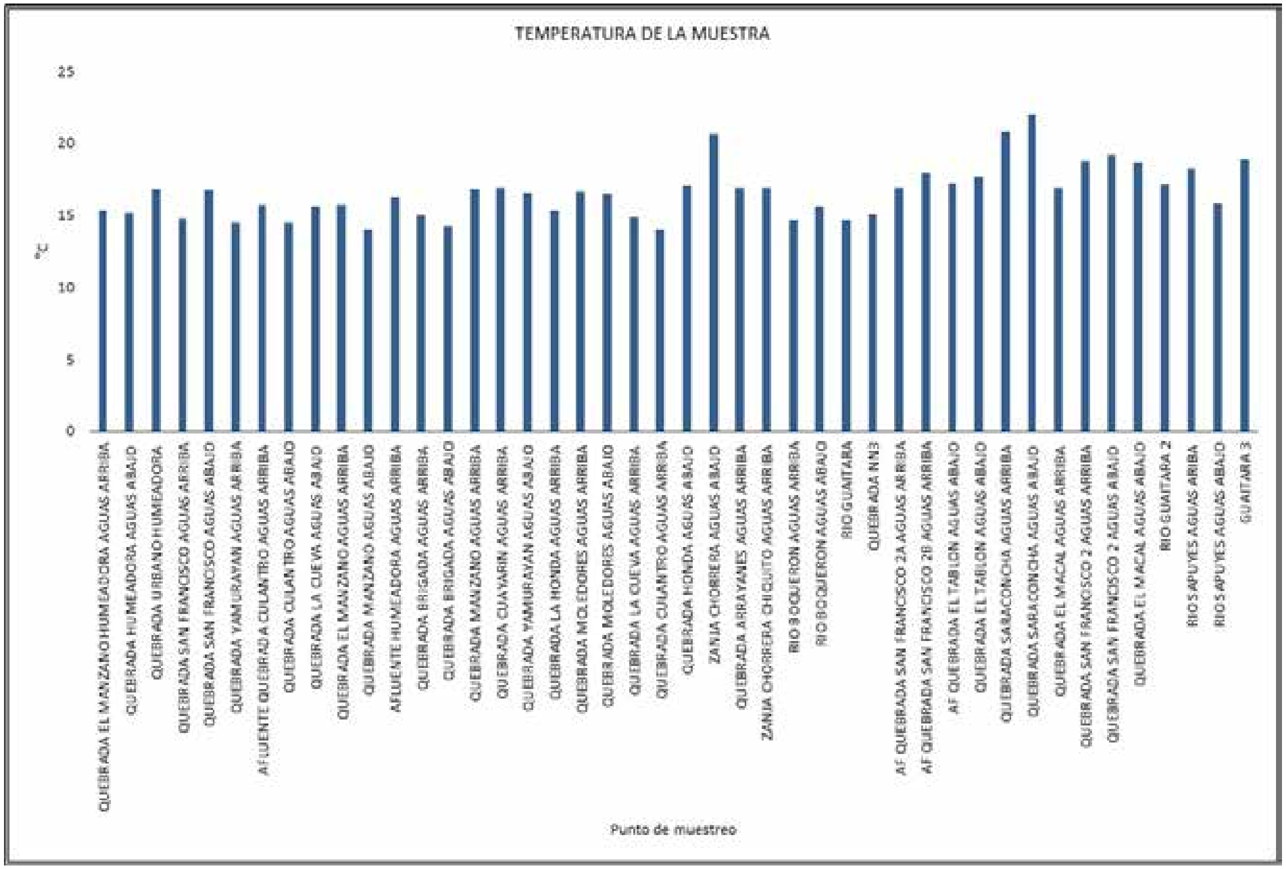
The dissolved oxygen is inversely proportional to the temperature, because at a higher temperature the dissolved oxygen escapes more easily in the body of water, a phenomenon that was not so evident in the monitoring stations, this because the temperature in these changes quickly According to the time of monitoring, between day and night, which makes this phenomenon can not be appreciated.

· **PH.**

The values of pH in the stations monitored did not present great variations, since they oscillated between 6.31 units and 8.5 units (**Figure 5.47**). The only values found below 6.5 units were found in the San Francisco stream (upstream and downstream) and in the Yamurayán stream upstream, which implies that for these points the water is not fit for consumption With only disinfection (according to article 39 of Decree 1594/84), for which a conventional treatment must be made before being used for this purpose.

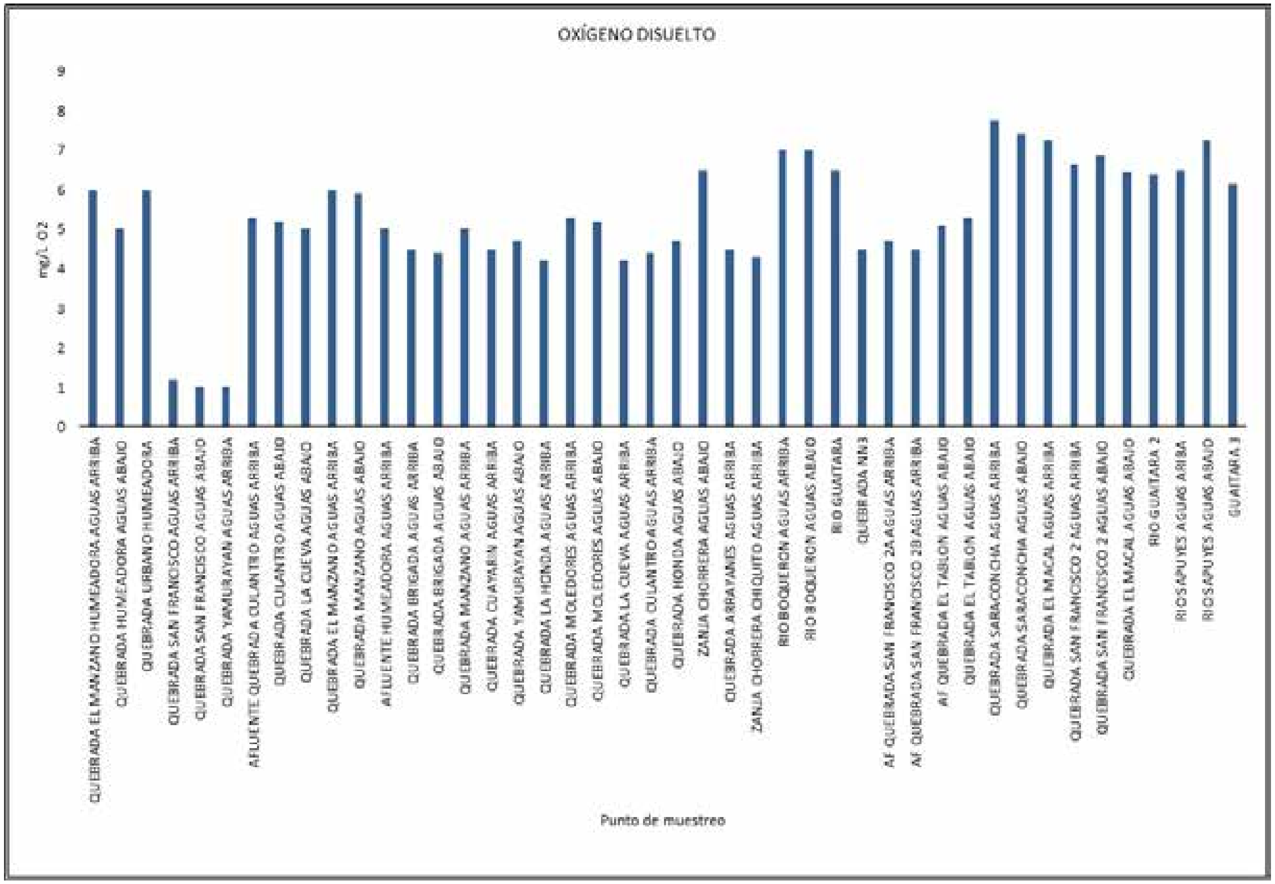
The other stations in terms of pH are suitable for human / domestic consumption (using only disinfection), as well as for agricultural, livestock use (in compliance with articles 40 and 41 of the decree mentioned respectively). This result indicates that in the monitoring stations, this variable provides adequate levels for the correct establishment and development of hydrobiological communities.

Figure 5.44 Temperature values recorded in the bodies of water evaluated.



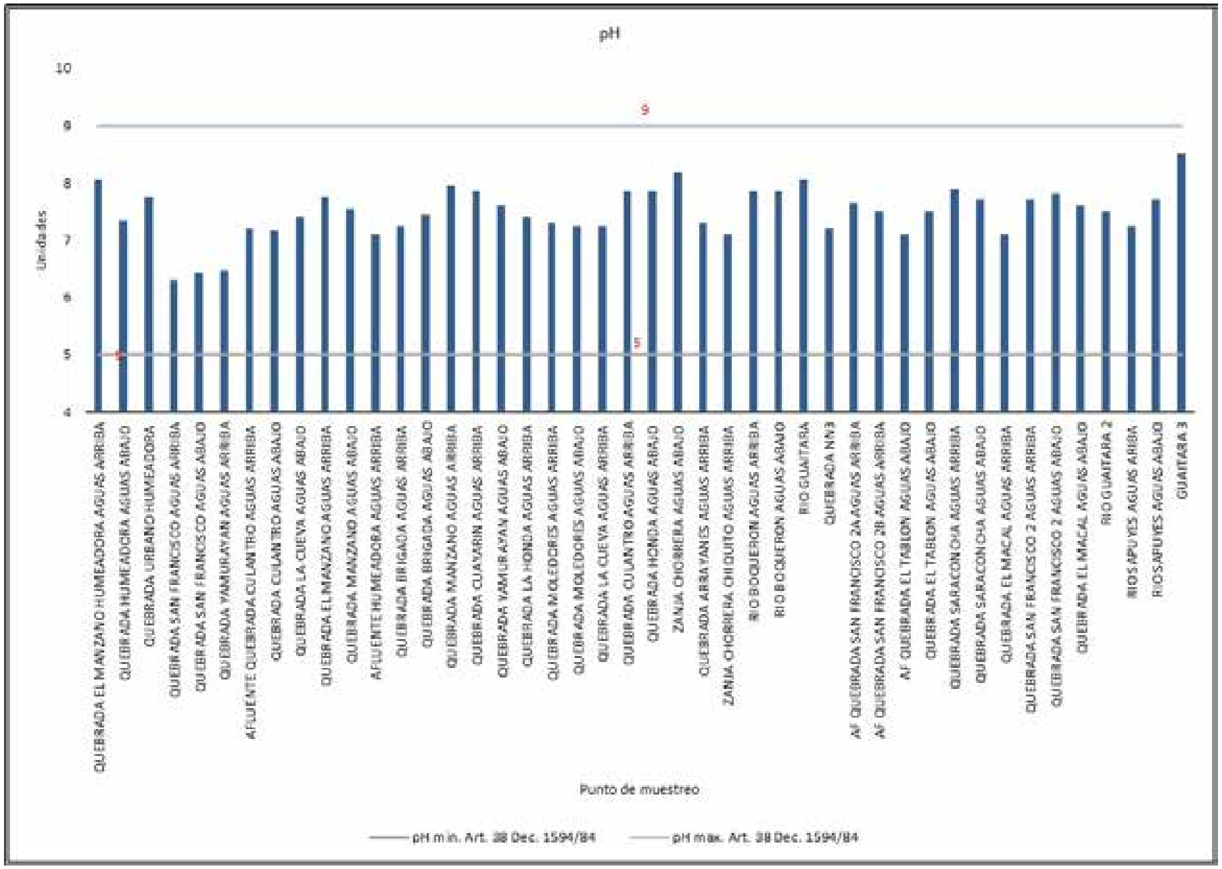
Source: MCS Consulting and Environmental Monitoring SAS, 2017.

Figure 5.45 Dissolved oxygen values recorded in the bodies of water evaluated.



Source: MCS Consulting and Environmental Monitoring SAS, 2017.

Figure 5.46 PH values recorded in the bodies of water evaluated.



Source: MCS Consulting and Environmental Monitoring SAS, 2017.

· **Conductivity and Dissolved Solids.**

Conductivity is an indirect measure of productivity as it relates all the ions present in the water, which is why it is closely related to the total dissolved solids representing the concentration of substances or minerals dissolved in natural waters. This is how conductivity measures the capacity of water to transfer electrical current, which increases mainly with dissolved ion content and temperature, and is expressed as microSiemens per centimeter (µS / cm) (Rorldán and Ramirez, 2008).

For this monitoring the conductivity value in the monitored water bodies oscillates between 64 µS / cm and 445 µS / cm, these results indicate that in general the bodies of water have similar contributions of dissolved minerals, since they fluctuate between 30 mg / L and 220 mg / L (**Figure 5.48**). These variables do not have values specified in the normativity, however some authors report that the conductivity affects the diversities of the species, reason why its measurement in the surface currents is important (Roldán, 2003).

· **Total Suspended Solids, Sedimented Solids, Total Solids, True Color and Turbidity.**

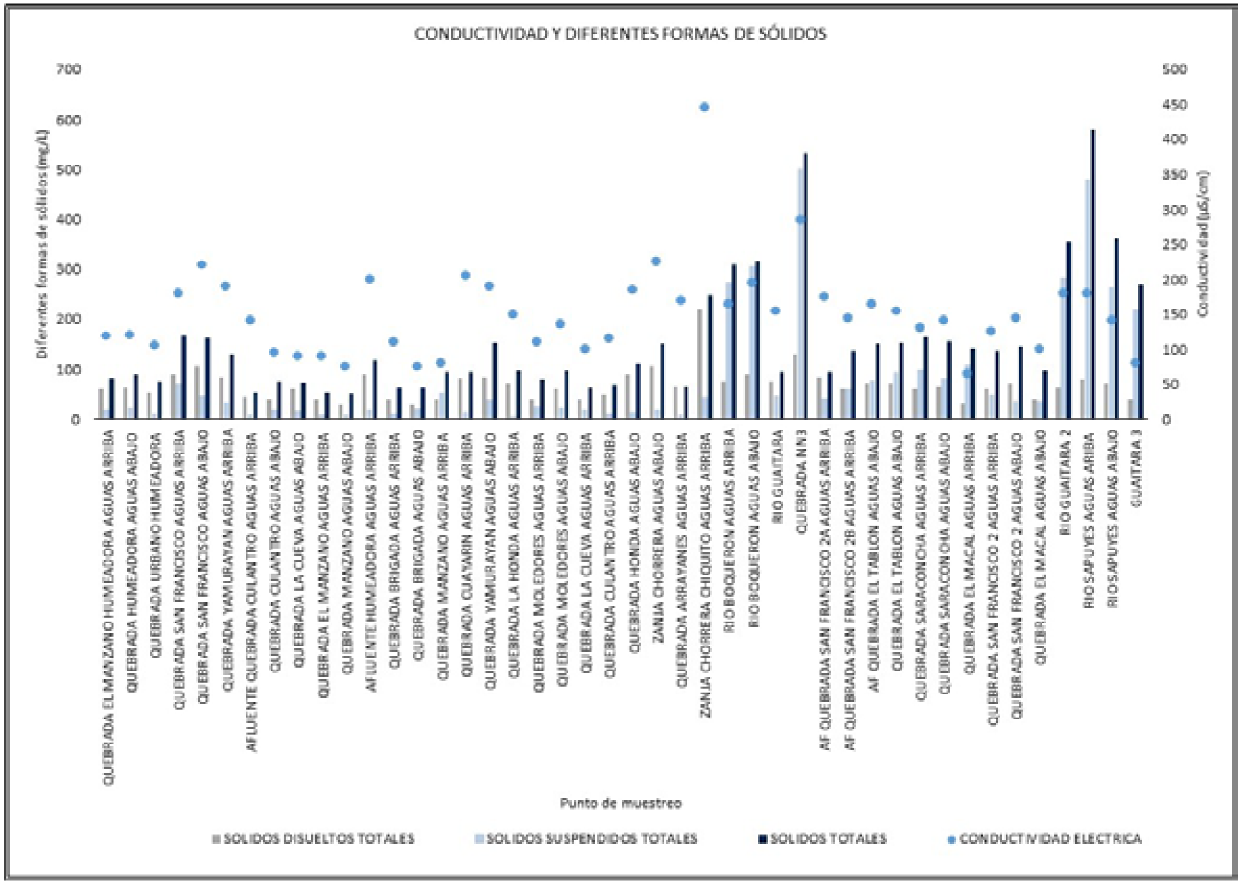
Total suspended solids are all substances in the solid state, other than water, whose size is greater than 0.20 µm and which are as their name indicates, suspended therein; This parameter is also related to the sedimentable solids that are defined as that portion of the solids that precipitate as a consequence of the gravity after a time of rest and whose quantity is determined precipitating them in an Imhoff cone. Also, both parameters have a direct effect on turbidity. By definition, total solids are the sum of all previous ones (Sawyer, 2000).

Total suspended solids at the monitored stations had values between 6 mg / L and 500 mg / L (**Figure 5.48**). As for sedimentable solids, these values were lower than the detection limit of the method <0.1 mg / mL and 0.6 mg / mL, with the highest values being found in the stations where the highest suspended solids Of dissolved. According to the above, it is established that, despite the fact that solids do not present limits in environmental regulations, a high presence of these can generate unpleasant taste in the water and have adverse effects to the people who ingest these waters. Also, because the total suspended solids influence the degree of turbidity of the waters, it is possible that the photosynthetic processes carried out by aquatic plants will also be affected.

Turbidity is an expression of the optical effect caused by the dispersion and interference of light rays passing through a sample of water; That is, it is the optical property of a suspension that causes the light to be dispersed and not transmitted through the suspension. This parameter is related to the presence of total suspended solids, which is why the highest turbidity values were recorded in the stations with the highest sediment trapping capacity, with concentrations between 4.2 NTU and 348 NTU, with the NN 3 The only sampling point that exceeded the 190 NTU (10 UJT) stipulated as maximum permissible limit in Article 39 of Decree 1594 of 1984, reason why, the majority of evaluated stations are in compliance with the current environmental norm (**Figure 5.49**).

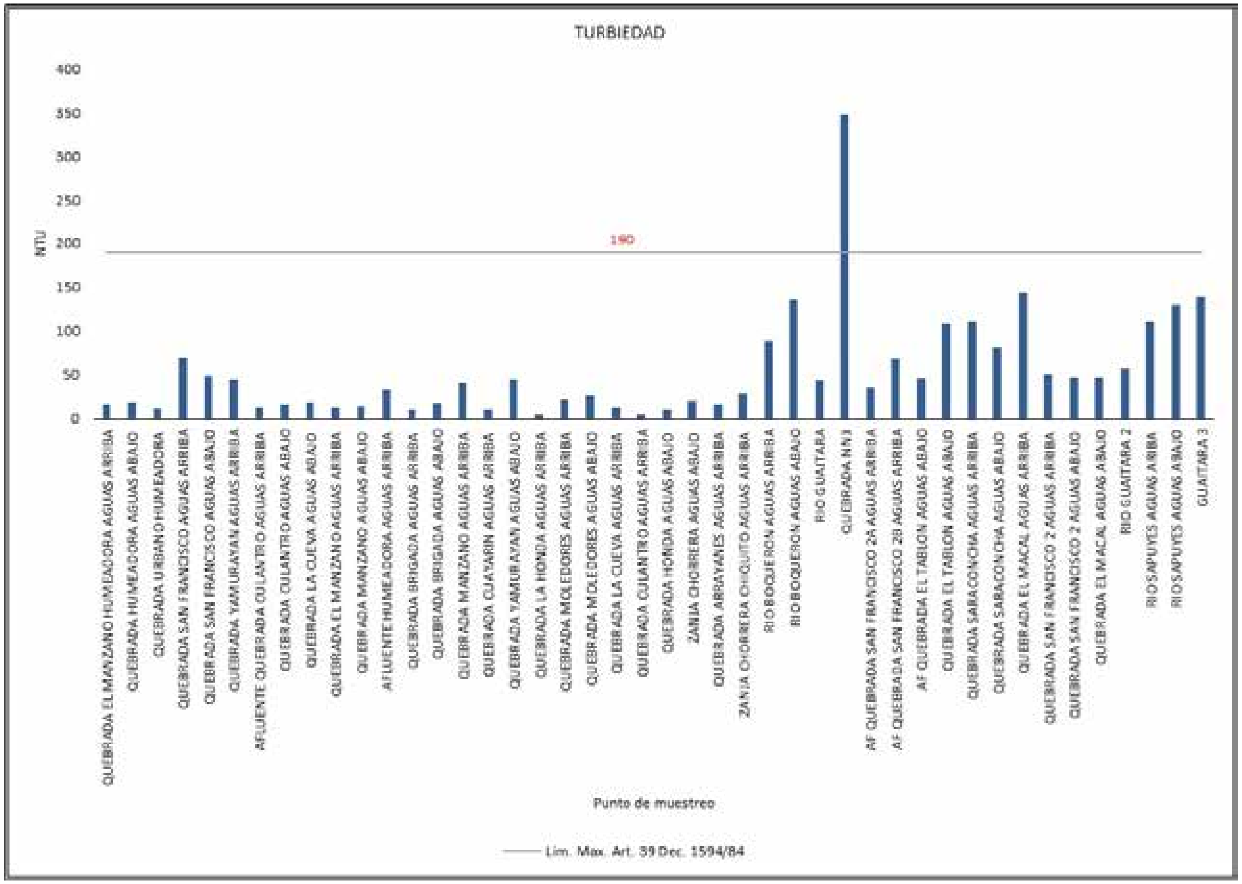
This corroborates that although the sedimentable ones are part of the suspended solids, the analytical technique to measure the turbidity does not consider them completely, which is why these differences occur, even though there is proportionality between turbidity and suspended solids. On the other hand, total solids refer to the sum of the parameters mentioned above, for which values from 52 mg / L to 580 mg / L were found. The results show that the behavior is similar to that described for the suspended solids, this indicates that the particles in suspension contribute much of the total solids.

Figure 5.47 Conductivity values, dissolved solids, suspended solids and totals recorded in the monitored water bodies.



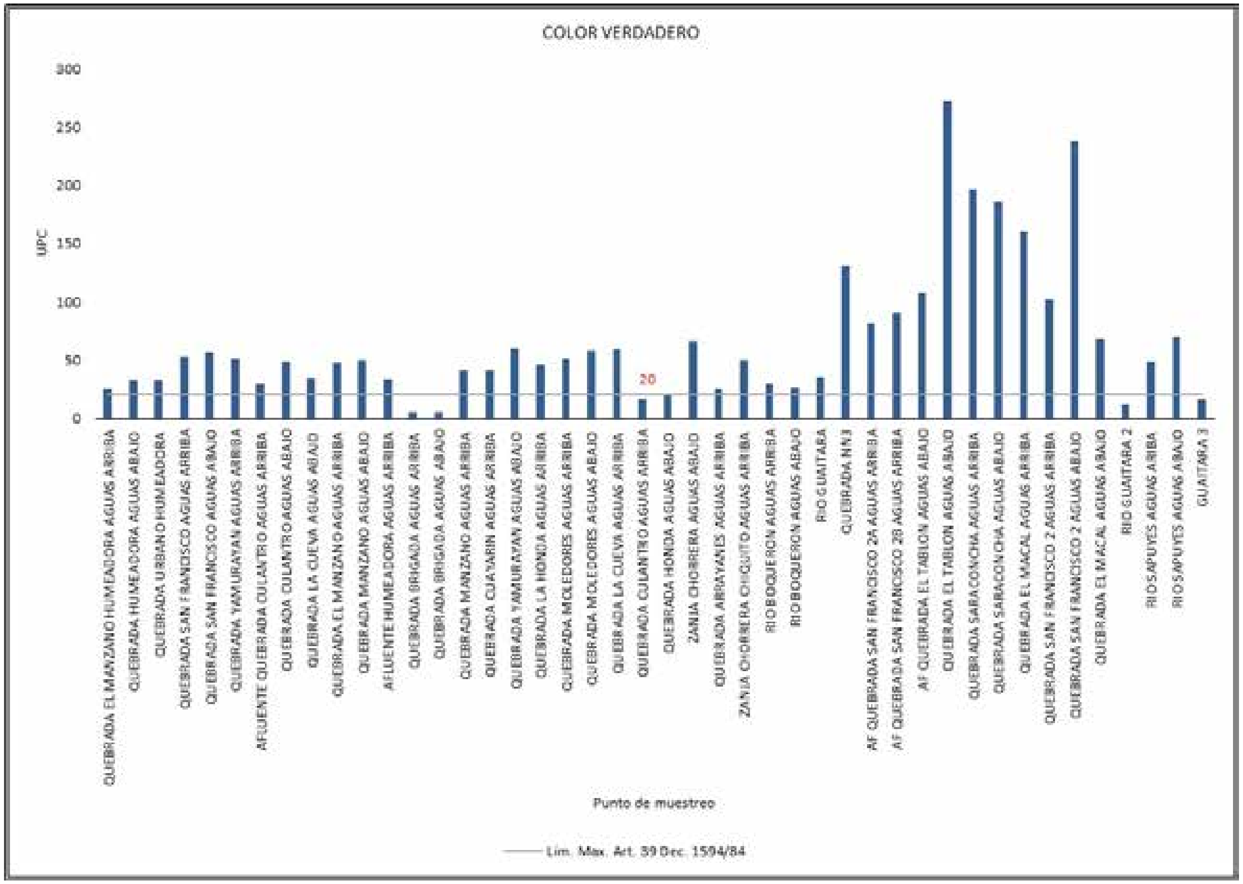
Source: MCS Consultoria y Monitoreo Ambiental SAS, 2017

Figure 5.48 Turbidity values recorded in bodies of water.



Source: MCS Consultoria y Monitoreo Ambiental SAS, 2017

Figure 5.49 True color values recorded in bodies of water.



Source: MCS Consulting and Environmental Monitoring SAS, 2017.

Finally, the true color reported concentrations between <5 UPC (detection limit of the technique used) and 272 UPC, with 89% of the monitoring stations with concentrations that are above the 20 UPC stipulated as the maximum permissible limit in Article 39 of Decree 1594 of 1984, requiring disinfection treatments prior to their use for human consumption, while, the other analyzed sites, are in full compliance with the established in the norm of reference, as shown in the **Figure 5.50**.

- **Alkalinity, Acidity, Bicarbonates and Hardness.**

The first two parameters are closely related; The first one, is defined as the measure to neutralize acids, which confers buffer properties, that is, hinders their changes in pH, is directly related to the amount of carbonate ions and bicarbonates present in the water and the second indicates the capacity Quantitative determination of a substance to react with a base at a designated pH (Romero, 1995).

Knowing the alkalinity and acidity of water is fundamental to determine its ability to maintain biological processes and sustained productivity, as the value of these variables in water has influence on the kinetics of chemical reactions, as well as reflects changes in quality Of water sources (Roldán and Ramírez, 2008).

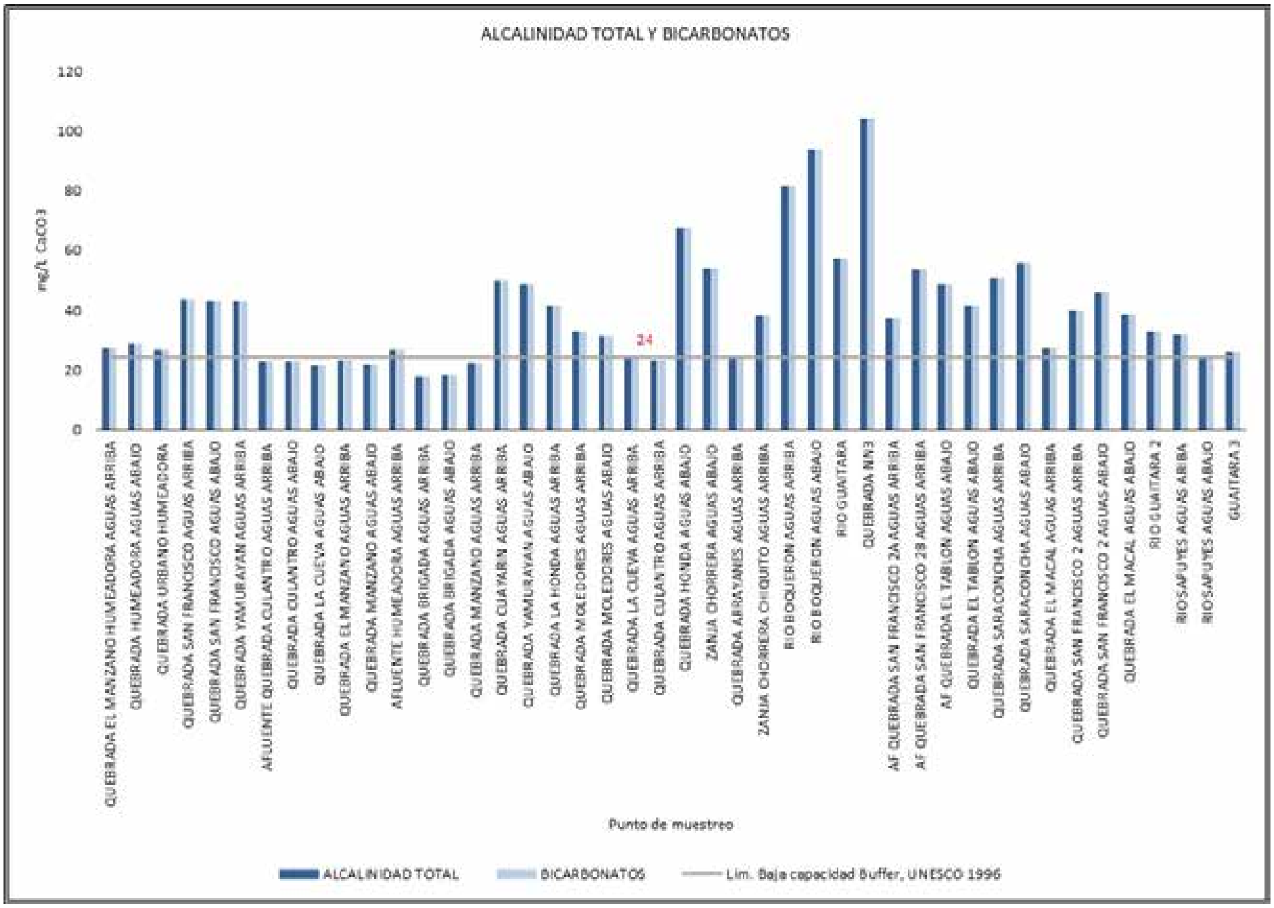
In general, alkalinity values in tropical waters are low (less than 100 mg / L) (Roldán, 1992). For the monitoring stations, results were observed that are related to the aforementioned reference, with reports between 17.8 mg / L and 104 mg / L (**Figure 5.51**), Meeting 75% of the stations with the 24 mg / L set as the minimum limit by UNESCO (1996), to be called with good Buffer capacity.

Total acidity was found in water bodies evaluated with values ranging from below the limit of detection by the analytical technique used (<2 mg / L) and 20.1 mg / L (**Table 5.57** to **Table 5.65**). In general, the values are consistent with the pH records found for their basicity or acidity, recorded for each water stream evaluated.

Bicarbonates are salts that are part of transient states of carbon. These salts play an important role in buffering the pH, as well as defining the temporal and total hardness of aquatic systems. In a large part, the bicarbonates, carbonates and hydroxides determine the concentration of alkalinity in a body of water, because when acidity conditions increase, the reaction between the acid and the carbonate base combined, brings an increase in neutral bicarbonate (Wetzel, 1981; Roldan, 1989).

Bicarbonate concentrations ranged from 17.8 to 104 mg / L, taking into account that the presence of bicarbonates in natural waters helps to maintain ion balance and avoid corrosive or fouling properties, and it is rare to find water that exceeds 500 mg / L of carbonates (Mc.Neely *Et al.* 1979 In: Sandi W, 2008). As for the limit established by UNESCO (1996), 75% of the stations with 24 mg / L established as the minimum limit by UNESCO (1996) are meeting the criteria for good buffering (**Figure 5.51**).

Figure 5.50 Values of total alkalinity and bicarbonates recorded at the monitored sampling stations



MCS Consultoria y Monitoreo Ambiental SAS, 2017

The total hardness of the water is defined by the amount of calcium and magnesium ions present in it. Calcium hardness is determined by calcium compounds, mainly calcium carbonates. Waters that have low hardness values are called "soft waters" and are biologically unproductive. In contrast, water with high hardness values are called "hard" and are usually very productive. The hardness scale ranges from water with less than 10 mg / L, which are not very productive, medium productive waters with values between 10 and 25 mg / L and very productive waters with values higher than 25 mg / L (Ohle, 1934, taken from Roldan and Ramírez, 2008).

In terms of hardness waters can be classified as soft waters (0-75 mg / L CaCO3), moderately hard (75-150 mg / L CaCO3), hard (150-300 mg / L CaCO3) and very hard water (greater than 300 Mg / L) (Romero, 1995). Total hardness had concentrations between 19 mg / L and 128 mg / L (40 stations being classified as soft water and 4 in moderately hard water) and calcium hardness between 13.3 mg / L and 89.6 mg / L, as shown in the **Table 5.57** to **Table 5.65**.

· **Biochemical Oxygen Demand (BOD5), Chemical Oxygen Demand (COD) and Total Organic Carbon.**

BOD5 is the oxygen measurement required by microorganisms to degrade organic matter present; While 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 levels of BOD5 presented values ranging from 5 to 20 mg / L. On the other hand, COD presented a concentration below the detection limit of the method (<20 mg / L) up to 31 mg / L for most monitored stations.

The results allow to deduce that the lotic waters do not present some degree of organic pollution, therefore it is not considered that there is contamination by non-biodegradable organic matter (Marín, 2009). Thus, it is considered that the bodies of water evaluated have a satisfactory degree of biodegradability and that the organic matter present is moderately biodegradable (Marín, 2009).

· **Macronutrients.**

For the analyzed stations, nitrate concentrations were recorded from 0.71 mg / L to 8.41 mg / L, low values that do not represent any affectation for the environment in relation to this parameter. On the other hand, the nitrites showed lower concentrations than the detection values of the method (less than 0.003 mg / L) up to 0.08 mg / L. This demonstrates that a significant organic decomposition process is being carried out continuously in this system.

In general, all the stations present a higher proportion of nitrates than of nitrites. This, together with the relatively low values of BOD5 in most stations, indicates that although there is an impact by organic contamination by livestock, these bodies of water carry processes of Oxidation of the same in advanced degrees of degradation.

According to the above results, it is clear that both nitrates and nitrites do not exceed the permissible limits established by regulations for consumption / human / domestic use and in the specific case of nitrites additionally complies with the related regulations for use Livestock (Decree 1594/84). The above implies that as these parameters, all waters are suitable for any destination.

With regard to ammoniacal nitrogen, this parameter did not exceed the limit allowed by the regulations, since the results were between the minimum limit of quantification by the analytical technique implemented in the laboratory (<1 mg / L) up to 1,28 mg / L , Verifying the absence of recent contamination by significant concentrations of nitrogen compounds of industrial anthropic origin or direct and direct discharge of wastewater.

In relation to inorganic phosphorus, values ranging from below the limit of detection (<0.1 mg / L) to 3.1 mg / L were registered, values that did not show much variation (with a standard deviation of 0.2). The results shown for this parameter are mainly due to the organic matter coming from the adjacent vegetation and by the cattle ranch.

On the other hand, organic phosphorus showed values below 0.1 mg / L for most stations (undetectable result using the analytical technique used for its evaluation) up to a detectable value of 3.25 mg / L. These high values of organic phosphorus may be due to recent contributions of organic matter by livestock activity.

In relation to phosphates, values from below the limit of detection were recorded by the analytical technique from <0.03 mg / L to 1.32 mg / L. As expected, the concentration of phosphates in all seasons was proportional to that of inorganic phosphorus, which is logical, since phosphates are the bioavailable form of inorganic phosphorus.

Water bodies with total phosphorus concentrations higher than 0.1 mg / L are considered highly eutrophic, whereas concentrations below 0.005 mg / L are considered to be very unproductive, most uncontaminated fresh waters have concentrations of 0, 01 to 0.05 mg / L (Wetzel, 2000). At the evaluated points, concentrations between 0.1 mg / L and 3.3 mg / L were found, all these bodies being classified as highly eutrophic.

- **Chlorides and Sulphates.**

Chlorides are a parameter that measures the concentration of chloride anions dissolved in water. It is related to the geochemical nature of the basins and can be increased by human activity due to the generation of excrement. Also, it is one of the main anions that contributes to salinity, in addition, in the fresh waters, this parameter is inversely related to the diversity of species. Chlorides presented values below the detection limit of the method (<4 mg / L) up to 49.1 mg / L. It is noteworthy that the values obtained in all stations are however low because values higher than 250 mg / L are detrimental to health and obey to that they are one of the ions more widely distributed in nature and obey the type of soil (Sawyer, 2000). It should be noted that these are values that are in accordance with the regulations, which set a limit of 250 mg / L for human consumption and domestic use, therefore in this parameter are suitable for such use.

Sulphate, for its part, is one of the ions widely distributed in nature and can occur in natural waters from a few to several thousand milligrams per milliliter. This nutrient is the main form of sulfur that can be incorporated by several groups of autotrophic organisms, for the biosynthesis of organic sulfur substances like some amino acids. For sulfates, values below the detection limit of the method (<5 mg / L) were reported up to 6.13 mg / L, concentrations that are not high, since above 400 mg / L are considered toxic levels, Not suitable for human consumption (Decree 1594/84).

- **Total Phenols, Total Hydrocarbons and Fats and Oils.**

These chemicals are part of the family of organic compounds. Many of them are naturally supplied to bodies of water as waste products and decomposition of living things. However, they can reach ecosystems through industrial water spills and in high concentrations can be toxic to aquatic life.

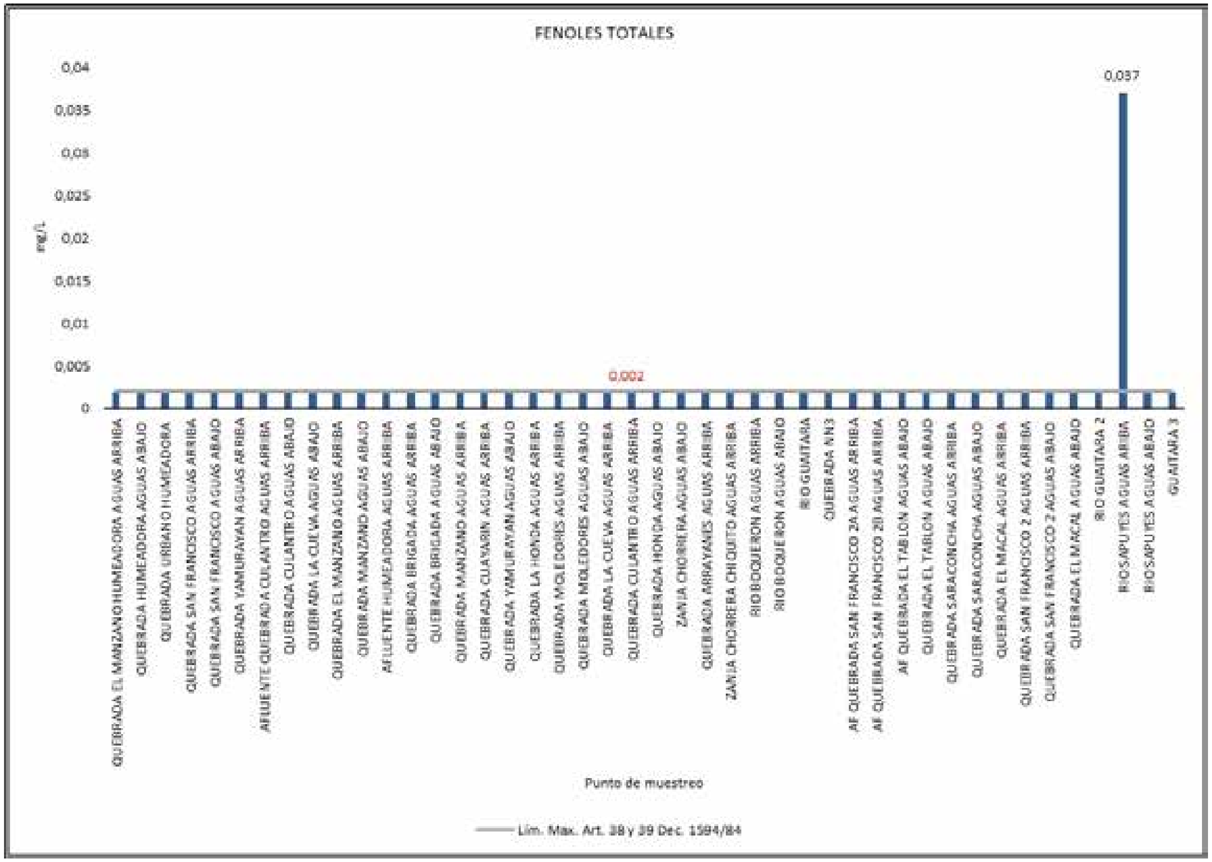
Total hydrocarbon concentrations ranged from below the detection limit (<1.4 mg / L) to 1.6 mg / L, while for fats and oils concentrations were reported to be below the limit of quantification (< 1.4 mg / L) to 10.9 mg / L. On the other hand, the total phenols reported concentrations below the minimum acceptance limit by the analytical technique implemented in the laboratory (<0.002 mg / L) in most monitoring stations, except in the Sapuyes river upstream, where it registered 0.037 Mg / L, being the only point that is not complying with the 0.002 mg / L stipulated as maximum permissible limit in Articles 38 and 39 of Decree 1594 of 1984 (**Figure 5.52**).

- **Surfactants (SAAM).**

These substances refer to Methyl Blue Active Substances (SAAM) or detergents, which when discharged into natural water bodies usually reduce oxygen access, soften water and increase toxicity causing harmful effects on aquatic life .

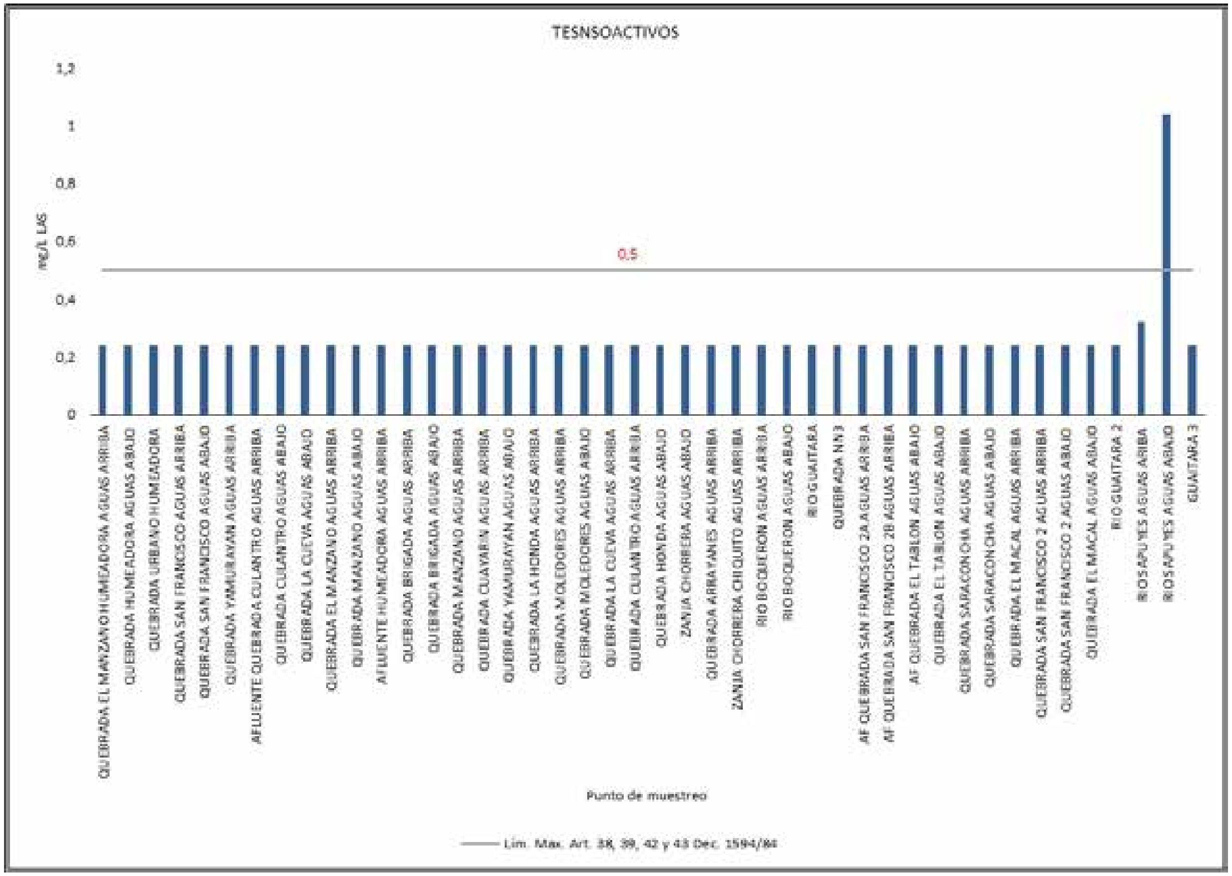
The SAAM levels in the majority of water bodies evaluated had a concentration below the detection limit of the method (<0.24 mg / L), except in the downstream Sapuyes river where it recorded 1.04 mg / L, Being the only point that is not complying with the 0.5 mg / L stipulated as maximum permissible limit in Articles 38 and 39 of Decree 1594 of 1984 (**Figure 5.53**).

Figure 5.51 Total phenol values recorded at the monitored sampling stations.



Source: MCS Consultoria y Monitoreo Ambiental SAS, 2017

Figure 5.52 Values of surfactants at monitored sampling stations.



Source: MCS Consultoria y Monitoreo Ambiental SAS, 2017

- **Other Ions.**

Metals are generally found in trace concentrations in natural systems and some of them are essential for the normal development of life, and the absence of sufficient amounts of them could limit the growth of algae.

However, several of these metals, such as those having a very high molecular weight, when their concentrations are very high may be harmful to organisms.

Regarding the results of the metals that are contemplated in Decree 1594 of 1984 as cadmium, chromium, barium, lead, selenium and nickel presented results inferior to the respective limit of detection in all the sampling stations, indicating a fulfillment With that established in Decree 1594 of 1984, which does not generate restrictions regarding the use of the surface currents evaluated.

As for iron, values between 0.15 (limit of detection of the technique used) and 1,08 mg / L were found, complying with the 5 mg / L stipulated as the maximum permissible limit in Article 40 of Decree 1594 of 1984. However, it is noteworthy that these levels are attributed to the soil type and are contributed to the bodies of water by leaching and in no case are derived from impacts of anthropic origin, this can be affirmed since the iron is widely distributed in the Bark and no other parameter indicates industrial pollution.

On the other hand the essential macronutrients, the calcium had values ranging from 4.97 mg / L and 32.10 mg / L; Magnesium presented values between 1.09 mg / L and 7.92 mg / L mg / L; For sodium presented values between 3.98 mg / L and 28.4 mg / L; Finally potassium presented values between the limit of detection of the technique used (0.27 mg / L) and 2.67 mg / L.

The other parameters analyzed in this study had low concentrations that are among the normal ranges for this type of water, in addition they are in full compliance with the stipulated in the Articles 38 to 40 of the Decree 1594 of 1984.

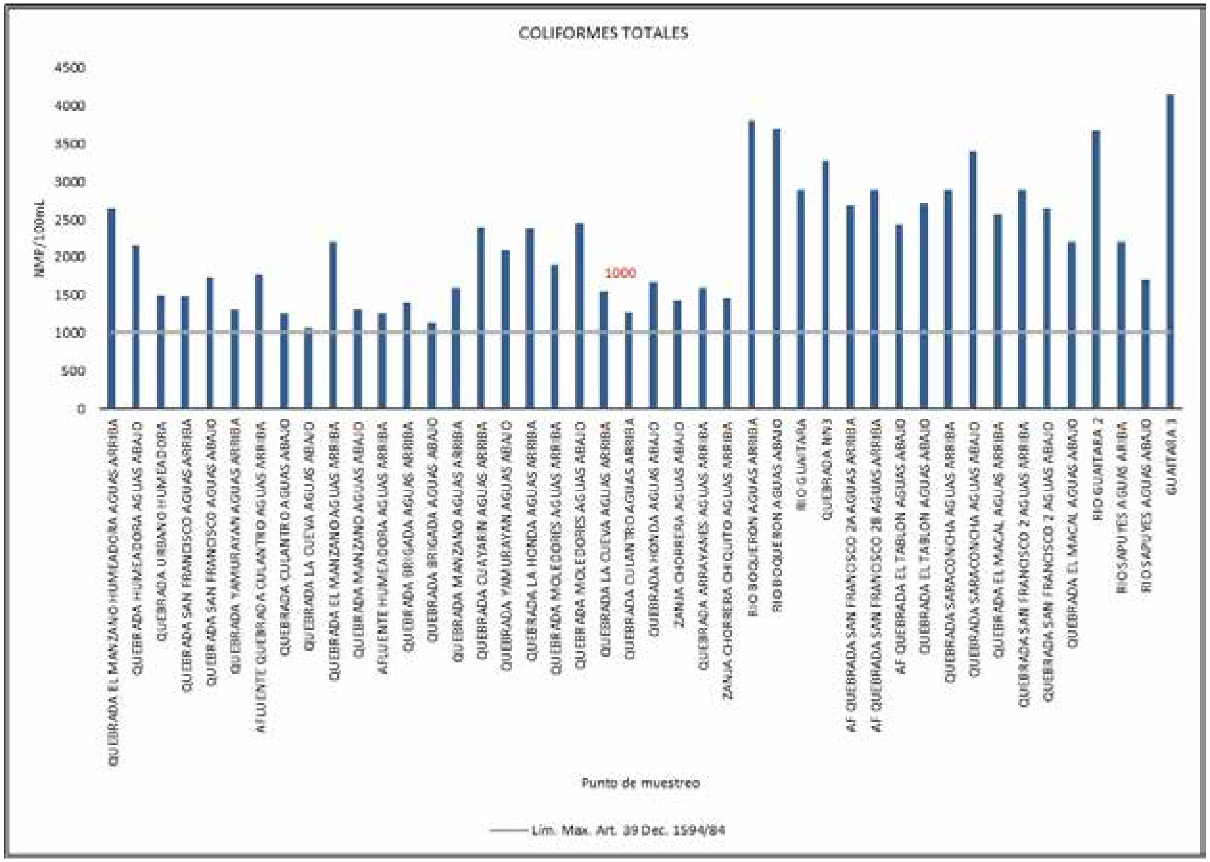
- **Total and Fecal Coliforms.**

Coliforms are a group of microorganisms that by themselves do not constitute pathogenic organisms, but they are susceptible of monitoring since they are often associated with organisms that are, becoming organisms indicative in the bodies of water. These microorganisms commonly inhabit the intestines of humans and other warm-blooded organisms and because they are more resistant than pathogenic bacteria, the absence of these indicates that water is bacteriologically safe for human health.

Total coliforms showed values between 1056 and 4150 NMP / 100 mL (**Figure 5.54**), Being in non-compliance, exceeding the limit established in Article 39 of Decree 1594 of 1984 (1000 NMP / 100mL), but meeting in compliance with the limits established in articles 38 and 40 of said decree, not exceeding 5000 NMP / 100mL.

For fecal coliforms, values ranging from 110 NMP / 100 mL to 990 NMP / 100 mL were presented, fully complying with the 1000 NMP / 100 mL as stipulated as maximum permissible limit in Article 40 of Decree 1594 of 1984, being able to give any destination To the evaluated water resource, according to this parameter.

Figure 5.53 Values of total coliforms recorded in water bodies.



MCS Consulting and Environmental Monitoring SAS, 2017.

5.1.6.2 Quality and pollution indices.

· **Water Quality Index (WQI).**

As a methodological tool for the determination of the water quality of currents (WQI) developed by the National Health Foundation of the United States (Canter, 1998), in which the greatest number of parameters (such as dissolved oxygen, Fecal coliforms, pH, BOD_5, Nitrates, phosphates, turbidity and total solids), assigning each one a percentage according to the degree of importance, such that dissolved oxygen, coliforms and pH are the most important parameters to take into account in order to Determine the state of a stream of water.

This index is very useful to establish the water quality of the water currents, because it identifies in a quantitative and qualitative way, its potential for agricultural and consumer uses.

In the **Table 5.66** The assignment of the WQI values for the sampled streams is presented.

Table 5.66 Water Quality Index (WQI) and quality parameters.

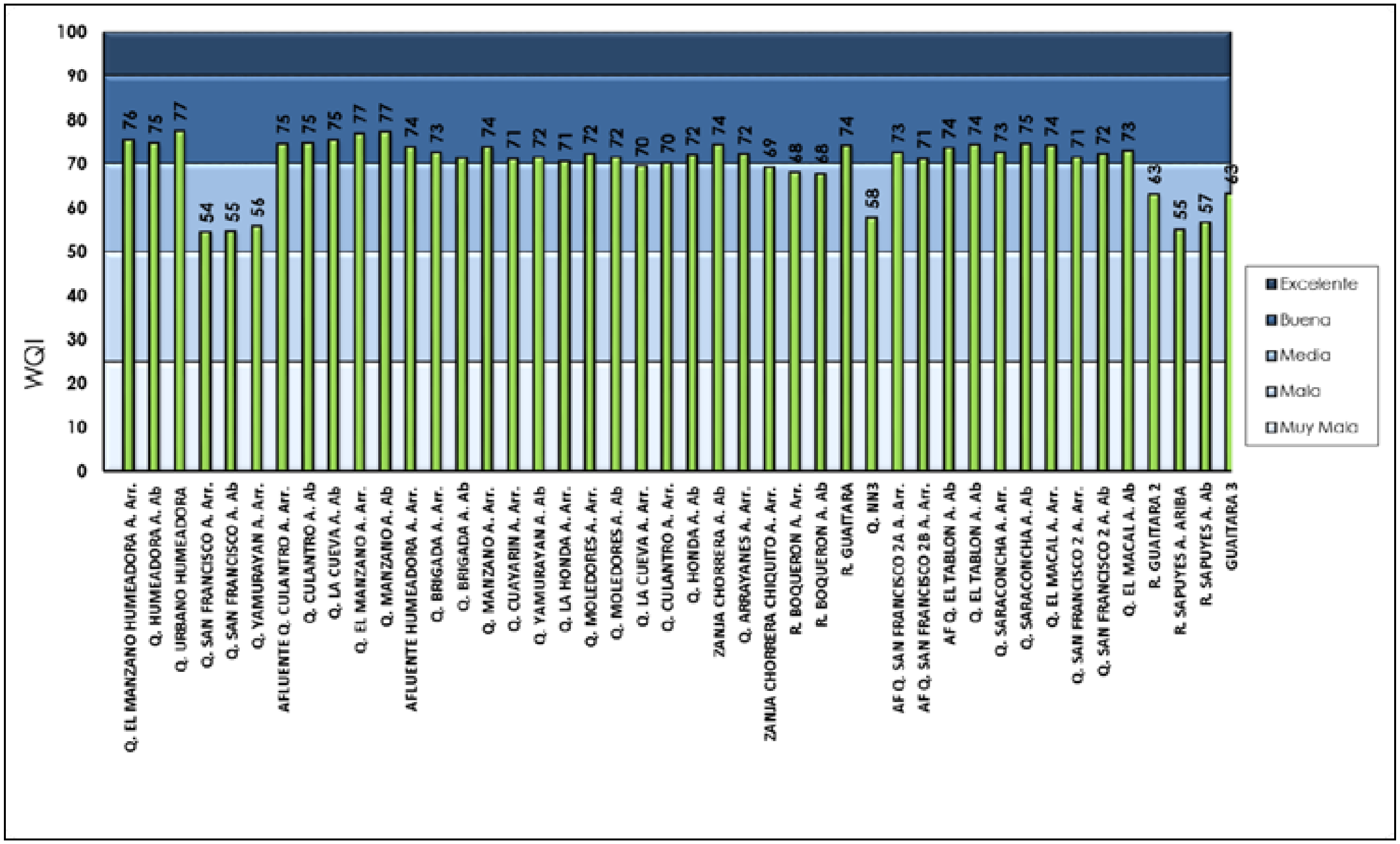
SEASONS	WQI
BROKEN THE SMOOTHING APPLE WATER ABOVE	75,5
WET BLEEDING WATER DOWN	74,7
MOISTURIZING URBAN BREAK	77,4
SAN FRANCISCO AGUAS ARRIBA BROKEN	54,5
SAN FRANCISCO WATER BOW DOWN	54,7
BROKEN YAMURAYAN AGUAS TOP	55,8
AFFLUENT BROKEN CULANTRO WATER ABOVE	74,6
BREAK CULANTRO WATERS DOWN	74,7
BROKEN DOWN THE CAVE WATERS	75,5
BROKEN THE MANZANO WATERS ABOVE	76,9
BROWN MANZANO WATERS DOWN	77,2
HYGIENE HYGIENE WATER UP	73,9
BROKEN BRIGADE AGUAS ABOVE	72,5
BROKEN BRIGADE WATERS DOWN	71,3
BROWN MANZANO AGUAS TOP	73,9
CUAYARIN WATER	71,2
BROKEN YAMURAYAN WATERS DOWN	71,5
BROKEN LA HONDA AGUAS ARRIBA	70,7
BROKEN WATER SPRINGS ABOVE	72,3
BROKERS GROUNDS WATERS DOWN	71,5
BREAKING THE CAVE AGUAS ABOVE	69,6
CULANTRO BREAK WATER UP	70,3
BROKEN HONDA WATERS DOWN	72,0
ZANJA CHORRERA WATERS DOWN	74,3
ARRAYANES WATER BROOK TOP	72,2
ZANJA CHORRERA CHIQUITO AGUAS ARRIBA	69,3
RIO BOQUERON AGUAS ARRIBA	68,1

SEASONS	WQI
RIO BOQUERON WATERS DOWN	67,8
RIO GUAITARA	74,1
BROKEN NN3	57,7
SAN FRANCISCO 2A WATCHED UP ARA	72,6
SAN FRANCISCO 2B WATCHED UP AGUAS ARRIBA	71,2
AF BROKEN THE TABLON WATERS DOWN	73,6
BROKEN DOWN THE TABLON WATERS	74,3
SARACONCHA BROOKES AGUAS ARRIBA	72,7
BROKEN SARACONCHA WATERS DOWN	74,6
BROKEN THE MACAL WATERS ABOVE	74,2
BROKEN SAN FRANCISCO 2 AGUAS ARRIBA	71,5
SAN FRANCISCO BROKEN 2 WATERS DOWN	72,2
BROKEN THE MACAL WATERS DOWN	72,9
RIO GUAITARA 2	63,2
RIO SAPUYES AGUAS ARIBA	55,2
RIO SAPUYES AGUAS ABAJO	56,7
GUAITARA 3	63,2
WQI INTERPRETATION	
0-25	VERY BAD QUALITY (MM)
26-50	BAD QUALITY (M)
51-70	MEDIUM QUALITY (R)
71-90	GOOD QUALITY (B)
91-100	EXCELLENT QUALITY (E)

Source: MCS Consultoria y Monitoreo Ambiental SAS, 2017

In the **Figure 5.55** The distribution of water flows monitored according to the obtained value of WQI is graphically evaluated. According to this, 14 of the 44 stations have average water quality as a consequence mainly of the presence of fecal type coliforms, as well as high values of total solids but values relatively high to means of dissolved oxygen and average content of the others Parameters used in the calculation of the index such as pH, turbidity, nitrates and phosphates. The remaining 30 stations had good water quality, possibly due to the lowest values of fecal coliforms, low BOD_5, Turbidity and mainly lower solids content.

Figure 5.54 Values of water quality index (WQI) in monitored water bodies.



Source: MCS Consulting and Environmental Monitoring SAS, 2017.

· **Pollution Indices (ICO).**

Among the contamination indexes were: mineralization index (ICOMI), suspended solids pollution index (ICOSUS) and organic matter pollution index (ICOMO). The ICOMI is expressed in the variables of conductivity, hardness and alkalinity, while ICOMO takes into account the values of total coliforms, BOD_5 And dissolved Oxygen and ICOSUS only involves the concentration of suspended solids, which refer to the organic and inorganic compounds present in the water.

These indexes are very useful to establish the water quality of the water currents, because it identifies the degree of intervention of the water bodies (Ramírez et al., 1997). In the **Table 5.67** The results of the ICO values are presented for each stream of water sampled in this study.

The contamination index for mineralization (ICOMI) showed a high contamination in the small chorrito ditch, while in the NN3 ravine and the tributary of the ravine the plank downstream, a medium contamination occurred. On the other hand, it can be **Figure 5.56** Y **Table 5.67,** That the majority of monitoring points had a very low contamination, corresponding to only 9 stations a low contamination.

The suspended solids contamination index (ICOSUS) presented a very high contamination for the Boquerón river downstream, the NN3 ravine, the Guáitara 2 river and the Sapuyes river upstream, whereas for the Boquerón river upstream, the Sapuyes river Below and Guáitara River 3 presented a high contamination. On the other hand, the stream of the Downstream Plank and the downstream affluent along with the Saraconcha and Macal streams, reported a low contamination, corresponding to the other sampling points, a very low suspended solids contamination.

The ICOMO organic matter contamination index showed high contamination in the Saraconcha, San Francisco 2, Macal and Sapuyes rivers, while in the 12 colored spots of yellow in the **Table 5.67** There was an average contamination, corresponding to the other evaluated stations a very low contamination, as shown in the table mentioned.

The index of trophic contamination (ICOTRO) at the points monitored, 38 reported very low pollution, 3 low pollution and 3 very high pollution, this index is determined essentially by the concentration of total phosphorus.

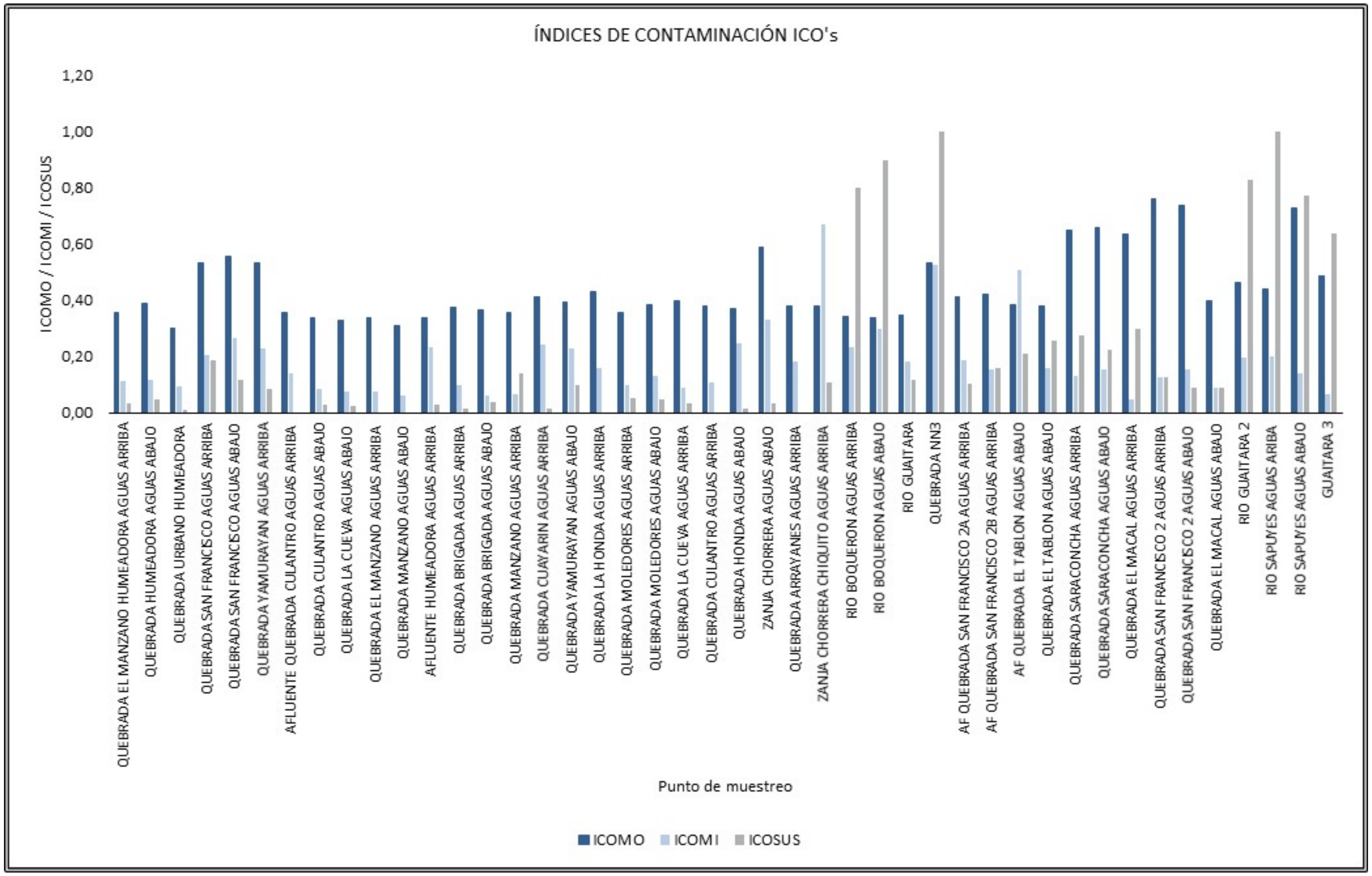
Table 5.67 Contamination Indices (ICO's) obtained in the bodies of water evaluated.

SEASONS	ICOMO	ICOMI	ICOSUS	ICOTRO
BROKEN THE SMOOTHING APPLE WATER ABOVE	0,36	0,11	0,03	0,10
WET BLEEDING WATER DOWN	0,39	0,11	0,05	0,10
MOISTURIZING URBAN BREAK	0,30	0,10	0,01	0,10
SAN FRANCISCO AGUAS ARRIBA BROKEN	0,53	0,20	0,19	0,22
SAN FRANCISCO WATER BOW DOWN	0,55	0,27	0,12	0,31
BROKEN YAMURAYAN AGUAS TOP	0,53	0,23	0,08	0,29
AFFLUENT BROKEN CULANTRO WATER ABOVE	0,35	0,14	0,00	0,10
BREAK CULANTRO WATERS DOWN	0,34	0,08	0,03	0,10
BROKEN DOWN THE CAVE WATERS	0,33	0,08	0,02	0,10
BROKEN THE MANZANO WATERS ABOVE	0,34	0,08	0,00	0,10
BROWN MANZANO WATERS DOWN	0,31	0,06	0,00	0,10
HYGIENE HYGIENE WATER UP	0,34	0,23	0,03	0,10
BROKEN BRIGADE AGUAS ABOVE	0,38	0,10	0,01	0,10

SEASONS	ICOMO	ICOMI	ICOSUS	ICOTRO
BROKEN BRIGADE WATERS DOWN	0,37	0,06	0,04	0,10
BROWN MANZANO AGUAS TOP	0,35	0,07	0,14	0,10
CUAYARIN WATER	0,41	0,24	0,02	0,10
BROKEN YAMURAYAN WATERS DOWN	0,39	0,23	0,10	0,10
BROKEN LA HONDA AGUAS ARRIBA	0,43	0,16	0,00	0,10
BROKEN WATER SPRINGS ABOVE	0,35	0,10	0,05	0,10
BROKERS GROUNDS WATERS DOWN	0,38	0,13	0,05	0,10
BREAKING THE CAVE AGUAS ABOVE	0,40	0,09	0,03	0,10
CULANTRO BREAK WATER UP	0,38	0,11	0,00	0,10
BROKEN HONDA WATERS DOWN	0,37	0,25	0,02	0,10
ZANJA CHORRERA WATERS DOWN	0,59	0,33	0,03	0,10
ARRAYANES WATER BROOK TOP	0,38	0,18	0,00	0,10
ZANJA CHORRERA CHIQUITO AGUAS ARRIBA	0,38	0,67	0,11	0,10
RIO BOQUERON AGUAS ARRIBA	0,34	0,23	0,80	0,10
RIO BOQUERON WATERS DOWN	0,33	0,30	0,90	0,10
RIO GUAITARA	0,34	0,18	0,12	0,10
BROKEN NN3	0,53	0,52	1,00	0,10
SAN FRANCISCO 2A WATCHED UP ARA	0,41	0,19	0,10	0,10
SAN FRANCISCO 2B WATCHED UP AGUAS ARRIBA	0,42	0,15	0,16	0,10
AF BROKEN THE TABLON WATERS DOWN	0,38	0,50	0,21	0,10
BROKEN DOWN THE TABLON WATERS	0,38	0,16	0,26	0,10
SARACONCHA BROOKES AGUAS ARRIBA	0,65	0,13	0,27	0,10
BROKEN SARACONCHA WATERS DOWN	0,66	0,15	0,22	0,10
BROKEN THE MACAL WATERS ABOVE	0,64	0,05	0,30	0,10
BROKEN SAN FRANCISCO 2 AGUAS ARRIBA	0,76	0,13	0,12	0,10
SAN FRANCISCO BROKEN 2 WATERS DOWN	0,74	0,16	0,09	0,10
BROKEN THE MACAL WATERS DOWN	0,40	0,09	0,09	0,10
RIO GUAITARA 2	0,46	0,19	0,83	0,86
RIO SAPUYES AGUAS ARRIBA	0,44	0,20	1,00	1
RIO SAPUYES AGUAS ABAJO	0,73	0,14	0,77	1
GUAITARA 3	0,49	0,07	0,63	0,10
ICOS INTERPRETATION (Pollution Level)				
0-0,2		VERY LOW		
0,21-0,4		LOW		
0,41-0,6		MEDIUM		
0,61-0,8		HIGH		
0,81-1,0		VERY HIGH		

Source: MCS Consulting and Environmental Monitoring SAS, 2017.

Figure 5.55 Values of contamination indexes (ICO's) in monitored water bodies.



Source: MCS Consultoria y Monitoreo Ambiental SAS, 2017

In general, according to the results obtained for the four pollution indices evaluated, it is observed that the majority of the stations presented low values to means of contamination by organic matter, low of pollution by mineralization and low of contamination by drag of sediments, which Indicates that the bodies of water have great capacity of degradation of nutrients by the high rate of recycling of the same ones, due to the temperatures and oxygenation that they present in the zone of study.

- **Index of Langelier.**

Taking into account the Langelier index, negative values (<0) were recorded for all evaluated stations, establishing corrosive water for all water bodies monitored during this study. This result suggests as a corrective measure to increase pH and / or alkalinity values (**Table 5.68** to **Table 5.74**), Whether the resource will be used for consumption purposes. The values recorded are between -3.65 to -0.4, and the sites evaluated are less corrosive, corresponding to the Boquerón River both upstream and downstream, the Guáitara River, the Chorrera trench downstream and the Saraconcha Stream upstream , Since these were the only points that registered values greater than -1.

Table 5.68 Results of the factors calculated for each variable in the Langelier index.

SURFACE WATER PARAMETERS	BROKEN THE SMOOTHING APPLE WATER ABOVE	WET BLEEDING WATER DOWN	MOISTURIZING URBAN BREAK	SAN FRANCISCO AGUAS ARRIBA BROKEN	SAN FRANCISCO WATER BOW DOWN	BROKEN YAMURAYAN AGUAS TOP
DATE	**06/03/2017**	**06/03/2017**	**06/03/2017**	**27/02/2017**	**27/02/2017**	**27/02/2017**
TEMPERATURE SAMPLE	15,35	15,15	16,75	14,75	16,7	14,5
PH	8,05	7,35	7,75	6,31	6,42	6,46
TOTAL ALKALINITY	27	28,7	26,5	43,2	42,8	42,8
CALCULIC HARDNESS	24,4	26,9	24,6	38,4	40,3	43,9
Langelier	-2,05	-2,05	-2,25	-3,09	-2,88	-2,94

* Values of 0 perfectly balanced water; <0 corrosive water; > 0 fouling water.

Source: MCS Consulting and Environmental Monitoring SAS, 2017.

Table 5.69 Results of the factors calculated for each variable in the Langelier index.

SURFACE WATER PARAMETERS	AFFLUENT BROKEN CULANTRO WATER ABOVE	BREAK CULANTRO WATERS DOWN	BROKEN DOWN THE CAVE WATERS	BROKEN THE MANZANO WATERS ABOVE	BROWN MANZANO WATERS DOWN	HYGIENE HYGIENE WATER UP
DATE	**02/03/2017**	**02/03/2017**	**02/03/2017**	**05/03/2017**	**05/03/2017**	**05/03/2017**
TEMPERATURE SAMPLE	15,65	14,5	15,6	15,65	13,95	16,3
PH	7,2	7,15	7,4	7,75	7,55	7,1
TOTAL ALKALINITY	22,5	22,6	21,3	22,8	21,9	26,7
CALCULIC HARDNESS	15,9	23,2	20,4	13,3	14,2	37,2
Langelier	-3,6	-3,65	-3,4	-3,05	-3,25	-2,2

* Values of 0 perfectly balanced water; <0 corrosive water; > 0 fouling water.

Source: MCS Consulting and Environmental Monitoring SAS, 2017.

Table 5.70 Results of the factors calculated for each variable in the Langelier index.

SURFACE WATER PARAMETERS	BROKEN BRIGADE AGUAS ABOVE	BROKEN BRIGADE WATERS DOWN	BROWN MANZANO AGUAS TOP	CUAYARIN WATER	BROKEN YAMURAYAN WATERS DOWN	BROKEN LA HONDA AGUAS ARRIBA
DATE	**04/03/2017**	**04/03/2017**	**04/03/2017**	**28/02/2017**	**28/02/2017**	**28/02/2017**
TEMPERATURE SAMPLE	15	14,2	16,8	16,9	16,5	15,3
PH	7,25	7,45	7,95	7,85	7,6	7,4
TOTAL ALKALINITY	17,8	18,2	22,3	49,6	48,7	41,1
CALCULIC HARDNESS	17,1	21,8	13,4	39,5	43,9	31,9
Langelier	-3,55	-3,35	-2,75	-1,45	-1,7	-2

* Values of 0 perfectly balanced water; <0 corrosive water; > 0 fouling water.

Source: MCS Consulting and Environmental Monitoring SAS, 2017.

Table 5.71 Results of the factors calculated for each variable in the Langelier index.

SURFACE WATER PARAMETERS	BROKEN WATER SPRINGS ABOVE	BROKERS GROUNDS WATERS DOWN	BREAKING THE CAVE AGUAS ABOVE	CULANTRO BREAK WATER UP	BROKEN HONDA WATERS DOWN	ZANJA CHORRERA WATERS DOWN
DATE	**08/03/2017**	**08/03/2017**	**03/03/2017**	**03/03/2017**	**09/03/2017**	**09/03/2017**
TEMPERATURE SAMPLE	16,6	16,4	14,8	14	17,05	20,6
PH	7,3	7,25	7,25	7,85	7,85	8,2
TOTAL ALKALINITY	32,8	31,3	23,9	23,1	67,4	53,9
CALCULIC HARDNESS	19	19,9	17,9	20,7	43,4	56,8
Langelier	-2,7	-2,75	-3,55	-3,55	-1,15	-0,4

* Values of 0 perfectly balanced water; <0 corrosive water; > 0 fouling water.

Source: MCS Consulting and Environmental Monitoring SAS, 2017.

Table 5.72 Results of the factors calculated for each variable in the Langelier index.

SURFACE WATER PARAMETERS	ARRAYANE S WATER BROOK TOP	ZANJA CHORRERA CHIQUITO AGUAS ARRIBA	RIO BOQUERON AGUAS ARRIBA	RIO BOQUERON WATERS DOWN	RIO GUAITARA	BROKEN NN3	SAN FRANCISCO 2A WATCHED UP ARA
DATE	**07/03/2017**	**07/03/2017**	**26/02/2017**	**26/02/2017**	**26/02/2017**	**26/02/2017**	**12/03/2017**
TEMPERATURE SAMPLE	16,85	16,85	14,65	15,55	14,65	15,1	16,85
PH	7,3	7,1	7,85	7,85	8,05	7,2	7,65
TOTAL ALKALINITY	24,4	38,2	81,4	93,8	57	104	37,1
CALCULIC HARDNESS	24,7	88,9	37,2	35	39,5	62,1	23,8
Langelier	-3,4	-2,2	-0,95	-0,95	-0,95	-1,3	-2,35

* Values of 0 perfectly balanced water; <0 corrosive water; > 0 fouling water.

Source: MCS Consulting and Environmental Monitoring SAS, 2017.

Table 5.73 Results of the factors calculated for each variable in the Langelier index.

SURFACE WATER PARAMETERS	SAN FRANCISCO 2B WATCHED UP AGUAS ARRIBA	AF BROKEN THE TABLON WATERS DOWN	BROKEN DOWN THE TABLON WATERS	SARACONCHA BROOKES AGUAS ARRIBA	BROKEN SARACONCHA WATERS DOWN	BROKEN THE MACAL WATERS ABOVE
DATE	**12/03/2017**	**12/03/2017**	**12/03/2017**	**14/03/2017**	**14/03/2017**	**14/03/2017**
TEMPERATURE SAMPLE	17,85	17,2	17,6	20,75	22	16,9
PH	7,5	7,1	7,5	7,9	7,7	7,1
TOTAL ALKALINITY	53,3	48,5	41,4	50,7	55,6	26,9
CALCULIC HARDNESS	31,1	89,6	24,6	33	34,9	14
Langelier	-1,5	-1,4	-2,5	-1	-1,2	-2,9

* Values of 0 perfectly balanced water; <0 corrosive water; > 0 fouling water.

Source: MCS Consulting and Environmental Monitoring SAS, 2017.

Table 5.74 Results of the factors calculated for each variable in the Langelier index.

SURFACE WATER PARAMETERS	BROKEN SAN FRANCISCO 2 AGUAS ARRIBA	SAN FRANCISCO BROKEN 2 WATERS DOWN	BROKEN THE MACAL WATERS DOWN	RIO GUAITARA 2	RIO SAPUYES AGUAS ARIBA	RIO SAPUYES AGUAS ABAJO	GUAITARA 3
DATE	**13/03/2017**	**13/03/2017**	**13/03/2017**	**16/03/2017**	**15/03/2017**	**15/03/2017**	**27/03/2017**
TEMPERATURE SAMPLE	18,75	19,2	18,65	17,15	18,25	15,75	18,85
PH	7,7	7,8	7,6	7,5	7,25	7,7	8,5
TOTAL ALKALINITY	39,8	45,9	38,4	32,9	31,5	23,9	26
CALCULIC HARDNESS	34,3	38,3	24,9	21,6	31,6	27,7	19,2
Langelier	-1,6	-1,5	-2,4	-2,5	-2,05	-2,4	-1,5

* Values of 0 perfectly balanced water; <0 corrosive water; > 0 fouling water.

Source: MCS Consulting and Environmental Monitoring SAS, 2017.

· **Neutralizing capacity or Buffer of bodies of water.**

From the alkalinity values and the comparison with the limit established by UNESCO (1996), it can be concluded that 75% of the monitoring points have a good neutralizing capacity or buffer, since the values exceed 24 mg / L (**Figure 5.51**). These results can be explained by the time of the monitoring, since in the transition season the water bodies reduce their level, affecting the dilution capacity (CVC, 2004).

Regarding bicarbonates, the same behavior was observed as for alkalinity, with values that exceed 24 mg / L in 75% of the sampling stations, confirming the good buffer capacity according to UNESCO (1996) and therefore The bodies of water are not susceptible to changes in pH.

In general, the points with the greatest buffer capacity were the NN3 stream, and the Boquerón river both upstream and downstream, water bodies that have a buffer system (acid - base balance) that allows the optimum pH values to be maintained for the processes Intrinsic to each system.

· **Index of Potential Impact on Water Quality (IACAL).**

By means of the secondary information obtained from IDEAM 2017 and http: //sig.anla.gov.co, it is possible to establish the states of water quality and pressure by contamination for dry season and average year; Where for the dry season and the middle year the highest values are obtained, indicating that all the stations have a potential alteration index of the high water quality (**Table 5.75**, **Figure 5.57** Y **Figure 5.59**).

The results obtained indicate that pollutant loads of biodegradable and non-biodegradable organic matter (BOD and COD), total suspended solids, nutrients (total nitrogen-NT and total phosphorus-PT) and other variables produced in the area of influence by the headwaters Municipalities and urban centers and that are later discharged into the water systems of this area significantly affect the quality of the resource, limiting its self-purification in both epochs due to the low level of the bodies of water evaluated.

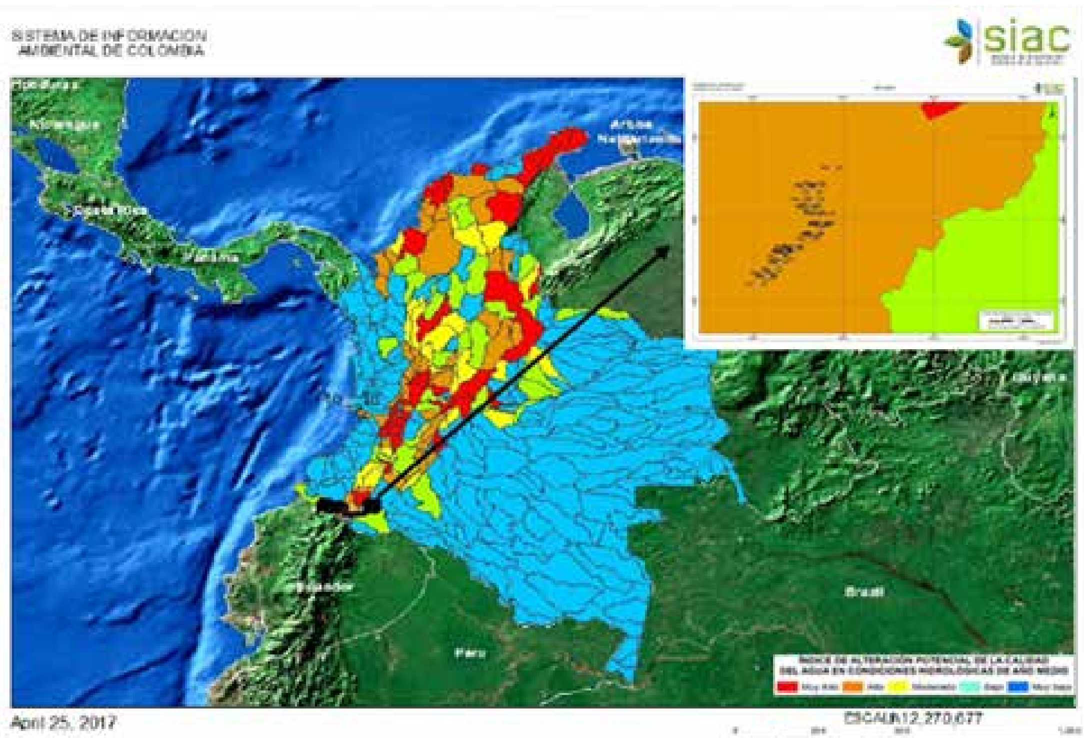
Table 5.75 IACAL weighting values for water bodies monitored in dry and medium year.

CODE	SAMPLING POINT	IACAL (Middle and Dry Year) Average category (NT + PT + SST + BOD (COD-BOD) / 5)
1	BROKEN THE SMOOTHING APPLE WATER ABOVE	High
2	WET BLEEDING WATER DOWN	High
3	MOISTURIZING URBAN BREAK	High
4	SAN FRANCISCO AGUAS ARRIBA BROKEN	High
5	SAN FRANCISCO WATER BOW DOWN	High
6	BROKEN YAMURAYAN AGUAS TOP	High
7	AFFLUENT BROKEN CULANTRO WATER ABOVE	High
8	BREAK CULANTRO WATERS DOWN	High
9	BROKEN DOWN THE CAVE WATERS	High
10	BROKEN THE MANZANO WATERS ABOVE	High
11	BROWN MANZANO WATERS DOWN	High
12	HYGIENE HYGIENE WATER UP	High
13	BROKEN BRIGADE AGUAS ABOVE	High
14	BROKEN BRIGADE WATERS DOWN	High
15	BROWN MANZANO AGUAS TOP	High
16	CUAYARIN WATER	High
17	BROKEN YAMURAYAN WATERS DOWN	High
18	BROKEN LA HONDA AGUAS ARRIBA	High
19	BROKEN WATER SPRINGS ABOVE	High
20	BROKERS GROUNDS WATERS DOWN	High
21	BREAKING THE CAVE AGUAS ABOVE	High
22	CULANTRO BREAK WATER UP	High
23	BROKEN HONDA WATERS DOWN	High
24	ZANJA CHORRERA WATERS DOWN	High
25	ARRAYANES WATER BROOK TOP	High
26	ZANJA CHORRERA CHIQUITO AGUAS ARRIBA	High
27	RIO BOQUERON AGUAS ARRIBA	High
28	RIO BOQUERON WATERS DOWN	High
29	RIO GUAITARA	High
30	BROKEN NN3	High
31	SAN FRANCISCO 2A WATCHED UP ARA	High
32	SAN FRANCISCO 2B WATCHED UP AGUAS ARRIBA	High
33	AF BROKEN THE TABLON WATERS DOWN	High
34	BROKEN DOWN THE TABLON WATERS	High
35	SARACONCHA BROOKES AGUAS ARRIBA	High
36	BROKEN SARACONCHA WATERS DOWN	High

CODE	SAMPLING POINT	IACAL (Middle and Dry Year) Average category (NT + PT + SST + BOD (COD-BOD) / 5)
37	BROKEN THE MACAL WATERS ABOVE	High
38	BROKEN SAN FRANCISCO 2 AGUAS ARRIBA	High
39	SAN FRANCISCO BROKEN 2 WATERS DOWN	High
40	BROKEN THE MACAL WATERS DOWN	High
41	RIO GUAITARA 2	High
42	RIO SAPUYES AGUAS ARIBA	High
43	RIO SAPUYES AGUAS ABAJO	High
44	GUAITARA 3	High

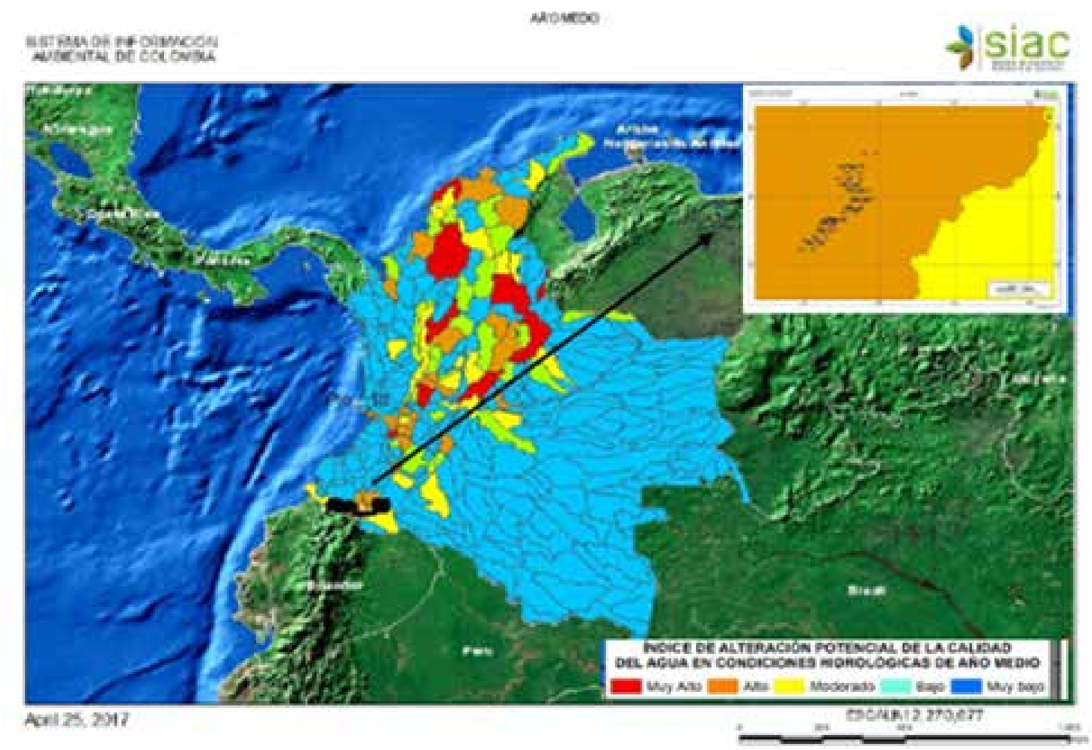
Source: IDEAM 2017 and http: //sig.anla.gov.co.

Figure 5.56 Index of potential alteration of water quality in water bodies monitored in dry year.



Source: IDEAM 2017 and http: //sig.anla.gov.co.

Figure 5.57 Index of potential alteration of water quality in the bodies of water monitored in the middle year.



Source: IDEAM 2017 and http: //sig.anla.gov.co

5.1.6.3 Multitemporal analysis of water quality in the study area.

This analysis is carried out, considering that in the area of influence of the Rumichaca - Pasto dual carriageway project, San Juan - Pedregal section, previous studies of the water quality in the main streams have been carried out, which allows to obtain data on its Behavior in the time and to be able to monitor the quality of the water resource.

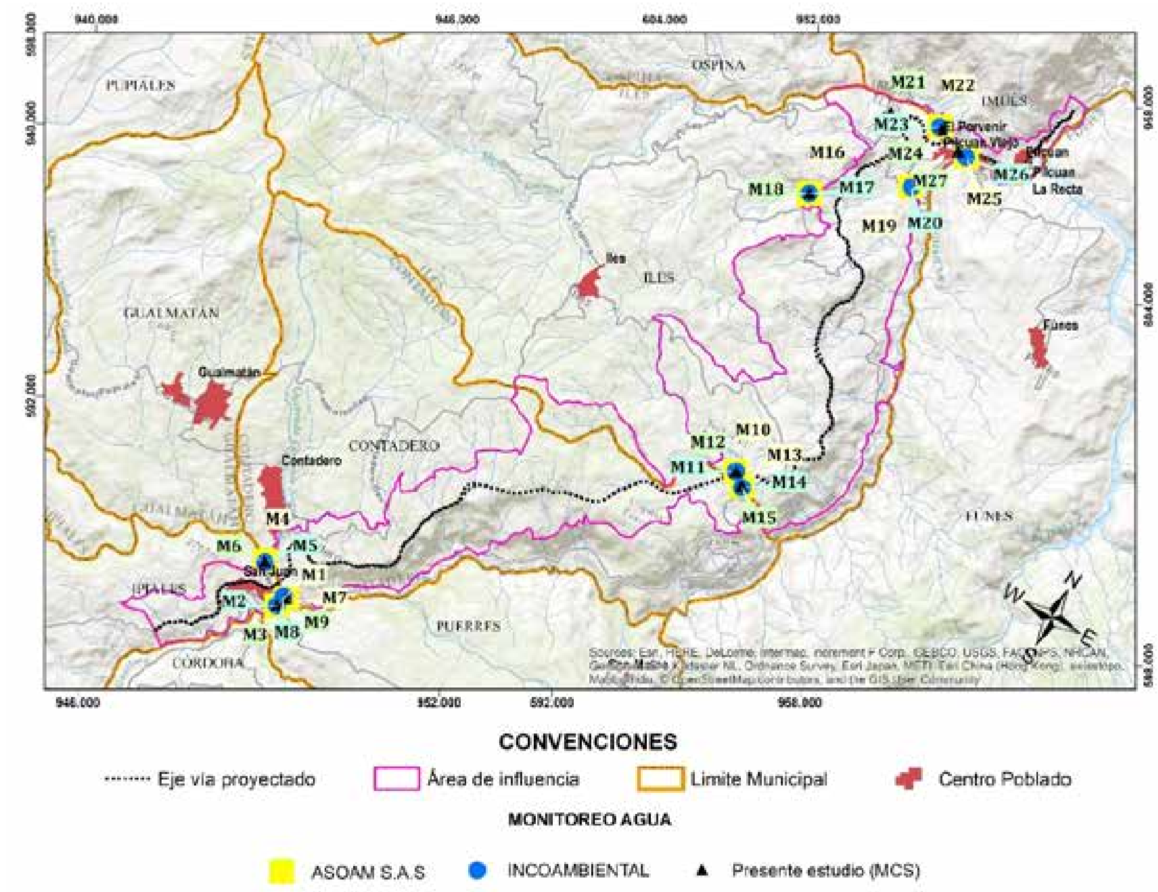
For the multitemporal analysis, the information of the monitoring carried out by the SH Consortium in the study area was taken by contracting the ASOAM SAS Environmental Agrosolutions laboratory (laboratory accredited by IDEAM under resolution 1556 of August 14, 2015, Amended by Resolution 2191 of October 7, 2015 for water quality monitoring) and INCO AMBIENTAL SAS (laboratory accredited by IDEAM under resolution 2189 of October 07, 2015, for the performance of monitoring of water quality). water quality). In these studies were carried out 9 monitoring stations on the San Juan - Pedregal stretch, these points are compared with the monitoring of the present study. The names of the stations with their respective coordinates and the date of the monitoring were found in the **Table 5.76**; Spatial distribution occurs in the **Figure 5.59**.

Table 5.76 Monitoring points for the multitemporal analysis of water quality.

STATION	ID	NAME OF THE STATION IN THE STUDY THAT WAS TAKEN	COORDINATES DATUM MAGNA SIRGAS ORIGIN BOGOTÁ		SOURCE	SAMPLING DATE
			EAST	NORTH		
1	M1	Guáitara River	948495	590756	ASOAM SAS	24 - Aug - 2016
	M2	Guáitara River	948495	590756	INNOVATIVE	09 - Dec - 2016
	M3	Guáitara River	948503	590762	Present study	26 - Feb - 2017
2	M4	Upstream Boquerón River	947870	591392	ASOAM SAS	21 - Apr - 2016
	M5	Upstream Boquerón River	947893	591358	INNOVATIVE	11 - Dec - 2016
	M6	Upstream Boquerón River	947873	591368	Present study	26 - Feb - 2017
3	M7	Boquerón River downstream	948597	590968	ASOAM SAS	21 - Apr - 2016
	M8	Boquerón River downstream	948523	590981	INNOVATIVE	11 - Dec - 2016
	M9	Boquerón River downstream	948589	590972	Present study	26 - Feb - 2017
4	M10	Upstream Humidifier Gully	954839	597388	ASOAM SAS	28 - Apr - 2016
	M11	Upstream Humidifier Gully	954841	597387	INNOVATIVE	11 - Dec - 2016
	M12	Quebrada El Manzano (Humidor) upstream	954840	597388	Present study	06 - Mar - 2017
5	M13	Downstream Humidifier Gully	955078	597206	ASOAM SAS	28 - Apr - 2016
	M14	Downstream Humidifier Gully	955101	597178	INNOVATIVE	11 - Dec - 2016
	M15	Downstream Humidifier Gully	955074	597201	Present study	06 - Mar - 2017
6	M16	Quebrada El Macal upstream	953397	602713	ASOAM SAS	29 - Apr - 2016
	M17	Quebrada El Macal upstream	953395	602717	INNOVATIVE	11 - Dec - 2016
	M18	Quebrada El Macal upstream	951530	602195	Present study	14 - Mar-2014
7	M19	Quebrada El Macal downstream	955018	603796	ASOAM SAS	27 - Apr - 2016
	M20	Quebrada El Macal downstream	955031	603800	INNOVATIVE	11 - Dec - 2016
	M21	Quebrada El Macal downstream	954870	603721	Present study	13 - Mar -2017
8	M22	Sapuyes River upstream	954927	605082	ASOAM SAS	22 - Apr - 2016
	M23	Sapuyes River upstream	954925	605066	INNOVATIVE	09 - Dec - 2016
	M24	Sapuyes River upstream	954977	605045	Present study	15 - Mar -2017
9	M25	Sapuyes River downstream	955660	604838	ASOAM SAS	22 - Apr - 2016
	M26	Sapuyes River downstream	955649	604826	INNOVATIVE	09 - Dec - 2016
	M27	Sapuyes River downstream	955466	604839	Present study	15 - Mar -2017

Source: GEOCOL CONSULTORES SA, 2017.

Figure 5.58 Location of monitoring points for multi-temporal analysis of water quality.



Source: GEOCOL CONSULTORES SA, 2017.

Likewise, the water quality index (WQi) was calculated to evaluate the conditions of each of the water sources considered.

5.1.6.3.1 Results.

Then in the **Table 5.77** The results of the monitoring carried out for the area of influence of the Rumichaca - Pasto dual carriageway project, San Juan - Pedregal stretch in previous years and currently for each body of water, are presented.

Table 5.77 Comparison of the physicochemical parameters analyzed.

WATER BODY		RÍO BOQUERÓN						PERMISSIBLE LIMITS DECREE 1594/84 MIN. OF HEALTH AND MIN. OF AGRICULTURE		
Monitoring Point		**Upstream**			**Downstream**			**Art. 38**	**Art. 39**	**Art. 40**
settings	**Units**	**April**	**December**	**March**	**April**	**December**	**March**			
Flow	L / sec		794	8965		794	13076	NE	NE	NE
PH	Units	7,32	8,08	7,85	7,11	7,97	7,85	5,0 - 9,0	6,5 - 8,5	4,5 - 9,0
Temperature	(° C)	21,5	15,8	14,65	20,9	15,8	15,55	NE	NE	NE
Dissolved oxygen	(Mg / l)	4,62	5,5	7	4,33	5,5	7	NE	NE	NE
Conductivity	(MS / cm)	428	208	165	396	208	195	NE	NE	NE
BOD	Mg O_2 / L	15,3	11,68	<5	8,4	9,7	<5	NE	NE	NE
COD	Mg O_2 / L	34,5	18,54	<20	20,8	11,34	<20	NE	NE	NE
SOLID SUSPENDED SOLIDS	Mg / L	<20	22	273	<20	20	305	NE	NE	NE
SOLID DISSOLVED SOLIDS	Mg / L	-	130	75	-	129	90	NE	NE	NE
OILS AND FATS	Mg / L	<9.0	5,95	<1.40	<9.0	7,05	<1.40	SPV	SPV	NE
TOTAL HYDROCARBONS	Mg / L			<1.40			<1.40	NE	NE	NE
ALKALINITY	Mg $CaCO_3$ / L	53,8	89,21	81,4	57	86,85	93,8	NE	NE	NE
TOTAL HARDNESS	Mg $CaCO_3$ / L	56	60,37	53,2	64	59,25	50	N.E.	N.E.	N.E.
CALCULIC HARDNESS	mg $CaCO_3$/L	-	33,2	37,2	-	32,56	35	N.E.	N.E.	N.E.
TURBIDITY	UNT	8,75	3,7	87,7	7	2,31	135	N.E.	N.E.	N.E.
REAL COLOR	UPC	54,8	127	29,2	72,9	54	26,9	75	20	N.E.
NITRATES	mg N-NO_3/L		0,466	1,12		0,633	0,808	10	10	N.E.
NITRITES	mg N-NO_2/L		0,884	<0,0030		1,65	<0,0030	1	1	N.E.
TOTAL NITROGEN KJELDAHL	mg N/L	<3,00	<5,0	<3,00	<3,00	<5,0	<3,00	N.E.	N.E.	N.E.
TOTAL PHOSPHORUS	mg/L	1,62	<0,08	<0,1	1,38	0,36	<0,1	N.E.	N.E.	N.E.
PHENOLES	mg/L	<0,002	<0,002	<0,002	<0,002	<0,002	<0,002	0,002	0,002	N.E.
ZINC	mg/L	<0,014	0,01	<0,12	<0,014	0,02	<0,12	15	15	2
BARIUM	mg/L	<0,141	<0,8	<0,6	<0,141	<0,8	<0,6	1	1	N.E.
CADMIUM	mg/L	<0,0048	<0,006	<0,010	<0,0048	<0,006	<0,010	0,01	0,01	0,01
CALCIUM	mg/L			13,8			13,8	N.E.	N.E.	N.E.
COPPER	mg/L	0,0188	<0,01	<0,15	0,0101	<0,01	<0,15	1	1	0,2
CHROME	mg/L	<0,0046	<0,01	<0,11	<0,0046	<0,01	<0,11	N.E.	N.E.	N.E.
MERCURY	mg/L	<0,0006	<0,001	<0,002	0,001	<0,001	<0,002	0,002	0,002	N.E.
NICKEL	mg/L	0,011	0,01	<0,15	0,0193	0,01	<0,15	N.E.	N.E.	0,2
SILVER	mg/L	<0,007	<0,01	<0,050	<0,007	<0,01	<0,050	0,05	0,05	N.E.
LEAD	mg/L	<0,0054	<0,01	<0,050	<0,0054	<0,01	<0,050	0,05	0,05	5
SELENIUM	mg/L	<0,0055	<0,0152	<0,010	<0,0055	<0,0152	<0,010	0,01	0,01	0,02
ARSENIC	mg/L	<0,010	<0,001	<0,010	<0,010	<0,001	<0,010	0,05	0,05	0,1
TOTAL COLIFORMS	NMP/100mL	1600	46000	3800	9200	79000	3690	20 000	1 000	5 000
FACIAL COLIFORMS	NMP/100mL	1400	13000	1300	170	27000	1100	2 000	N.E.	1 000

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

Continuación: Tabla 5.77

WATER BODY		Qda. HUMEADORA						PERMISSIBLE LIMITS DECREE 1594/84 MIN. OF HEALTH AND MIN. OF AGRICULTURE		
Monitoring Point		Upstream			Downstream			Art. 38	Art. 39	Art. 40
settings	Units	April	December	March	April	December	March			
Flow	L / sec		23	4		92	270	NE	NE	NE
PH	Units	7,43	7,53	7,1	7,12	7,54	7,35	5,0 - 9,0	6,5 - 8,5	4,5 - 9,0
Temperature	(°C)	19,6	16,4	16,3	20,5	13,6	15,15	N.E.	N.E.	N.E.
Dissolved oxygen	(mg/L)	3,94	5,3	5	4,12	5,4	5	N.E.	N.E.	N.E.
Conductivity	(µS/cm)	396	160	200	426	110	120	N.E.	N.E.	N.E.
DBO	mg O2/L	4,6	5,13	<5	6,8	5,4	<5	N.E.	N.E.	N.E.
DQO	mg O2/L	25,6	10,26	<20	28,1	15,3	<20	N.E.	N.E.	N.E.
SOLID SUSPENDED SOLIDS	mg/L	<20	58	16	<20	40	22	N.E.	N.E.	N.E.
SOLID DISSOLVED SOLIDS	mg/L	-	69,5	90	-	64	64	N.E.	N.E.	N.E.
OILS AND FATS	Mg / L	<9,0	5,22	<1,40	<9,0	5,95	<1,40	S.P.V.	S.P.V.	N.E.
ALKALINITY	mg CaCO3/L	62,1	44,29	26,7	39,4	34,05	28,7	N.E.	N.E.	N.E.
TOTAL HARDNESS	mg CaCO3/L	36	39,69	53,2	42	40,79	38,4	N.E.	N.E.	N.E.
CALCULIC HARDNESS	mg CaCO3/L	-	23,96	37,2	-	24,97	26,9	N.E.	N.E.	N.E.
TURBIDITY	UNT	26,6	27	32,2	28,6	22,6	19,3	N.E.	N.E.	N.E.
REAL COLOR	UPC	80,5	134	33,15	84,6	144	32,22	75	20	N.E.
NITRATES	mg N-NO3/L		0,173	0,825		0,145	0,752	10	10	N.E.
NITRITES	mg N-NO2/L		1,43	0,0082		1,43	0,0075	1	1	N.E.
TOTAL NITROGEN KJELDAHL	mg N/L	<3,00	<5,0	<3,00	<3,00	<5,0	<3,00	N.E.	N.E.	N.E.
AMMONIACAL NITROGEN	mg N-NH4/L		1,06	<1,00		0,78	<1,00	1	1	N.E.
TOTAL PHOSPHORUS	mg/L	0,289	<0,08	<0,1	0,22	<0,08	<0,1	N.E.	N.E.	N.E.
PHENOLES	mg/L	<0,002	<0,002	<0,002	<0,002	<0,002	<0,002	0,002	0,002	N.E.
ZINC	mg/L	<0,014	0,03	<0,12	<0,014	0,01	<0,12	15	15	2
BARIUM	mg/L	0,245	<0,8	<0,6	0,287	<0,8	<0,6	1	1	N.E.
CADMIUM	mg/L	<0,0048	<0,006	<0,010	<0,0048	<0,006	<0,010	0,01	0,01	0,01
COPPER	mg/L	0,0098	<0,01	<0,15	0,0152	<0,01	<0,15	1	1	0,2
CHROME	mg/L	<0,0046	<0,01	<0,11	<0,0046	<0,01	<0,11	N.E.	N.E.	N.E.
MERCURY	mg/L	0,0017	<0,001	<0,002	0,0017	<0,001	<0,002	0,002	0,002	N.E.
NICKEL	mg/L	0,005	0,01	<0,15	<0,0045	<0,01	<0,15	N.E.	N.E.	0,2
SILVER	mg/L	<0,007	<0,01	<0,050	<0,007	<0,01	<0,050	0,05	0,05	N.E.
LEAD	mg/L	<0,0054	<0,01	<0,050	<0,0054	<0,01	<0,050	0,05	0,05	5
SELENIUM	mg/L	<0,0055	<0,0152	<0,010	<0,0055	<0,0152	<0,010	0,01	0,01	0,02
ARSENIC	mg/L	<0,010	<0,001	<0,010	<0,010	<0,001	<0,010	0,05	0,05	0,1
TOTAL COLIFORMS	NMP/100mL	790	790	1250	490	490	2160	20 000	1 000	5 000
FACIAL COLIFORMS	NMP/100mL	100	100	207	490	490	156	2 000	N.E.	1 000

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

Continuation: Table 5.77

WATER BODY		RIO SAPUYES						PERMISSIBLE LIMITS DECREE 1594/84 MIN. OF HEALTH AND MIN. OF AGRICULTURE		
Monitoring Point		Upstream			Downstream			Art. 38	Art. 39	Art. 40
settings	Units	April	December	March	April	December	March			
Flow	L / sec		*	11070		*	12590	NE	NE	NE
pH	Units	7,28	7,1	7,25	7,32	6,73	7,7	5,0 - 9,0	6,5 - 8,5	4,5 - 9,0
Temperature	(°C)	22,1	18,3	18,25	22,5	18,7	15,75	N.E.	N.E.	N.E.
Dissolved oxygen	(mg/L)	4,33	6,2	6,5	4,52	6,2	7,25	N.E.	N.E.	N.E.
Conductivity	(µS/cm)	434	150	180	482	138	140	N.E.	N.E.	N.E.
DBO	mg O2/L	19,4	12,53	20	16,2	11,56	17	N.E.	N.E.	N.E.
DQO	mg O2/L	35,6	19,98	31	21,4	17,46	27	N.E.	N.E.	N.E.
SOLID SUSPENDED SOLIDS	mg/L	37,3	150	478	32,3	107,5	264	N.E.	N.E.	N.E.
SOLID DISSOLVED SOLIDS	mg/L	-	91	80	-	88	70	N.E.	N.E.	N.E.
OILS AND FATS	mg/L	<9,0	10	10,9	<9,0	5,48	3,45	S.P.V.	S.P.V.	N.E.
ALKALINITY	mg CaCO3/L	82,8	53,83	31,5	97,3	49,46	23,9	N.E.	N.E.	N.E.
TOTAL HARDNESS	mg CaCO3/L	72	65,47	45,2	64	47,1	39,6	N.E.	N.E.	N.E.
CALCULIC HARDNESS	mg CaCO3/L	-	21,58	31,6	-	22,64	27,7	N.E.	N.E.	N.E.
TURBIDITY	UNT	24	48,9	111	29,2	22,9	130	N.E.	N.E.	N.E.
REAL COLOR	UPC	37,2	279	49,12	46,2	155	70,18	75	20	N.E.
NITRATES	mg N-NO3/L		0,18	5,42		0,138	8,411	10	10	N.E.
NITRITES	mg N-NO2/L		1,012	0,0394		0,923	0,0487	1	1	N.E.
TOTAL NITROGEN KJELDAHL	mg N/L	<3,00	<5,0	<3,0	<3,00	<5,0	<3,0	N.E.	N.E.	N.E.
TOTAL PHOSPHORUS	mg/L	0,11	<0,08	3,3	0,088	<0,08	2,1	N.E.	N.E.	N.E.
PHENOLES	mg/L	<0,002	<0,002	0,037	<0,002	0,03	<0,002	0,002	0,002	N.E.
ZINC	mg/L	<0,146	0,01	<0,12	<0,146	0,02	<0,12	15	15	2
BARIUM	mg/L	<0,141	<0,8	<0,6	<0,141	<0,8	<0,6	1	1	N.E.
CADMIUM	mg/L	<0,0048	<0,006	<0,01	<0,0048	<0,006	<0,01	0,01	0,01	0,01
COPPER	mg/L	<0,0088	<0,01	<0,15	<0,0088	<0,01	<0,15	1	1	0,2
CHROME	mg/L	<0,0046	<0,01	<0,11	<0,0046	<0,01	<0,11	N.E.	N.E.	N.E.
MERCURY	mg/L	<0,0006	<0,001	<0,002	<0,0006	<0,001	<0,002	0,002	0,002	N.E.
NICKEL	mg/L	<0,0045	<0,01	<0,15	<0,0045	0,01	<0,15	N.E.	N.E.	0,2
SILVER	mg/L	<0,007	<0,01	<0,05	<0,007	<0,01	<0,05	0,05	0,05	N.E.
LEAD	mg/L	<0,0054	<0,01	<0,05	<0,0054	<0,01	<0,05	0,05	0,05	5
SELENIUM	mg/L	<0,0055	<0,0152	<0,01	<0,0055	<0,0152	<0,01	0,01	0,01	0,02
ARSENIC	mg/L	<0,010	<0,001	<0,01	<0,010	<0,001	<0,01	0,05	0,05	0,1
TOTAL COLIFORMS	NMP/100mL	9400	110000	2200	17000	79000	1700	20 000	1 000	5 000

WATER BODY		RIO SAPUYES						PERMISSIBLE LIMITS DECREE 1594/84 MIN. OF HEALTH AND MIN. OF AGRICULTURE		
Monitoring Point		Upstream			Downstream			Art. 38	Art. 39	Art. 40
settings	Units	April	December	March	April	December	March			
FACIAL COLIFORMS	NMP/100mL	330	11000	680	7900	49000	800	2 000	N.E.	1 000

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

Continuation: Tabla 5.77

WATER BODY		MACAL BREAK						PERMISSIBLE LIMITS DECREE 1594/84 MIN. OF HEALTH AND MIN. OF AGRICULTURE		
Monitoring Point		Upstream			Downstream			Art. 38	Art. 39	Art. 40
settings	Units	April	December	March	April	December	March			
Flow	L / sec		293	968		293	2140	N.E.	N.E.	N.E.
pH	Units	7,12	6,96	7,1	7,62	7,55	7,6	5,0 - 9,0	6,5 - 8,5	4,5 - 9,0
Temperature	(°C)	20,5	17,7	16,9	19,2	18	18,65	N.E.	N.E.	N.E.
Dissolved oxygen	(mg/L)	4,12	5,4	7,25	4,56	5,2	6,45	N.E.	N.E.	N.E.
Conductivity	(µS/cm)	396	45	64	426	0,114	100	N.E.	N.E.	N.E.
DBO	mg O2/L	5,2	2,68	<5	29,3	<2,0	13	N.E.	N.E.	N.E.
DQO	mg O2/L	34,5	5,22	<20	36,4	3,42	23	N.E.	N.E.	N.E.
SOLID SUSPENDED SOLIDS	mg/L	<20	13	106	<20	18	36	N.E.	N.E.	N.E.
SOLID DISSOLVED SOLIDS	mg/L	-	33,5	31,5	-	65	40	N.E.	N.E.	N.E.
OILS AND FATS	mg/L	<9,0	6,4	<1,40	<9,0	5,42	<1,40	S.P.V.	S.P.V.	N.E.
ALKALINITY	mg CaCO3/L	58	24,64	26,9	68,3	32,57	38,4	N.E.	N.E.	N.E.
TOTAL HARDNESS	mg CaCO3/L	36	23,41	20,1	44	44,51	35,2	N.E.	N.E.	N.E.
CALCULIC HARDNESS	mg CaCO3/L	-	13	14	-	19,8	24,9	N.E.	N.E.	N.E.
TURBIDITY	UNT	26	25,5	144	10,7	53,4	46,9	N.E.	N.E.	N.E.
REAL COLOR	UPC	80,5	148	160,94	36,3	268	67,709	75	20	N.E.
NITRATES	mg N-NO3/L		0,034	1,48		0,215	1,68	10	10	N.E.
NITRITES	mg N-NO2/L		0,481	0,0294		2,01	0,0246	1	1	N.E.
TOTAL NITROGEN KJELDAHL	mg N/L	<3,00	<5,0	<3,00	<3,00	<5,0	<3,00	N.E.	N.E.	N.E.
TOTAL PHOSPHORUS	mg/L	<0,062	<0,08	<0,1	<0,062	0,38	0,1065	N.E.	N.E.	N.E.
PHENOLES	mg/L	<0,002	<0,002	<0,002	<0,002	<0,002	<0,002	0,002	0,002	N.E.
ZINC	mg/L	<0,146	0,02	<0,12	<0,146	0,01	<0,12	15	15	2
BARIUM	mg/L	<0,141	<0,8	<0,6	<0,141	0,102	<0,6	1	1	N.E.
CADMIUM	mg/L	<0,0048	<0,006	<0,010	<0,0048	<0,006	<0,01	0,01	0,01	0,01
COPPER	mg/L	<0,0088	<0,01	<0,15	<0,0088	<0,01	<0,15	1	1	0,2
CHROME	mg/L	<0,0046	<0,01	<0,11	<0,0046	<0,01	<0,11	N.E.	N.E.	N.E.
MERCURY	mg/L	<0,0006	<0,001	<0,002	0,0039	<0,001	<0,002	0,002	0,002	N.E.
NICKEL	mg/L	<0,0045	0,01	<0,15	<0,0045	0,02	<0,15	N.E.	N.E.	0,2
SILVER	mg/L	<0,007	<0,01	<0,050	<0,007	<0,01	<0,05	0,05	0,05	N.E.
LEAD	mg/L	<0,0054	<0,01	<0,050	<0,0054	<0,01	<0,05	0,05	0,05	5

WATER BODY		MACAL BREAK						PERMISSIBLE LIMITS DECREE 1594/84 MIN. OF HEALTH AND MIN. OF AGRICULTURE		
Monitoring Point		Upstream			Downstream			Art. 38	Art. 39	Art. 40
settings	Units	April	December	March	April	December	March			
SELENIUM	mg/L	<0,0055	<0,0152	<0,010	<0,0055	<0,0152	<0,01	0,01	0,01	0,02
ARSENIC	mg/L	<0,010	<0,001	<0,010	<0,010	<0,001	<0,01	0,05	0,05	0,1
TOTAL COLIFORMS	NMP/100mL	330	2000	2560	230	2000	2200	20 000	1 000	5 000
FACIAL COLIFORMS	NMP/100mL	20	2000	600	<1.8	2000	264	2 000	N.E.	1 000

MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

Continuation: Table 5.77

WATER BODY		RÍO GUÁITARA			PERMISSIBLE LIMITS DECREE 1594/84 MIN. OF HEALTH AND MIN. OF AGRICULTURE		
Monitoring Point					Art. 38	Art. 39	Art. 40
settings	Units	August	December	March			
Flow	L / sec		8962	27533	NE	N.E.	N.E.
pH	Units	7,07	7,2	8,05	5,0 - 9,0	6,5 - 8,5	4,5 - 9,0
Temperature	(°C)	11,3	18,1	14,65	N.E.	N.E.	N.E.
Dissolved oxygen	(mg/L)	7,28	6,8	6,5	N.E.	N.E.	N.E.
Conductivity	(µS/cm)	141,2	148	155	N.E.	N.E.	N.E.
DBO	mg O2/L	13	6,1	<5	N.E.	N.E.	N.E.
DQO	mg O2/L	90	16,02	<20	N.E.	N.E.	N.E.
SOLID SUSPENDED SOLIDS	mg/L	<10	40	46	N.E.	N.E.	N.E.
SOLID DISSOLVED SOLIDS	mg/L	-	101	75	N.E.	N.E.	N.E.
OILS AND FATS	mg/L	<10	7,71	<1,40	S.P.V.	S.P.V.	N.E.
ALKALINITY	mg CaCO3/L	9,18	61,16	57	N.E.	N.E.	N.E.
TOTAL HARDNESS	mg CaCO3/L	34,58	84,04	56,4	N.E.	N.E.	N.E.
CALCULIC HARDNESS	mg CaCO3/L	-	33,75	39,5	N.E.	N.E.	N.E.
TURBIDITY	UNT	3,27	12,2	42,9	N.E.	N.E.	N.E.
REAL COLOR	UPC	<46	65,1	35,8	75	20	N.E.
NITRATES	mg N-NO3/L		0,604	1,01	10	10	N.E.
NITRITES	mg N-NO2/L		0,173	<0,0030	1	1	N.E.
TOTAL NITROGEN KJELDAHL	mg N/L	0,38	<5,0	<3,00	N.E.	N.E.	N.E.
TOTAL PHOSPHORUS	mg/L	<0,062	<0,08	<0,1	N.E.	N.E.	N.E.
PHENOLES	mg/L	<0,002	0,02	<0,002	0,002	0,002	N.E.
ZINC	mg/L	< 0,050	0,07	<0,12	15	15	2
BARIUM	mg/L	< 0,050	<0,8	<0,6	1	1	N.E.
CADMIUM	mg/L	<0,0048	<0,006	<0,010	0,01	0,01	0,01
COPPER	mg/L	< 0,10	<0,01	<0,15	1	1	0,2
CHROME	mg/L	<0,0046	<0,01	<0,11	N.E.	N.E.	N.E.
MERCURY	mg/L	< 1,00	<0,001	<0,002	0,002	0,002	N.E.
NICKEL	mg/L	<0,02	0,01	<0,15	N.E.	N.E.	0,2
SILVER	mg/L	< 0,04	<0,01	<0,050	0,05	0,05	N.E.

WATER BODY		RÍO GUÁITARA			PERMISSIBLE LIMITS DECREE 1594/84 MIN. OF HEALTH AND MIN. OF AGRICULTURE		
Monitoring Point					Art. 38	Art. 39	Art. 40
settings	Units	August	December	March			
LEAD	mg/L	< 0,01	<0,01	<0,050	0,05	0,05	5
SELENIUM	mg/L	< 0,01	<0,0152	<0,010	0,01	0,01	0,02
ARSENIC	mg/L	<0,010	<0,001	<0,010	0,05	0,05	0,1
TOTAL COLIFORMS	NMP / 100mL	260	160000	2890	20 000	1 000	5 000
FACIAL COLIFORMS	NMP/100mL	20	5400	890	2 000	N.E.	1 000

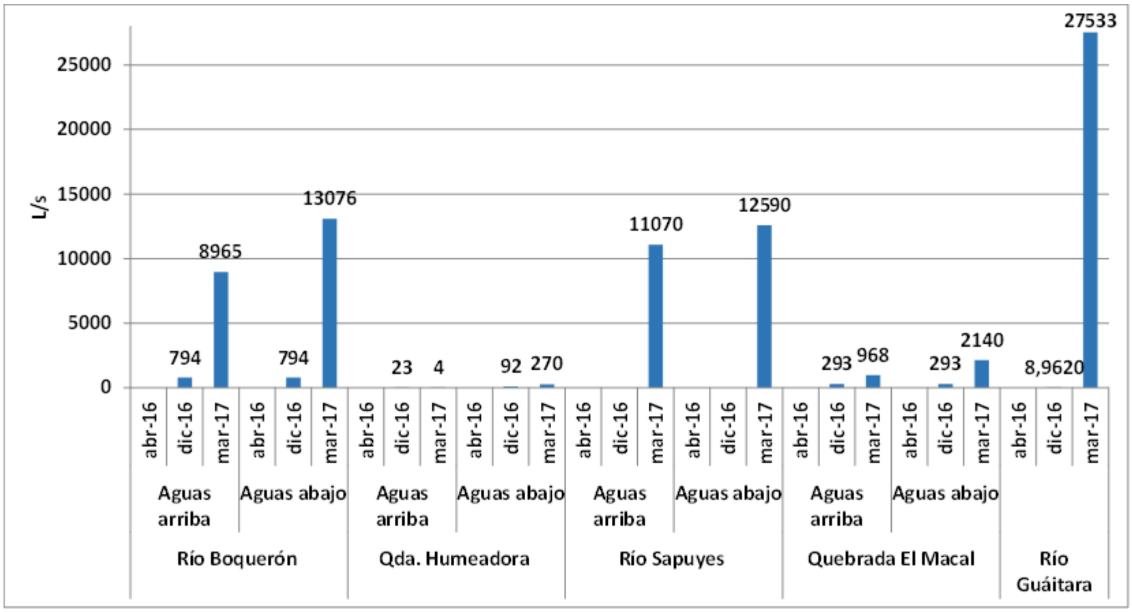
Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

5.1.6.3.2 Análisis de resultados.

- **Flow.**

The results obtained from Caudal allow to clearly see the increase in the values of the stations located downstream with reference to the upstream stations in most of the evaluated water bodies. On the other hand, the Boquerón river reported a homogeneous value of flow in the upstream and downstream station (794 L / s) for the month of December 2016, however in March 2017, there was an increase in the flow between Upstream and downstream, from 8965 L / s to 13076 L / s respectively (**Figure 5.60**), The Queue Humidor presented the highest flow values for the month of March in the downstream station (270 L / s) with reference to the month of December (4 L / s). On the other hand, the El Macal stream presented higher flow values for the month of March (upstream 968 L / s and downstream 2140 L / s) compared to December (upstream and downstream 293 L / s) . A similar behavior was presented by the monitoring station on the Guáitara river, since it reported the highest value of flow for the month of March with 27533 L / s with reference to the month of December presented a value of 8.96 L / s (**Figure 5.60**). In general, it can be observed that the values presented a considerable variation in the month of March in comparison with the results obtained in the monitoring carried out in December of 2016, evidencing in the majority of the stations a higher flow in the month of March. This behavior is due to the influence of the climatic season in the region, where rainfall is higher during the month of March compared to December (rainy season and dry season).

Figure 5.59 Values of Flow, reported in the different monitoring.

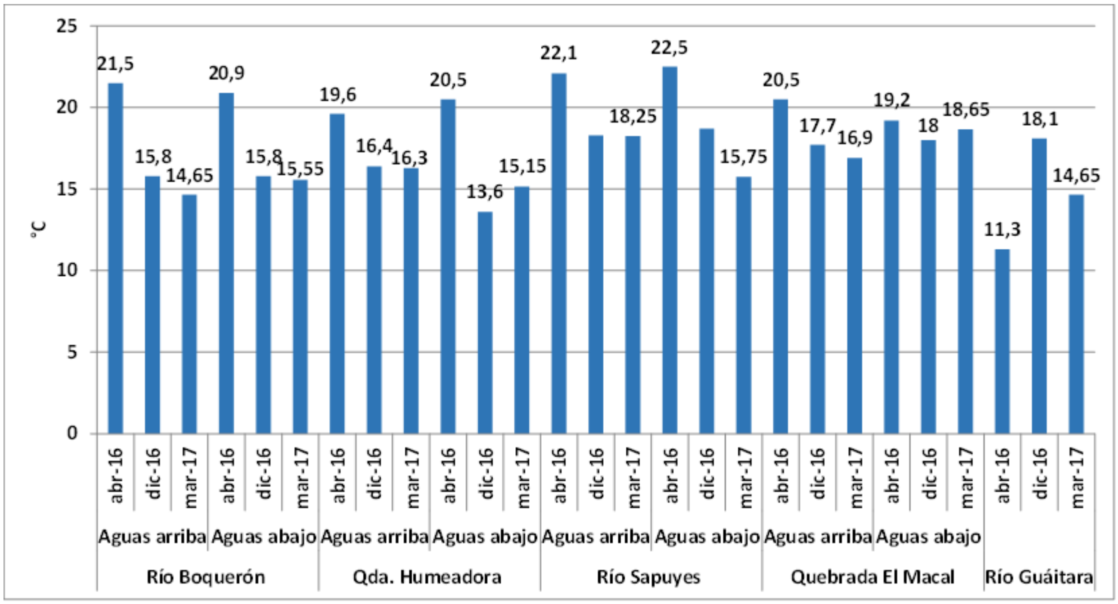


Source: MCS Consulting and Environmental Monitoring SAS, 2017.

· **Temperature.**

The values of temperature reported an average value of 17.46 ± 2.75 ° C in the stations monitored (river Boquerón, Quebrada Humeadora, broken Macal, Sapuyes river, upstream and downstream respectively, and river Guáitara) throughout the Phase values, these values are within the average annual temperature for the region, which oscillates in the three monitoring dates between 11.3 ° C and 22.5 ° C, the highest temperature occurred in the Sapuyes river Below the month of April of 2016 reporting a value of 22.5 ° C and the minimum temperature was reported for the Guáitara River with 11.3 ° C (**Figure 5.61**). The Boquerón River presents heterogeneous temperature results between the three monitoring periods, presenting the lowest temperatures for March 2017 (14,65 ° C upstream and 15,55 ° C downstream) compared to the values obtained In April 2016 (21.5 ° C upstream and 20.9 ° C downstream) (**Figure 5.61**). On the other hand, the Quebrada Humeadora in the months of December 2016 and March of 2017 presented similar values of temperature, reporting the temperature in the month of December (13.6 ° C), the highest temperatures occurred in the month of April 2016 at 20.5 ° C. It is clear that temperature declines in March 2017 compared to April 2016 (**Figure 5.61**). On the other hand, the Sapuyes River presented a similar behavior to the previous mentioned body of water, however, the five bodies of water Sapuyes river presented the highest temperatures (22.1 ° C, April 2016), this way it is evident The decrease in temperature between April 2016 and March 2017 for four of the five bodies of water evaluated. For its part, the Guáitara River presented a different behavior to the other water bodies, reporting an increase in temperature over time from 11.3 ° C in April 2016 to 18.1 ° C for December 2016 and 14.65 ° C in the month of March 2017. The values reported here are a consequence of variables specific to the sampling point, sampling time, climatic epoch and physical characteristics of the water body.

Figure 5.60 Temperature values, reported in the different monitoring.

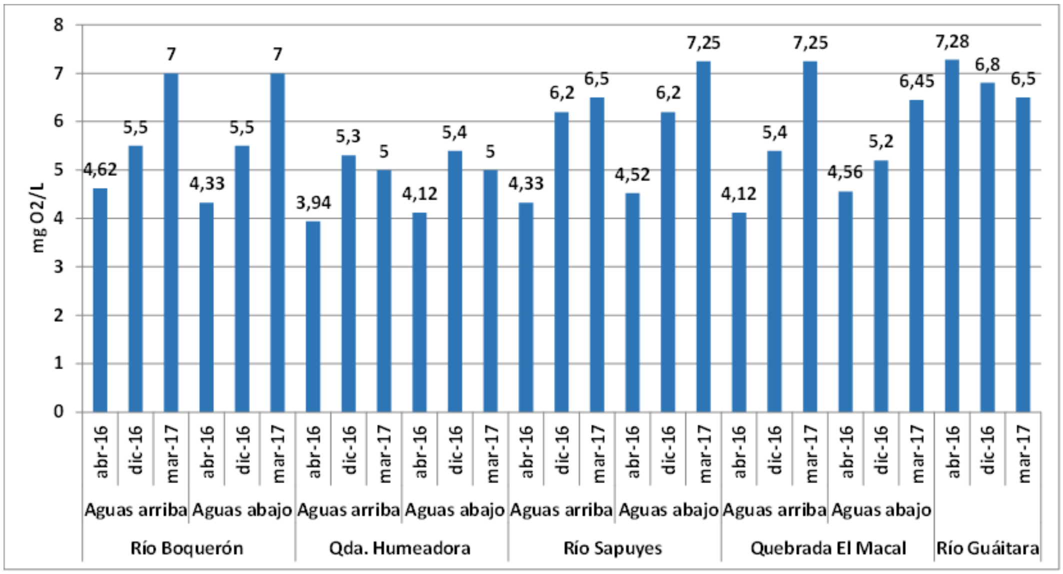


Source: MCS Consulting and Environmental Monitoring SAS, 2017.

- **Dissolved oxygen.**

In the case of dissolved oxygen (DO), the concentrations recorded during the monitoring periods at the nine stations had an average value of 5.70 ± 1.07 mg / L ranging from 3.94 to 7.28 mg / L ., The Boquerón river had the highest values of dissolved oxygen for the month of March of 2017 with 7 mgO_2/ L and in April 2016 the lowest concentrations were reported with 4.33 mg O_2/ L (**Figure 5.62**). A similar behavior was observed for the Sapuyes river, El Macal stream. On the other hand, the river Guáitara reported an inverse behavior to the other bodies of water, presenting higher concentrations in April 2016 with 7.28 mgO_2/ L and 6.5 mgO_2/ L for the month of March 2017. These conditions are influenced directly by the temperature characteristic of the area and the time of sampling. There is a marked variation between the values taken between April 2016 and March 2017, this is due to the increase in March due to the climatic (rain) season, which generates a Greater oxygenation of water.

Figure 5.61 Dissolved Oxygen values, reported in the different monitoring.

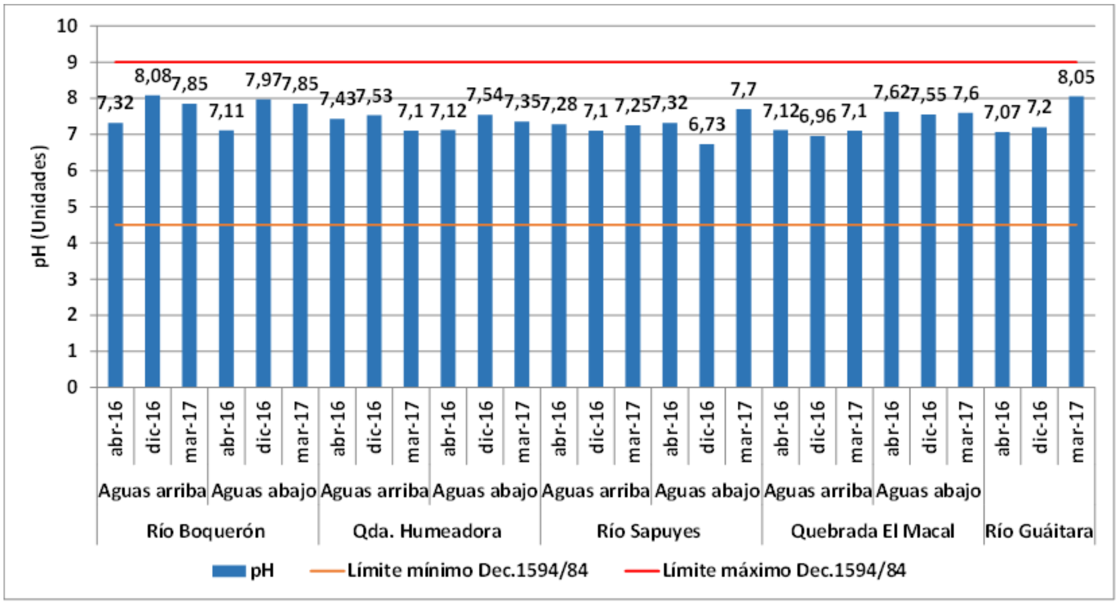


Source: MCS Consulting and Environmental Monitoring SAS, 2017.

- **PH.**

PH In general, there was a trend towards neutrality in the bodies of water evaluated during the monitoring period, presenting an average value of 7.40 ± 0.35 units, the monitoring station upstream on the Boquerón river presented the highest value (8,08 units) for the month of December 2016, on the other hand, the Sapuyes river monitoring station downstream reported the lowest value (6.73 units) for the same date (**Figure 5.63**). The levels obtained are within what is reported for uncontaminated surface freshwater bodies where the pH generally fluctuates between 5 and 9 (Romero, 1995). At the normative level, the stations comply with the optimal range stipulated in Decree 1594/84, not representing a risk in the use of the resource in agricultural activities, recreational activities and for the preservation of flora and fauna. The values obtained for the bodies of water evaluated in the different periods did not present significant variations. When comparing the pH values with the current environmental regulations, all stations comply with the limits established in Decree 1594 of 1984 (Articles 38, 39, 40).

Figure 5.62 PH values, reported in the different monitoring.

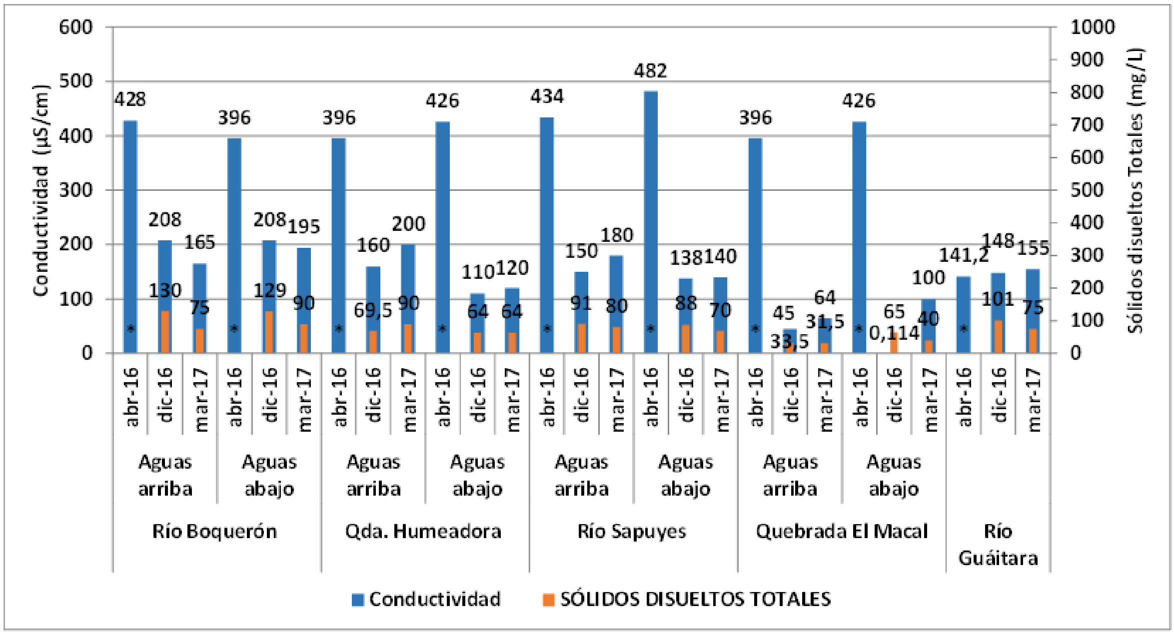


Source: MCS Consulting and Environmental Monitoring SAS, 2017.

- **Conductivity - Total dissolved solids.**

The conductivity values were between 0.045 and 482 µS / cm, presenting the highest conductivity in the Sapuyes river downstream for April 2016 and lower value in the Macal stream upstream in December of the same year. The boquerón river reported the lowest value for the month of March 2017 with 165 µS / cm, while the month of April 2016 reported the highest value with 428 µS / cm (**Figure 5.64**), Presented a decrease in the month of March of 2017 with reference to the previous months (April and December of 2016). On the other hand, the humidista stream presented the lowest value in the month of December 2016 with 160 µS / cm and 426 µS / cm in the month of April 2016, evidencing a resignation in the agreement between the months of April and December, However for the month of March 2017 there is a slight increase (**Figure 5.64**). Similar behavior was reported in the Sapuyes river and the El Macal gully. For the Guáitara river, the opposite behavior was observed, presenting the highest values in the month of March 2017 and December 2016 with 155 and 148 µS / cm, respectively, and the lowest value for April 2016 (**Figure 5.64**). It is clearly observed the peaks of increase of this parameter in the transition from dry season to rainy season during the time of monitoring of water bodies, due to the lower amount of water at higher concentration of salts (**Figure 5.64**). The above parameter is related to the total dissolved solids for each period and each system, which reflect the highest values in the months of December 2016 compared to the values obtained in March 2017, the highest concentration (130 Mg / L) was reported in the Boquerón River and in the creek the upstream macal presented the lowest value (31.5 mg / L). According to the results a minimum difference between the upstream and downstream stations of the bodies is observed, at the same time a decrease in the conductivity for the month of December of 2016 and March of 2017 is evidenced with reference to the values obtained in for the April 2016, this is due to the climatic epoch present for the month of March where the flow rate increases in the bodies of water allowing a greater dilution of the ions in the same.

Figure 5.63 Conductivity values and total dissolved solids, reported in the different monitoring.



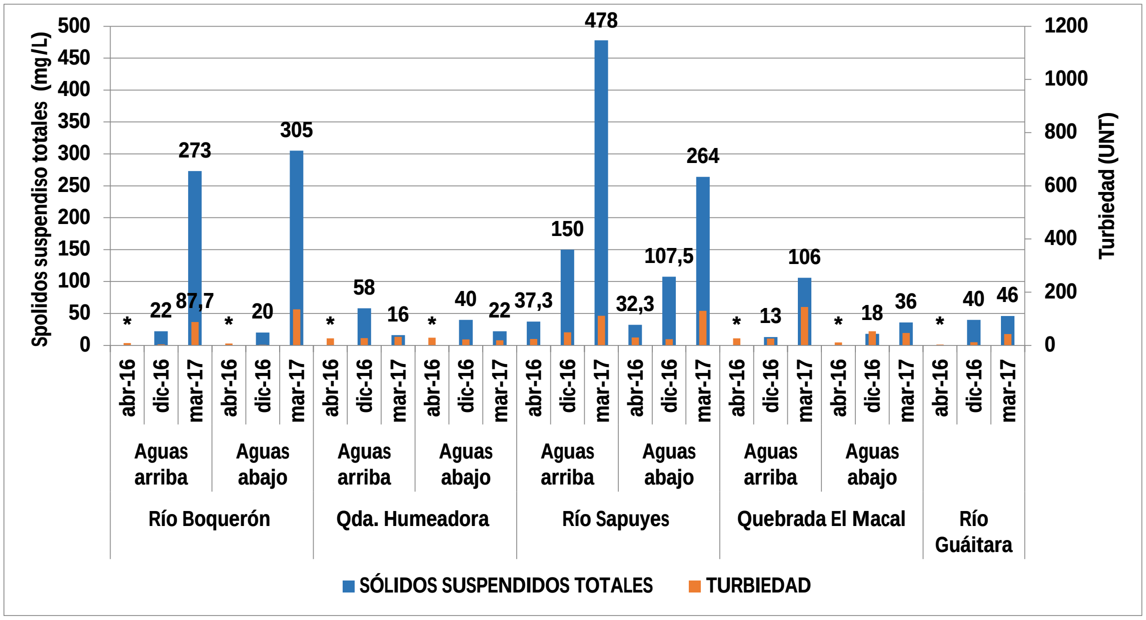
* Parameter records are not available.

Source: MCS Consulting and Environmental Monitoring SAS, 2017.

· **Total suspended solids - Turbidity.**

On the other hand, solids (<10 mg / L) for the Guáitara River in the month of August of 2016, (<20 mg / L) for the total suspended samples presented values that ranged from below the detection limit for the analytical technique used for laboratory analysis The other bodies of water evaluated for the month of April 2016, the highest concentration reported the Sapuyes River upstream in March 2017 (**Figure 5.65**). Thus, it is observed that the bodies of water evaluated showed an increase in sedimentable solids concentrations for the monitoring carried out in March 2017 with reference to the month of April 2016, which is related to the climatic season of the area, Due to the fact that in the month of March the presence of the rains generates greater entrainment and washing, increasing in this way the sedimented solid concentrations. The suspended solids are directly related to the turbidity, recording the same behavior described above (**Figure 5.65**).

Figure 5.64 Values of total suspended solids and Turbidity, reported in the different monitoring.

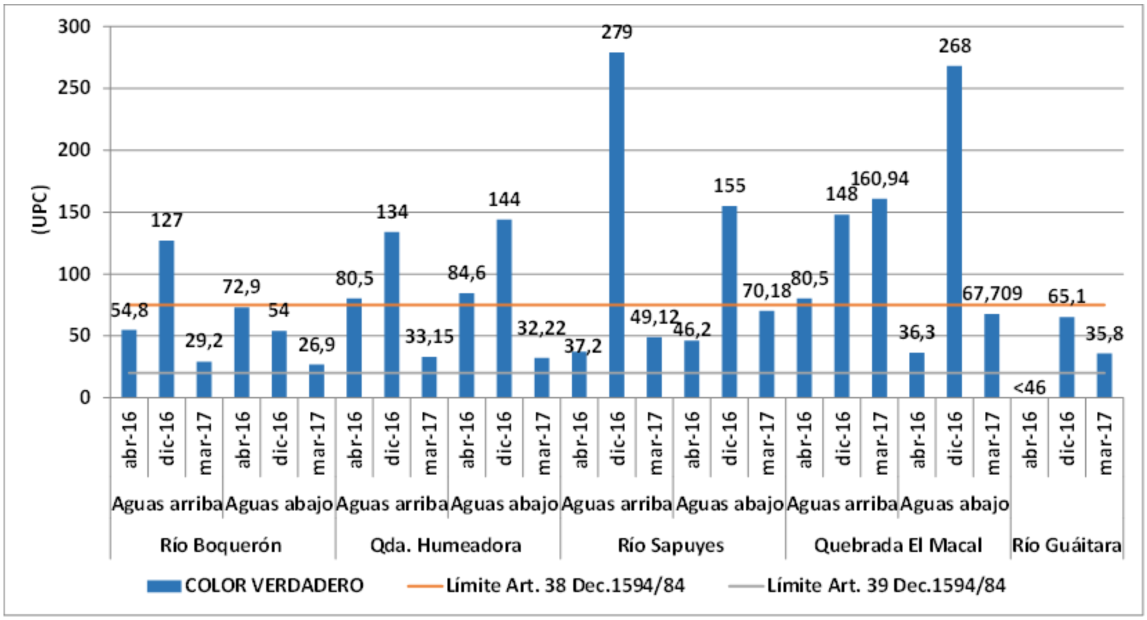


Source: MCS Consulting and Environmental Monitoring SAS, 2017.

- **Color.**

On the other hand, the **color** Reported heterogeneous values among the evaluated stations, reporting the highest values in the Macal stream downstream and the Sapuyes river upstream with 279 and 268 UPC (**Figure 5.66**). The Boquerón river presents a decrease in the values in the downstream station with reference to the upstream station, the highest values occur in the months of April and December, while in March 2017, Decrease in the color values, this behavior is also present in the Humidor stream (**Figure 5.66**). In the Sapuyes River and the Quebrada El Macal there is an increase behavior in the values of real color, increasing in the stations downstream in relation to the station located upstream for the months of April, 2016 and March 2017, in the month December 2016, on the other hand, there is a decrease in the actual color values (**Figure 5.66**). These values are mainly due to the fact that the solids in suspension and the presence of residual substances containing metals such as iron or manganese are removed for analysis. It is clearly observed that in December 2016 the highest values were presented in the stations evaluated with reference to the months of April, 2016 and March 2017. These values do not comply with what is stipulated in the current environmental regulations, so it can be concluded that the resource should be applied conventional treatment in case of being used for domestic use and / or human consumption. However, for the Guáitara river in April 2016, the current environmental regulations were complied with for the upstream station, with values lower than the limits stipulated in articles 38 and 39 of Decree 1594/84.

Figure 5.65 True Color values, reported in the different monitoring.

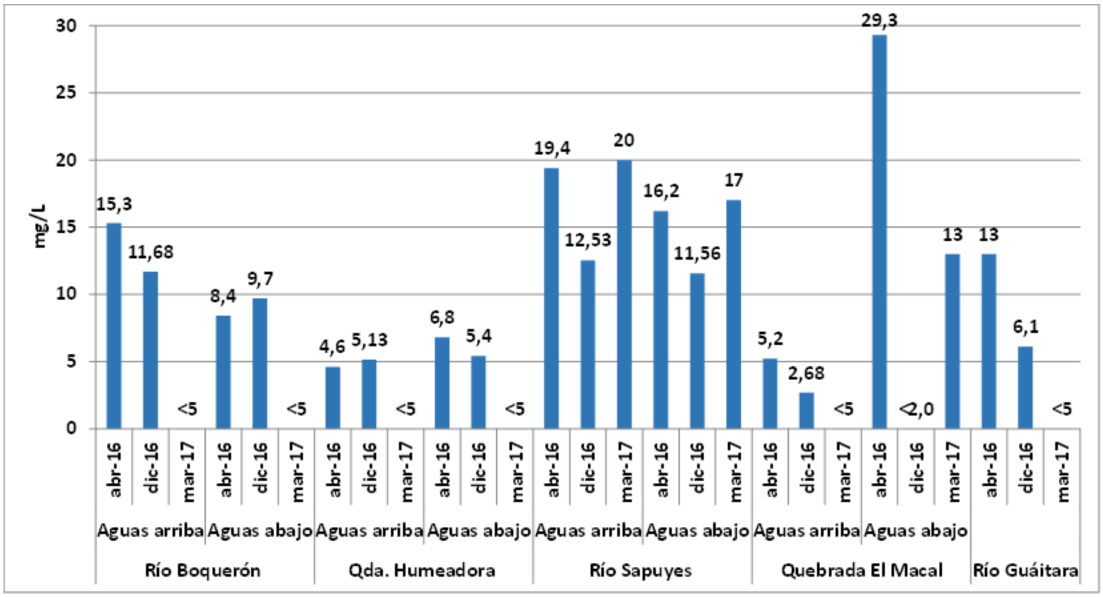


Source: MCS Consulting and Environmental Monitoring SAS, 2017.

- **BOD - COD**

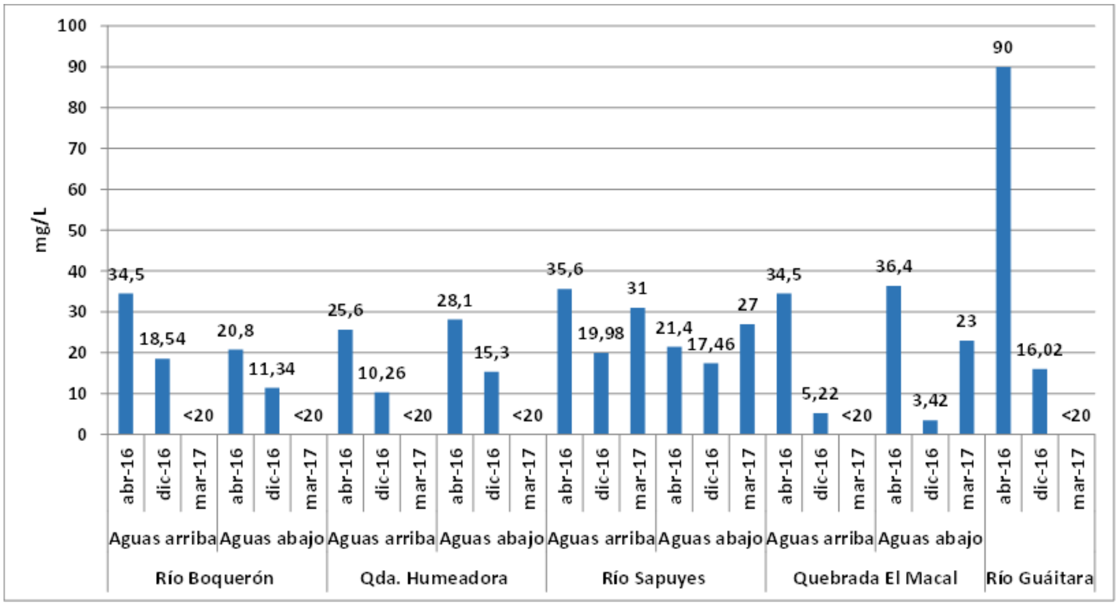
The Biochemical Oxygen Demand (BOD_5) In the El Macal gully downstream showed the highest value (29.3 mg / L) April 2016, this is possibly due to the decomposition of mainly vegetal organic matter and the entrainment of the same to the body of water by the rains , However, in most of the bodies of water evaluated in the downstream stations there is a decrease in the concentration compared to the upstream station, for the different monitoring dates. On the other hand, the downstream Humidifier raft reported an increase in BOD concentrations in relation to the upstream season for the months of April and December of 2016, similar behavior presented the Macal ravine for the month of March 2017, this is due Possibly to the decomposition of organic matter in the interior of this tributary (**Figure 5.67**). The **COD** (<20 mg / L) and 90 mg / L, the latter value was presented at the monitoring station on the Guáitara river in The month of August 2016. For all bodies of water in the Boquerón River, in the month of March, values lower than the limit of detection for the analytical technique used for analysis (<20 mg / L) in the upstream and downstream stations were reported. The highest values were reported in the upstream stations in April 2016 for each of the bodies of water evaluated, and the lowest values in the months of March 2017. Although in the standard there are no values specified for this variable, Marín (2009), reports that concentrations higher than 8 mg / L, are related to environments affected by the presence of organic matter (**Figure 5.68**).

Figure 5.66 BOD5 values, reported in the different monitoring.



Source: MCS Consulting and Environmental Monitoring SAS, 2017.

Figure 5.67 COD values, reported in the different monitoring.



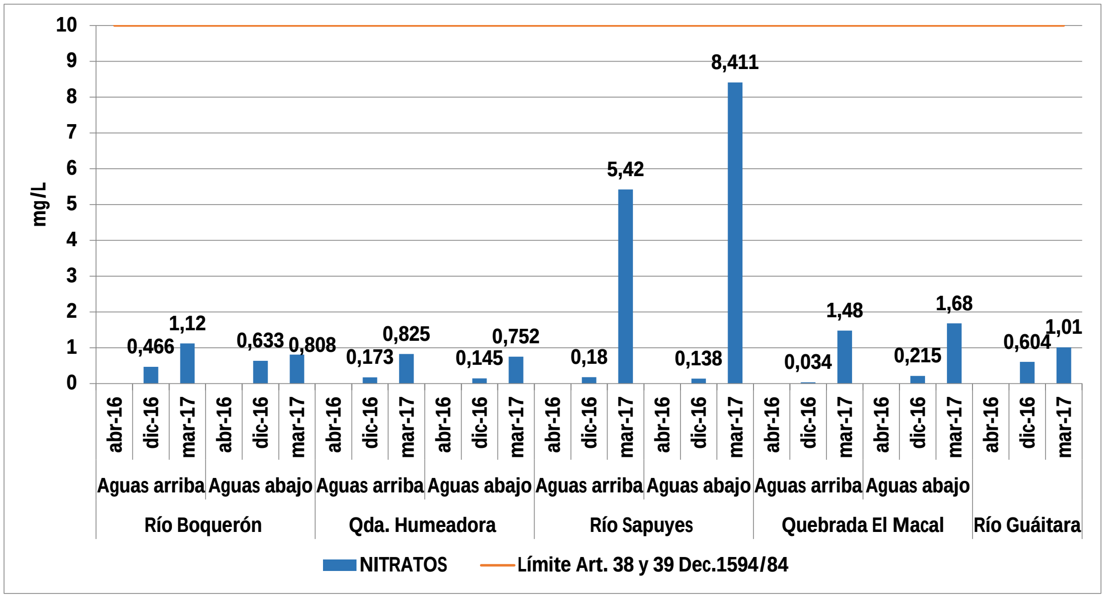
Source: MCS Consulting and Environmental Monitoring SAS, 2017.

- **Nitrates - Nitrites - Total Nitrogen.**

On the other hand the nitrates that this relation with the degradation of the organic matter, had concentrations that oscillate between 0.0034 mg / L for the ravine Macal upstream in the month of December of the 2016 and 8,411 mg / in the Sapuyes river waters Below for the month of March 2017 (**Figure 5.69**). The Boquerón River for December 2016 reported a slight increase between the upstream (0.466) and downstream (0.633 mg / L) stations; in March, on the other hand, there was a decrease in concentrations From 1.12 mg / L to 0.808 mg / L, upstream and downstream, respectively (**Figure 5.70**). On the other hand, in the other bodies of water an increase of the concentrations in the downstream station with respect to the upstream station was observed. Due to the time for the two monitoring periods on the five bodies of water, the highest concentrations are observed in March 2017 and the lowest in December (**Figure 5.70**). This behavior is due to the rainy season in the area for the month of March. These values comply with the current environmental regulations (10 mg / L), so it can be concluded that the resource can be used for domestic use and / or human consumption, as well as for agricultural use, in terms of concentration Of nitrates.

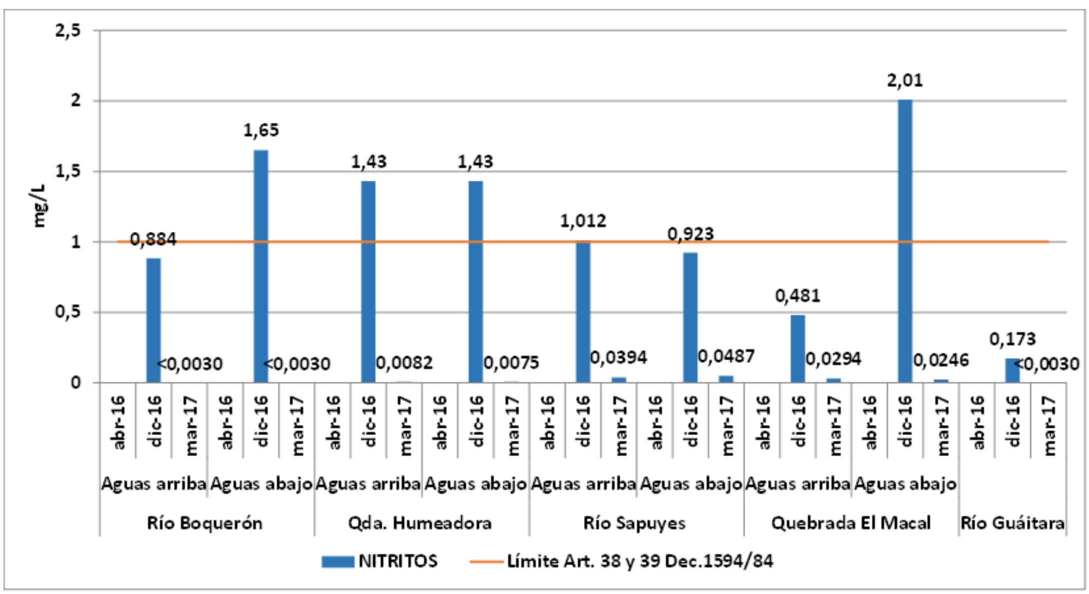
Reverse behavior was reported for nitrites reporting the highest concentration in the downstream gorge with 2.01 mg / L in the month of December 2016 and the lowest concentration for the Downstream gully with 0.0075 mg / L (**Figure 5.70**). The results show a homogeneous behavior, reporting a decrease in the nitrite concentration in the downstream stations in relation to the downstream stations and the lowest concentrations for the month of March 2017 in relation to the month of December 2016. The values of nitrites in the river Boquerón in the downstream station, Humidifier stream upstream and downstream, Sapuyes river upstream and ravine El Macal downstream for the month of December 2016 (**Figure 5.70**), Suggest the use of a conventional treatment if the resource for human consumption and / or domestic use is to be used for agricultural use, according to the limit established by Articles 38 and 39 of Decree 1594 of 1984 (1 mg / L). Finally, total nitrogen (Kjeldahl) presented homogeneous values with concentrations lower than the limit of detection for the analytical technique used for laboratory analysis, in the majority of the stations evaluated for the different epochs, with the exception of the Guáitara river in the Month of August of 2016 that presented / displayed a value of 0,38 mg / L.

Figure 5.68 Nitrate values, reported in the different monitoring.



Source: MCS Consulting and Environmental Monitoring SAS, 2017.

Figure 5.69 Nitrite values, reported in the different monitoring.

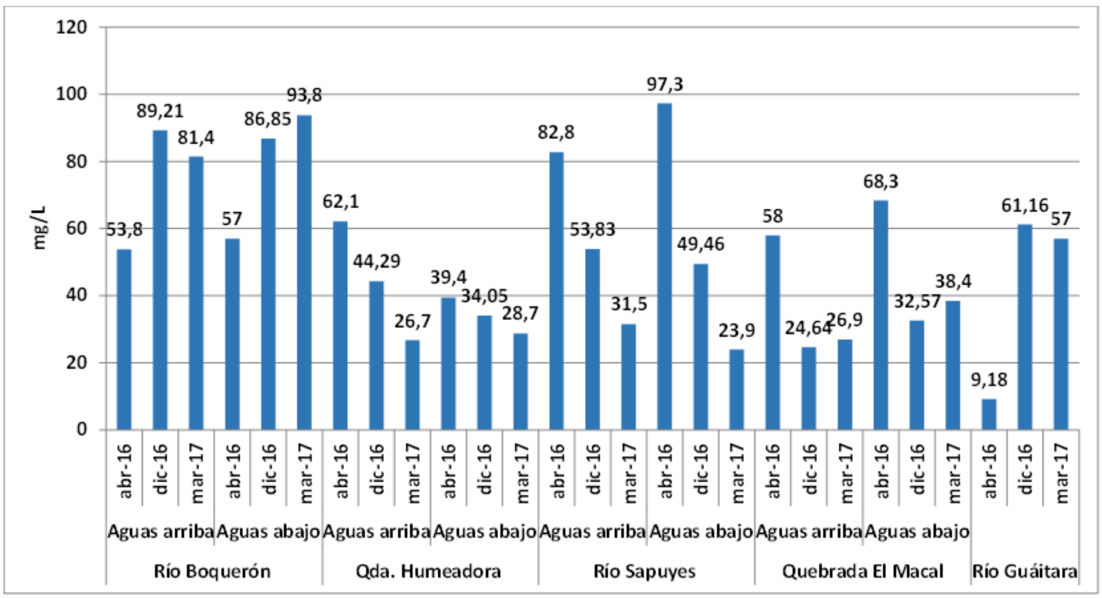


Source: MCS Consulting and Environmental Monitoring SAS, 2017.

- **Alkalinity - Total hardness - Calcium hardness.**

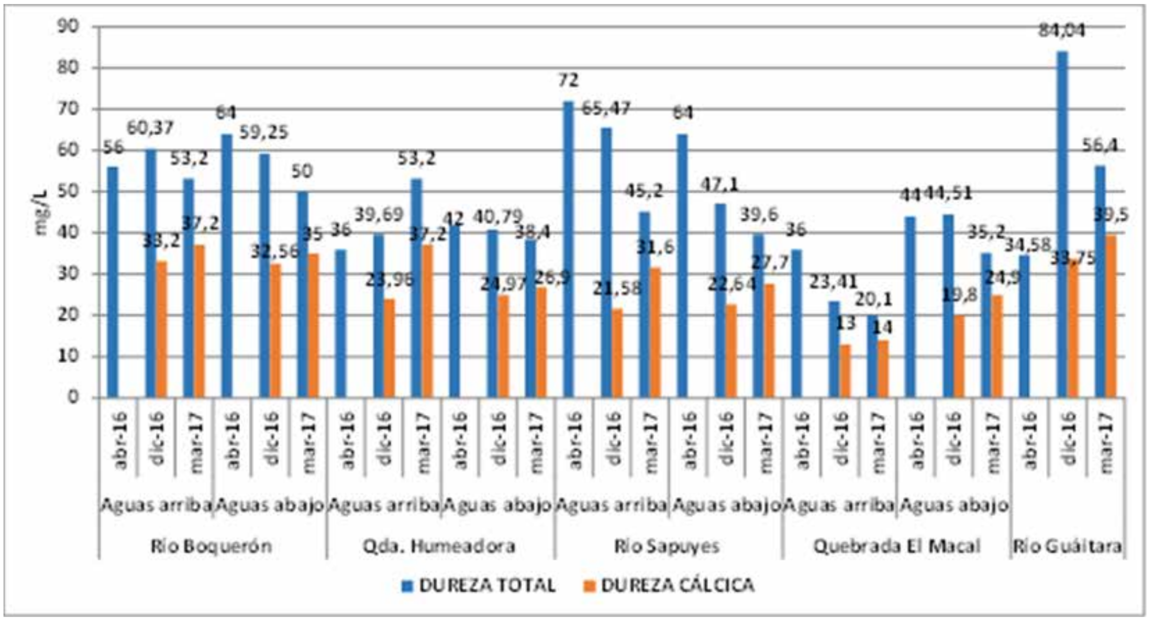
Alkalinity, on the other hand, reported concentrations ranging from 9.18 to 97.3 mg / L for the monitoring station on the Sapuyes River upstream and downstream respectively in April 2017. In general terms, the majority of stations evaluated have high and similar concentrations between monitoring stations (upstream and downstream) (**Figure 5.71**). On the other hand, the river Boquerón, Guáitara and the ravine El Macal reported increase in the alkalinity values for the downstream station with reference to the upstream station in the three monitoring periods. On the other hand the ravine the Humeadora reported decrease in the values of alkalinity for the downstream station with reference to the upstream station, in the three times. The same behavior presented the total and calcium hardness reporting similar concentrations between the upstream and downstream monitoring stations for each of the evaluated water bodies, at the same time it does not present a marked pattern between the different monitoring dates (**Figure 5.72**).

Figure 5.70 Alkalinity values, reported in the different monitoring.



MCS Consulting and Environmental Monitoring SAS, 2017.

Figure 5.71 Values of total hardness and calcium hardness, reported in the different monitoring.

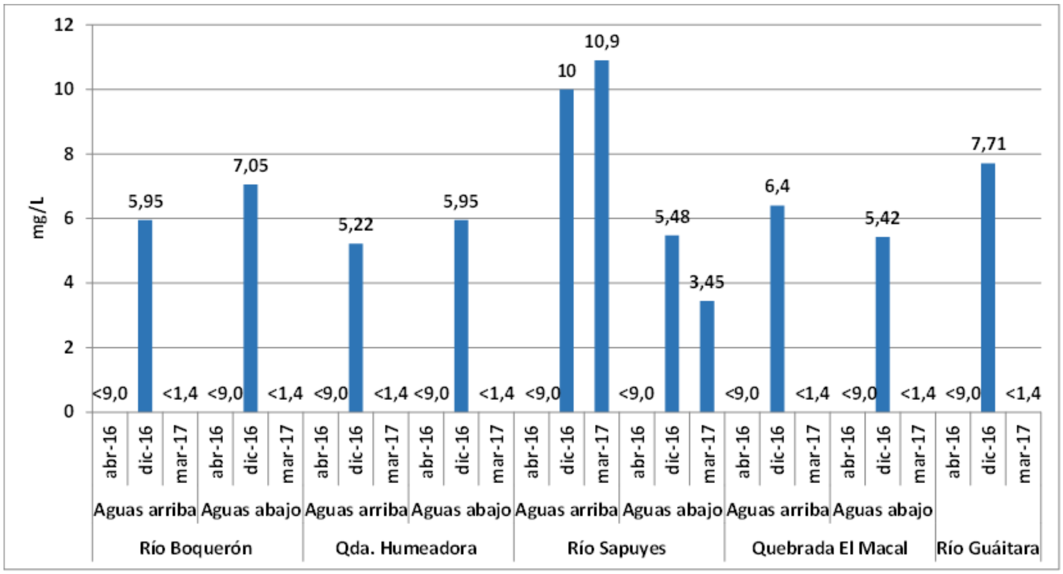


MCS Consulting and Environmental Monitoring SAS, 2017.

- **Fats and oils - Phenols.**

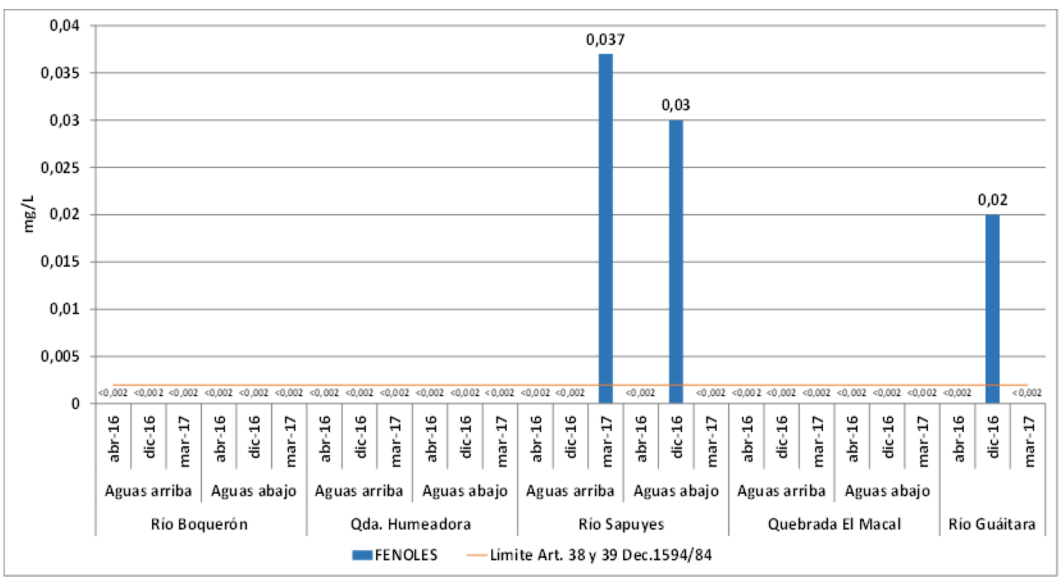
Variables Fats and Oils, Phenols (Chemicals that are part of the family of organic compounds), which are directly related to the activity of hydrocarbon extraction, in most stations monitored, during the phases evaluated in April, August, 2016 and March 2017 showed undetectable values for fats and oils by means of the analytical technique used for their respective evaluation (<9.0 mg / L, <10 mg / L, <1,40 mg / l), with the exception of Sapuyes river (upstream, downstream) that reported values of 10.9 and 3.45 mg / L, respectively, however in December 2016 values ranging from 10 mg / L were reported (Sapuyes river upstream) And 5.22 mg / L (upstream humidifier stream). The phenols reported concentrations of 0.02 mg / L for the Guáitira station, 0.03 mg / L for the Sapuyes river downstream in December 2016, and 0.037 for the Sapuyes river upstream in the month March 2017. When comparing with environmental regulations, non-compliance with current environmental regulations can be affirmed, because it exceeds the limits stipulated in article 38 and 39 (<0.002 mg / L) (**Figure 5.73**). Phenols reported concentrations of 0.02 mg / L for the Guáitira station, 0.03 mg / L for the Sapuyes river downstream in December 2016, and 0.037 for the Sapuyes river upstream in March 2017. When comparing with environmental regulations, non-compliance with current environmental regulations can be affirmed, because it exceeds the limits stipulated in article 38 and 39 (<0.002 mg / L) (**Figure 5.74**). However, the other stations in the periods that were evaluated complied with the current environmental norm.

Figure 5.72 Fat and oil values, reported in the different monitoring.



Source: MCS Consulting and Environmental Monitoring SAS, 2017.

Figure 5.73 Phenol values, reported in the different monitoring.

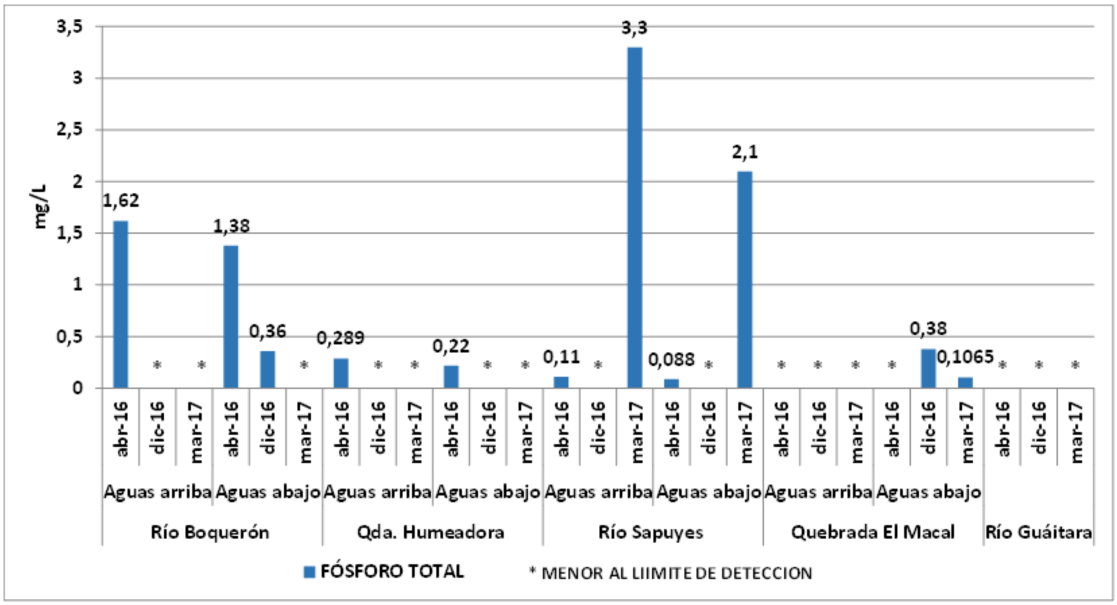


Source: MCS Consulting and Environmental Monitoring SAS, 2017.

- **Match.**

Phosphorus reported concentrations between, less than the limit of detection of analytical technique used for its analysis and, 3.3 mg / L during the monitoring performed in the ten water bodies. The highest concentrations in the Sapuyes river upstream and downstream (3.3 and 2.1 mg / L, respectively) were reported for the month of March 2017, followed by the Boquerón River upstream and downstream (1.62 And 1.38 mg / L, respectively) in the month of April 2016, in both cases and the same as the other stations, the decrease in the concentrations for the downstream stations with reference to the station upstream of each one is evident Of the evaluated water bodies that reported values (**Figure 5.75**). This behavior is possibly due to the decomposition of organic matter (vegetal) in the bodies of water.

Figure 5.74 Phosphorus values, reported in the different monitoring.

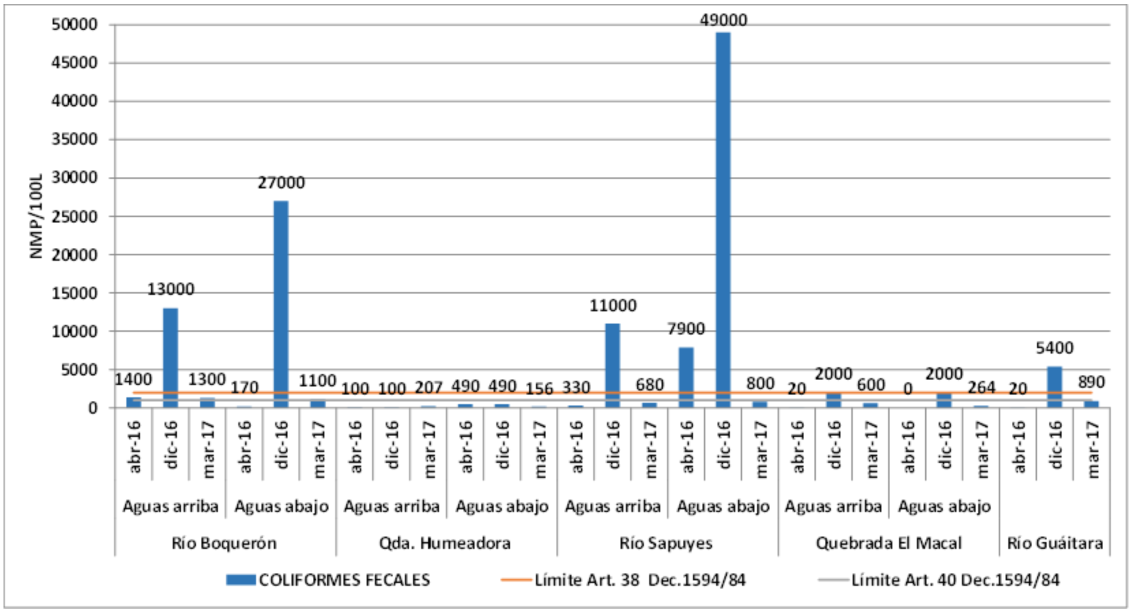


Source: MCS Consulting and Environmental Monitoring SAS, 2017.

- **Fecal coliforms.**

The fecal coliforms presented values ranging from 20 to 49000 NPM / 100 ml, the highest concentration of which occurred in the Sapuyes stream downstream in December 2016, in contrast, in the Guáitara river, the lowest concentration For the month of August 2016. When comparing with current environmental regulations (Dec.1594 / 84), it is evident that the monitoring stations of the Boquerón River upstream, the Sapuyes River downstream in April 2016, the Boquerón River upstream and downstream, Guáitara River , The Macal upstream and downstream, Sapuyes river upstream and downstream for monitoring of the month of December of the same year, exceed the limits established in article 40, of said decree, reason why the resource can not be destined to Agricultural purposes. For the month of March, 2017, the majority of the stations reported concentrations lower than the limit established in environmental regulations Decree 1594 of 1984 (art.38 and 40). However, at the monitoring stations on the Boquerón River (upstream and downstream), they exceed the limit established in Article 40 (1000 NMP / 100mL). In the course of time it is observed that the concentrations of fecal coliforms are heterogeneous with a tendency to decrease in the months of April 2016 and March 2017 with reference to the month of December 2016 (**Figure 5.76**). This behavior is possibly due to the activity of some wild animals that use water bodies as a drinking fountain.

Figure 5.75 Fecal coliform values, reported in the different monitoring.

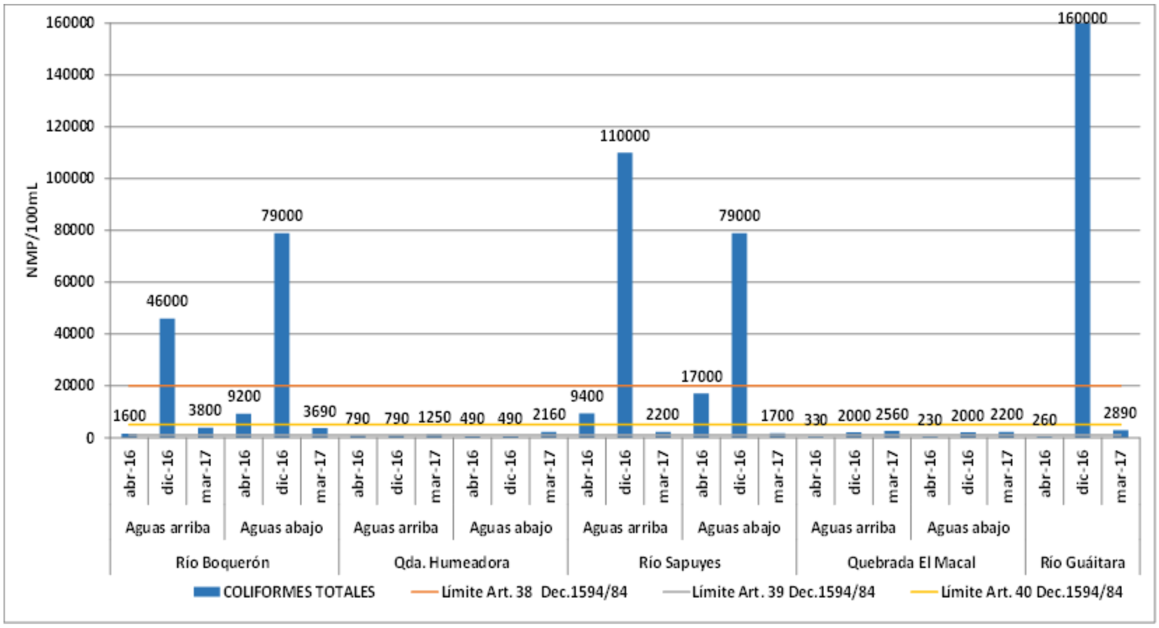


Source: MCS Consulting and Environmental Monitoring SAS, 2017.

- **Total coliforms.**

On the other hand, the total Coliforms reported concentrations between 260 NMP / 100mL for Guáitara River and 160000 NMP / 100mL Sapuyes river downstream. When comparing with current environmental regulations (Decree 1594/84), the Guáitara, Boquerón river upstream and downstream, Sapuyes upstream and downstream, in December 2016, has concentrations above the maximum limit allowed in Article 38, 39, 40, however, in April 2016, the Humeadora ravine upstream and downstream, the Guáitara River in August complied with the current environmental regulations, presented lower concentrations than those stipulated in the articles 38, 39 and 40 (**Figure 5.77**). When reviewing the behavior over time shows heterogeneous concentrations during the monitoring periods presents a tendency to increase in the month of December for all stations evaluated.

Figure 5.76 Values of total coliforms, reported in the different monitoring.



Source: MCS Consulting and Environmental Monitoring SAS, 2017.

To conclude, the evaluated metals such as arsenic, cadmium, chromium, selenium, silver and lead had lower concentrations than the detection limit for the analytical technique, using them for their respective analysis in the laboratory at all the stations evaluated during the three monitoring. On the other hand, the barium presented a similar behavior with the difference that the Macal stream downstream, for the month of December, 2016, was the only station that reported a concentration of 0.102 mg / L. At the stations evaluated in April 2016, copper and mercury reported values ranging from 0.0098 mg / L to 0.018 mg / L for copper and in the case of mercury 0.001 and 0.017 mg / L, for monitors August, December 2016 and March 2017, concentrations below the limit of detection were reported by the analytical technique used for analysis.

For its part, the **Zinc** Presented values ranging from 0.01 mg / L (Boquerón River upstream, Humidifier Stream downstream) and 0.07 mg / L (Guáitara River) for the month of December 2016, however, for the other monitoring Performed in April, August 2016 and March 2017, concentrations below the limit of detection of the analytical technique used for its analysis were reported. Finally, the **nickel** For April 2016 reported values of 0.011 and 0.0193 mg / L for the Boquerón river monitoring stations upstream and downstream, respectively, in the broken station Humeadora was presented a value of 0.005 mg / L, on the other On the other hand, in December 2016, concentrations that ranged from below the detection limit for the analytical technique used for analysis (<0.01mg / L) and 0.02mg / L (broken Macal downstream) . Finally, for March, concentrations below the limit of detection of the analytical technique used for its analysis (<0.15 mg / L) were present in all evaluated stations. When comparing with environmental regulations Decree 1594 of 1984, evidence of the compliance of the metals analyzed for the monitoring stations at different times.

· **Water quality indices.**

In the present study, the Water Quality Index (WQI) developed by the National Health Foundation of the United States (Canter, 1998) was calculated, which is a methodological tool for the determination of water quality. The calculations were performed for each of the monitoring points used for the elaboration of the multitemporal analysis.

In the **Table 5.78** The allocation of the WQI values for each of the analyzed water sources is presented.

Table 5.78 Water quality index (WQI) and quality parameters.

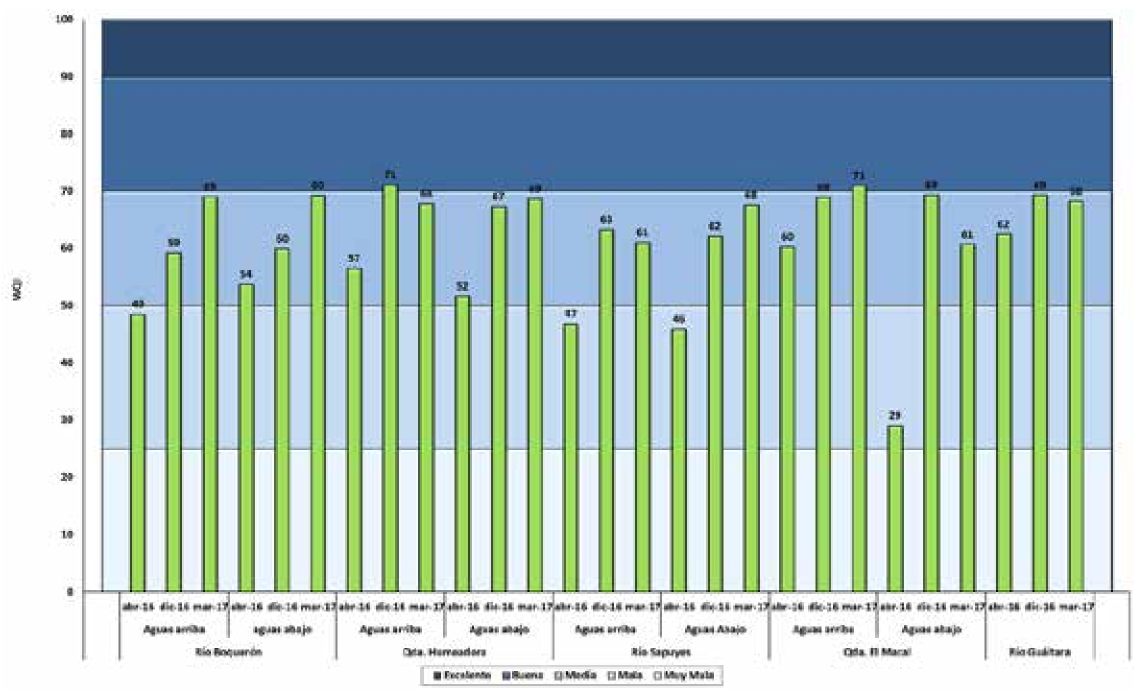
SOURCE	MONITORING POINT	DATE	WQI	QUALITY INDEX RANKS
Boquerón River	Upstream	**Ago-16**	49	BAD QUALITY (M)
		Dec-16	59	MEDIUM QUALITY (R)
		Mar-17	69	MEDIUM QUALITY (R)
	Downstream	**Ago-16**	54	MEDIUM QUALITY (R)
		Dec-16	60	MEDIUM QUALITY (R)
		Mar-17	69	MEDIUM QUALITY (R)
Qda. Smoker	Upstream	**Ago-16**	57	MEDIUM QUALITY (R)
		Dec-16	71	GOOD QUALITY (B)
		Mar-17	68	MEDIUM QUALITY (R)
	Downstream	**Ago-16**	52	MEDIUM QUALITY (R)
		Dec-16	67	MEDIUM QUALITY (R)
		Mar-17	69	MEDIUM QUALITY (R)
Sapuyes River	Upstream	**Ago-16**	47	BAD QUALITY (M)
		Dec-16	63	MEDIUM QUALITY (R)
		Mar-17	61	MEDIUM QUALITY (R)
	Downstream	**Ago-16**	46	BAD QUALITY (M)
		Dec-16	62	MEDIUM QUALITY (R)
		Mar-17	68	MEDIUM QUALITY (R)
El Macal Gorge	Upstream	**Ago-16**	60	MEDIUM QUALITY (R)
		Dec-16	69	MEDIUM QUALITY (R)
		Mar-17	71	GOOD QUALITY (B)
	Downstream	**Ago-16**	29	BAD QUALITY (M)
		Dec-16	69	MEDIUM QUALITY (R)
		Mar-17	61	MEDIUM QUALITY (R)
Guáitara River		**Ago-16**	62	MEDIUM QUALITY (R)
		Dec-16	69	MEDIUM QUALITY (R)
		Mar-17	68	MEDIUM QUALITY (R)

Source: Fieldwork MCS Consulting and Environmental Monitoring SAS, 2017.

Quality Scale Very Poor: **0 - 25** Mala: **26 - 50** Half: **51 - 70** Good food.: **71-90** Excellent: **91 - 100**

The estimated quality index determines that the river Boquerón presented data that determine in general for the stations located upstream and downstream with an average water quality, except for the upstream station for the month of April 2016 that presented a Very poor water quality, which is due to the high concentrations of total and fecal Coliforms. On the other hand, the stream Humidor presented a similar behavior, I report in most of the stations an average quality for the stations upstream and downstream, however, the upstream station for the month of December of 2016 reported a quality of the water Good. The Sapuyes river for the month of April of 2016 in the two monitoring stations presented poor water quality, on the contrary, in the other epochs an average water quality was reported. The Quebrada El Macal in general presented a medium water quality with the exception of the station located upstream in the month of March (**Figure 5.78**). Finally, the Guáitara river presented for the three months a homogeneous water quality (average quality). The good quality of the water that was presented in the upstream and downstream El Macal streams is due to the increase in dissolved oxygen, low concentrations of suspended and total solids, fecal and total coliforms and turbidity of these stations. Otherwise it happened in the stations boquerón river upstream, river Sapuyes upstream and downstream, ravine El Macal downstream for the month of April 2016 (**Figure 5.78**), Where high concentrations of fecal and total coliforms, suspended solids and BOD are reported. This is probably due to the low water flow in April 2016, which results in low dilution of suspended solids, low degradation of organic matter and possible water spills from populated areas or sidewalks near the points of Monitoring Most of the evaluated stations showed a homogeneous behavior over time, this is due to the low concentrations of nitrates and BOD_5, Good dissolved oxygen concentration, total solids and turbidity, parameters influenced by effects of agricultural and livestock activities as well as by the composition of the soils and rocks of the area.

Figure 5.77 Values of water quality index (WQI) for monitored stations.



Source: MCS Consulting and Environmental Monitoring SAS, 2017.

It is emphasized that throughout the study period (in which there are records for the two stations) from 2016 to 2017, there is no evidence of additional contamination of anthropic origin over time, generally stable records were present, where The few differences are evidently due to the climatic epoch of study being specific events without a clear tendency.

- **Conclusions.**

It was possible to show variations in the different climatic epochs on the physicochemical parameters evaluated in the related water bodies in the different studies, however there are parameters such as pH, temperature, dissolved oxygen, which presented similar concentrations during the different periods, without However, parameters such as dissolved solids, conductivity, turbidity, nitrites among others showed increase in the month of March compared to other months, this is reacted with the transition period, rains occurring in the region for that month. Concerning the current environmental regulations, partial compliance was observed in most of the stations, however parameters such as total and fecal coliforms, phenols, presented concentrations higher than allowed in the current environmental regulations.

5.1.7 Uses of water.

The uses of the water resource in the area of influence of the Rumichaca - Pasto dual carriageway project, San Juan - Pedregal section are presented in a general way, as well as the specific uses in the points of the sources on which they are requested For the development of the project, according to the information gathered in the field.

In the process of determining uses and users of the water resource, it was investigated through secondary information from municipal municipalities (Ipiales, Contadero, Ilés and Imués) and the Regional Autonomous Corporation of Nariño (CORPONARIÑO), in order to establish a base for The current and potential uses of water sources to intervene.

Subsequently, a tour of the intervention area was carried out, where secondary information was correlated and additional information was collected in the field, through the investigation of the community upstream and downstream of the points in which It is intended to make the capture and / or dumping for the work of the project.

5.1.7.1 Domestic use.

In general, in the area where the area of influence of the dual carriageway project Rumichaca - Pasto, San Juan - Pedregal stretch, is located, for domestic use superficial water is used. The catchments are made in nacederos, in which they construct tanks of collection and storage (**Photography 5.82**), Or in the high parts of the micro-watersheds, which are sources supplying veredal or municipal aqueducts (**Photo 5.83** to **Photo 5.85**), Distributing this resource to the communities belonging to the supply area. Likewise, in some houses, they have reservoirs for the supply of water during cuts in the service of aqueducts (**Photo 5.86**).

Photography 5-82 Collection tank in a nest of the Vereda Plank Alto.

AND: 955820 N: 598517

Photography 5-83 Aqueduct of the condominium Arcoiris (Pilcuan).

AND: 954060 N: 604342

Source: GEOCOL CONSULTORES SA, 2017.

Photography 5-84 Aqueduct of the path San José de Quisnamuez.

AND: 953585 N: 596053

Source: GEOCOL CONSULTORES SA, 2017.

Photography 5-85 Acueducto corregimiento of San Juan.

Source: GEOCOL CONSULTORES SA, 2017.

Source: Plan of efficient use and saving of the municipality municipality of Ipiales (pueaa), 2008 - 2011.

Photography 5-86 Aljibe of a house in the village of Ospina Pérez.
AND: 952272 N: 595129

Source: GEOCOL CONSULTORES SA, 2017.

5.1.7.2 Agricultural Use.

The agricultural areas within the area of influence of the project correspond to potato crops as the predominant one, followed by maize, wheat, beans, beans, peas, ulloco, goose, barley, carrots and vegetables. Where water is used for irrigation (**Photo 5.87**) And spraying.

Photography 5-87 Irrigation of crops in the village of La Providencia.
AND: 948454 N: 591477

Source: GEOCOL CONSULTORES SA, 2017.

Two irrigation districts were identified, one called "ASOSANFRANCISCO" in San Francisco, Contadero municipality, which has existed for approximately 25 years, has 96 users and intersects in five points with the layout of the dual carriageway project Rumichaca - Pasto , Section San Juan - Pedregal, although the catchment is outside the area of influence of the project (**Photography 5.88**). There is another private district, which belongs to five partners and has a crossing with the layout of the project, these crossing sites are presented in the **Table 5.79**.

Photography 5-88 Collection point of the irrigation district ASOSANFRANCISCO in the village of Loma de Yáez.

AND: 947720 N: 594032

Source: GEOCOL CONSULTORES SA, 2017.

Table 5.79 Points of crossing of the irrigation districts with the layout of the project.

IRRIGATION DISTRICT	COORDINATES DATUM MAGNA SIRGAS ORIGINS WEST	
	EAST	NORTH
ASOSANFRANCISCO	949214	592111
	948834	591868
	948536	591905
	948585	591831
	948376	591995
Private district	948206	591650

Source: GEOCOL CONSULTORES SA, 2017.

5.1.7.3 Livestock Use.

The use of water resources in livestock activities is basically for consumption by smaller species and mainly of cattle, which take water directly from the streams (**Photo 5.89**) Or on some farms, the water is handcrafted by hoses from the streams to the troughs.

Photography 5-89 Abrevadero in the creek La Cueva, El Corantro path.

AND: 950979 N: 594734

Source: GEOCOL CONSULTORES SA, 2017.

5.1.7.4 Main sources of pollutants.

In the area of influence of the project the contamination of some water sources is evidenced, because the surrounding community makes a bad disposition of the solid residues on the margins of these bodies of water (**Photo 5.90**).

Photography 5-90 Disposal of solid waste in the margin of Chorrera Chiquita ditch, high plank sidewalk.

AND: 955820 N: 598517

Source: GEOCOL CONSULTORES SA, 2017.

On the other hand, in communities where there is no sewage system, the wastewater generated is discharged directly to water sources, as well as water generated in places where economic activities are carried out artisanally such as food processing and vehicle washing.

For example, Boquerón river is contaminated mainly by the spills of Ipiales, Pupiales, Contadero, Gualmátan and by the direct dumping of houses and pig stables in the municipality of Contadero. (PORH Río Boquerón, 2011).

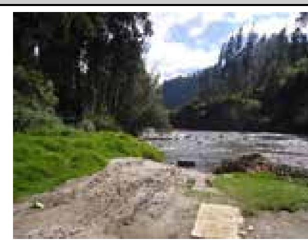
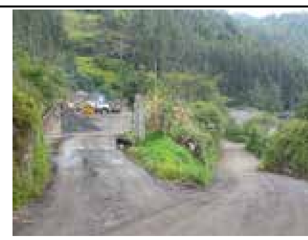
On the other hand, economic activities such as livestock and agriculture also contribute to the deterioration of the water resource, since the large amount of waste and dumping that these activities generate can be transported to the bodies of water through runoff, thus significantly altering the Physicochemical and bacteriological characteristics of water, subjecting these bodies of water to eutrophication processes.

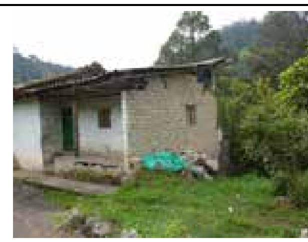
5.1.7.5 Water demand at harvest sites.

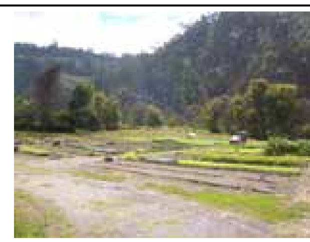
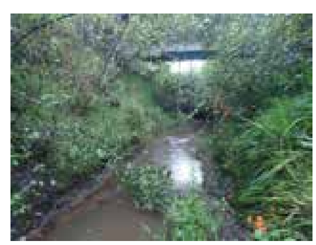
Reference is made below to the uses and / or points of dumping to which the sources susceptible of use by the project can be influenced directly or indirectly. This concept is generated based on the routes and the rapprochement with the communities. It should be noted that 1 km of travel (according to the access possibility) was carried out upstream and downstream of the defined catchment points (**Table 5.80**).

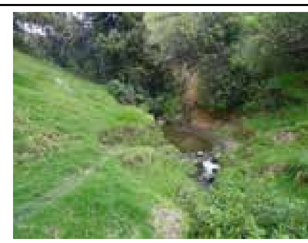
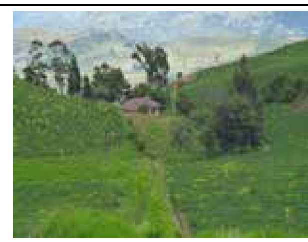
The uses for the present study at catchment points were identified based on decree 3930 of 2010, which in Chapter IV, article 9, establishes and defines uses for water resources. On the other hand, the analysis of minimum flow rates for different return periods, the demand for water resources, and the analysis of current or potential conflicts over the availability and uses of water is presented in Chapter 7: Demand, use and use and / or allocation of natural resources - 7.1 Surface water.

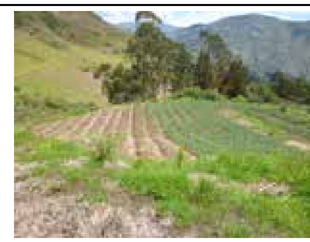
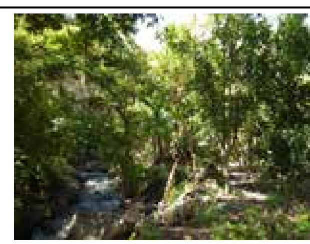
Table 5.80 Uses and users upstream and downstream of catchment sites in the Project Influence Area.

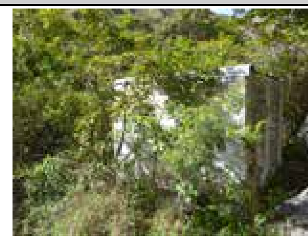
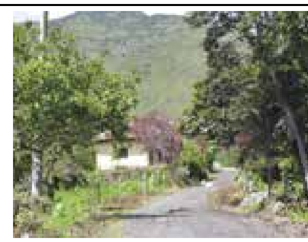
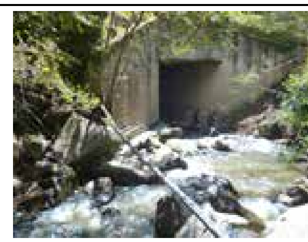
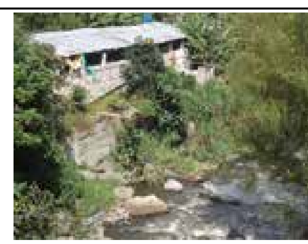
SITE		APPLICATIONS	OBSERVATIONS	PHOTOGRAPHIC REGISTRATION AND COORDINATES
Capture 1 Rio Guáitara (San Juan)		In the site there is an access to the river, however in the visit it was not possible to establish the use that is given to the body of water in the point, also in the PORH of the main channel of the river Guáitara there are no identified uses in the site.	The point is located north of San Juan, leaving the village on the Pan-American route to Pasto and approximately 850 meters to the right takes a unpaved road in a distance of 150 meters.	 **AND:** 948503; N: 590762
Upstream	245 m	Dumping, Industrial Use	On the right margin at 245 meters from the catchment point is a crusher (San Juan Crusher), which performs discharges directly to the river Guáitara from the industrial works.	 AND: 948362; N: 590565
Upstream	260 m	Shedding	Approximately 260 meters upstream from the catchment point, houses are found that generate domestic type waters which are directly discharged to the Guáitara River, since they are not immersed in the sewerage network of the town of San Juan, which is the center Population closest to the catchment point.	 AND: 948362; N: 590565

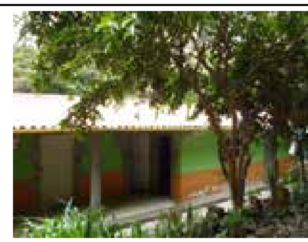
SITE		APPLICATIONS	OBSERVATIONS	PHOTOGRAPHIC REGISTRATION AND COORDINATES
Upstream	473 m	Shedding	Approximately 473 meters upstream from the catchment point, houses that generate domestic type water are seen, which are dumped directly into the Guáitara River.	 AND: 948081; N: 590546
Upstream	493 m	Shedding	Approximately 493 meters upstream from the catchment point, houses are found that generate domestic type water which is dumped directly into the Guáitara River.	 AND: 948062; N: 590542
Upstream	860 m	Shedding	The dumping is considered as domestic, is produced by approximately 1173 people, corresponds to the only dumping in the sewerage network of San Juan, is made by means of bleachers and is made directly to the river Guáitara	 AND: 948117; N: 590221 Source: PORH of the main channel of Guáitara River, 2011.
Downstream	10 m	Shedding	On the right bank 10 meters from the catchment point is a farm porcicola (La Hacienda) belonging to the municipality of Puerres, which makes domestic and industrial landfills due to economic activity.	 AND: 948563; N: 590681
Downstream	85m	Shedding	On the left bank at 85 meters from the catchment point is a car wash, which has the respective permits for such activity, performs industrial-type discharges to the river Guátara, it should be noted that the site has a dumping plant Which is composed of: degreaser, grease trap and septic tank.	 AND: 948560; N: 590826

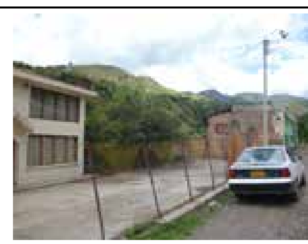
SITE		APPLICATIONS	OBSERVATIONS	PHOTOGRAPHIC REGISTRATION AND COORDINATES
Capture 2, Dumping 1. Rio Boquerón (San Juan)		Any	The point is located north of San Juan, leaving the hamlet by the Pan American route to Pasto and approximately 1 km to the left is access to the point.	 AND: 948589; N: 590972
Upstream	57 m	Shedding	Approximately 57 meters upstream there are water spills of industrial type, coming from a hatchery of chickens, these waters fall directly to the River Boquerón.	 AND: 948531; N: 590977
Upstream	965	Shedding	At 965 meters upstream they carry out spills to the river Boquerón from the mills Diana	 AND: 947823; N: 591440
Downstream	79 m	Shedding, Irrigation	On the right bank at 79 meters from the point of catchment and / or dumping, there is a forest nursery of CORPONARIÑO, where the capture of the river Boquerón is irrigated and domestic water is poured to that source.	 AND: 948665; N: 590954
Capture 3, Dumping 2. Humane Gully (Contour)		Any Downstream was not identified any use, in addition to the aesthetic that is observed by the fall in the waterfall.	To 20 meters upstream of this point originated the Hummingbird ravine after the union of 4 tributaries (Los Arrayanes, El Manzano, Urbano and an unnamed ravine). In the area there are no catchment points or dumps near the georeferenced point both upstream and downstream, however taking into account secondary information, this source in the upper part is receiving spills from the San José de Quisnamuez villages Of Contadero	 AND: 955074; N: 597201

SITE		APPLICATIONS	OBSERVATIONS	PHOTOGRAPHIC REGISTRATION AND COORDINATES
			and Alto del Rey, Urbano and Tamburán belonging to the municipality of Iles.	
Upstream	506 m	Livestock	To 506 meters upstream, in the stream Los Arrayanes there is a trough.	 AND: 954623; N: 597220
Capture 4 Quebrada Moledores (Contadero)		Any	The point is located in the path El Tablón, limits with the path La Esperanza; The access is made by walking and is before the beginning of the abyss, therefore the capture would be carried out by gravity. Downstream was not identified any use, in addition to the aesthetic that is observed by the fall in the waterfall.	 AND: 956019; N: 598991
Upstream	547 m	Shedding, Irrigation	In the left margin to 547 meters of the point of capture, is realized captación for irrigation (potato and onion crops). This house has a septic tank, which can generate by runoff vertimientos to the ravine Moledores.	 AND: 955838; N: 598479
Capture 5. Quebrada San Francisco (Iles)		Any	The point is located in the village of Tablón Alto, on the road to the municipal head of Iles; Is before the beginning of the abyss, therefore the capture would be carried out by gravity.	 AND: 953962; N: 601557

SITE		APPLICATIONS	OBSERVATIONS	PHOTOGRAPHIC REGISTRATION AND COORDINATES
Downstream	393 m	Shedding	In the left margin at 393 meters from the catchment point, a housing is observed that has a septic tank as a wastewater treatment system, which can generate by runoff vertimientos to the ravine San Francisco.	AND: 954322; N: 601700
Downstream	461 m	Irrigation	On the left bank 461 meters from the catchment point, onion plantations are observed, which have an irrigation system coming from the San Francisco creek.	AND: 954411; N: 601668
Capture 6. Quebrada El Macal (Iles)		Any	El Punto is located on an alternate route to the Pan-American highway that links the paths of El Porvenir with the Capulí. This site does not have a drainage work and the vehicles pass over the channel of the ravine.	AND: 954870; N: 603721
Upstream	146 m	Possible Shedding	On the left bank at 146 meters from the catchment point, there is a construction of a warehouse, which once it comes into operation will generate spills to the Quebrada El Macal.	E 954756; N: 603632
Upstream	180 m	Shedding	Approximately 180 meters upstream from the catchment point, a dwelling that generates wastewater of the domestic type is seen, which is dumped directly into the El Macal ravine.	AND: 954740; N: 603600

SITE		APPLICATIONS	OBSERVATIONS	PHOTOGRAPHIC REGISTRATION AND COORDINATES
Upstream	386 m	Possible Capture	In the left margin at 386 meters from the catchment point, a storage tank of water is observed in apparent abandonment, since it is in very poor conditions and no inlet or outlet conduits of water are observed.	AND: 954624; N: 603424
Downstream	141 m	Shedding, Irrigation	In the left margin to 141 meters of the point of reference, is realized capture for irrigation. In the same house with a septic tank, which can generate by runoff vertimientos to the ravine El Macal.	 AND: 955011; N: 603708
Downstream	203 m	Industrial	On the right margin at 203 meters from the point referred to, a capture for industrial use, according to the demands of the resource that requires the crusher present on the site.	 AND: 955057; N: 603790
Capture 7, Dumping 4. Sapuyes River (Imués)		Any	The point is located in the path El Porvenir, on the road to the path Pilcuán, Is located on the bridge that crosses the Sapuyes river.	 AND: 954844; N: 605090
Downstream	62 m	Shedding	Approximately 62 meters downstream from the catchment and / or dumping site, a dwelling is found that generates wastewater of domestic types and comes from poultry activities, which are dumped directly into the Sapuyes river.	AND: 954882; N: 605115

SITE		APPLICATIONS	OBSERVATIONS	PHOTOGRAPHIC REGISTRATION AND COORDINATES
Downstream	103 m	Shedding	Approximately 103 meters downstream from the catchment and / or dumping site, a dwelling is found that generates domestic wastewater which is dumped directly into the Sapuyes river.	 AND: 954931; N: 605101
Downstream	189 m	Shedding	Approximately 189 meters downstream from the catchment and / or dumping site, a dwelling is generated that generates domestic wastewater which is dumped directly into the Sapuyes river.	 AND: 955019; N: 605077
Downstream	242 m	Shedding	Approximately 242 meters downstream from the catchment and / or dumping site, a dwelling is found that generates domestic wastewater which is directly dumped into the Sapuyes river.	 AND: 955073; N: 605088
Downstream	288 m	Shedding	Approximately 288 meters downstream of the catchment and / or dumping site, a dwelling is found that generates domestic wastewater which is dumped directly into the Sapuyes river.	 AND: 955112; N: 605019
Downstream	298 m	Shedding	Approximately 298 meters downstream from the catchment and / or dumping site, a dwelling is found that generates domestic wastewater which is dumped directly into the Sapuyes river.	 AND: 955120; N: 605012

SITE		APPLICATIONS	OBSERVATIONS	PHOTOGRAPHIC REGISTRATION AND COORDINATES
Downstream	303 m	Shedding	Approximately 303 meters downstream from the catchment and / or dumping site, a dwelling is generated that generates domestic wastewater which is dumped directly into the Sapuyes river.	 AND: 955126; N: 605002
Downstream	344 m	Shedding	Approximately 344 meters downstream from the catchment and / or dumping site, a dwelling is found that generates domestic wastewater which is directly dumped into the Sapuyes River.	 AND: 955162; N: 604990
Downstream	370 m	Shedding	Approximately 370 meters downstream from the catchment and / or dumping site, a dwelling is found that generates domestic wastewater which is dumped directly into the Sapuyes river.	 AND: 955186; N: 604987
Downstream	380 m	Shedding	Approximately 380 meters downstream from the catchment and / or dumping site, a dwelling is found that generates domestic wastewater which is dumped directly into the Sapuyes river.	 AND: 955197; N: 604980
Downstream	562 m	Shedding	Approximately 562 meters downstream from the catchment and / or dumping site, a dwelling is found that generates domestic wastewater which is dumped directly into the Sapuyes river.	 AND: 955373; N: 604936

SITE		APPLICATIONS	OBSERVATIONS	PHOTOGRAPHIC REGISTRATION AND COORDINATES
Downstream	577 m	Shedding	Approximately 577 meters downstream of the catchment and / or dumping site is the Pilcual Viejo Educational Center, which generates domestic wastewater which is directly dumped into the Sapuyes River.	 AND: 955372; N: 604883

Source: GEOCOL CONSULTORES SA, 2017.

5.1.8 Hydrogeology.

5.1.8.1 National Hydrogeological Context.

In the national context, several general hydrogeological studies of an exploratory nature have been developed, mainly by governmental entities such as the Regional Autonomous Corporation of Nariño - CORPONARIÑO, the Colombian Geological Service - SGC (formerly INGEOMINAS), Instituto Geográfico Agustín Codazzi - IGAC and the Institute of Hydrology, Meteorology and Environmental Studies - IDEAM, in which the relationship between surface currents and groundwater presented in the region and its quality has been evaluated at various levels taking into account the Different units of hydrogeological interest.

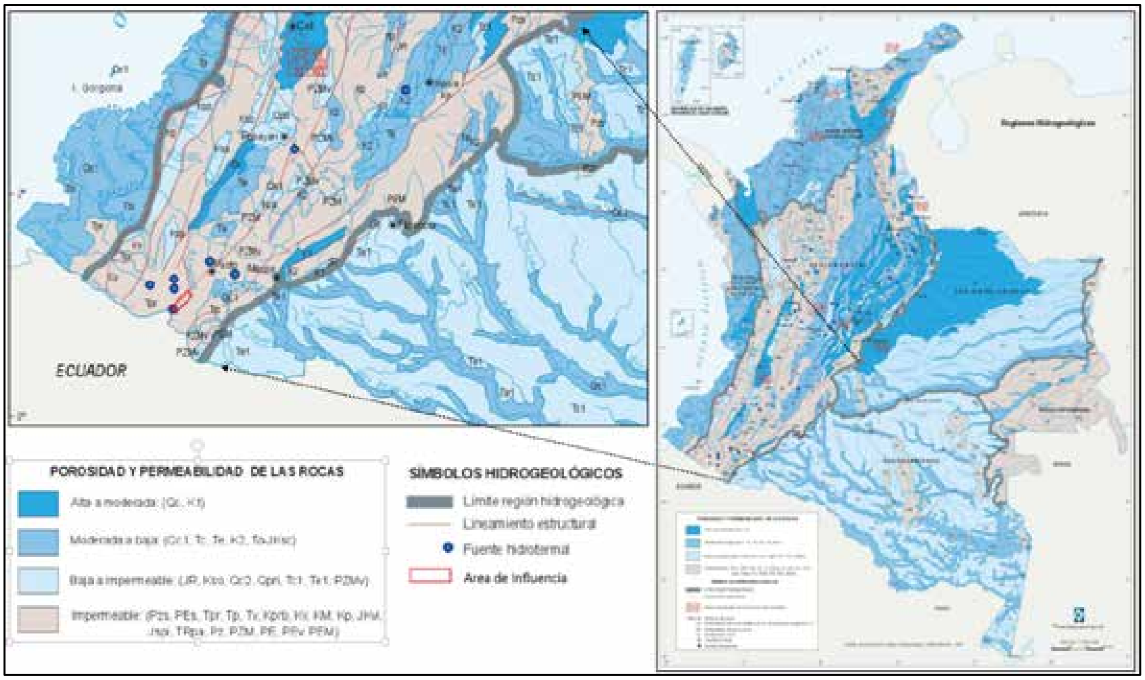
In 1987 the National Geological-Mining Research Institute (INGEOMINAS) drew up the Hydrogeological Map of Colombia at a scale of 1: 2,500,000 with its respective report, within the framework of the International Hydrogeological Program (IHP) coordinated by UNESCO. As one of its objectives the elaboration and edition of the Hydrogeological Map of South America in scale 1: 5'000.000. The Hydrogeological Map of Colombia shows the regional distribution of potential aquifer areas and the chemical quality of their waters, also revealing regions with gaps of hydrogeological information.

Based on the division by provinces, proposed by UNESCO for the Hydrogeological Map of South America, the Colombian territory was divided into six hydrogeological provinces, forming part of them one or more watersheds and where areas with geomorphological, geological, And hydrogeological conditions. These provinces are: Andean Vertiente-Atlántica, Coastal Atlantic-Coastal, Coastal-Pacifica, Amazon, Orinoco and Northern Shield.

According to the Map of Hydrogeological Regions (INGEOMINAS 2002), the area object of the present study is in the hydrogeological province Andean Region; In this province is a great lithological variety consisting of sediments and rocks ranging from the Precambrian to the Recent. These sediments and rocks appear from impermeable to medium permeability, the valleys and terraces being the centers of water storage in the area it is possible to capture groundwater by means of cisterns, piezometers and nacederos (**Figure 5.79**).

The study area is located on tertiary pyroclastic rocks of acid and intermediate composition, classified as units practically impermeable, that is to say, units with no hydrogeological interest, low to medium porosity and very low permeability, where it is only viable the water catchment Of the most superficial units by means of cisterns and nacederos.

Figure 5.78 Map of Hydrogeological Regions of Colombia.

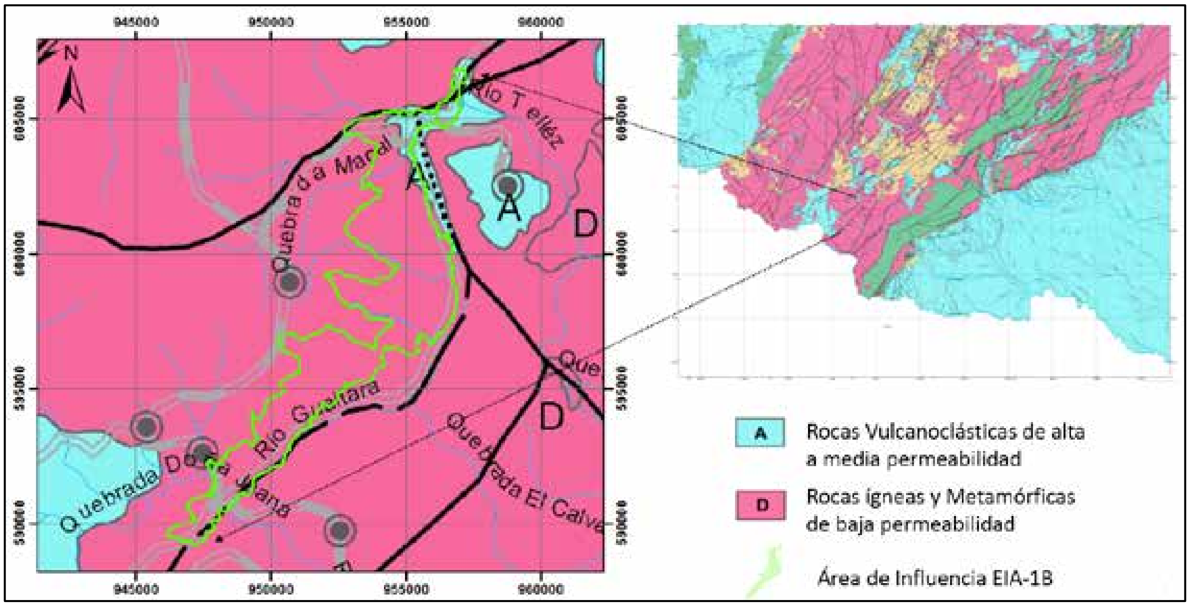


Source: (Elaborated by INGEOMINAS 1987) (Presented by IGAC 2002).

5.1.8.2 Regional Hydrogeological Context - Plate 1: 500,000.

According to the Colombian permeability map of Plate 5-18, prepared by the Colombian Geological Survey in 2008, two hydrogeological units are located in the study area: high-to-medium permeability rocks, volcanic rocks And metamorphic rocks of low permeability that are composed of geological units with no capacity to absorb or transmit water, to the north arise intergranular geological units constituted by sedimentary rocks and volcanoclastic sediments of high to medium permeability.

Figure 5.79 Permeability Map of Colombia Iron 5 - 18 - Scale 1 - 500,000.



Source: Iron 5-18, Colombian Geological Survey - 2008.

5.1.8.3 Regional Hydrogeological Context - Nariñense Altiplano Aquifer System SAM6.6.

According to the document "Groundwater in Colombia: An Overview "IDEAM (2013) The area of influence is in part of the SAM-6.6 Nariñense Altiplano Aquifer System that belongs to the physiographic region known as the Túquerres-Ipiales plateau (Bermoudes 2009) (**Figure 5.81**). For the aquifer system the following generalities stand out:

- **Hydroclimic generalities.**

The annual precipitation in the great part of the area presents values inferior to 1000 mm. It should be noted that although the bimodal rainfall regime is well defined, ie there are two periods of higher rainfall, the number of rainy days at a monthly level is relatively constant, summing approximately 215 days annually (Bermoudes, 2009). Hydrographically the area belongs to the Guáitara river basin, the main surface and groundwater catchment (Bermoudes, 2009).

- **Geological and hydrogeological.**

The lithostratigraphic units present in the area can be grouped into two basic groups. The first group corresponds to Neogene-Pleistocene lavas and ignimbrites, whereas the second group includes the unconsolidated volcanic deposits of the Quaternary, which come essentially from the volcanic complexes of Azufral, Cumbal, Chiles-Cerro Negro, Pajablanca and some volcanoes of the Real Ecuadorian mountain range.

Recent units of alluvial, lacustrine and slope origin have very limited extensions. (Ibid.) The second unit constitutes a very complex, heterogeneous and anisotropic hydrogeological system. (Ibid.)

The hydrogeological system consists of an alternation of potentially aquiferous units and aquitars of varying thickness and thickness, where free, semi-confined and confined aquifers of relatively low hydraulic characteristics are developed. Free, semi-confined and confined aquifers form a unique hydraulic system. (Ibid.)

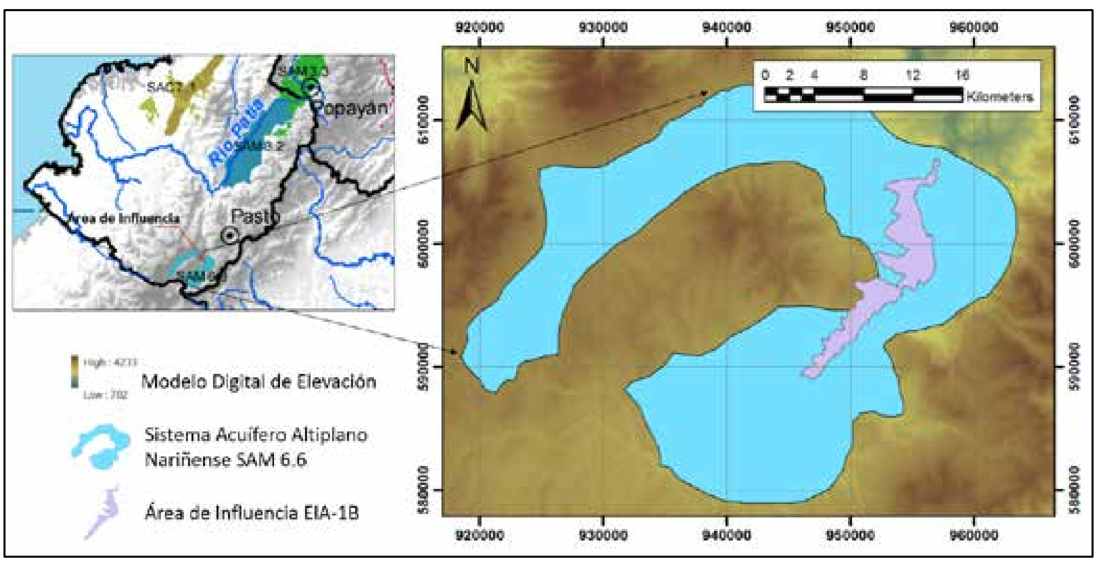
· **General Groundwater Uses.**

From the study carried out by Bermoudes (2009), it is inferred that in the area there are a total of 353 abstractions of groundwater, of which 307 corresponds to aljibes, 8 to wells and 38 to springs (IDEAM 2014).

The water is mainly used for domestic consumption benefiting up to 5-8 inhabitants per well and occasionally for public supply (veredal schools and family welfare homes), in addition some wells are used for irrigation and livestock. (Bermoudes, 2009. p.31).

The extraction of water is done manually by means of flushing, with an average of up to 100-150 l / day. In very few wells have been installed windmills and motor pumps that increase the volume of water extracted up to 3000 l / day. (Bermoudes, 2009. p 32).

Figure 5.80 Aquifer Systems of Colombia.



Source: (IDEAM 2014).

5.1.8.4 Local Hydrogeological Context.

· **Predominant geological units.**

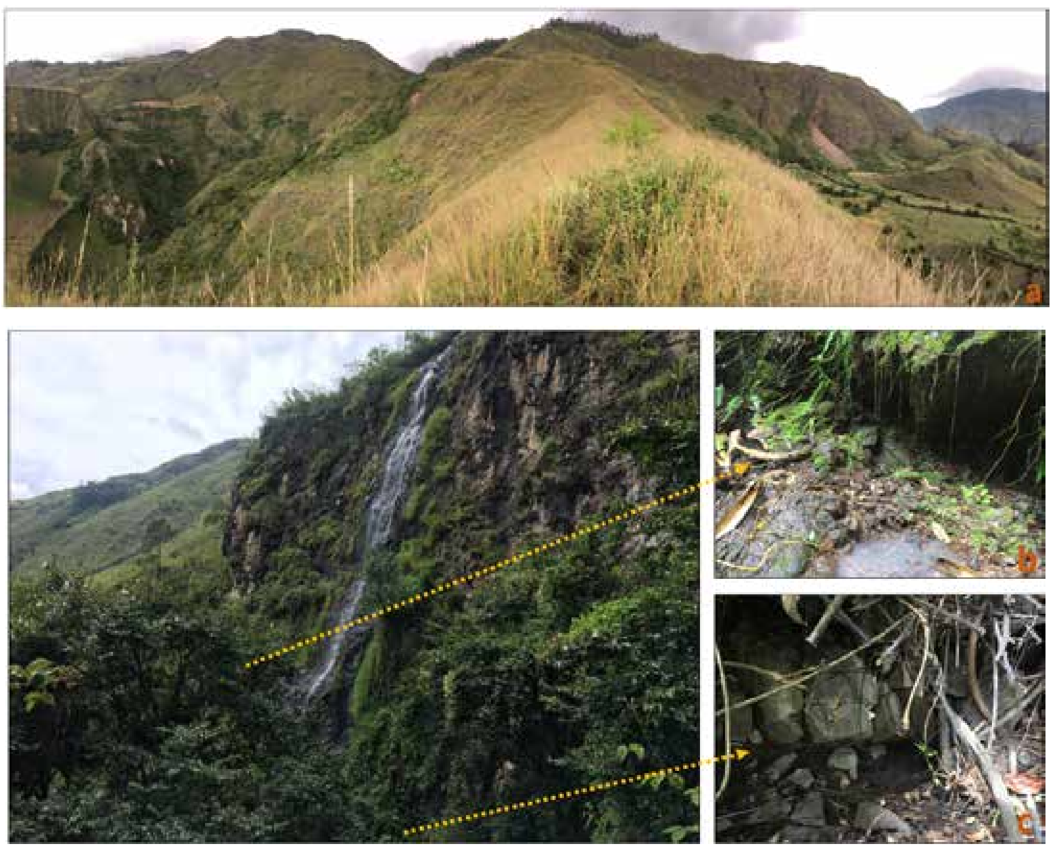
In this sector, the Lavas and pyroclastic unit of the neogene (NQlp), mainly formed by pyroclastic deposits of flow and fall, which are generally in an advanced state of weathering in the upland sector, generate clay, brown, gray and white soils; These materials form a hydrogeological unit of regional extension of weak potentiality, limited by the thickness of the meteorized horizons and granulometric constitution (**Photography 5.91**).

Photography 5-91 A) Panoramic of deudational slopes formed by residual soils of the laval and pyroclastic unit NQlp in the upland sector, b) piezometer in residual soils with static level to less than 1.0 meters of depth, c) outcropping of water in the cut of The access road to the municipality of Iles "anthropic upwelling", d) characteristic spring in residual soils and saproplite of the Lavas and Piroclastos regional unit.

Source: GEOCOL CONSULTORES SA, 2017. Urban Park Municipality of Iles, E: 955317, N: 597528

Pyroclasts are inter-stratified with lava flows of considerable thickness, which in some cases are isolated outcrops in the form of windows under pyroclastic deposits and in others are extensions covering several kilometers. The lavas are basically andesitic in composition and pyroclast accumulations in general show leucocratic rocks that form ash and tuff, with abundant fragments of pumice angular to subred, of variable size between ash and bomb, which generally have oxidized lytic and show a hue Reddish due to the oxidation of ferromagnesian minerals, mainly those associated with dacites, rhyolites and pumitas; These are supported matrixes that in some sectors are found as pyroclastic agglomerates, while in others they are pyroclastic breccias. These fresh materials are considered with limited groundwater resources, that is, they have a "negligible" potentiality, although in some sectors there are occasional outcroppings of groundwater as springs, mainly occurring in the drastic slope changes of The slopes and in the high parts of the micro-basins where the drainage of the hillside is**Photo 5.92**). Some outcrops may also occur in fresh lava materials only because of porosities and secondary permeabilities.

Photography 5-92 A) Panoramica of steep slopes conformed by the unit of lavas and piroclastos NQlp, b) characteristic spring in the contact of pyroclasts deposited on lava materials, c) outcropping of water in fractured lavas in contact with deposits of slope.



Source: GEOCOL CONSULTORES SA, 2017. Vereda Tablón Bajo - Municipality of Iles, E: 955098, N: 600556

On the southern side of the area of influence emerges the unit called Rumichaca Ash Deposit (Qdcr); These volcano-sedimentary deposits belong to several generations of sandy and silt-sandy sediments, with intercalations of falling pumitas. The thickness of this sequence can reach 200 m in the canyon of the river Guáitara, south Ipiales. This unit is characterized by smoothing the topography, especially of the lower slope areas (**Photo 5.93**). The strata in general are composed of layers of decimetrical to centimetric thickness, formed by fine sands and silts, the product of wind transport of volcanic ash, which reveal dry climatic conditions during their deposition, which are interspersed with deposits of ash fall and pumice Thickness ranging from a few centimeters to more than two meters (**Photo 5.93**). The episodes of pumice fall show intense quaternary volcanism in the area; Said pumice is highly vesiculated, white, with some hornblende and biotite crystals. In this unit, it is frequent to use the groundwater in a specific way using water tanks and springs; however, the potentiality of the water unit is "Weak", due mainly to the granulometry of the constituent materials.

Photography 5-93 Outcrop of Rumichaca Ash Reservoirs (Qdcr).

Source: GEOCOL CONSULTORES SA, 2017. Vereda San Juan - Municipality of Ipiales, E: 947030, N: 589528

To the north side of the area of influence on the road that from Pedregal leads to Pilcuan Viejo the Lavas unit (TQvl) emerges forming the Caldera de Imués that still conserves the volcanic morphology. The different flows tend to have tabular forms, commonly resting in the valleys of the Sapuyes and Guáitara rivers, modeling an abrupt topography, consisting of very narrow, deep and staggered V valleys. They are intercalated with other lava flows or with flow pyroclastic deposits and are generally presented as massive and block lavas. Generally in the contact between these two types of materials (lavas and pyroclasts) are outcrops of groundwater either by natural cause (Manantiales) or by artificial cause (anthropic upheaval due to the cut of the national road)**Photo 5.94**).

Photography 5-94 A) Panoramic steep slopes formed by the Lavas TQvl unit in the Pilcuán sector, b) characteristic spring in the contact between pyroclasts and lavas, c) outcropping of water in the cut of the national road "anthropic upwelling - in fractured lavas ", D) upwelling of water in the cut of the national road" anthropic upwelling - in the contact between pyroclasts and lavas ".

Source: GEOCOL CONSULTORES SA, 2017. Vereda Pilcuán - Municipality of Imués, E: 956461, N: 605540.

In the lower parts of the slopes alluvial sediments are associated with the main channels of rivers and ravines that drain the area, where their extent and thickness are inversely proportional to the depth and narrowness of the generated valley, so that in the valleys in V incised And closed decimetric thicknesses are generated covering areas smaller than one meter; While in the wider V valleys, the thicknesses are metric and the areas covering these sediments are more than 50 m on average (**Photography 5.95**). In general, the alluvial deposits consist of subangular to sub-rounded particles (depending on the transport to which they were subjected) ranging from blocks to guijos with or without matrix, of varied lithologic composition that corresponds mostly to the volcanic and volcano-sedimentary rocks that Cover the area where the channel drains.

Photography 5-95 A) Panoramic of the alluvial deposits unit in the narrow valley of the Sapuyes river, b) anthropic upwelling of groundwater in the sector of the old road access to the municipality of Iles, c) upwelling of groundwater in the discharge to the Sapuyes river, D) Sapuyes river at the height of the sector of Pilcuan Nuevo.

Source: GEOCOL CONSULTORES SA, 2017. Vereda Silamag - Municipality of Imués, E: 954933, N: 605120.

There are also Coluvial Deposits (Qc) constituted by angular debris of different sizes, poorly selected and with low matrix content. In general, they are clastosoportados and predominates a unique lithology inside the deposit. These accumulations are recent and continue to present themselves as a result of terrestrial dynamics, climate and anthropic activity; Are related to strong morphological changes, with sectors where rock units are heavily weathered or where rocks have a high degree of fracturing; In these materials is generally young groundwater, ie these local aquifers are generally recharged by direct precipitation over the outcrop area, however, the potentiality of the unit is "Weak" to "Despicable", recording levels Is more than 5.0 meters deep.

Photography 5-96 Characteristic view of colluvial deposits with subterranean water manifestations (piezometer UF2SZ2-S8 sector Tablón Bajo).

Source: GEOCOL CONSULTORES SA, 2017. Vereda Tablón Bajo - Municipality of Iles, E: 955365, N: 600420

- **Hydrogeological Units.**

From the field survey, from the geological, hydrogeological, pedological and geomorphological information evaluation acquired in the present study, a characterization of the existing hydrogeological units in the study area, from the point of view of their capacity to store And to allow the flow of groundwater, in order to identify the presence of aquifers according to their potential and to differentiate them from the impermeable units according to the methodology of homogenous hydrogeological zones of Colombia used by the Colombian Geological Survey (**Table 5.81**).

Table 5.81 General classification of hydrogeological units.

TONALITY	UNITY	AVERAGE SPECIFIC CAPACITY (l / s / m)
A. SEDIMENTS AND ROCKS WITH ESSENTIAL INTERGRANULAR FLOW		
	Continuous aquifers of regional extension, of very high productivity, conformed by quaternary sediments not consolidated of fluvial environment. Free and confined aquifers with water of good chemical quality for human consumption.	Very high Greater than 5.0
	Continuous aquifers of regional extension, of high productivity, conformed by unconsolidated quaternary sediments and tertiary sedimentary rocks, little consolidated of fluvial, glaciofluvial, marine and volcanoclastic environment. Free and confined aquifers with water of good chemical quality for human consumption.	high Between 2.0 and 5.0
	Continuous aquifers of regional extension, of medium productivity, conformed by unconsolidated quaternary sediments and tertiary sedimentary rocks of little river, glaciofluvial, marine and volcanoclastic. Aquifers generally confined to waters of good chemical quality for human consumption.	Half Between 1.0 and 2.0
	Discontinuous aquifers of local extension, low productivity, formed by quaternary sediments and tertiary sedimentary rocks poorly consolidated of lacustrine, colluvial, eolic and marginal alluvial environments. Free and confined aquifers with waters of regular chemical quality for human consumption.	Low Between 0.05 and 1.0

TONALITY	UNITY	AVERAGE SPECIFIC CAPACITY (l / s / m)
B. FLOW ROCKS ESSENTIALLY THROUGH FRACTURES (FRACTURED AND / OR CARSATED ROCKS)		
	Discontinuous aquifers of regional extension, of very high productivity, conformed by sedimentary rocks cretaceous carbonate, consolidated, marine environment. Generally confined aquifers, with waters of good chemical quality for human consumption.	Very high Greater than 5.0
	Discontinuous aquifers of regional extension of regional extension, of high productivity, conformed by clastic sedimentary rocks and carbonated, tertiary and Cretaceous consolidated, of transitional environment to marine. Aquifers confined to waters of good chemical quality for human consumption, usually hard.	high Between 2.0 and 5.0
	Continuous aquifers of regional extension, of average productivity, conformed by sedimentary and volcanic rocks pyroclastic, marine and continental environment. Free and confined aquifers with waters of good chemical quality. Thermal sources associated with tectonics are often found.	Half Between 1.0 and 2.0
	Discontinuous aquifers of regional and local extension, of low productivity, conformed by sedimentary and volcanic rocks, tertiary to paleozoic consolidated, of marine and continental environment. Aquifers generally confined to waters of good chemical quality for human consumption.	Low Between 0.05 and 1.0
C. SEDIMENTS AND ROCKS WITH LIMITED TO NO RESOURCE OF UNDERGROUND WATERS.		
	Complex of sediments and rocks with very low productivity, constituted by unconstrained quaternary deposits of lacustrine, deltaic and marine environments, and by sedimentary rocks from Cretaceous to poorly consolidated to very consolidated, of continental or marine origin. They store regular water to very poor chemical quality for human consumption, usually salted in coastal regions.	Very low Less than 0.05
	Complex of igneous metamorphic rocks with very low to no productivity, very compact and sometimes fractured, tertiary to precámbricas. Thermal sources associated with tectonics are often found.	Very Low to None Less than 0.05
	Regions composed of clay deposits or beaches with salt water.	Very Low to None Less than 0.05

Source: (INGEOMINAS 2000).

The classification of the geological units was made taking into account four groups namely:

- Aquifer: Geological unit capable of storing water and transmitting it, with good conditions of permeability and porosity.
- Acupuncture: They are very low permeability rocks that store water but do not allow the flow of it in significant quantities. The term aquitard applies to rocks that store water but only allow the movement of groundwater in very small quantities, considered negligible.
- Water: can store water in large quantities, but it does not have the possibility to transmit it and drain with great difficulty. In hydrogeology they are assumed as waterproof.
- Acuifugos: Formations incapable of storing and transmitting water, are shown as impermeable unless they excite fractures that can emit flows.

The main units in which the area of study can be divided from the hydrogeological point of view are listed in the **Table 5.82**, And are displayed on the **Figure 5.82 And in the Cartographic Annex, Map No. 18. Hydrogeology**.

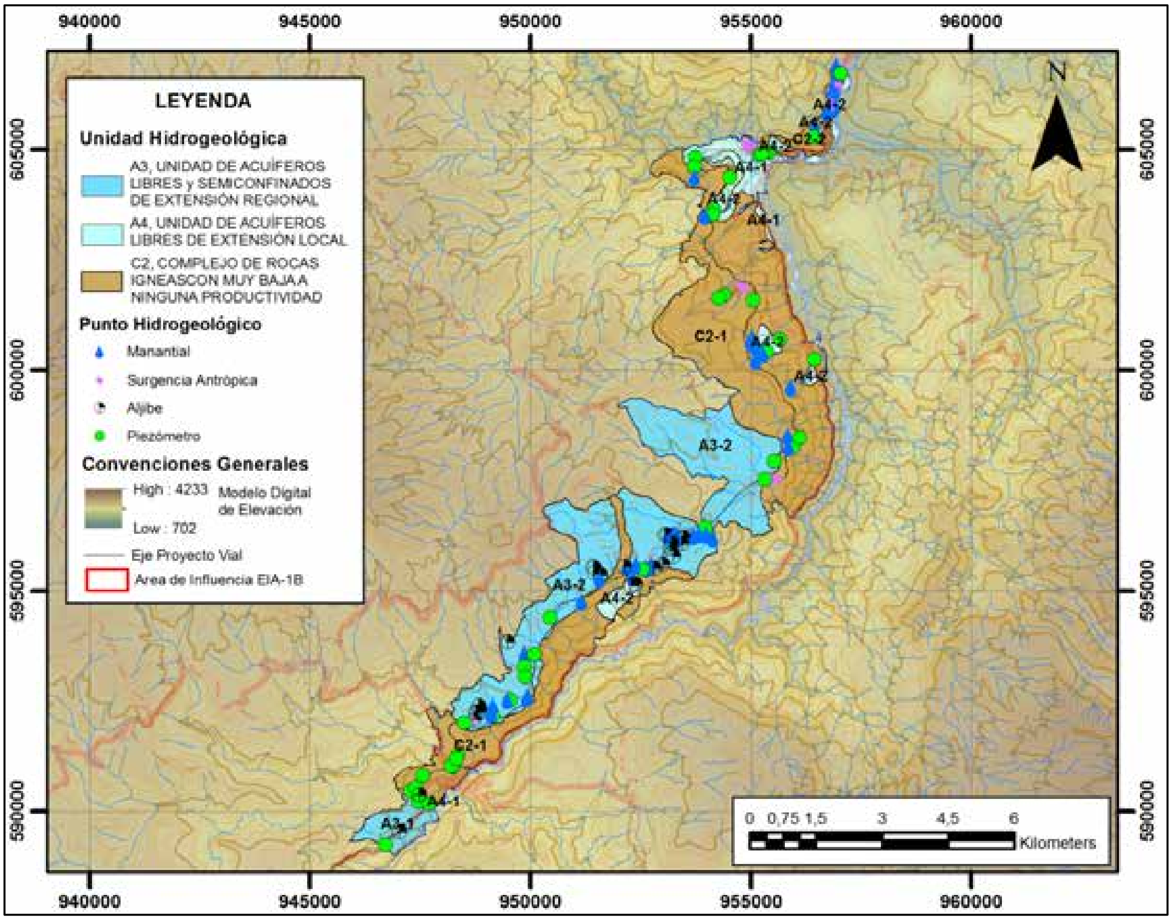
Table 5.82 Classification of hydrogeological units in the local context.

Type of Unit	Convention	PROPERTIES	GEOLOGICAL FORMATION	CHARACTERISTICS HYDROGEOLOGICAL
A. SEDIMENTS AND ROCKS WITH ESSENTIAL INTERGRANULAR FLOW		**UNIT OF FREE AND SEMICONFINED AQUATICS OF REGIONAL EXTENSION - A3**		
	A3-1	Storage capacity	Ash deposits of Rumichaca - Qdcr Intergranular geological units. Constituted by alluvial sediments, volcanoclastic and sedimentary rocks little consolidated continental.	Continuous aquifers of regional extension, of medium to low productivity, with essentially intergranular flow. They are sedimentary deposits formed mainly by gravel and sand and volcano-sedimentary deposits composed of sand, sandy silts and rock fragments of volcanic extrusive origin and flows with intercalations of falling pumitas, conformed by volcanic glass, quartz, micas and amphiboles.
		HIGH / MEDIUM		
		Permeability		
		HALF		
		Transmitting Capacity		
		MIDDLE-LOW		
		Average specific capacity (l / s / m)		
		Low - Medium Between 0.05 and 2.0		
	A3-2	Storage capacity	Residual Soil and Saprolite of Lavas and Piroclastos - NQlp Intergranular geological units. Made of weathered vulcanoclastic materials.	Continuous aquifers of regional extension, of medium to low productivity, with essentially intergranular flow. Soil and saprolite soils formed by the weathering of lava rocks and neogene age pyroclasts. The potentiality of the aquifer is "weak", limited by the thickness of the weathered horizons and granulometric constitution
		HIGH / MEDIUM		
		Permeability		
		MIDDLE-LOW		
		Transmitting Capacity		
		LOW / VERY LOW		
		Average specific capacity (l / s / m)		
		Low - Medium Between 0.05 and 2.0		
		UNIT OF LOCAL EXTENSION FREE AQUATICS - A4		
	A4-1	Storage capacity	Aluvial Reservoir - Qal Intergranular geological units. Constituted by alluvial sediments not consolidated.	Discontinuous aquifers of local extension, of low productivity and with essentially intergranular flow. They are sedimentary deposits formed mainly by gravel and sand; Its extension and thickness are inversely proportional to the depth and narrowness of the valley generated by the river channels.
		HIGH / MEDIUM		
		Permeability		
		HALF		
		Capacity of To transmit		
		HALF		
		Average specific capacity (l / s / m)		
		Low Between 0.05 and 1.0		
	A4-2	Storage capacity	Coluvial Deposit - Qc Intergranular geological units. Consisting of unconsolidated outstanding deposits.	Discontinuous aquifers of local extension, of low productivity and with essentially intergranular flow. They are deposits formed mainly by blocks of rock of varied size embedded in argillaceous silt matrix; Its extension and thickness are variable, are recharged by direct precipitation over the
		HIGH / MEDIUM		
		Permeability		
		LOW		
		Capacity of To transmit		

Type of Unit	Convention	PROPERTIES	GEOLOGICAL FORMATION	CHARACTERISTICS HYDROGEOLOGICAL
C. SEDIMENTS AND ROCKS WITH LIMITED TO NO RESOURCE OF UNDERGROUND WATERS.		LOW / VERY LOW		outcrop area, the potentiality of the unit is "weak" to "negligible", the recording of static levels is more than 5.0 meters deep.
		Average specific capacity (l / s / m)		
		Low Between 0.05 and 1.0		
		C. COMPLEX OF VERY LOW ENGINE ROCKS AT ANY PRODUCTIVITY, VERY COMPACT AND IN FRACTURED OCCASIONS C2		
	C2-1	Storage capacity	Lavas and pyroclasts (NQlp) Lava spills and fresh flow and fall pyroclastic deposits, with abrupt to steep morphology	Generally it forms aquifers in a fresh state, however, in areas of active geotectonics, discontinuous aquifers of local extension, of low productivity with flow through fractures (porosity and secondary permeability) can be formed. The potentiality of the unit is "negligible" and very low permeability.
		MIDDLE-LOW		
		Permeability		
		LOW / VERY LOW		
		Capacity of To transmit		
		LOW / VERY LOW		
		Average specific capacity (l / s / m)		
		Very Low to None Less than 0.05		
	C2-2	Storage capacity	Lavas (tQvl) They are intercalated with other lava flows or with flow pyroclastic deposits and are generally presented as massive and block lavas. The main structures shown by the different flows are laminar flow fracturing in plastic or semi-solid state and columnar fracturing by cooling	Generally it forms aquifers in a fresh state, however, in areas of active geotectonics, discontinuous aquifers of local extension, of low productivity with flow through fractures (porosity and secondary permeability) can be formed. It is also possible to find groundwater in sectors of contact between recent pyroclastic deposits and ancient lava flows. However, the potentiality of the unit is "negligible" and very low permeability.
		MIDDLE-LOW		
		Permeability		
		LOW / VERY LOW		
		Capacity of To transmit		
		LOW / VERY LOW		
		Average specific capacity (l / s / m)		
		Very Low to None Less than 0.05		

Source: GEOCOL CONSULTORES SA, 2017.

Figure 5.81 Hydrogeological map of the area of influence.



Source: GEOCOL CONSULTORES SA, 2017.

From the point of view of the specific capacity and according to the guidelines of the Hydrogeological Atlas of Colombia, the units identified are described below:

o **Type A. Sediments and rocks with essentially intergranular flow.**

§ **Rumichaca Ash "A3-1" Aquifer.**

The aquifer is formed by volcano-sedimentary deposits that belong to several generations of sandy and silt-sandy sediments, with intercalations of falling pumitas. The thickness of this sequence can reach 200 m in the canyon of the river Guáitara, south Ipiales. It rests discordantly on Lavas and Piroclastos of the neogen (NQlp), to which, generally, it is assigned the degree of aquitard.

This aquifer contains water predominantly under free to semi-confined conditions, locally it can behave as confined, due to very compact clay or ash intercalations. The static levels in this aquifer range from 6 to 30 m and the production flows are very low with an average of 1 l / s. The transmissivity fluctuates from 0.01 to 10 m2 / day with storage coefficients of 1.0 E^{-01} Up to 1.0 E^{-05}, Indicating the development of free to semi-finite aquifers with weak to negligible potentiality.

For the calculation of the resources and passive reserves at the forecast level in this aquifer the following data were used for the total unit: transmissivity (T) of 10 m2 / d, hydraulic gradient (i) of 0.02 and width of current B) of 1500 m (along the road project the direction of preferential flow is perpendicular to the axis of the road); In the passive reserves were used: area of 1363528 m2, thickness of 200 m and an effective porosity of 0.21. The results of these calculations were: resources of 0.1095 Mm3 / year (millions of cubic meters a year) corresponding to the horizontal recharge, and passive reserves of 57 Mm3 (million cubic meters). Taking into account the results of Hydroclimatic Balance carried out by INGETEC (2016) The estimated infiltration in the section of the UF1 is 38.5 mm per year, which corresponds to 3.5% of the average annual precipitation, that is, that for the area of influence is estimated a total vertical recharge of the order Of 0.056 Mm3 / year. The current extraction of the aquifer is estimated in the order of 4 LPS = 0.12 Mm3 / year used to cover domestic and agricultural supply needs mainly. Therefore, the change in aquifer storage is in the order of 0.0358 Mm3 / year, part of which is discharged to the river currents at the bottom of the slopes.

§ **Aquifer Residual Soil and Saprolite of Washes and Pyroclasts "A3-2".**

The aquifer is formed by pyroclastic deposits of flow and fall that are generally in an advanced state of weathering. The thickness of this sequence can reach 30 m in the highland sector. This aquifer contains water predominantly under free to semi-confined conditions, locally it can behave as confined, due to very compact clay or ash intercalations. The static levels in this aquifer range from 1 to 10 m and the production flows are very low with an average of 1 l / s. The transmissivity fluctuates from 0.01 to 10 m2 / day with storage coefficients of 1.0 E^{-01} Up to 1.0 E^{-05} And weak to negligible potentiality.

For the calculation of the resources and passive reserves at the forecast level in this aquifer, the following data were used for the total unit: transmissivity (T) of 5 m2 / d, hydraulic gradient (i) of 0.02 and width of current B) of 11000 m (along the road project the direction of preferential flow is perpendicular to the axis of the road); In the passive reserves were used: area of 13703920 m2, thickness of 30 m and an effective porosity of 0.18. The results of these calculations were: resources of 0.4015 Mm3 / year (millions of cubic meters a year) corresponding to the horizontal recharge, and passive reserves of 74 Mm3 (million cubic meters). Taking into account the results of Hydroclimatic Balance carried out by INGETEC (2016) The estimated infiltration in the section of the UF2 is 20.9 mm per year, which corresponds to 1.9% of the average annual precipitation, that is, that for the area of influence is estimated a total vertical recharge of the order Of 0.286 Mm3 / year. The current extraction of the aquifer is estimated in the order of 20 LPS = 0.63 Mm3 / year used to cover domestic and agricultural supply needs mainly. Therefore, the change in aquifer storage is of the order of 0.057 Mm3 / year, part of which is discharged to the river currents at the bottom of the slopes.

§ **Aquifer Alluvial Reservoirs "A4-1".**

The aquifer is composed of subangular to sub-rounded particles (depending on the transport to which they were subjected) ranging from blocks to guijos with or without matrix, of varied lithologic composition corresponding mostly to the volcanic and volcano-sedimentary rocks that cover the area Where the channel drains. Its extension and thickness are inversely proportional to the depth and narrowness of the generated valley. Therefore, for purposes of analysis, this unit is negligible, since its outcrops are limited mainly to the narrow valley of the River Guitara, where also no groundwater catchment points were identified, although there may be natural upwellings corresponding to the discharge of Aquifers to river systems.

§ **Aquifer Coluvial Reservoirs "A4-2".**

The aquifer is formed by blocks of various sizes embedded in sandy and clay silty matrix, of varied lithologic composition corresponding mostly to volcanic and volcano-sedimentary rocks that cover the area where the channel drains. Its extension and is variable, are recharged by direct precipitation over the outcrop area, the potentiality of the unit is "Weak" to "Despicable", the recording of static levels is more than 5.0 meters deep.

o **Type C. sediments and rocks with limited to no groundwater resources.**

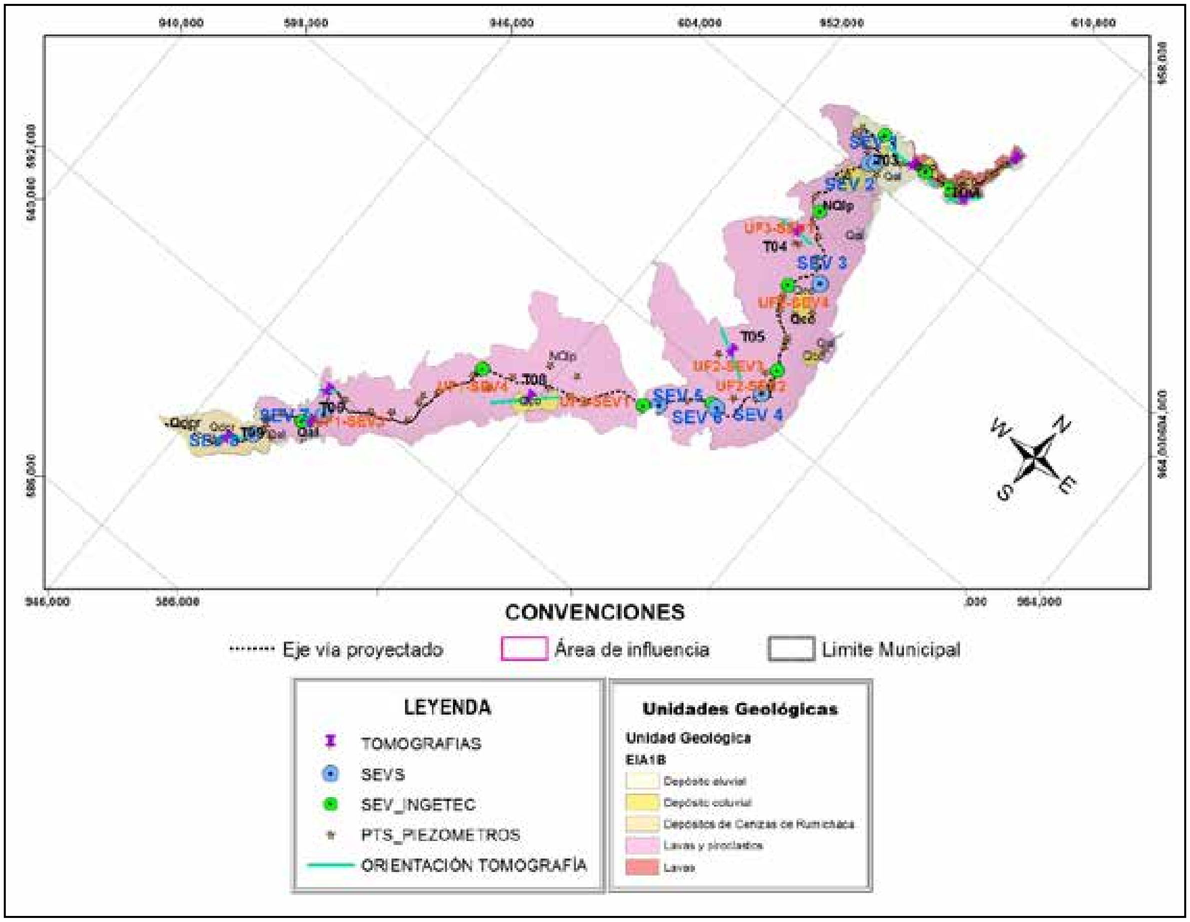
§ **Aqueous Lavas and Pyroclasts (NQlp) "C2-1" and Lavas (TQvl) "C2-2".**

Complex of rocks of igneous origin with very low to no productivity, very compact and sometimes fractured, tertiary to neogenous. Groundwater outcrops are occasionally found in particular sectors where some recent pyrocalstic deposits rest on lava materials, and where the lavas in question have a high degree of fracturing.

· **Geometric model of aquifers.**

Within the information available for the realization of the geometric model of aquifers, there were seismic exploration images, mechanical drilling registers, indirect subsoil explorations by SEV Electrical Vertical Surveys and continuous electric tomographies, together with field control from Surface data (**Figure 5.83**).

Figure 5.82 Underground exploration map.



Source: GEOCOL CONSULTORES SA, 2017.

Below is how the secondary information and the information collected in the present study were processed, analyzed and implemented.

o **Results of direct exploration of the subsoil (Secondary information).**

In the geotechnical prospecting plan carried out by the SH Consortium (2016), it considers the information from previous phases to the project and obtained from the observation of the current and adjacent road cuts. The information coming basically consists of the results of mechanical probes, pips and refractive seismic profiles.

The surveys carried out previously allow us to know in the first instance the lithology of the subsoil, and secondly, they allow to carry out a monitoring of the static levels of the water since they installed piezometers type Casagrande (Table 5.83).

Table 5.83 Summary of Perforations performed in the geotechnical exploration stage.

Drill Name	East Coordinate	North Coordinate	Depth (m)	Water table Reported (m)	Groundwater Level Monitored (feb_2017) (m)	Geological Unit
UF2SZ2-8	955365	600420	15	Dry	6.4	Coluvial Deposit
UF2SZ2-11	954393	601703	15	Dry	0.3	Lavas y Piroclastos
UF2SZ2-12	954269	601640	10	2	3.6	
UF2S13	955062	601588	38	Dry	33.05	
UF2S6	955317	597528	25	Does not report	4.63	
UF2S8	955970	598267	20	Does not report	19.05	
UF2S9	956109	598479	55	Does not report	18	
UF-S26	948200	591025	27	Does not report	21.5	

Source. Modified by Grupo Prointec and Jorge Fandiño SAS 2016 Infrastructure

Towards the northeast of the area of influence (Km 42 - Km 45) the perforations in general investigated the Lavas unit, which are presented as massive and block lavas. Most of the samples were found to be dry, with groundwater levels monitored after 33.05 m.

In contrast, towards the northwest (km40 - km42) some piezometers investigated layers of Coluvial and Alluvial deposits corresponding to poorly selected, clastosoporate and oligomictic gravels. The groundwater levels found during monitoring for these units are between 5 and 10 meters deep.

The geological unit that defines the southern zone of the area of influence corresponds to Lavas and pyroclasts (NQlp), Grupo Prointec and Jorge Fandiño Infraestructura SAS (2016) do not report the presence of water tables in these perforations; Likewise, with the current monitoring (February 2017) the vast majority of piezometers were found to be dry.

- **Seismic exploration results (Secondary information).**

The exploration report made by Ulloa & Diez Ltda. (2016), contains the results of the Seismic Refraction tests carried out in the Ipiales -Pasto road corridor, in the department of Nariño. The exploration was oriented both to the acquisition of basic information of the subsoil as depths and thicknesses of the layers, form of the contact between layers and continuity or discontinuity of the interpretative model, as well as the obtaining of basic seismic parameters such as the compressional and cutting speeds Of each layer (**Table 5.84**).

Table 5.84 Seismic lines in the area of influence.

LINE REHEARSED	LINE EXECUTED				LITOLOGICAL UNIT
	HOME SECTION		FIN SECTION		
	AND	N	AND	N	
SEG_RUMICHA_PS-Z1B3-1	950042.69	592018.00	950051.30	591958.64	N2-Vi
SEG_RUMICHA_PS-Z1B7-1	950824.82	593082.06	950873.49	593065.83	N2-Vi
SEG_RUMICHA_PS-Z1B7-2	950990.40	593218.36	951037.64	593189.22	N2-Vi

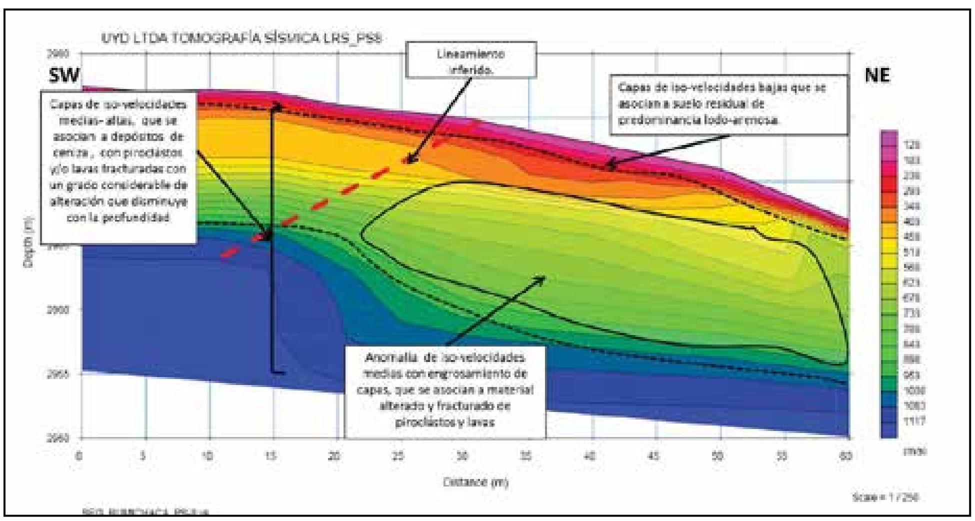
LINE REHEARSED	LINE EXECUTED				LITOLOGICAL UNIT
	HOME SECTION		FIN SECTION		
	AND	N	AND	N	
SEG_RUMICHACA_PS-Z1B4-1	950336.00	592141.00	950332.00	592081.00	N2-Vi
SEG_RUMICHACA_PS-3	947152.93	589623.99	947258.92	589647.75	N2-Vi
SEG_RUMICHACA_PS-4	947550.98	590021.86	947560.77	590132.36	N2-Vi
SEG_RUMICHACA_PS-5	947561.98	590187.16	947578.04	590134.17	N2-Vi
SEG_RUMICHACA_PS-6	948255.00	592067.00	948315.00	592070.00	N2-Vi
SEG_RUMICHACA_PS-7	950746.00	594874.00	950804.00	594887.00	N2-Vi
SEG_RUMICHACA_PS-8	950933.00	594903.00	950992.00	594912.00	N2-Vi
SEG_RUMICHACA_PS-9	951535.00	595048.00	951627.00	595124.00	N2-Vi
SEG_RUMICHACA_PS-Z1B2-1	949161.00	592414.00	949207.00	592524.00	N2-Vi
SEG_RUMICHACA_PS-Z1B6-1	949811.00	593358.00	949911.00	593424.00	N2-Vi

N2-Vi: Fluxes of lavas and ignimbrites of andesitic composition

Source. Modified Ulloa & Diez, 2016

Ulloa & Diez according to their interpretation determine that for this functional unit there are two mainly geological units, one layer of ash deposits and lapilli altered and another layer consisting of lavas and ignimbritas, its definition is correlated with the cartography made by this study Corroborating the definition of the units of lava and pyroclasts. According to the anomalies of the isovelocities found through each seismic line the lithological changes are evidenced, as example the contrasts identified in the Seismic Line PS8 in the **Figure 5.84**.

Figure 5.83 Example of profile Seismic Line PS8.



Source. Ulloa & Diez, 2016.

In general, all the seismic sections surveyed in this section show a homogeneity in the contrast of materials, showing surface layers with poorly consolidated materials (weathered materials) on more competent levels associated with ash deposits with little degree of compaction and considerable degree of alteration, or Igneous rocks in fresh condition.

- **Results of geoelectric prospecting - 1D (Secondary information).**

INGETEC, in 2016, carried out the Hydrogeological Analysis of the Rumichaca - Pedregal Road Project. For this purpose, I carried out 12 vertical electrical surveys (SEV) with AB stretches between 200 and 250 m and distributed in the 3 functional units, thus obtaining information on the resistivities Up to 50 m deep. Ten (10) of this group of SEVs are part of the area of influence of the present study, which are listed below, together with the summary of the interpretation made by the firm in mention to detect the water table.

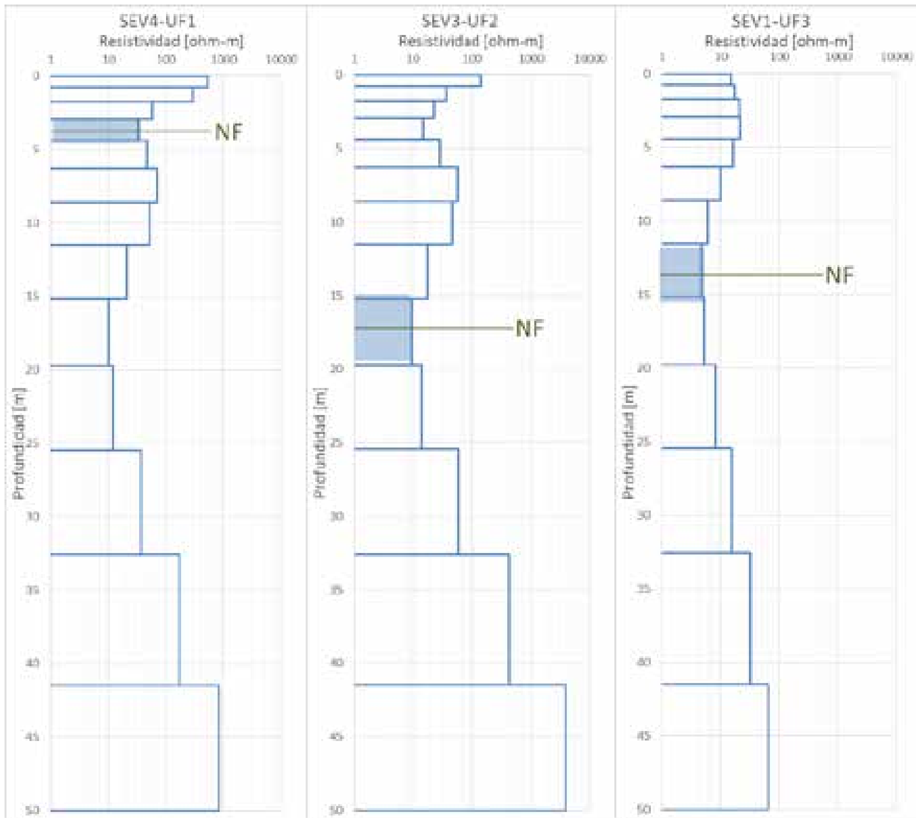
Table 5.85 Vertical Electrical Surveys Coordinates - INGETEC.

Functional Unit	Test	COORDINATES		Water table detection			
		NORTH	EAST	Resistivity OHM / M	PROF (m)	ZONE	Geological Unit
UF1	UF1-SEV3	590933,0	948050,0	20	3	Vadosa	Ashes of Rumichaca (Q1dcr)
	UF1-SEV4	594621,7	950530,8	50	5	Vadosa	
UF2	UF2-SEV1	596404,5	954012,3	30	3	Vadosa	Lavas and pyroclasts (NQlp) and deposits pyro clastic sand slime
	UF2-SEV2	597485,1	955220,3	20	6	Vadosa	
	UF2-SEV3	599080,0	955905,0	10	17	Permeable	
	UF2-SEV4	600807,3	954802,5	80	6	Vadosa	
UF3	UF3-SEV1	602625,0	954260,0	8	14	Permeable	Colluvial deposits (Qc)
	UF3-SEV2	604986,2	954282,8	20	17	Permeable	
	UF3-SEV3	604956,0	955578,0	80	45	Permeable	Andesites and Lavas (NQlp)
	UF3-SEV4	604995,0	956235,0	80	45	Permeable	

Source. Modified INGETEC 2016.

The **Figure 5.85** Shows the geoelectric sections elaborated by INGETEC (2016), these allow to define a contrast between the layers of smaller and greater depth taking into account the differentiation of resistivities to layers that are saturated; In general there are resistivities between 10 and 1000 ohm-m, the lowest associated with soils and unconsolidated deposits of sandy matrix which favor saturation.

Figure 5.84 Example of geoelectric sections Raised by INGETEC in 2016.

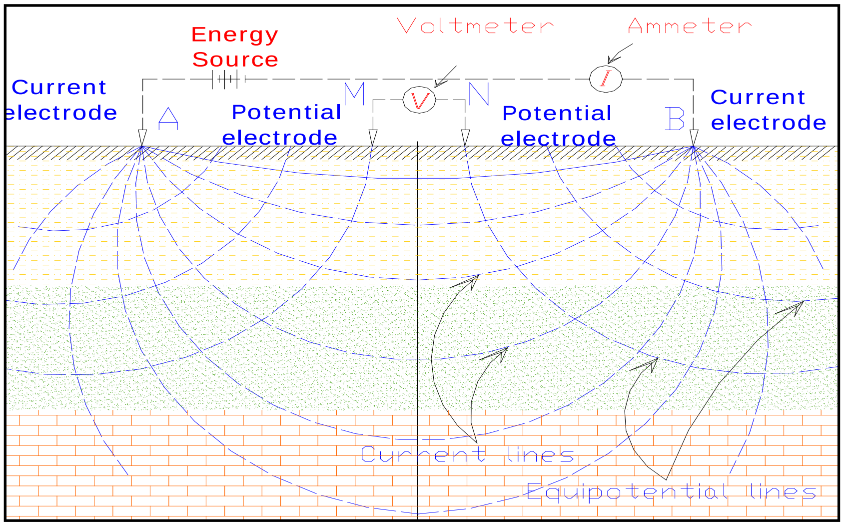


Source. INGETEC 2016

o **Geoelectric prospecting results - 1D (Primary information)**

The "SEV" Vertical Electrical Probing method presents the changes of resistivity of the rocks in depth under the measuring center at the same point. To make a SEV the most used device is the Schlumberger type (**Figure 5.86**), Which consists of an arrangement of four electrodes. To this effect an external source is used to generate current that is introduced to the subsoil through the electrodes A and B, this current generates a field of potentials, the difference of potentials is measured between the electrodes M and N. The investigated depth is related With the distance of the electrodes A and B. The reading of current (I) and of the potential difference (ΔV) allows to calculate the resistance (R).

Figure 5.85 Schlumberger Arrangement.



Source: GEOCOL CONSULTORES SA, 2017.

According to Ohm's law:

$$R = \frac{\Delta V}{I}$$

For a homogeneous medium, the resistivity (r) Is obtained by multiplying the resistance (R) by a geometric coefficient (K).

$$\rho = KR$$

For the Schlumberger device, this coefficient is calculated as:

$$K = \pi \frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN}$$

Where:

$$\rho_a = K\frac{\Delta V}{I}$$

The methodology applied in SEVs basically comprises the acquisition of data in the field, the processing of the information and the interpretation of the data.

§ **1D Geoelectric Acquisition.**

For the data acquisition of resistivity by means of Vertical Electrical Probes (SEV's), the equipment USER TERRAMETER SAS 1000 (**Photo 5.97**). The 1D geophysical exploration included eight (8) vertical electrical probes, the distribution of which was assigned by the Hydrogeologist Wilson Patiño, with a 200 m AB / 2 sounding, and locating by means of a Garmin Dakota GPS (**Table 5.86**).

Photography 5-97 Execution of SEV2 -EIA1A with measuring equipment TERRAMETER SAS 1000.

Source: GEOCOL CONSULTORES SA, 2017. Vereda Pilcuan - Municipality of Imués, E: 954540, N: 604363

Table 5.86 Geographical location of the SEVs executed.

SEV	X	Y
SEV 1	954540	604363
SEV 2	954423	604245
SEV 3	955378	601322
SEV 4	955995	598437
SEV 5	955391	597493
SEV 6	954298	596655
SEV 7	948370	591376
SEV 8	947382	589971

Source. GEOCOL CONSULTORES SA, 2017.

The resistivity value obtained for a given distance between current electrodes in a layered medium of a sequence of layers having different lithology is influenced by the different horizons traversed by the current flow, thus obtaining values of resistivity Apparent against the distance AB / 2.

It is important to mention that the geoelectric exploration does not include an analysis of the total thickness of the aquifers, the interpretation performed in depth is defined taking into account 1/3 of the research opening (AB = 400 meters), therefore, the geoelectric information For this study is reliable up to 133 meters deep.

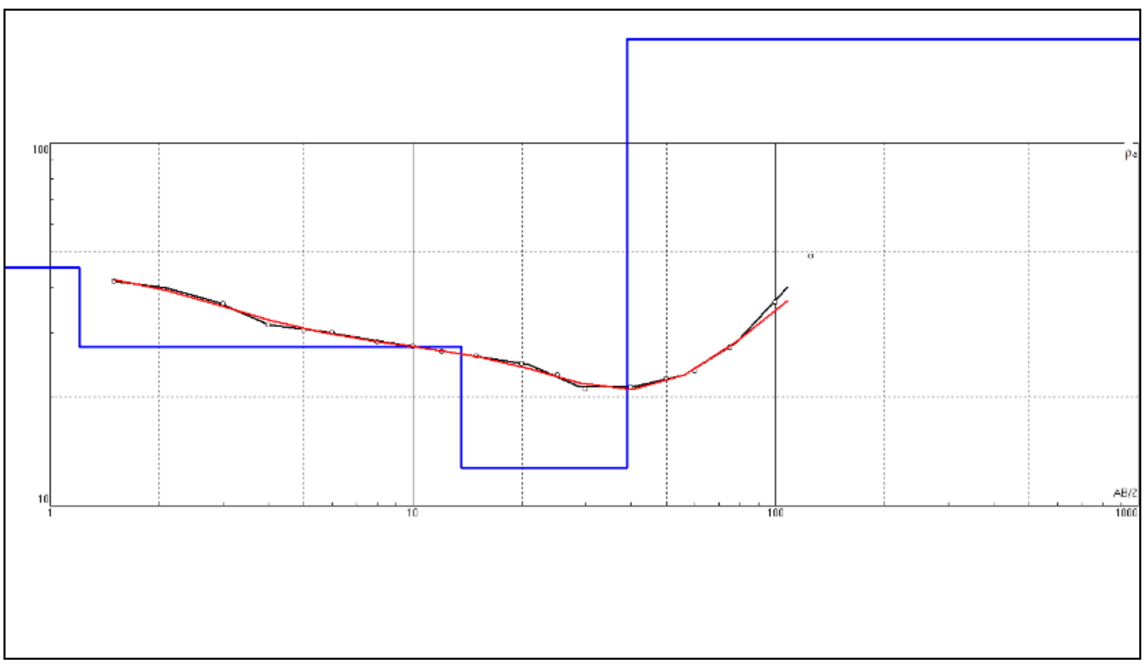
§ **Interpretation of vertical electric soundings.**

The resistivity obtained from a field test or vertical electrical survey (SEV) is actually an apparent resistivity, taking into account that the subsoil is not homogeneous, neither linear nor isotropic. The next step is to perform the inversion of the data obtained in the field.

During the processing of the information, the field data of the SEV (AB / 2 against ra) are inserted in logarithmic paper. The field curves previously interpreted by comparison with abacuses are currently processed by specialized software. These programs are generally based on the solution of inverse problems, which consists of calculating the ra for each distance AB / 2 of a synthetic layer model. To this model, the thickness of the layer and the value of ra are changed to obtain a concordance of the ra value measured in the field, with the value of ra calculated in the synthetic layer model.

The curves obtained in the field are subjected to the adjustment process of the splices presented by varying the MN distance, then read the new apparent resistivity values defined and are taken to a spreadsheet, which in turn is inserted in the program Of interpretation IPI2win, for each survey is entered a hypothetical model and then it is refined by means of mathematical processes, adjusting the curve until reaching a value of maximum precision and obtaining the definitive model of the previous analysis the resistivity curves are obtained (**Figure 5.87**).

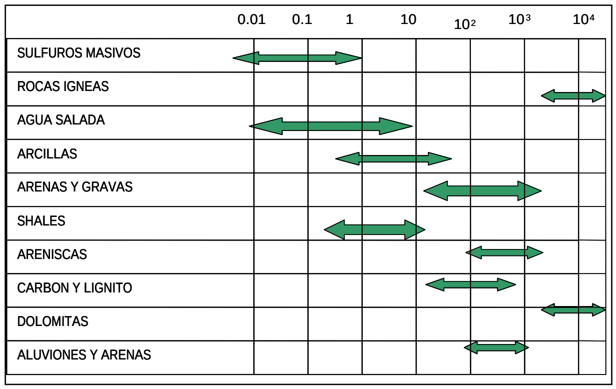
Figure 5.86 Example of interpretation of SEV06 EIA1B - Error of 2.73% in the calibration of the data.



Source. GEOCOL CONSULTORES SA, 2017.

Taking into account the typical behavior of various kinds of lithologies in Ohm - meters, the different lithological layers that took place in the geo - electric interpretation were defined, as shown in **Figure 5.88.**

Figure 5.87 Typical Resistivity Ranges (Ohms-Meter) for different materials.



Source: Http://www.ncwater.org/Education_and_Technical_Assistance/Ground_Water/Analysis}.

Table 5.87 Description of identified lithologic levels In geoelectric exploration.

CAP	RANGE OF RESISTIVITY	DESCRIPTION
LITHOLOGY 1	Up to 28 Ohm-m	Clays, silts and saturated ash
LITHOLOGY 2	Up to 50 Ohm-m	Colluvial deposit in sandy matrix and partially saturated tuffs
LITOLOGY 3	50 to 200 Ohm-m	Sand-sized pyroclasts and ash
LITHOLOGY 4	Greater than 200 Ohm-m	Andesitas - Lavas y Piroclastos

Source. GEOCOL CONSULTORES SA, 2017.

The layer defined as *Litología 1,* Presents a range of resistivities up to 28 Ohm-m And consists of ashes of clayey and silty matrix, usually associated with saturated materials.

The layer defined as *Litología 2,* Has been associated with deposits of sand and partially saturated tuff, generally corresponds to deposits in sandy loam matrix. It is also associated with colluvial deposits.

The *Litología 3,* Which corresponds to resistivity range between 50 and 200 Ohm-m, is associated with pyroclasts and ash as saturated sand.

The *Litología 4,* Evidence values higher than 200 Ohm-m, corresponds to pyroclasts with higher degree of consolidation and fresh lavas.

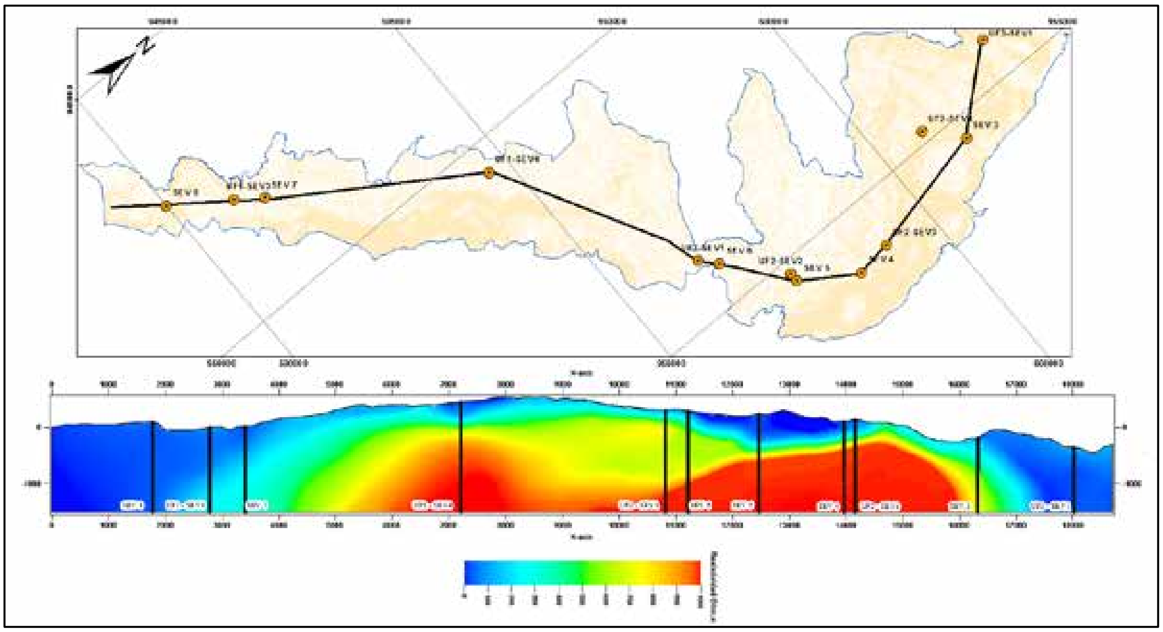
In general the four layers are determined by partially saturated to saturated lavas and pyroclasts, characterizing and corroborating the surface geological unit (Lavas and Piroclastos NQlp), which is also evident both in the results of direct exploration of the subsoil and in the results Of antecedent indirect exploration.

§ **Horizontal continuity - 2D (longitudinal sections from correlation of SEVs)**

The following is a section of correlation of vertical electric soundings elaborated within the area of influence, from the geophysical prospecting program described above. This section shows the variation of materials in depth as a function of the electrical resistivity; The cold color range (violet-blue) represents the lowest resistivity values, warm tones (yellow-red) are the highest.

In general terms, the best aquifer conditions are detected in the southwest of the area of influence, which is valid considering the results of direct exploration of the subsoil and concentration of groundwater points in this sector (Km20-Km30).

Figure 5.88 Longitudinal correlation of vertical electrical probes.

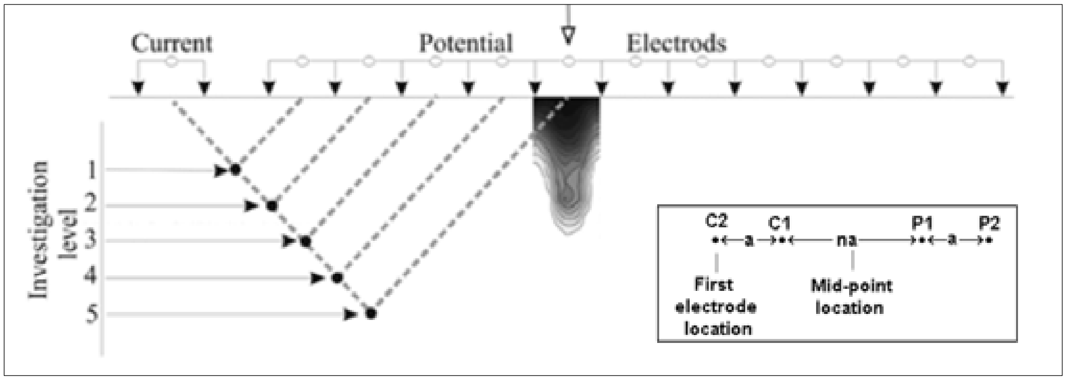


Source. GEOCOL CONSULTORES SA, 2017.

§ **Horizontal Continuity - 2D (Continuous Electrical Scans).**

In recent times this geoelectric technique has advanced significantly. It is based on a Dipole-Dipole configuration generating 2D and 3D modes. It consists of obtaining a series of measurements of apparent resistivity with a defined tetraelectronic device and with a constant separation between the electrodes denominated "to". Then the distance between pairs of emitter-receiver electrodes is multiplied by an integer value called "na", so the end result will be a cut with multi-level "n" depth gauges.

Figure 5.89 Dipole-Dipole Array for continuous electric tomography.



Source. Study of flow in vadose zone from electrical resistivity surveys, Fernando de Morais 2008

The dipole-dipole device has the characteristic of presenting a great resolving power to the presence of lateral geological changes in the subsoil, both structural, fault, diaclases, fractures, as well as lithologic and sedimentary, for example, paleocauces.

The results are turned into pseudo profiles which show the distribution of apparent resistivities by isoresistivity curves. These pseudo sections give a first idea of the existence of "anomalies" and an estimate of their position and depth. But to obtain a real geoelectric distribution representative of the terrain the data must be inverted. In order to achieve this, different inversion codes are used to obtain 2D tomography of the subsoil. The resulting 2D profile shows true resistivities and depths in 2D, which are then usually correlated with available geological information. (**Photography 5.98** Y **Table 5.88**).

Photography 5-98 Performing Tomography 10.

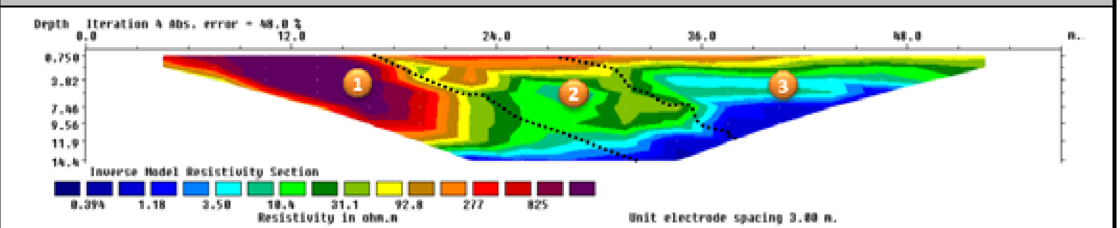
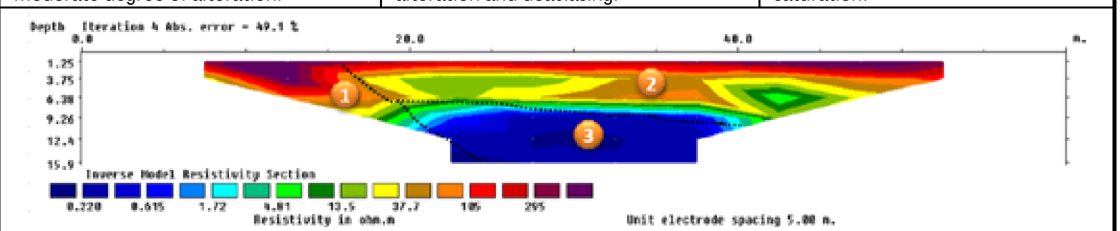
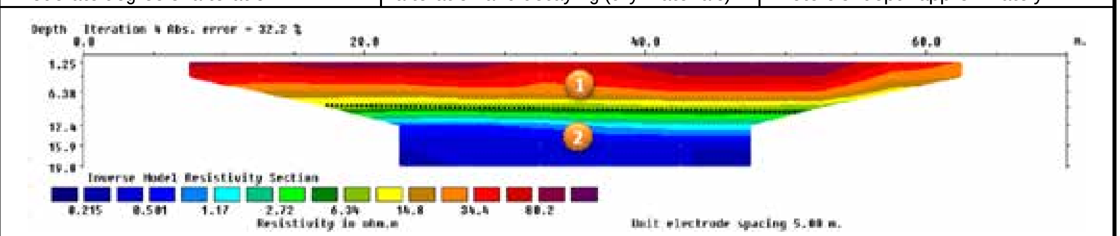
Source. GEOCOL CONSULTORES SA, 2017. Vereda Las Vereda Las Cruces - Ipiales, E: 943585, N: 585673.

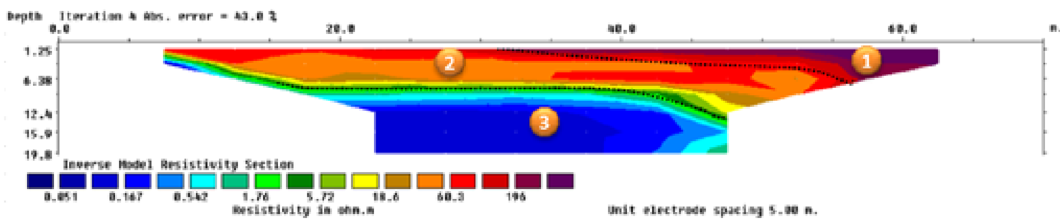
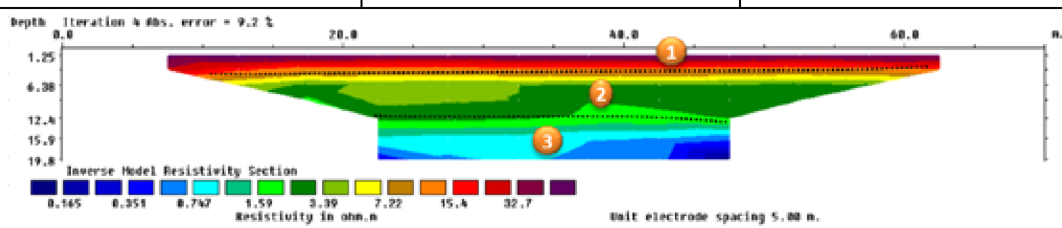
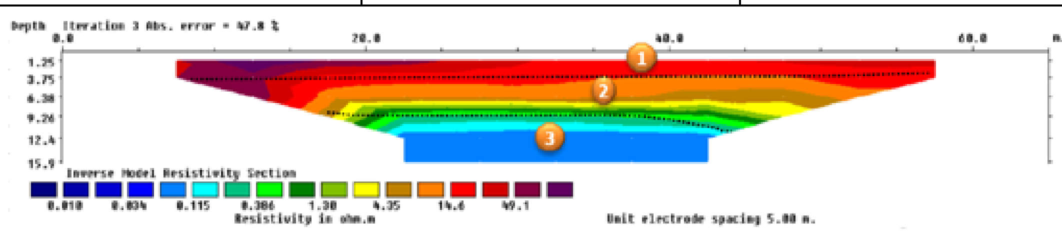
Table 5.88 Location of continuous electrical tomography performed in the area of influence.

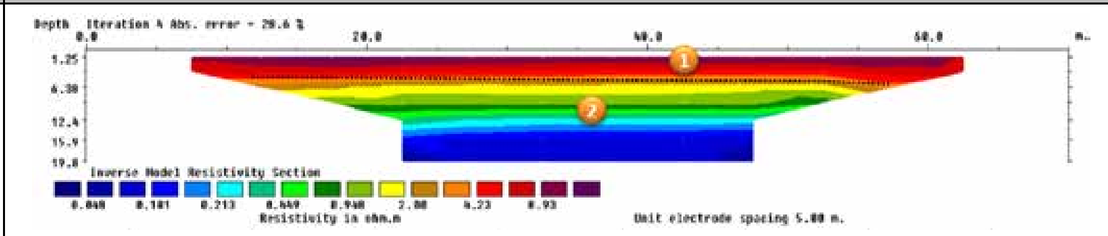
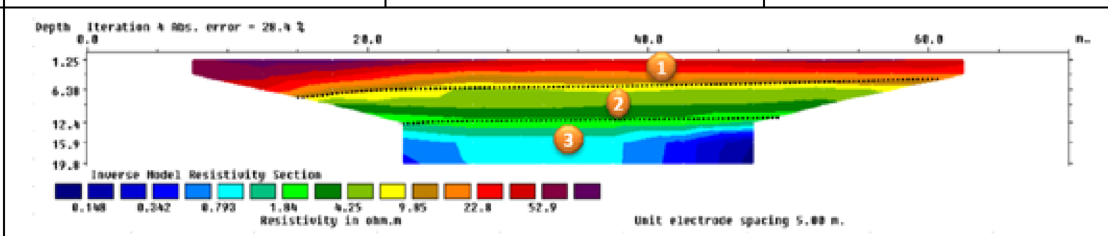
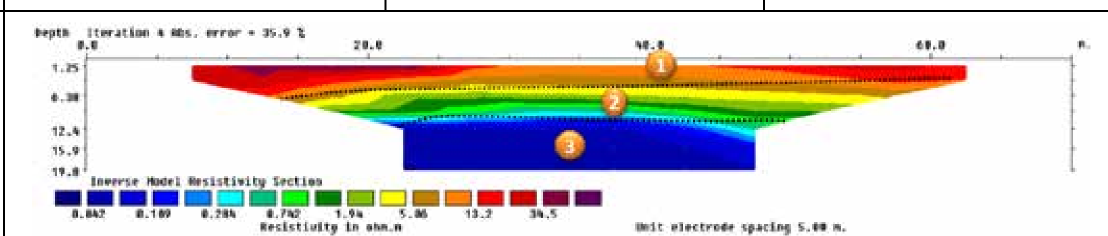
ID	X (initial)	Y (initial)	X (end)	And finally)	Average height (msnm)	Length (m):
Tomography 1	957008	606531	957009	606590	1793	57
Tomography 2	956701	605041	956671	604988	1817	60
Tomography 3	955241	604870	955184	604891	1832	70
Tomography 4	954154	601908	954190	601860	2454	70
Tomography 5	954781	598720	954833	598690	2797	70
Tomography 6	948219	591030	948188	591081	2502	65
Tomography 7	948040	591856	948055	591798	2580	70
Tomography 8	951813	594792	951864	594822	2832	70
Tomography 9	946933	589464	946976	589505	2543	70

Source. GEOCOL CONSULTORES SA, 2017.

Table 5.89 Abstract of interpretation of electrical tomographies.

<table>
<tr><th>#</th><th colspan="3">INTERPRETATION</th></tr>
<tr><td rowspan="2">Tomography 1</td><td colspan="3">
</td></tr>
<tr><td>1. Layers of high isoresistivities that are associated with solid and en bloc Lavas, interspersed with pyroclasts with moderate degree of alteration.</td><td>2. Layers of low isoresistivities - means that are associated with pyroclasts and lava, with a considerable degree of alteration and deaclasing.</td><td>3. Layers of low isoresistivities that are associated with little consolidated pyroclasts, with presence of saturation.</td></tr>
<tr><td rowspan="2">Tomography 2</td><td colspan="3">
</td></tr>
<tr><td>1. Layers of high isoresistivities that are associated with solid and en bloc Lavas, interspersed with pyroclasts with moderate degree of alteration.</td><td>2. Layers of low isoresistivities - means that are associated with pyroclasts and lava, with a considerable degree of alteration and decaying (dry materials).</td><td>3. Layers of low isoresistivities that are associated with pyroclasts with presence of saturation after 10.0 meters of depth approximately.</td></tr>
<tr><td>Tomography 3</td><td colspan="3">
</td></tr>
</table>

<table>
<tr><th>#</th><th colspan="3">INTERPRETATION</th></tr>
<tr><td></td><td>1. Average isoresistance layers (on the order of 80 Ω • m) that are associated with dry alluvial materials; Its lithology is made up of gravels, from block to block size with very variable composition and medium to thick sand matrix.</td><td>2. Layers of low isorescitivities that are associated with saturated alluvial materials; With fine matrix, silt size or clay.</td><td></td></tr>
<tr><td rowspan="2">Tomography 4</td><td colspan="3">
</td></tr>
<tr><td>1. High isoresisivity layers associated with flow and fall pyroclastic deposits that are generally in an advanced state of meteorization, interspersed with lava flows; In dry condition.</td><td>2. Layers of low isorescitivities - averages associated with pyroclasts and lavas, with a considerable degree of alteration and weathering, corresponds to residual soils and saprolite (dry materials).</td><td>3. Low isoresistance layers associated with pyroclasts with presence of saturation after approximately 8.0 meters of depth.</td></tr>
<tr><td rowspan="2">Tomography 5</td><td colspan="3">
</td></tr>
<tr><td>1. Average isoresistance layers (on the order of 30 Ω • m), are associated with fill materials of the veredal.</td><td>2. Layers of low isorescitivities - averages associated with pyroclasts and lavas, with a considerable degree of alteration and weathering, corresponds to residual soils and saprolite (dry materials).</td><td>3. Layers of low isoresistivities that are associated with pyroclasts with presence of saturation after approximately 12.0 meters of depth.</td></tr>
<tr><td rowspan="2">Tomography 6</td><td colspan="3">
</td></tr>
<tr><td>1. Layers of average isoresistivities (on the order of 50 Ω • m) are associated with filler materials from the national route.</td><td>2. Layers of low isoresistivities - averages associated with pyroclasts and lavas, with a considerable degree of alteration and weathering, corresponds to residual soil and saprolite (dry materials).</td><td>3. Layers of low isoresistivities that are associated with pyroclasts with presence of saturation after 10.0 meters of depth approximately.</td></tr>
</table>

#	INTERPRETATION		
Tomography 7			
	1. Layers of low isoresistivities (on the order of 8 Ω • m) are associated with organic materials, silts and clays.	2. Layers of low isoresistivities that are associated with residual soils and pyroliths saprolites with presence of saturation, lateral continuity is homogeneous.	
Tomography 8			
	1. Layers of average isoresistivities (on the order of 50Ω • m) are associated with fillers of the veredal track and dry materials.	2. Layers of low isorescitivities - averages associated with pyroclasts and lavas, with a considerable degree of alteration and weathering, corresponds to residual soils and saprolite (dry materials).	3. Layers of low isoresistivities that are associated with pyroclasts with presence of saturation after approximately 12.0 meters of depth.
Tomography 1			
	1. Average isoresistance layers (on the order of 35 Ω • m) are associated with filler materials from the national road and dry materials.	2. Layers of low isorescitivities - averages associated with pyroclasts and lavas, with a considerable degree of alteration and weathering, corresponds to residual soils and saprolite (dry materials).	3. Layers of low isoresistivities that are associated with pyroclasts with presence of saturation after approximately 11.0 meters of depth.

Source. GEOCOL CONSULTORES SA, 2017.

For the majority of CT scans performed in the study area, materials belonging to interphase pyroclastic deposits with lava flows are recognized. Throughout the profiles, a difference of isoresistivities associated with the presence of saturated materials is distinguished. The lateral continuity is homogeneous. The possibility of finding groundwater is limited mainly to pyroclastic deposits and lava that have undergone some degree of alteration and / or weathering (residual soil and saprolite).

5.1.8.5 Isoresistance maps.

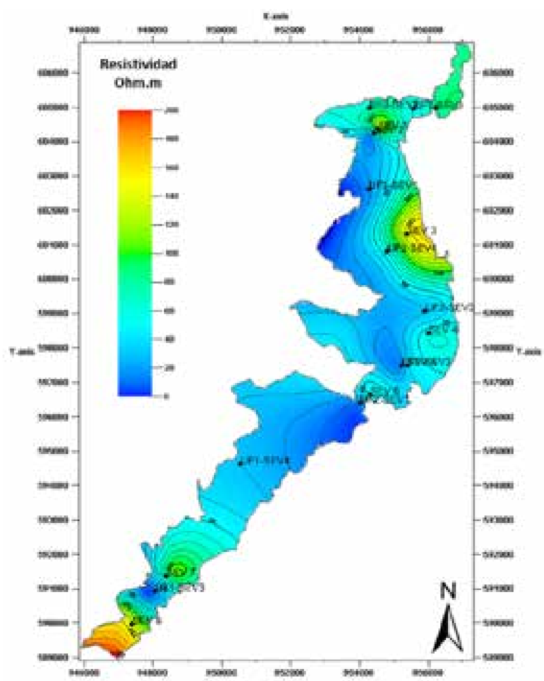
With the information of the probes referenced previously, the maps of isorresistividad were generated to different depths: 5, 10, 25, 50, 75 and 100 meters, making it possible to distinguish areas with similar geoelectric conditions and areas of hydrogeological interest. The maps are displayed in palette where the cold tonal palette (blue) represents the lowest resistivity values, the warm tones (yellow-red) are the highest and the green tones intermediate values. All maps have the same scale in order to make a strict spatial comparison, highlighting the following:

According to the maps of isorresistivity in general, similar conditions are presented for the first 20 meters of depth, characterized by high resistivities in the middle and north of the area, which reflects the presence of dry materials or with a low degree of saturation. Then, after 25 meters of depth, the tones in general show low to medium resistivities, characterizing the vadose zone of the residual Soil aquifer and Saprolito de Lavas and Piroclastos, and the saturated zone of the same.

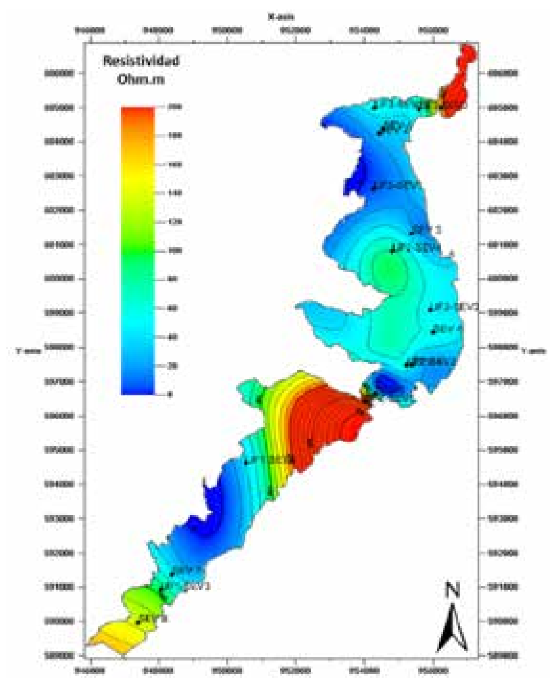
It is detected that the best aquifer conditions are to the southwest of the area of influence, which is valid taking into account the results of direct exploration of the subsoil, and concentration of groundwater points in this sector (Km20-Km30).

Figure 5.90 Maps of Isoresistivity from 5 to 100 meters deep.

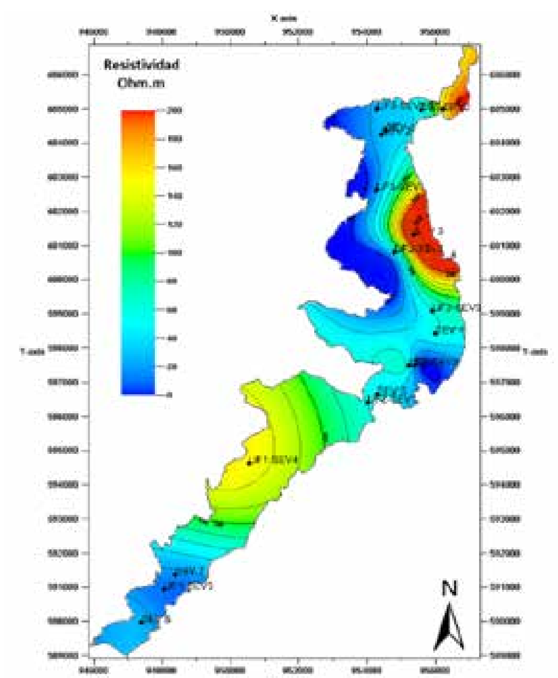
5 meters



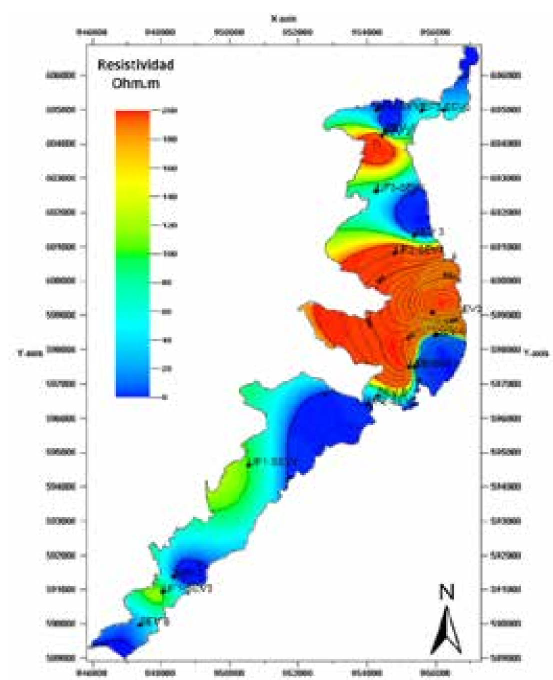
10 meters



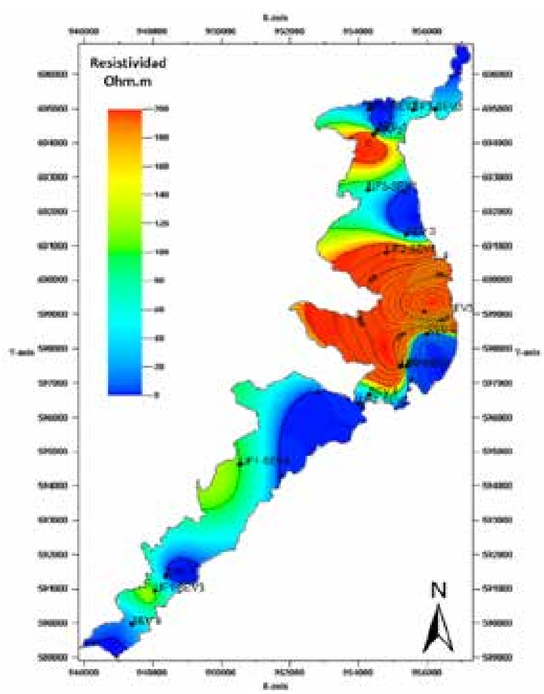
25 meters



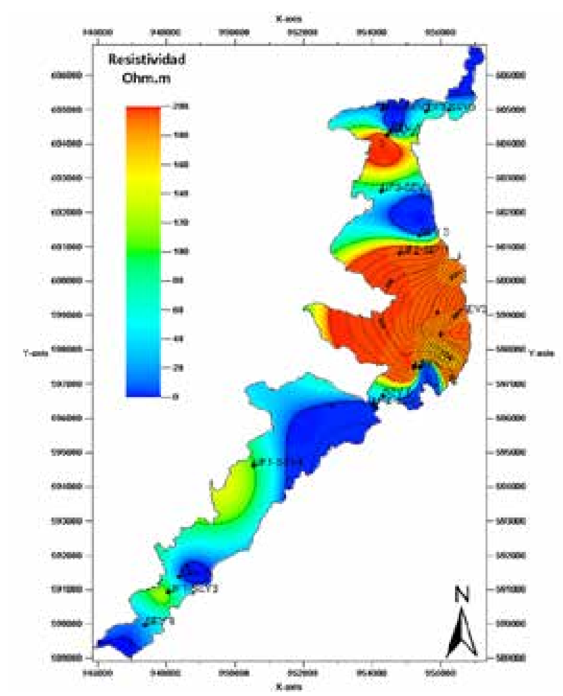
50 meters



75 meters



100 meters



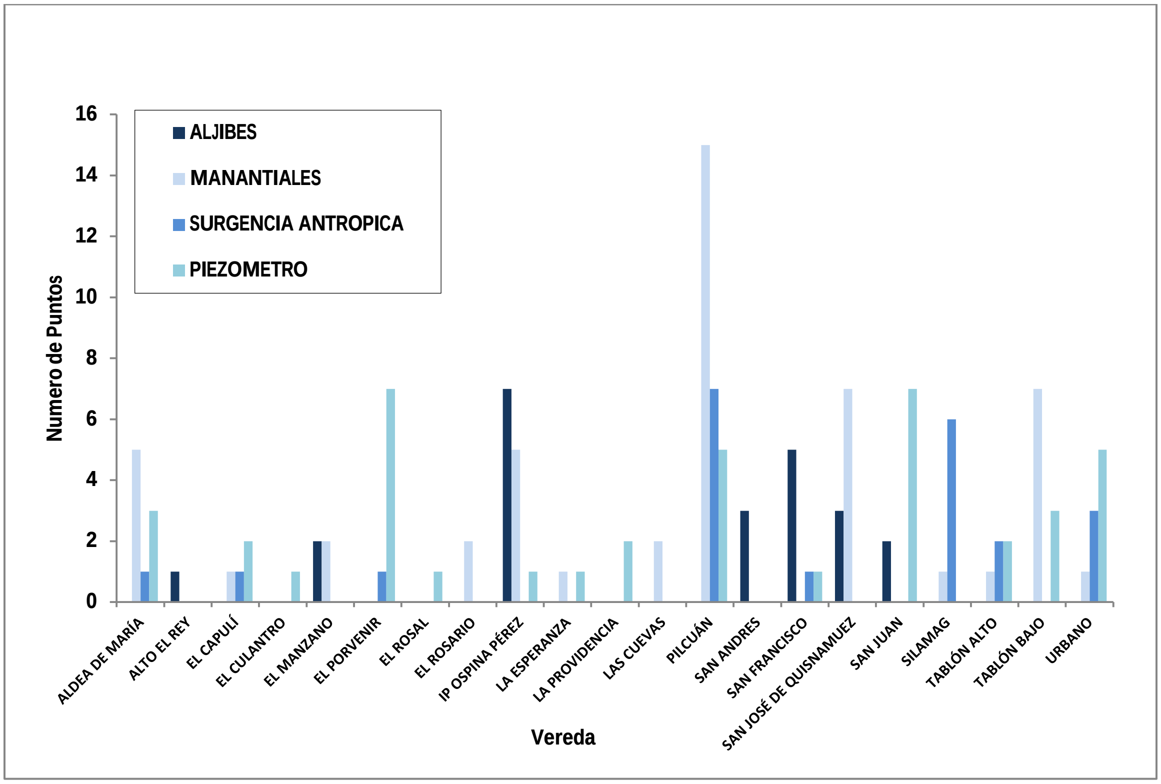
Source: GEOCOL CONSULTORES SA, 2017.

5.1.8.6 Inventory of groundwater points.

The inventory is a method of collecting and analyzing the data related to hydrogeology and coming from the information of users of so-called water points; Is the most suitable system to quickly know the hydrogeological characteristics of an area. In the strict sense, a groundwater point can be defined as a place, civil work or natural circumstance that allows direct or indirect access to an aquifer, these can include existing perforations (Piezometers or cisterns), whether or not exploited, abandoned Or destroyed. It also counts the sources or anthropic upwellings that must be considered as natural discharges of the aquifers (springs). The inventory generates an indicator of groundwater supply and is also a tool for capturing information related to the identification of uses and users of the underground resource in the area of influence. In addition, it allows establishing the possible interaction that these points can present with the implementation of the road project area.

In the local context, groundwater is an alternative supply of population for both public supply, domestic use and where agricultural consumption is the most demanded. Most of the cisterns are privately constructed in order to supply the dwellings or families in a particular way. The flow rates of these reservoirs range from 0.5 to 1.5 L / S. In the **Figure 5.92** A summary of the points inventoried by paths is presented.

Figure 5.91 Number of points inventoried per sidewalk.



Source: GEOCOL CONSULTORES SA, 2017.

The inventory carried out by the present consultancy contemplates 136 water points corresponding to: 23 reservoirs, 50 springs, 22 Anthropic Surgencias and 41 piezometers. Each of them is registered in the National Single Form for Groundwater Inventory (FUNIAS) of IDEAM and SGC (**Annex 7. Hydrogeology**).

The inventory in general contemplate:

- Identification of the geological unit captured.
- Record of static and dynamic levels by means of electric probe.
- Water quota at the inventoried points.
- Physical characteristics of the water point and characteristics of the catchment.
- Flows and operating times (information provided by aqueduct operators and / or landowners, in the case of municipal aqueducts was approached to the mayors and utility companies of each municipality).
- Uses and number of users.
- Current environmental conditions.

In the **Table 5.90** The identified points by type of catchment, depth range and average of static levels, **Table 5.91** Shows the general inventory of water points mentioned and in the **Figure 5.93** The location of the identified water points is shown. The inventory does not consider 100% of the existing points, however, are considered sufficient for the hydrogeological characterization of the region, it should be noted that this part of the analysis of secondary information reported in the study *"Rumichaca-Pasto Double Driveway Project"* Elaborated by Jorge Fandiño, Infrastructure SAS and group Pointec in March of 2016.

Table 5.90 Summary of the groundwater inventory.

TYPE OF POINT	NUMBER OF POINTS	AVERAGE DEPTH (m)	AVERAGE STATIC LEVEL (m)
Aljibes	23	10	6
Springs	50	-	-
Antropical Surgency	22	-	-
Piezometers	42	18	11

Source: GEOCOL CONSULTORES SA, 2017.

Table 5.91 General inventory of groundwater points.

SIDEWALK	KIND POINT	USE	X (m)	Y (m)	COTA (msnm)	PROF. (M)	STATIC LEVEL (m)
PILCUÁN	Antropical Surgency		957090	606896	1792		
PILCUÁN	Antropical Surgency		957078	606868	1793		
PILCUÁN	Spring	Agricultural	956933	606900	1868		
PILCUÁN	Spring	Agricultural	956968	606745	1827		
PILCUÁN	Spring	Agricultural	956963	606722	1826		
PILCUÁN	Spring	Agricultural	956944	606617	1867		
PILCUÁN	Spring	Agricultural	956942	606604	1869		
PILCUÁN	Spring	Agricultural	956893	606501	1887		
PILCUÁN	Spring	Agricultural	956837	606317	1817		
PILCUÁN	Spring	Agricultural	956987	606732	1821		
PILCUÁN	Piezometer		956897	606333	1793		
PILCUÁN	Antropical Surgency		956988	606467	1786		
PILCUÁN	Piezometer		957040	606726	1786	22	
PILCUÁN	Spring	Agricultural	956824	606118	1808		
PILCUÁN	Spring	Agricultural	956842	606113	1790		
PILCUÁN	Antropical Surgency		956840	606079	1790		
PILCUÁN	Antropical Surgency		956798	605961	1793		
PILCUÁN	Spring	Agricultural	956890	605983	1756		
PILCUÁN	Antropical Surgency		956794	605938	1792		
PILCUÁN	Spring	Agricultural	956725	605835	1810		
PILCUÁN	Spring	Agricultural	956720	605851	1817		
PILCUÁN	Spring	Agricultural	956746	605890	1813		
PILCUÁN	Spring	Agricultural	956461	605540	0	1,8	
PILCUÁN	Piezometer		956427	605292	1844		
PILCUÁN	Piezometer		955412	604938	1805		
PILCUÁN	Piezometer		955336	604952	1806	8	
PILCUÁN	Antropical Surgency		955208	604983	1810		

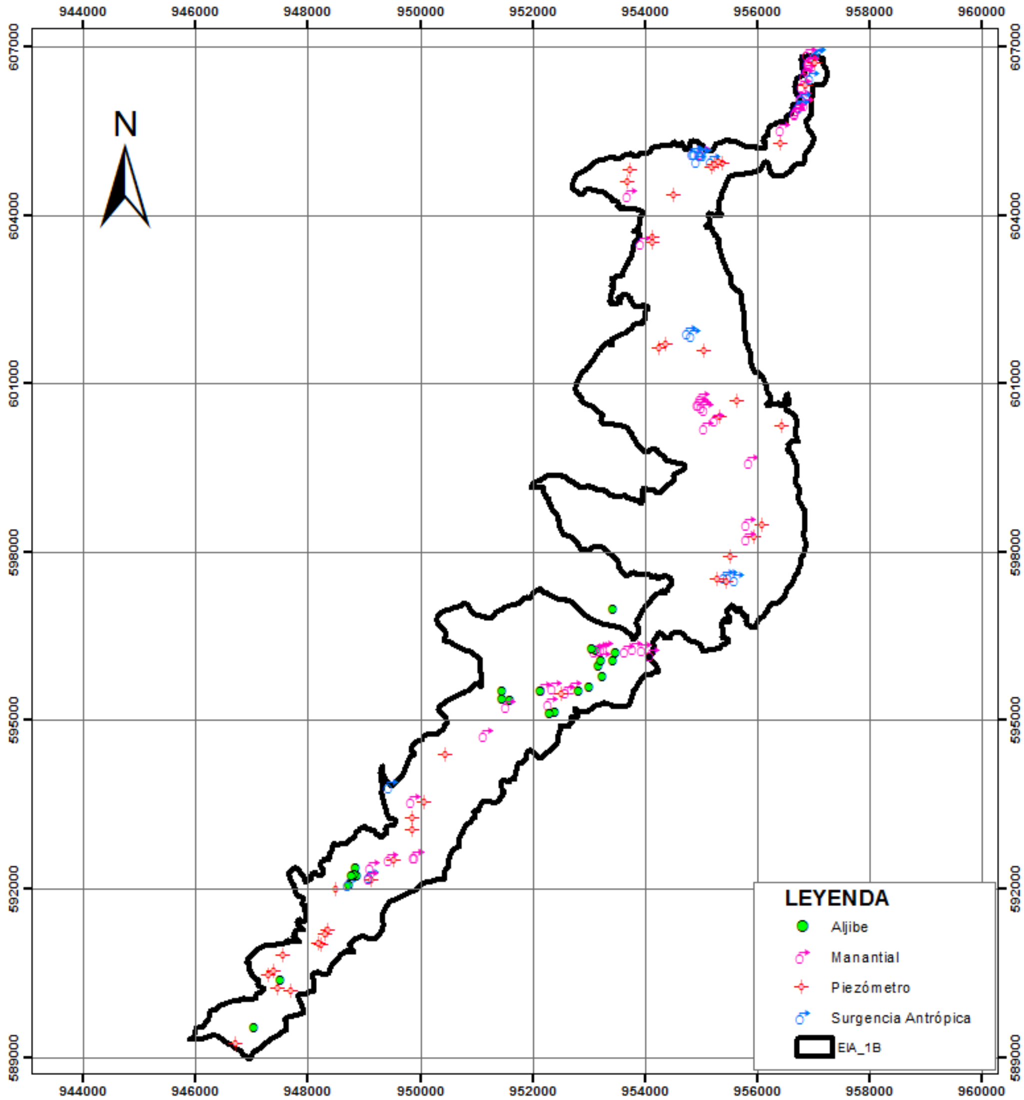
SIDEWALK	KIND POINT	USE	X (m)	Y (m)	COTA (msnm)	PROF. (M)	STATIC LEVEL (m)
SILAMAG	Antropical Surgency		955066	605106	1824	1,5	
SILAMAG	Antropical Surgency		955056	605103	1823		
SILAMAG	Spring	Agricultural	955036	605119	1822		
SILAMAG	Antropical Surgency		955037	605090	1822	1,58	
SILAMAG	Antropical Surgency		954933	605120	1835		
SILAMAG	Antropical Surgency		954907	605126	1819		
SILAMAG	Antropical Surgency		954890	605126	1820		
FUTURE	Antropical Surgency		954962	604992	1831		
FUTURE	Piezometer		955204	604876	1826		
FUTURE	Piezometer		955254	604909	1803		
FUTURE	Piezometer		953749	604828	1925	28,6	
FUTURE	Piezometer		953718	604609	2028		
THE ROSARY	Spring	Agricultural	953725	604372	2035		
FUTURE	Piezometer		954530	604370	2056		
FUTURE	Piezometer		954167	603621	2073		
FUTURE	Piezometer		954145	603526	2064		
THE ROSARY	Spring	Agricultural	953962	603517	2140		
THE HOPE	Piezometer		956451	600242	2045		
LOW TABLET	Piezometer		955667	600701	2176		
LOW TABLET	Piezometer		955365	600420	2257	15,48	6,4
LOW TABLET	Spring	Agricultural	955283	600362	2291		
LOW TABLET	Spring	Livestock	955107	600228	2430		
LOW TABLET	Spring	Public supply	955098	600556	2269		
LOW TABLET	Spring	Public supply	954983	600663	2303		
LOW TABLET	Spring	Public supply	955028	600755	2271		
LOW TABLET	Spring	Public supply	955003	600656	2290		
LOW TABLET	Spring	Public supply	955050	600602	2290		
THE HOPE	Spring	Public supply	955901	599607	2383		
HIGH BOARD	Piezometer		954393	601703	2424		0,3
HIGH BOARD	Piezometer		954269	601640	2447		3,6
LOW TABLET	Piezometer		955062	601588	2393		33,05
HIGH BOARD	Antropical Surgency		954785	601918	2355		
HIGH BOARD	Antropical Surgency		954852	601869	2345		
URBAN	Antropical Surgency		955445	597563	2723		
URBAN	Antropical Surgency		955523	597564	2730		
URBAN	Antropical Surgency		955630	597515	2738		
URBAN	Piezometer		955536	597934	2785		
URBAN	Piezometer		955317	597528	2753	13,3	4,63
URBAN	Piezometer		955970	598267	2669	20	19,05
URBAN	Spring	Agricultural	955849	598259	2685		
URBAN	Piezometer		956109	598479	2706	20	18
HIGH BOARD	Spring	Agricultural	955840	598515	2688		
URBAN	Piezometer		955483	597487	2685		
SAN JOSÉ DE QUISNAMUEZ	Spring	Agricultural	953981	596279	2824		

SIDEWALK	KIND POINT	USE	X (m)	Y (m)	COTA (msnm)	PROF. (M)	STATIC LEVEL (m)
SAN JOSÉ DE QUISNAMUEZ	Spring	Public supply	954140	596191	2802		
SAN JOSÉ DE QUISNAMUEZ	Spring	Domestic use	953829	596295	2828		
SAN JOSÉ DE QUISNAMUEZ	Spring	Domestic use	953687	596251	2832		
HIGH THE KING	Cistern	Domestic use	953434	596970	2889	4	1,14
SAN JOSÉ DE QUISNAMUEZ	Cistern	Domestic use	953427	596069	2888	4	1,2
IP OSPINA PÉREZ	Spring	Domestic use	952744	595586	2911		
IP OSPINA PÉREZ	Cistern	Domestic use	952808	595514	2892	8,14	2,99
IP OSPINA PÉREZ	Spring	Domestic use	952627	595516	2907		
IP OSPINA PÉREZ	Piezometer		952542	595484	2945	22,2	
IP OSPINA PÉREZ	Spring	Domestic use	952402	595590	2976		
IP OSPINA PÉREZ	Spring	Agricultural	952200	595562	2959		
IP OSPINA PÉREZ	Cistern	Agricultural	952127	595534	2971	6	4,96
IP OSPINA PÉREZ	Spring	Domestic use	952317	595312	2886	2	
SAN JOSÉ DE QUISNAMUEZ	Spring	Domestic use	953271	596122	2858		
THE APPLE TREE	Spring	Domestic use	953211	596264	2850		
THE APPLE TREE	Cistern	Domestic use	953119	596254	2871	19	17,7
THE APPLE TREE	Spring	Domestic use	953138	596252	2865		
THE APPLE TREE	Cistern	Domestic use	953059	596270	2892	22	20
SAN JOSÉ DE QUISNAMUEZ	Spring	Domestic use	953260	596280	2842		
SAN JOSÉ DE QUISNAMUEZ	Spring	Agricultural	953314	596288	2837		
SAN JOSÉ DE QUISNAMUEZ	Cistern	Agricultural	953466	596199	2858	5	3
IP OSPINA PÉREZ	Cistern	Agricultural	953241	595780	2918	6	0,45
IP OSPINA PÉREZ	Cistern	Agricultural	953173	595959	2900	7	6,5
SAN JOSÉ DE QUISNAMUEZ	Cistern	Agricultural	953214	596064	2877	7	5,2
IP OSPINA PÉREZ	Cistern	Domestic use	952388	595139	2858	7	1,5
IP OSPINA PÉREZ	Cistern	Domestic use	952287	595117	2862	7	1,9
THE CULANTRO	Piezometer		950454	594397	2912	10	
THE CAVES	Spring	Agricultural	951167	594753	2948		
SAN ANDRES	Cistern	Domestic use	951456	595392	3015	12	9,7
SAN ANDRES	Cistern	Agricultural	951593	595348	3009	15	13,5
THE CAVES	Spring	Domestic use	951574	595268	2991		
SAN ANDRES	Cistern	Agricultural	951446	595522	3026	10	7,5
IP OSPINA PÉREZ	Cistern	Agricultural	953002	595588	2931	8	5,7
THE CAPULÍ	Antropical Surgency		949480	593834	2939	78	15,8
SAN FRANCISCO	Cistern	Domestic use	948712	592062	2664	4	0,7
SAN FRANCISCO	Antropical Surgency		948736	592081	2665		
SAN FRANCISCO	Cistern	Domestic use	948842	592378	2702	15	10
SAN FRANCISCO	Cistern	Domestic use	948871	592237	2680	8	5
SAN FRANCISCO	Cistern	Domestic use	948815	592242	2679	8	2,9

SIDEWALK	KIND POINT	USE	X (m)	Y (m)	COTA (msnm)	PROF. (M)	STATIC LEVEL (m)
THE CAPULÍ	Spring	Domestic use	949870	593576	2862		
THE CAPULÍ	Piezometer		950092	593554	2862		
THE CAPULÍ	Piezometer		949866	593275	2799	15,8	0,6
ALDEA DE MARÍA	Piezometer		949877	593055	2795	8,4	3,99
ALDEA DE MARÍA	Spring	Domestic use	949950	592591	2798		
ALDEA DE MARÍA	Spring	Domestic use	949926	592575	2797		
ALDEA DE MARÍA	Piezometer		949546	592511	2759	12,87	Dry
ALDEA DE MARÍA	Spring	Domestic use	949483	592525	2740		
ALDEA DE MARÍA	Piezometer		949153	592162	2661		
ALDEA DE MARÍA	Antropical Surgency		949116	592219	2665		
SAN FRANCISCO	Piezometer		948500	591999	2649		
SAN JUAN	Piezometer		948252	591014	2478	28	
SAN JUAN	Piezometer		948200	591025	2492	27	21,5
SAN FRANCISCO	Cistern	Domestic use	948766	592239	2676	5	0,1
ALDEA DE MARÍA	Spring	Domestic use	949117	592215	2666		
ALDEA DE MARÍA	Spring	Domestic use	949153	592393	2687		
THE PROVIDENCE	Piezometer		948357	591269	2497		
THE PROVIDENCE	Piezometer		948329	591190	2485		
SAN JUAN	Piezometer		947567	590816	2509		
SAN JUAN	Piezometer		947299	590467	2543		
SAN JUAN	Piezometer		947400	590529	2484		
SAN JUAN	Piezometer		947472	590216	2520		
SAN JUAN	Piezometer		947706	590182	2412		
SAN JUAN	Cistern	Domestic use	947490	590366	2473	25,75	10,97
SAN JUAN	Cistern	Domestic use	947030	589528	2511	8,52	6,37
THE ROSAL	Piezometer		946717	589241	2573	22,66	

Source: GEOCOL CONSULTORES SA, 2017.

Figure 5.92 Location of the inventory of groundwater points within the area of influence.



Source: GEOCOL CONSULTORES SA, 2017.

5.1.8.7 Aljibes.

Most of the cisterns were built by manual excavation and were lined with brick or cement rings, many without a suitable cover or structure. None exceeds 26 meters deep and the average static level is 6 meters. The use is mainly domestic and for agriculture (**Photo 5.99** Y **Photo 5.100**). In the area of hydrogeological influence a total of 23 reservoirs were inventoried of which 1 is sealed.

Photography 5-99 Aljibe located on the sidewalk Alto El Rey, Municipality of Iles.

Coordinates: North 596970m, East: 953434m Magna origin Oeste

Photography 5-100 Aljibe located in the path IP Ospina Pérez, Municipality of Contadero.

Coordinates: North 595534 m, East: 952127m Magna origin Oeste

Source: GEOCOL CONSULTORES SA, 2017.

Below is a compilation of the cisterns and their distribution by sidewalk within the area of influence of the project. (Table 5.92).

Table 5.92 Distribution of cisterns by sidewalk.

SIDEWALK	NUMBER OF ALJIBES	PERCENTAGE
HIGH THE KING	1	4%
THE APPLE TREE	2	9%
IP OSPINA PÉREZ	7	30%
SAN ANDRES	3	13%
SAN FRANCISCO	5	22%
SAN JOSÉ DE QUISNAMUEZ	3	13%
SAN JUAN	2	9%

Source: GEOCOL CONSULTORES SA, 2017.

5.1.8.8 Springs.

A total of 50 nacederos or springs were identified in the area of influence, whose main use is agricultural, domestic and to a lesser extent livestock and public supply. Many of these have a conduit or pipe that is directed toward a tank or some buildup structure. (**Photo 5.101** Y **Photo 5.102**).

Photography 5-101 Manantial located in the path Pilcuán, Municipality of Imués

Coordinates: North 606900m, East: 956933m - Magna origen Oeste

Photography 5-102 Manantial located in the village Tablón Bajo, Municipality Iles.

Coordinates: North 600602m, East: 955050m Magna origin Oeste

Source: GEOCOL CONSULTORES SA, 2017.

The following table shows the compilation of springs found and the distribution of the same ones per sidewalk within the area of influence. (**Table 5.93**)

Table 5.93 Distribution of springs by sidewalk.

SIDEWALK	QUANTITY OF MANANTIALES	PERCENTAGE
ALDEA DE MARÍA	5	2%
THE CAPULÍ	1	2%
THE APPLE TREE	2	4%
THE ROSARY	2	4%
IP OSPINA PÉREZ	5	10%
THE HOPE	1	2%
THE CAVES	2	5%
PILCUÁN	15	30%
SAN JOSÉ DE QUISNAMUEZ	7	14%
SILAMAG	1	2%
HIGH BOARD	1	2%
LOW TABLET	7	14%
URBAN	1	2%

SIDEWALK	QUANTITY OF MANANTIALES	PERCENTAGE
		3%

Source: GEOCOL CONSULTORES SA, 2017.

5.1.8.9 Antropical Surgencias.

This type of hydrogeological point occurs especially in the slopes or cuts made in the road stretches of the region. 22 emergencies are identified in the area of influence of the project, of which there is no particular use by the community (**Photo 5.103** Y **Photo 5.104**).

Photography 5-103 Surgencia located in the path Pilcuán, Municipality of Imués.

Coordinates: North 606467m, East: 956988m
Magna origin Oeste

Photography 5-104 Surgencia located in the village of Silamag, Imués Municipality.

Coordinates: North 605090m, East: 955037m
Magna origin Oeste

Source: GEOCOL CONSULTORES SA, 2017.

Below is the compilation of anthropic upwellings found and the distribution of the path within the area of influence. (**Table 5.94**).

Table 5.94 Distribution of anthropic upwellings by sidewalk.

SIDEWALK	ANTROPICAL SURGERY	PERCENTAGE
ALDEA DE MARÍA	1	4%
THE CAPULÍ	1	4%
FUTURE	1	5%
PILCUÁN	7	32%
SAN FRANCISCO	1	5%
SILAMAG	6	27%
HIGH BOARD	2	9%
URBAN	3	14%

Source: GEOCOL CONSULTORES SA, 2017.

5.1.8.10 Piezometers.

The piezometers identified in the area of influence were 41, some of which are dry and others obstructed by soil or rock fragments. The average static level in piezomteors with water is 11 meters and none has depth greater than 30 meters. (**Photo 5.105** Y **Photo 5.106**).

Photography 5-105. Piezometer located in the village of Pilcuán, Municipality of Imués.

Coordinates: North 606726m, East: 957040m
Magna origin Oeste

Photography 5-106 Piezometer located in the village of El Porvenir, Iles Municipality.

Coordinates: North 604609m, East: 953718m
Magna origin Oeste

Source: GEOCOL CONSULTORES SA, 2017.

The following table shows the piezometer compilation and the distribution of these by footpath within the area of influence. (**Table 5.95**)

Table 5.95 Distribution of piezometers per sidewalk.

SIDEWALK	QUANTITY OF PIEZOMETERS	PERCENTAGE
ALDEA DE MARÍA	3	7%
THE CAPULÍ	2	5%
THE CULANTRO	1	3%
FUTURE	7	17%
THE ROSAL	1	3%
IP OSPINA PÉREZ	1	3%
THE HOPE	1	2%
THE PROVIDENCE	2	5%
PILCUÁN	5	12%
SAN FRANCISCO	1	2%
SAN JUAN	7	17%
HIGH BOARD	2	5%
LOW TABLET	3	7%
URBAN	5	12%

Source: GEOCOL CONSULTORES SA, 2017.

5.1.8.10.1 Parameter analysis In situ.

The results of on-site parameter analyzes for water samples from reservoirs, springs, anthropic upwellings and piezometers are presented below.

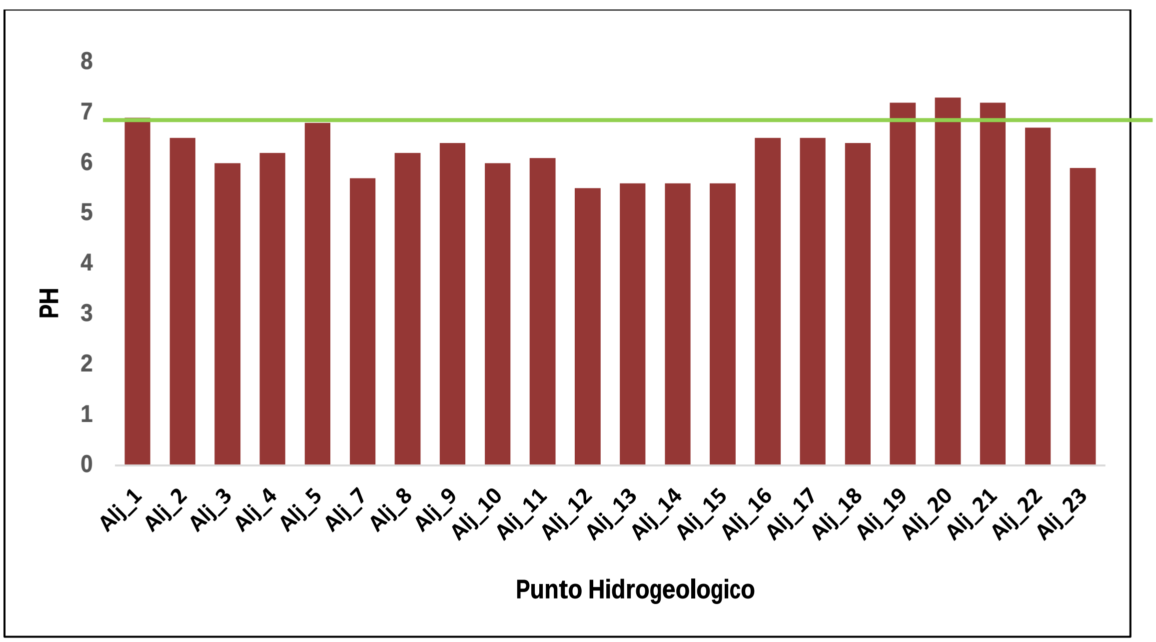
- **Temperature.**

The temperature of the sampling points taken varies between 14.3 and 25.7 ° C for the springs; 15.4 at 28 ° C for anthropogenic emergencies; 15 to 18.3 ° C for cisterns and 10 to 24 ° C for piezometers, a changing temperature throughout the area due to the different thermal floors in which the corridor is located. When considered of high magnitude (> 20 ° C) can cause the decrease of solubility of oxygen and therefore the stability of living beings.

- **PH.**

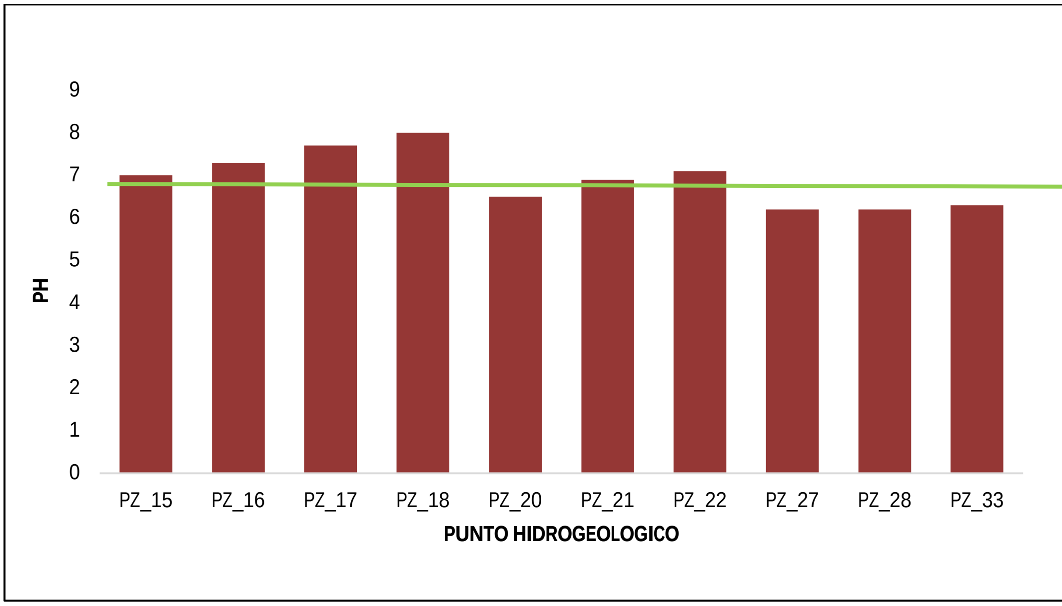
The pH value defines the acidity of the water, being for neutral waters pH = 7, for acidic waters pH <7 and for basic waters pH> 7. PH plays an important role in many chemical and biological processes of natural groundwater (carbonate balance, redox processes, etc.); Is easily alterable so its determination must be made at the time of sampling. The values of PH with respect to hydrogeological points inventoried in the road corridor are presented below. (**Figure 5.94** Y **Figure 5.95**).

Figure 5.93 Distribution of pH in groundwater along the road corridor



Source: GEOCOL CONSULTORES SA, 2017.

Figure 5.94 Distribution of pH in groundwater along the road corridor.



Source: GEOCOL CONSULTORES SA, 2017.

As can be seen in the previous figures, most of PH values are below 7 for data taken on cisterns and piezometers which means that most of the groundwater samples are basic, however, they do exist Data above 7 indicating presence of acid waters at some points.

- **Conductivity.**

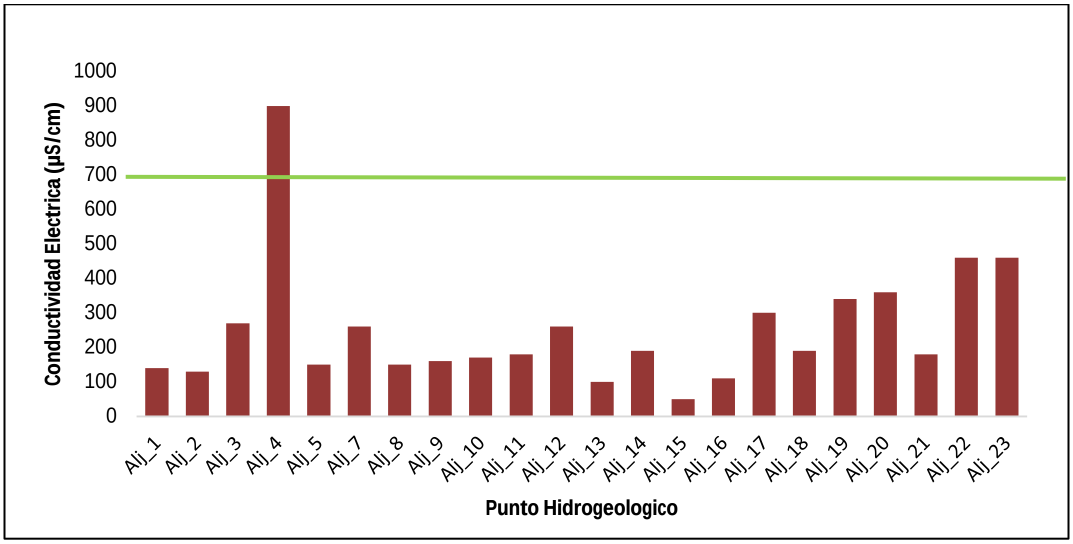
As a consequence of its ionic content, water becomes the conductor of electricity. As the ionic concentration increases, the conductivity (C) or capacity of a water to conduct the electric current also increases to some extent. The unit of measurement of conductivity is µS / cm (microsiemens / cm). The distribution of this parameter shows an inverse behavior to Dissolved Oxygen (DO).

It is indicative of the total ionizable matter present in the water. The pure water contributes minimally to the conductivity, and in its almost totality is the result of the movement of the ions of the impurities present. Conductivity measurement is a good way to control water quality, provided that:

- Do not be organic contamination by non-ionizable substances.
- Measurements are performed at the same temperature.
- The composition of the water is kept relatively constant.

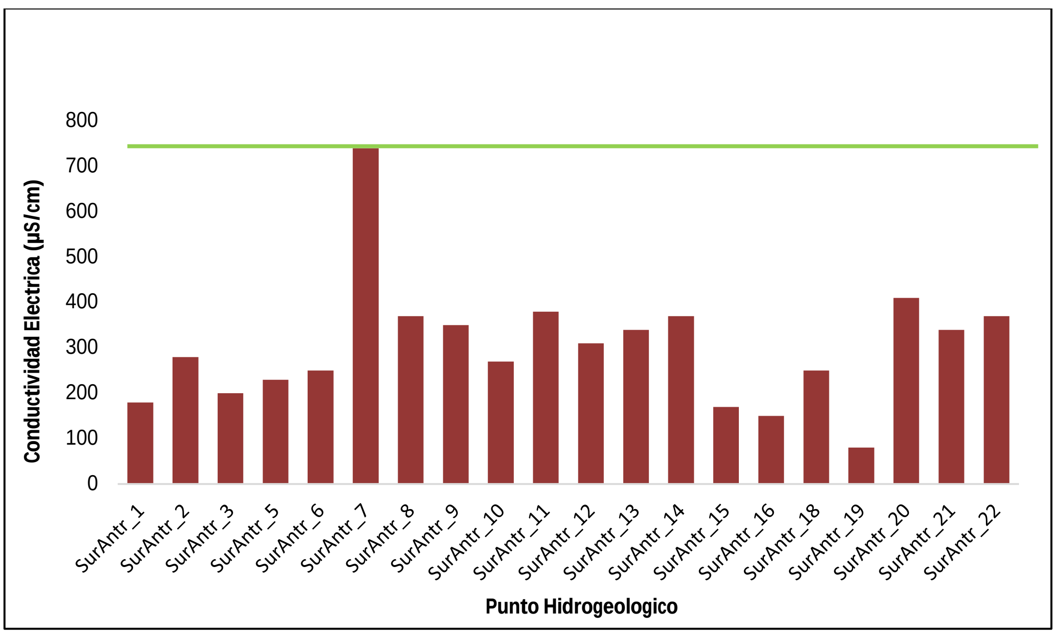
For the study area this parameter presents a variation between Cmin = 50 µS / cm and Cmax = 970 µS / cm (**Figure 5.96**, **Figure 5.97** Y **Figure 5.98**).

Figure 5.95 Distribution of conductivity in the In the road corridor - Aljibes.



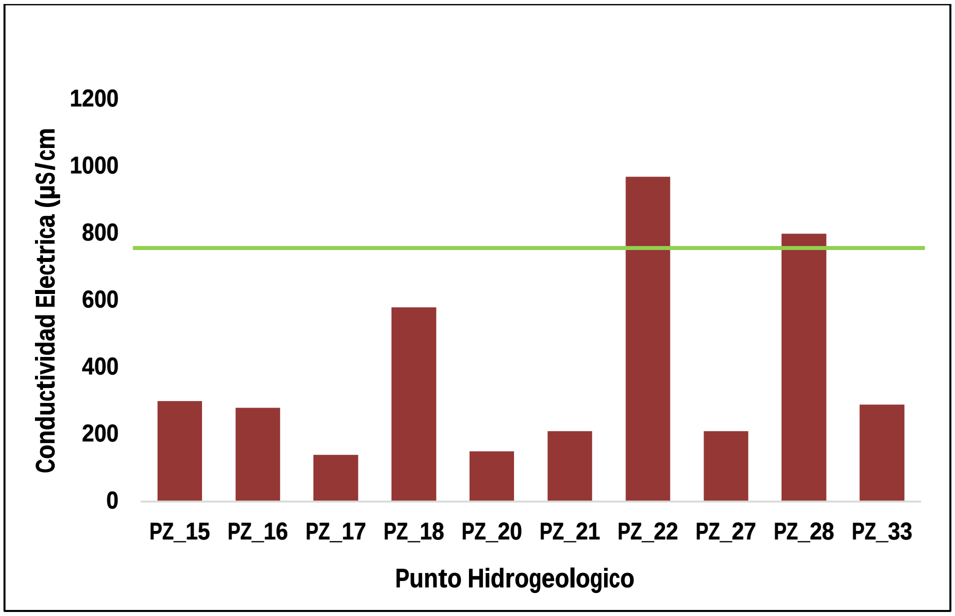
Source: GEOCOL CONSULTORES SA, 2017.

Figure 5.96 Distribution of conductivity in the road corridor - Antropical Surgencias



Source: GEOCOL CONSULTORES SA, 2017.

Figure 5.97 Distribution of conductivity in the in the road corridor - Piezometers.



Source: GEOCOL CONSULTORES SA, 2017.

According to the classification tables of the type of water from electrical conductivity measurements (**Table 5.96**), It is highlighted that in the area most of the groundwater is domestic drinking water for both cisterns, anthropic upwelling and piezometers (<800 µS / cm), however, in Aljibe 4 and piezometer 22 there is a value greater than 800 , Approaching a maximum for drinking water.

Table 5.96 Types of water from electrical conductivity.

TYPE OF WATER	ELECTRICAL CONDUCTIVITY (µS / cm)
Pure water	0.04
Distilled water	0.50
Mountain water	1.0
Water rain	5 to 50
Domestic water	500 to 800
Max. For drinking water	1055
Brackish water	2500 to 20,000
Seawater	45000 to 55000
Pickles	> 100000

Source: (Ríos Antonio 2011).

- **Dissolved solids Totals.**

They correspond to the sum of the minerals, salts, metals, cations or dissolved anions in the water. In the corridor this parameter varies from 46 to 479.

5.1.9 User Usage Analysis.

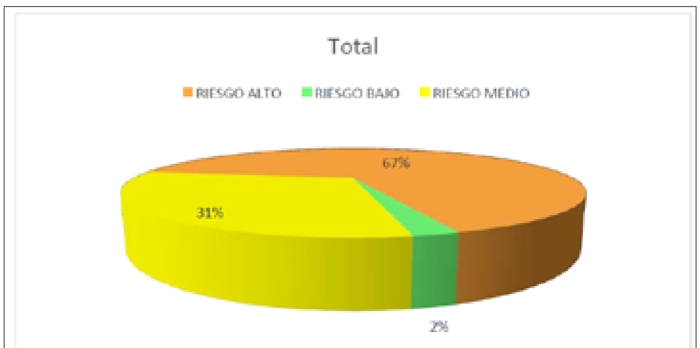
The analysis is carried out giving focus and relevance to the municipalities of greater influence in the development of the project, therefore reference will be made to the municipalities of Imués, Iles, Ipiales and Contadero.

5.1.9.1 Generalities.

The department of Nariño is divided into 64 municipalities with a total population of 1'701.840 inhabitants, of which 48.77% (830.093 inhabitants) is located in the urban area of the department, while the remaining 51.22% (871,747 inhabitants) is distributed in Rural area of the same. It includes important urban centers as its capital Pasto with 25.20% of the population of the department (428.948 inhabitants), San Andrés de Tumaco with 11.23% (191.218 inhabitants) and Ipiales with 8.13% (138,438 inhabitants) of the same, DANE 2013).

According to IRCA (Water Quality Risk Index for human consumption) annual average of each municipality reported to the SIVICAP (System for Monitoring the Quality of Drinking Water for human consumption) by the competent sanitary authority of the department of Nariño, which It is shown in **Figure 5.99** It was obtained that 2% of the population of the department consumed Water Without Risk, 31% Water with Medium Risk, and 67% Water with High Risk.

Figure 5.98 Level of risk in terms of water quality in Nariño according to IRCA.



Convención de Colores					
Sin Riesgo	Riesgo Bajo	Riesgo Medio	Riesgo Alto	Inviable Sanitariamente	No Reporta
0 - 5	5.1 - 14	14.1 - 35	35.1 – 80	80.1 - 100	

Source. National report on water quality for human consumption, IRCA Base, 2013.

Taking into account the information reported by DANE and SIVICAP, during the years 2007 to 2013 for the municipalities of the area of influence such as Imués, Iles, Ipiales and Contadero present high risk in water quality, this is associated with general statistics already That the department of Nariño reported a 43.67% corresponding to a high risk level.

5.1.9.2 Micro-basin and supply source of aqueducts.

The hydrographic distribution in the area of influence is determined by different micro-basins, in the Table 5.97 A list of the tributaries of the Sapuyes river is made, which according to the Plan of Efficient Use and Water Saving of Iles (PUEAA 2008) corresponds to the supply source of the municipal aqueduct of Iles.

Table 5.97 Microcuencas supplying the municipal aqueduct.

SUBWOOFER	MICROCUENCA	TRIBUTARY	URBAN HELMET OR TRAIL THAT SUPPLIES
Sapuyes	The Güingal	Q. El Carmen	Urban hull Iles
Sapuyes	The Güingal	Q. The bathroom	San Javier and the Rosary
Sapuyes	The Güingal	Q. The Bath-Güingal	The rosary
Sapuyes	The Güingal	Q. La Carbonera	Iscuazán
Sapuyes	The Güingal	Q. White straw	Urbanization El Mirador de los Andes and Iscuazán
Sapuyes	The Güingal	Q. The Tundal	Loma de Argotys
Sapuyes	The Güingal	Q. El Páramo	Yarqui
Guáitara	The Apple tree	Q. La Cruz Ciénaga	Alto del Rey
Guáitara	El Manzano	Q. Barro Blanco	Alto del Rey
Guáitara	El Manzano	Q. Ramal Los Arroyos	Alto del Rey
Guáitara	El Manzano	Q. La Palma	Tamburán
Guáitara	El Manzano	Q. Las Palmas	Urbano
Guáitara	El Manzano	Q. La Ciénaga	Urbano
Sapuyes	El Güingal	Q. El Cedral	San Francisco
Sapuyes	El Güingal	Q. Loma Redonda	Loma Alta
Guáitara	La Llave	Q. Quitasol	Villanueva
Guáitara	La Llave	Q. El Ciruelo	Tablón Alto
Guáitara	La Llave	Q. El Maco	Tablón
Guáitara	La Llave	Q. Nacedero	La Esperanza
Guáitara	La Llave	Q. El Baño	La Esperanza
Guáitara	La Llave	Q. El Baño	El Capulí
Guáitara	San Francisco	Q. Papasixe	El Capulí
Sapuyes	El Güingal	Q. Pescadillo	Bolívar
Sapuyes	El Güingal	Q. Cartagena	Bolívar
Sapuyes	El Güingal	Q. El Pailón	Rosario Occidente
Sapuyes	El Güingal	Q. La Soledad	El Mirador
Sapuyes	El Güingal	Q. El Pailón	San Antonio
Sapuyes	El Güingal	Q. Los Rosales	San Antonio
Sapuyes	El Güingal	Q. Güingal	El Carmen
Sapuyes	El Güingal	Q. Páramo Paja Blanca	The Common

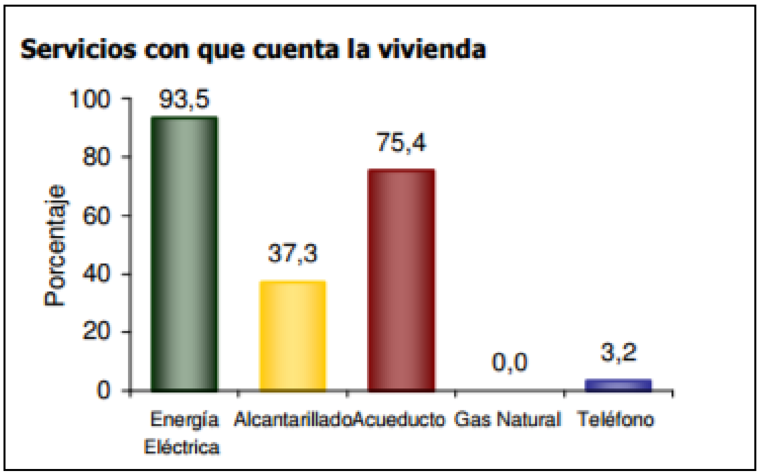
Source. PUEAA ILES 2008.

5.1.9.3 Users and status of the aqueducts.

· **Municipality of Iles.**

The municipality of Iles has an aqueduct that supplies the urban area (EMCOILES) and veredale aqueducts for the rural sector, administered by communal action boards, reports a flow of 7.51 L / s and according to the statistics of DANE 2005 a 75.4% have aqueduct service, as observed in **Figure 5.100**. However coverage reported by EMCOILES is 98.10% with 582 users view **Table 5.98**.

Figure 5.99 Coverage of public services in the municipality of Iles.



Source. DANE - 2005.

Table 5.98 Coverage of the aqueduct service in the municipality of Iles (Urbano- Rural).

LOCATION	NUMBER OF INHABITANTS	TOTAL HOUSING	NUMBER OF USERS	COVERAGE%	USERS WITH ANOTHER SYSTEM
Urban helmet	**1733**	**584**	**582**	**98.10%**	**2**
The hope	134	50	36	72%	14
Low Plank	129	33	33	100%	0
High Plank	150	22	20	90.90%	2
El Capulí	260	139	139	100%	0
Future	172	27	0	0%	27
San Javier	316	101	101	100%	0
New Villa	190	48	46	95.80%	2
Loma Alta	239	126	126	100%	0
The rosary	190	52	25	48.10%	27
Yarqui	248	80	80	100%	0
High El Rey	547	138	138	100%	0
Urban	269	108	108	100%	0

LOCATION	NUMBER OF INHABITANTS	TOTAL HOUSING	NUMBER OF USERS	COVERAGE%	USERS WITH ANOTHER SYSTEM
Tamburan	367	91	91	100%	0
Bolivar	342	84	84	100%	0
The looker	107	24	20	83.30%	4
Rosario West	165	46	46	100%	0
Loma de Argotys	331	81	81	100%	0
San Antonio	416	108	108	100%	0
El Carmen	209	73	51	69.90%	22
San Francisco	616	187	187	100%	0
The Common	159	50	48	96%	2
Iscuazán	383	88	61	69.30%	27
Total	7672	2340	2211		129

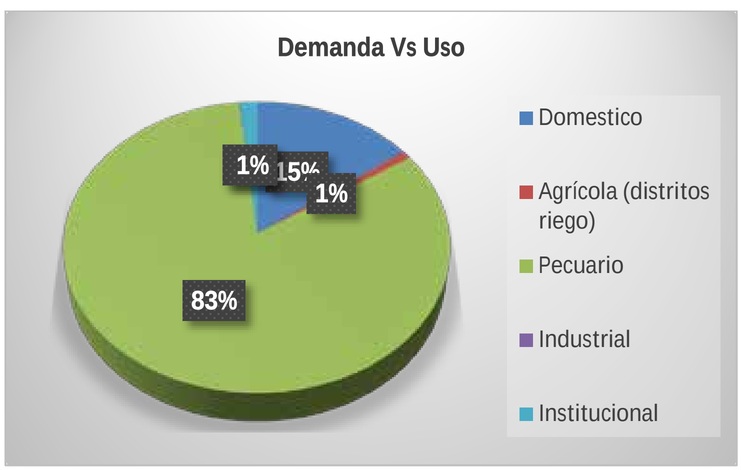
Source. PUEAA 2008

Table 5.99 Current demand and annual projection of the water resource in the municipality of Iles.

TYPE OF WATER RESOURCE USE	CURRENT WATER RESOURCE DEMAND (LTS / HAB / DAY)	ANNUAL PROJECTION OF THE GROWTH RATE OF DEMAND (TEN YEARS) LTS / DAY
Domestic	1150800	1441654
Agricultural (irrigation districts)	67251	84248
Livestock	6422728	8046007
Industrial	5230	6552
Institutional	122200	153085

Source. PUEAA 2008

Figure 5.100 Demand and projection of water regarding the use of the resource in the municipality of Iles.



Source: GEOCOL CONSULTORES SA, 2017.

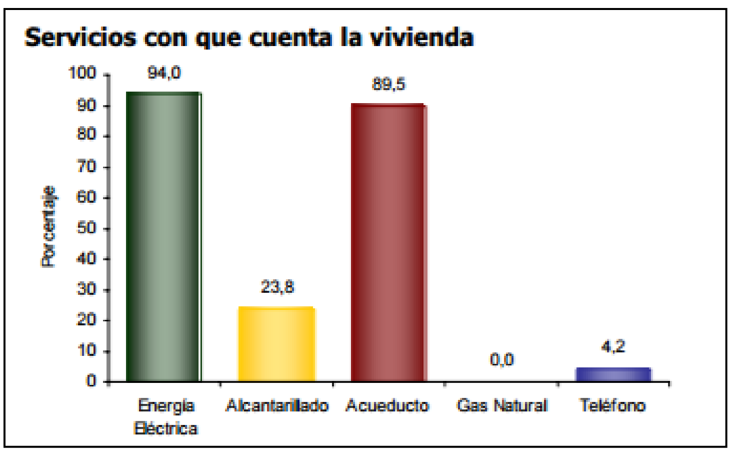
According to the above, it is concluded that for the municipality of Iles 83% of the water use is of the livestock type, followed by the domestic one with 15%, agricultural and institutional with 1% and the industrial use is minimal compared to the others .

For the case of veredale aqueducts, the Maco aqueduct supplying the Tablón Bajo settlement was identified in the area of influence according to the PUEAA (2007-2011). This tributary (Macó quebrada birth) has a flow record of 7 L / s Winter season and 1.2 L / s in summer. That is, during the dry season, it is possible that the source of supply to the aqueduct in question is the aquifer present in the Nariñense Altiplano.

- **Municipality of Contadero.**

The coverage of the aqueduct service for the municipality of Contadero is of the order of 90%, with main sources of supply through surface water bodies (**Figure 5.100**); Only some sidewalks have local aqueduct networks fueled by groundwater births (PUEAA 2008). On the other hand, taking into account the volume of related sources in the Table 5.100 It is estimated that 36.28 L / s is destined for domestic use, crops and dual purpose livestock, with the Chorrera Negra Gully being one of the source with the highest contributions.

Figure 5.101 Coverage of public services in the municipality of Contadero.



Source. DANE - 2005

Table 5.100 Demand of water in the most relevant micro-basins.

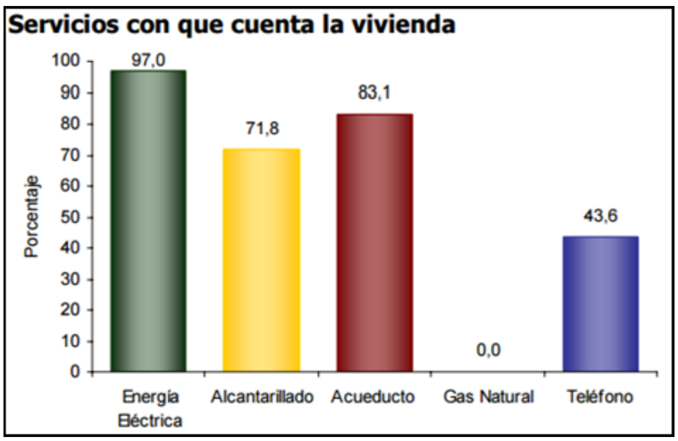
BROKEN	DO NOT. PEOPLE BENEFITED	HUMAN CONSUMPTION BY FAMILY (L / S)	DOMESTIC USE / CROPS / LIVESTOCK AND DOUBLE PURPOSE (L / S)
Black Chorrera (Irrigation)	1550	0.05	1.21
Smoker	61	0.006	0.7
Black chorrera	62	0.006	0.7
Black Chorrera (Irrigation)	300	0.03	33.67

Source. PUEAA 2008 - Modified GEOCOL 2017.

· **Municipality of Ipiales.**

According to PUEAA, the supply source is the Blanco River, which has an average flow of 400 L / s, of which 200 L / s are treated, the remainder is returned to the river. EMPOOBANDO calculates an availability per inhabitant of 50.65 L / day, with a service coverage of 94.55%, average consumption (m3 / month) of 243543 and a volume produced in the year of 7'095.600 m3. However, what is reported by DANE (2005) is a coverage of the aquifer service in the order of 83.1%, part of which is supplied by aquifers of the Rumichaca Ash unit particularly in some rural areas such as the San Juan sector in the Km15-Km-17.

Figure 5.102 Coverage of public services in the municipality of Ipiales.

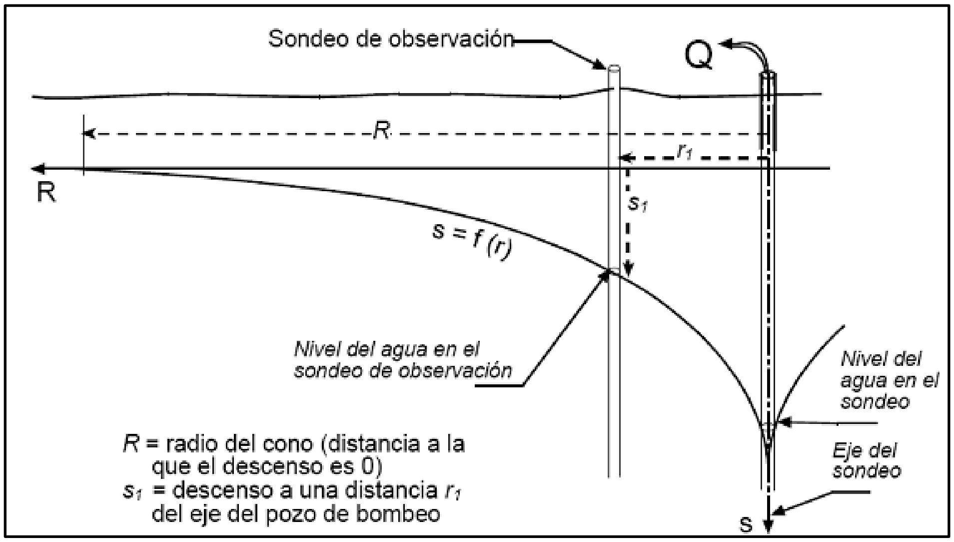


Source. DANE - 2005

5.1.9.4 Hydraulic properties of the aquifer units.

The hydraulic properties of the aquifer units found in the area of influence define the type of aquifer and its capacity to store and transmit water. The most accurate way to define the hydraulic properties of an aquifer is by performing well tests or pumping tests, in which the aquifer is subjected to pumping level variations to determine the maximum dampness and recoverability of the aquifer, Monitoring the discharge rate and the change of levels both in the pumping well and in other nearby wells, if any (**Figure 5.104**).

Figure 5.103 Cone of influence when pumping a catchment well.



Source: GEOCOL CONSULTORES SA, 2017.

Pumping tests are undoubtedly the most widely used method, with the easiest application and with the greatest guarantee of its results, which is traditionally used in order to know the hydraulic characteristics of aquifers, as well as the degree of perfection of the aquifer. Completion of groundwater abstractions. However, the method requires the presence of at least one (1) pumping well and one or more observation wells constructed with similar characteristics; Therefore, where such conditions do not exist it is desirable to use other methodologies such as Slug-type tests to evaluate static level recovery from sudden level change by pumping or injecting water and are applicable to low permeability media.

The calculation of the hydraulic parameters of the aquifers is very important, since they allow to know the behavior of the underground flow and the development of true hydrogeological maps and real. Obtainment should be made at the level of field data investigations through the execution of pumping tests, as well as the level of reliable hydrogeological information gathering. The most relevant parameters identified for the aquifer unit are the following:

- **Porosity.**

The porosity of a material is expressed by the ratio between the volume of its empty part or occupied by air and / or water and its total volume.

$$n = \frac{Vv}{Vt}$$

The effective porosity of a material is given by the ratio of the volume of water contained in a rock, released by gravity, Ve (free water volume) and total volume (VT).

$$me = \frac{Ve}{Vt} * 100$$

The following is an estimate of the magnitude ranges of porosity (n%) for different materials, in which the different units found in the study area can be correlated taking into account their genesis and constitution.

Table 5.101 Estimated porosity values.

MATERIAL	TOTAL POROSITY (%)	EFFECTIVE POROSITY (%)
Clays	40 to 60	0 to 5
Limos	35-50	3 to 19
Fine sands, silty sands	20 to 50	10 to 28
Thick or well-classified sand	21 to 50	22-35
Gravel	25 to 40	13 to 26
Shale intact	1 to 10	0.5 to 5
Shale fractured / altered	30 to 50	
Sandstone	5 to 35	0.5 to 10
Limestones, dolomites	0.1 to 25	0.1 to 5
Limestones, cartified dolomites	5 to 50	5 to 40
Non-fractured igneous and metamorphic rocks	0.01 to 1	0,0005
Fractured igneous and metamorphic rocks	1 to 10	0.00005 to 0.01

Source: Sanders, L. (1998)

- **Hydraulic conductivity (K).**

It is the measure of the ability of a porous medium to allow the flow of a specific fluid. Analytically the hydraulic conductivity is related, in the Darcy equation, to the coefficient of proportionality between the flow rate and the hydraulic gradient. Darcy formulated the law that regulates the movement of groundwater, measuring the flow rate Q as a function of permeability and observed that this equated to:

$$Q = K * A\left(\frac{h}{l}\right)$$

If K is the permeability coefficient, the area of the section through which water flows, h is the difference in load between the inlet and the outlet and the path to be made by the water. If you consider that:

$$\frac{Q}{A} = v$$

Being v, the average speed, results:

$$\frac{Q}{A} = v = K\left(\frac{h}{l}\right)$$

Calling the Hydraulic Gradient $i = \frac{h}{l}$, result:

$$v = K * i, \text{ where } K = \frac{v}{i}$$

The permeability coefficient (K) has the dimensions of a velocity, since the dimensional equation is:

$$K = \frac{\frac{L^3}{T}}{\frac{L}{L}} * L^2 = \frac{L}{T}$$

In general terms it can be said that the hydraulic conductivity depends on the intrinsic permeability of the porous medium, the specific gravity and the viscosity of the fluid. The hydraulic conductivity can be isotropic or anisotropic, depending on whether there are variations of importance of conductivity, in different directions.

The following tables show a frame of reference for the values of Hydraulic conductivity (K) for different materials, in which the different units found in the study area can be correlated taking into account their genesis and constitution of materials. However, this parameter was determined from the results of the Slug tests as explained below.

Table 5.102 Estimated values of conductivity Hydraulics (meters / day).

<table>
<tr><th colspan="2">MATERIAL</th><th>DOMÉNICO</th><th>SMITH & W</th><th>FREEZE</th><th>FETTER</th><th>SANDERS</th></tr>
<tr><td rowspan="9">Sediments</td><td>Gravel</td><td>25 to 2500</td><td>100 to 10^5</td><td>100 to 10^6</td><td>10 to 1000</td><td></td></tr>
<tr><td>Gravel with sand</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Gross sand</td><td>0.1 to 500</td><td rowspan="3">0.01 to 1000</td><td rowspan="3">1 to 1000</td><td rowspan="2">1 to 100</td><td>1 to 100</td></tr>
<tr><td>Middle Arena</td><td>0.1 to 50</td><td></td></tr>
<tr><td>Fine sand</td><td>0.02 to 20</td><td>0.01 to 1</td><td rowspan="2">0.01 to 1</td></tr>
<tr><td>Loamy sand</td><td></td><td></td><td>0.01 to 100</td><td>0.001 to 0.1</td></tr>
<tr><td>Silt. loess</td><td>10^{-4} To 2</td><td>10^{-4} To 1</td><td>10^{-4} To 1</td><td>0.001 to 0.1</td><td>10^{-4} To 1</td></tr>
<tr><td>Clay</td><td>10^{-6} To 4 * 10^{-4}</td><td>10^{-7} To 10^{-3}</td><td></td><td>10^{-6} To 10^{-3}</td><td>10^{-6} To 10^{-3}</td></tr>
<tr><td>Unaltered marine clay</td><td>10^{-7} At 2 * 10^{-4}</td><td></td><td>$10^{\text{-eleven}}$ To 10^{-7}</td><td></td><td></td></tr>
<tr><td rowspan="6">Sedimentary rocks</td><td>Crystallized limestones</td><td>0.1 to 2000</td><td>0.05 to 0.5</td><td>0.1 to 1000</td><td></td><td>0.1 to 10^7</td></tr>
<tr><td>Limestones, dolomites</td><td>10^{-4} To 0.5</td><td>0.001 to 0.5</td><td>10^{-4} To 1</td><td></td><td>10^{-4} To 1</td></tr>
<tr><td>Sandstone</td><td>3 * 10^{-5} To 0.5</td><td>10^{-5} To 1</td><td>10^{-5} To 1</td><td></td><td></td></tr>
<tr><td>Slitstone</td><td>10^{-6} At 0.001</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Intact sedimentary slates (Shale)</td><td>10^{-8} At 2 * 10^{-4}</td><td>10^{-8} To 10^{-4}</td><td>10^{-4} To 10^{-8}</td><td></td><td>10^{-4} To 10^{-8}</td></tr>
<tr><td>Fractured / altered Shale (Shale) slates</td><td></td><td>10^{-4} To 1</td><td></td><td></td><td></td></tr>
</table>

Source: Sanders, L. (1998)

Table 5.103 Permeability Values (According to Authors).

K (m / day)	Estimate Rating
K <10^{-2}	Very low
10^{-2} <K <1	Low
1 <K <10	Half
10 <K <100	high
K> 100	Very high

Source: (Villanueva Martínez and Iglesias López 1984), Adopted by ASI SAS, 2016

- **Transmissivity (T)** $\left[\frac{A}{T}\right]$.

It is the volume of water (at the existing kinematic viscosity), flowing per unit time (flow), under a unitary gradient, across a unitary aquifer width, throughout its thickness.

Darcy's Law is expressed as $Q = K * A * I$, If section A is equal to that of the aquifer, it has a length L and a height b, we have:

$$A = b * L$$

Then Darcy's Law can be written as:

$$Q = K * b * L * i$$

To product K * b, it is called transmissivity and is designated by T, leaving Darcy's Law:

$$Q = T * L * i$$

Its dimensions are those of a speed by a length:

$$T = L^2 * T^{-1}$$

The following are the transmissivity ranges depending on the type of aquifer and its potential as a source of groundwater.

Table 5.104 Transmission Values (According to Authors).

T (M^2/DAY)	ESTIMATED QUALIFICATION	POSSIBILITIES OF THE ACUÍFERO	POTENTIALITY
T <1	Very low	Wells less than 1 l / s with 10 m theoretical depression	Negligible
1 <T <10			Weak
10 <T <100	Low	Wells between 1 and 10 l / s with 10 m theoretical depression	Low
100 <T <500	Medium to High	Wells between 10 and 50 l / s with 10 m theoretical depression	Moderate
500 <T <1000	high	Few between 50 and 100 l / s with 10 m theoretical depression	high
T> 1000	Very high	Wells greater than 100 l / s with 10 m of theoretical depression	Very high

Source: (Villanueva Martínez and Iglesias López 1984) (Sen 1995), Adopted by ASI SAS, 2016.

- **Coefficient of Storage (S).**

It is the volume of water that an aquifer can give or receive in storage per unit area and per unit change in the head. In confined aquifers the storage coefficient is equal to the product of the specific storage by the thickness of the aquifer. In free aquifers it is approximately equal to the effective porosity. The type of aquifer depends on the exponential degree of the Storage Coefficient, ie:

Table 5.105 General classification of the aquifer type from the storage coefficient.

Aquifer	Exponential
FREE	<10-3
Semi-confined	10-2 - 10-3
CONFINED	> 10-4

Source: International Association of Hydrogeologists (IAH) "International Legend of Hydrogeological Maps", UNESCO, (1983)

- **Specific capacity.**

It is the flow or the amount of water that is produced in the pumping of a well, in an aquifer, for each meter (or unit of length) that descends the level of the water inside him, the units are: LPS / m. For example, if the sinkhole in the well is 5 m after an extended discharge at a constant flow rate of 10 LPS, the specific capacity of the well is 2 LPS / m; Depending on the results can be clarified the different types of aquifers from the point of view of their underground water supply as follows:

Table 5.106 Classification of aquifers according to the specific capacity.

AVERAGE SPECIFIC CAPACITY (l / s / m)	TYPE OF ACUFERO
Very high Greater than 5.0	Continuous and discontinuous aquifers of regional extension, of very high productivity.
high Between 2.0 and 5.0	Continuous and discontinuous aquifers of regional extension, of high productivity.
Half Between 1.0 and 2.0	Continuous and discontinuous aquifers of regional extension, of medium productivity.
Low Between 0.05 and 1.0	Continuous aquifers of local extension, of low productivity,
Very low Less than 0.05	Complex of sediments and rocks with very low productivity

Source: International Association of Hydrogeologists (IAH) "International Legend of Hydrogeological Maps", UNESCO, (1983).

- **Running Slug tests.**

The Slug tests were carried out in order to obtain the hydraulic conductivity of the aquifers and are applicable to low permeability media. The tests can be performed in two ways namely:

Constant Level: A known flow rate is introduced to maintain the level constant within the bore. Stabilizing the process, from the said flow rate and the length and diameter of the perforation, the permeability is calculated.

Variable Level: A volume of water is suddenly introduced or withdrawn in a survey, which causes an instantaneous rise or fall in the level of the perforation. The ascensos-tiempo or descensos-time are measured as the initial level is recovered.

For the present project the variable level method was used, which extracts a flow by causing the level to fall suddenly.

§ **Process.**

The test begins by measuring the static level (initial reading) using an electric probe, subsequently extracting a flow of water present inside the installed piezometers or community tanks by dropping the static level to the maximum depth, then Starts with taking Recovery vs. Time readings until you reach the initial position of the static level.

In order to generate reliable data, measurement equipment known as Water Lever Data Logger manufactured by the American company ONSET was used. Measurement by means of this method consists in the insertion of a device into the well, piezometer or cistern (), once the device Level begins to vary the device will send via Bluetooth the levels taken in time to an external electronic device, also used electrical level probes for contrast and datalogger record control.

Photography 5-107 Datalogger installation for Slug test record in Casagrande Piezometer.

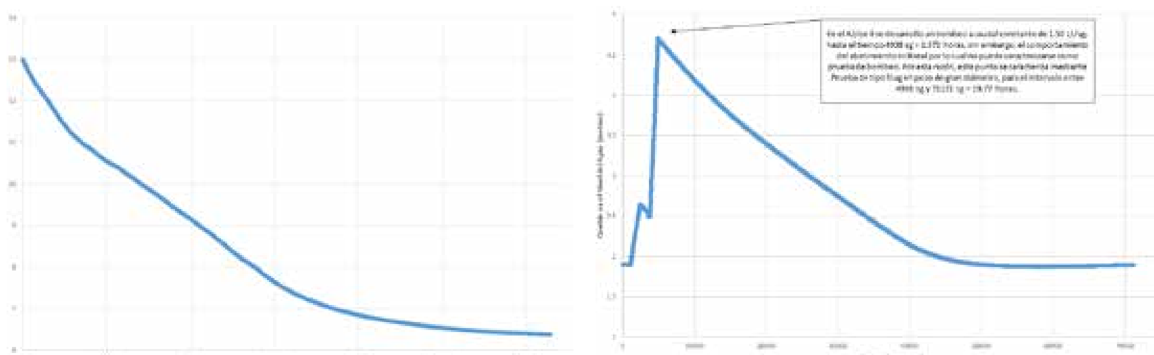
Photography 5-108 Installation of datalogger and pumping equipment for Slug test development in Ajibe.

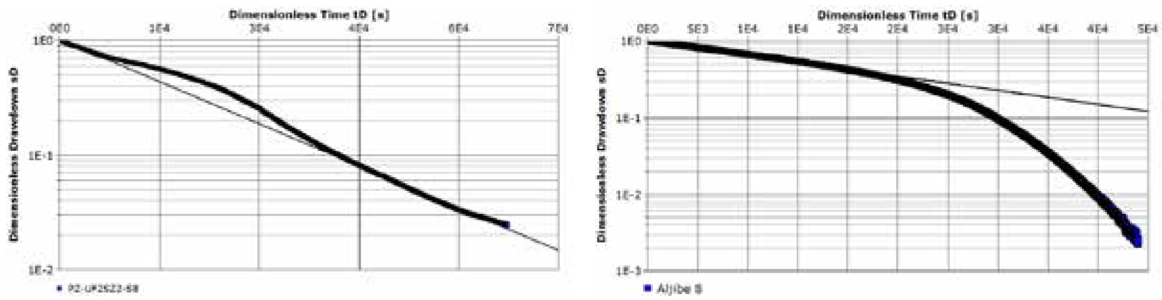
Source: GEOCOL CONSULTORES SA, 2017. AND: 955365, N: 600420.

Source: GEOCOL CONSULTORES SA, 2017. AND: 952808, N: 595514

After the Slug tests were completed with the readings, the recovery vs. time curves were elaborated to evaluate the behavior of the aquifers and subsequent calculation of the hydraulic properties in the AquiferTest 2011.1 specialized software. The following figures show an example of the recovery behavior with respect to the time of the studied aquifers.

Figure 5.104 Recovery curves vs time, (left, Slug test example in Piezometer PZ-UF2SZ2-S8, right Slug test in Aljibe 8).





Source: GEOCOL CONSULTORES SA, 2017.

According to the above graphs, recovery is generally rapid during the first few minutes after the withdrawal of water, however, as time passes the recovery becomes slow and the behavior of the curve is asymptotic indicating a Low permeability of materials.

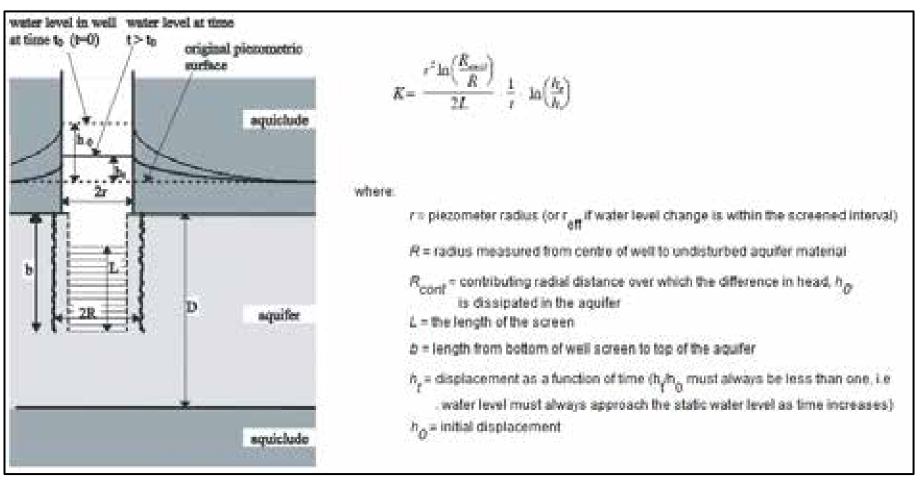
§ **Description of the method of calculation.**

Calculations made using Acuifer Test 2011.1 software provide three methods of analysis:

ü **Bouwer-Rice Slug Test.**

The Slug Bouwer-Rice (1976) test is designed to estimate the hydraulic conductivity of an aquifer. The solution is appropriate for the conditions shown in the following figure:

Figure 5.105 Analysis method Bouwer and Rice (1976).

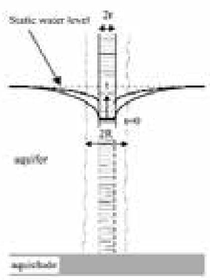


Source: Bouwer and Rice (1976).

ü **Hvorslev Slug Test.**

The slug test Hvorslev (1951) is designed to estimate the hydraulic conductivity of an aquifer. The rate of entry or exit, q, at the tip of piezometers at any time t is proportional to K of the soil and the unrecoverable head difference:

Figure 5.106 Analysis method Hvorslev (1951).



$$q(t) = \pi r^2 \frac{dh}{dt} = FK(H - h)$$

$$T_L = \frac{\pi r^2}{FK}$$

where:
- r is the effective radius of the piezometer
- F is a shape factor that depends on the dimensions of the piezometer intake (see Hvorslev (1951) for an explanation of shape factors)
- K is the bulk hydraulic conductivity within the radius of influence

$$K = \frac{\pi r^2 \left(\ln \frac{h_t}{h_0}\right)}{FT_L}$$

where:
- h_t is the displacement as a function of time
- h_0 is initial displacement

$$K = \frac{r^2 \ln(L / R)}{2 L T_L}$$

where:
- L is the screen length
- R is the radius of the well including the gravel pack
- T_L is the time lag when $h_t/h_0 = 0.37$

Source: Hvorslev (1951).

ü **Cooper-Bredehoeft-Papadopulos Slug Test.**

The Slug Cooper-Bredehoeft-Papadopulos (1967) test is applied to the instant injection or extraction of a volume of water from a well. If the water is removed from the well deck, then the initial head is below the equilibrium level and the method calculates the pressure drop. The reduction or accumulation s are given by the following equation:

Figure 5.107 Analysis method Cooper, Bredehoeft, and Papadopulos (1967).

$$s = \frac{2H_0}{\pi} \int_0^{\infty} \exp\left(-\frac{\beta u^2}{\alpha}\right)\left(J_0\left(\frac{ur}{r_c}\right)[uY_0(u) - 2\alpha Y_1(u)] - Y_0\left(\frac{ur}{r_c}\right)[uJ_0(u) - 2\alpha J_1(u)]\right)\left(\frac{1}{\Delta(u)}\right) du$$

and

$$\Delta(u) = [uJ_0(u) - 2\alpha J_1(u)]^2 + [uY_0(u) - 2\alpha Y_1(u)]^2$$

$$\alpha = (r_w^2 S)/r_c^2$$

$$\beta = (Tt)/r_c^2$$

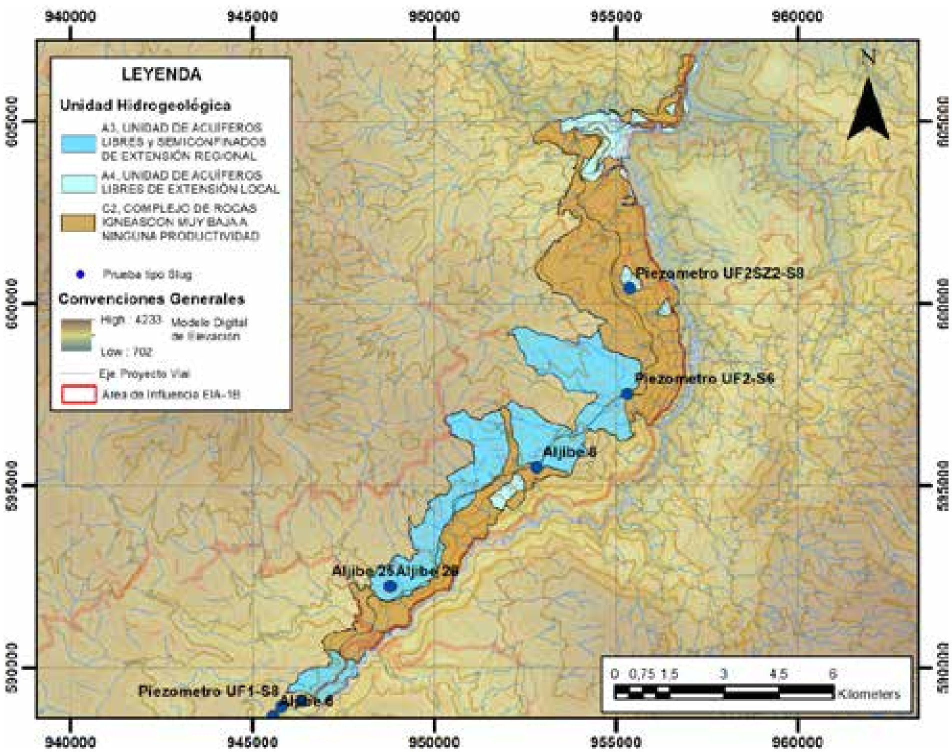
where
- H_0 = initial change in head in the well casing due to the injection or withdrawal
- r = radial distance from the injection well to a point on the radial cone of depression
- r_c = effective radius of the well casing
- r_w = effective radius of the well open interval
- T = Transmissivity of the aquifer
- S = Storativity of the aquifer
- t = time since the injection or withdrawal
- J_0 = Zero Order Bessel function of the first kind
- J_1 = First Order Bessel function of the first kind
- Y_0 = Zero Order Bessel function of the second kind
- Y_1 = First Order Bessel function of the second kind

Source: Cooper, Bredehoeft, and Papadopulos (1967).

§ **Results of hydraulic tests in the area of influence.**

According to the results of the groundwater source inventory, five (5) points were selected for the execution of Slug Test tests with the purpose of recognizing hydraulic parameters of the aquifers used by the community. The Slug test records and calculation reports are presented in the **Annex 7. Hydrogeology**.

Figure 5.108 Location of Slug-type tests executed in the area of influence.



Source: GEOCOL CONSULTORES SA, 2017

Table 5.107 Results of hydraulic characterization tests of aquifers.

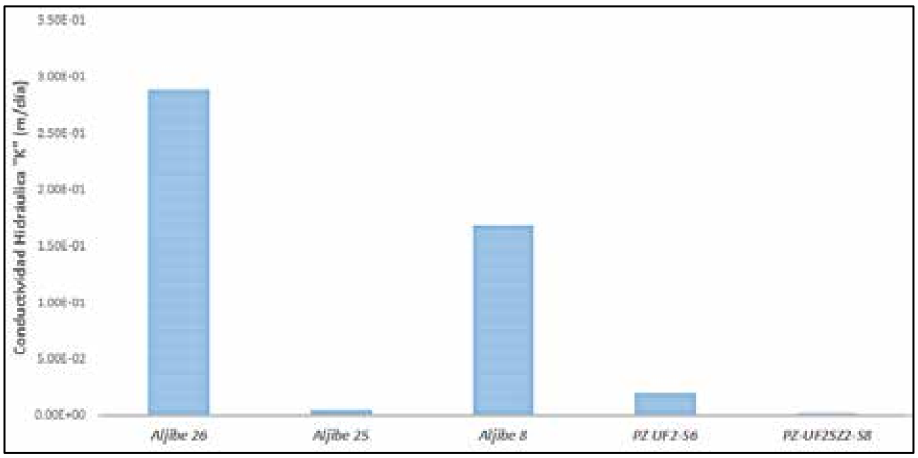
Point	East Coordinate (M)	North Coordinate (M)	Well Head Lift (Msnm)	Depth (M)	Discharge "Q" (lt / sg)	Static Level (M)	Dynamic Level (M)	Duration of Registration (hours)	Dejection (M)	Recovery (M) (%)		Transmissivity "T" (m^2/day)	Hydraulic Conductivity "K" (m / day)	Storage Coefficients "H.H"	Specific capacity (LPS / m)	Aquifer Characterized	conclusion
Aljibe 26	948766	592239	2696	5.0	1.50	0.10	1.12	19.78	1.02	1.02	100%	2.45x100	2.90x10-1	2.74x10-4	1.47	Soil residual and saprolite of Lavas and Piroclastos "A3"	It is characterized by a semi-confined aquifer (S <10-4), with specific capacity "Medium" (Between 1.0 and 2.0 LPS / m), "Weak" potentiality (1 <T <10), which classifies wells of less than 1 l / s with 10 m theoretical depression, and "Low" permeability (10-2 <K <1).
Aljibe 25	948815	592242	2695	8.0	1.50	2.90	6.67	19.78	3.77	0.32	8%	5.29x10-2	5.07x10-3	3.01x10-5	0.40	Soil residual and saprolite of Lavas and Piroclastos "A3"	It is characterized by a semi-finite aquifer (S <10-3), with specific capacity "Low" (<1.0 LPS / m), "negligible" potentiality (T <1), which classifies wells of less than 1 l / s with 10 m Theoretical depression, and "Very Low" permeability (K <10-2).
Aljibe 8	952808	595514	2913	10.0	1.50	1.87	4.71	19.78	2.84	2.83	100%	1.31x100	1.69x10-1	1.00x10-3	0.53	Soil residual and saprolite of Lavas and Piroclastos "A3"	It is characterized by a semi-confined aquifer (S <10-3), with specific capacity "Low" (<1.0 LPS / m), "Weak" potentiality (1 <T <10), which classifies wells of less than 1 l / s with 10 M theoretical

Point	East Coordinate (M)	North Coordinate (M)	Well Head Lift (Msnm)	Depth (M)	Discharge "Q" (lt / sg)	Static Level (M)	Dynamic Level (M)	Duration of Registration (hours)	Dejection (M)	Recovery (M) (%)		Transmissivity "T" (m^2/day)	Hydraulic Conductivity "K" (m / day)	Storage Coefficients "H.H"	Specific capacity (LPS / m)	Aquifer Characterized	conclusion
																	depression, and "Low" permeability (10-2 <K <1).
PZ UF2-S6	955317	597528	2767	25.0	Manual (Water hammer)	0.04	5.00	19.77	4.96	3.43	69%	4.83x10-1	1.98x10-2	1.29x10-5	-	Soil residual and saprolite of Lavas and Piroclastos "A3"	It characterizes a semi-confined aquifer to confined (S <10-4), with "Despicable" (T <1) potential, which classifies wells of less than 1 l / s with 10 m of theoretical depression, and "Very Low" permeability <10-2).
PZ-UF2SZ2-S8	955365	600420	2274	15.0	Manual (Water hammer)	6.21	12.99	18.3	6.78	6.62	98%	3.74x10-2	2.80x10-3	4.46x10-5	-	Colluvial deposit "A4"	It characterizes a semi-confined aquifer to confined (S <10-4), with "Despicable" (T <1) potential, which classifies wells of less than 1 l / s with 10 m of theoretical depression, and "Very Low" permeability <10-2).

Source: GEOCOL CONSULTORES SA, 2017.

The tests in general characterize the residual Soil Aquifer and Saprolite of Washes and Pyroclasts "A3", the results indicate the presence of two types of material. The first characterizes free to semi-finite type aquifers (S <10-3), with specific capacity "Low" (<1.0 LPS / m), "Despicable" potentiality (T <1 m2 / day), classifying wells less than 1 L / s with 10 m theoretical depression, and "Very Low" permeability (K <10-2 m / day). The second characterizes semi-confined aquifers (S <10-3), with specific capacity "Low" (<1.0 LPS / m), "Weak" potentiality (1 <T <10 m2 / day) Of 1 l / s with 10 m theoretical depression, and "Low" permeability (10-2 <K <1 m / day). These results contrast effectively with the hydrogeological model identified throughout the area of influence, where it is emphasized that the best aquifer conditions exist in the southwest of the same, however, the potentiality of the aquifer is weak.

Figure 5.109 Results of hydraulic conductivity "K" (m / day) for different points.



Source: GEOCOL CONSULTORES SA, 2017.

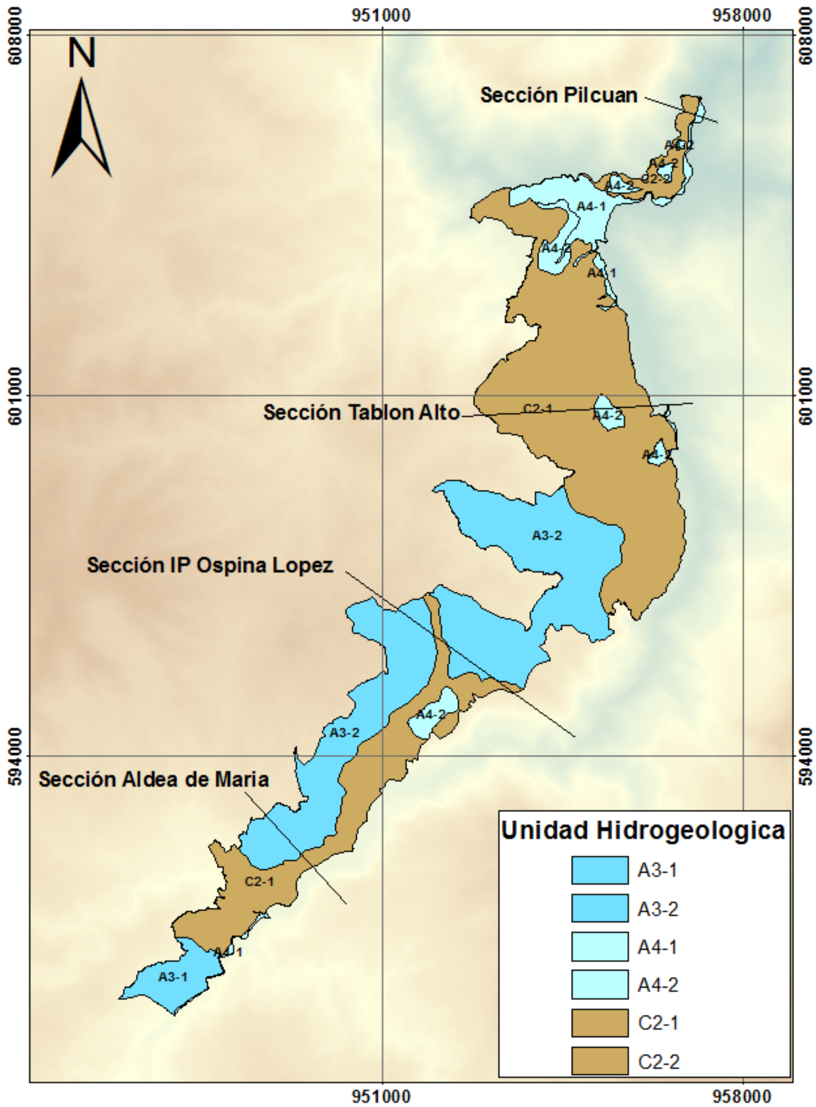
5.1.9.5 Conceptual model.

With the integration of available geological, geomorphological, hydrological, hydrogeological and hydraulic information, the conceptual hydrogeological model was elaborated, which can be defined as a simplified version of the real world (in this case an aquifer), which roughly represents the aspects More relevant with respect to the geological and hydrogeological characteristics of the environment. Simplification is introduced as a set of assumptions which express the real world to obtain a predictive analysis that serves as a management tool to plan the use of the underground water resource.

- **Sections of Analysis.**

The analysis of the conceptual hydrogeological model took into account four (4) sections of analysis that represent each of the different hydrosystemic behaviors along the road corridor and whose location is presented in the following figure (**Figure 5.111**):

Figure 5.110 Location of hydrogeological sections of analysis.

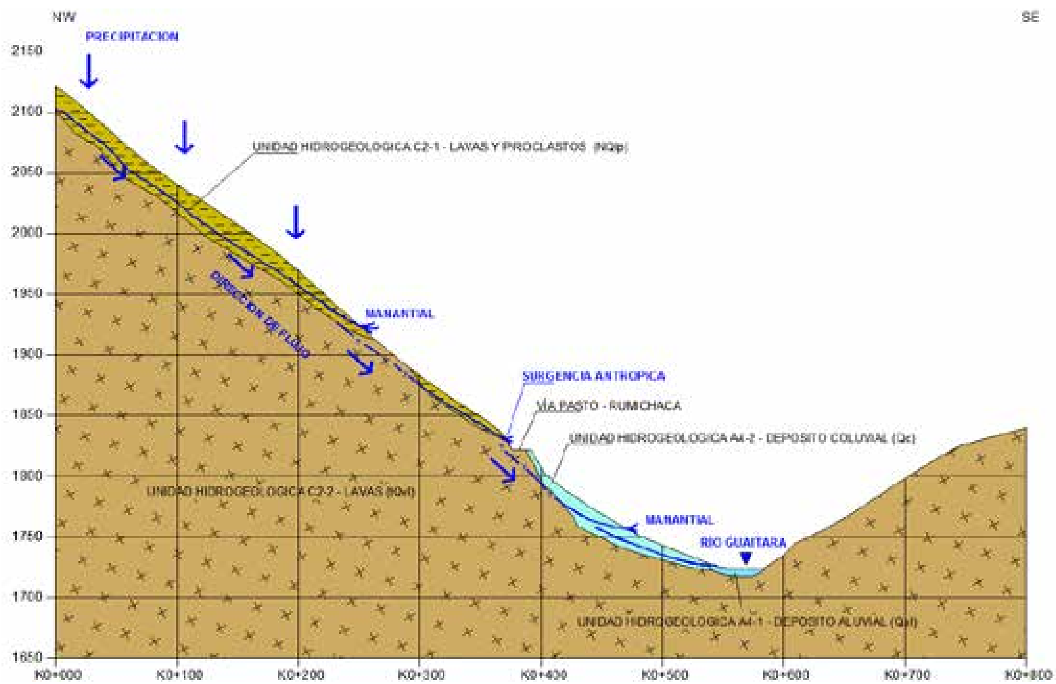


Source: GEOCOL CONSULTORES SA, 2017.

o **Pilcuan Section.**

In the Pilcuan section (**Figure 5.112**), The Lavas unit (TQvl) is present through flowing tabular forms, commonly resting in the valleys of the Sapuyes and Guáitara rivers, modeling an abrupt topography, consisting of very narrow, deep and staggered V valleys. They are intercalated with other lava flows or with flow pyroclastic deposits and are generally presented as massive and block lavas. Generally in the contact between these two types of materials (lavas and pyroclasts) are outcrops of groundwater either by natural cause (Manantiales) or by artificial cause (anthropic upwelling due to the cut of the national road). On the slope below the national track, colluvial deposits commonly occur where occasional outcroppings of water appear on the surface as a stream (Manantiales). However, the general discharge of these aquifer systems occurs in the foot of the slope, fed the base flows of the Gauitara and Sapuyes rivers. On the other hand, the presence of stored and lightly flowing groundwater in the Lavas unit (tQlv) is not ruled out, since in this sector these materials present a moderate degree of fracturing and disintegration due to tectonic events. (**Photo 5.94**).

Figure 5.111 Section Hydrogrologica Pilcual.



Source: GEOCOL CONSULTORES SA, 2017.

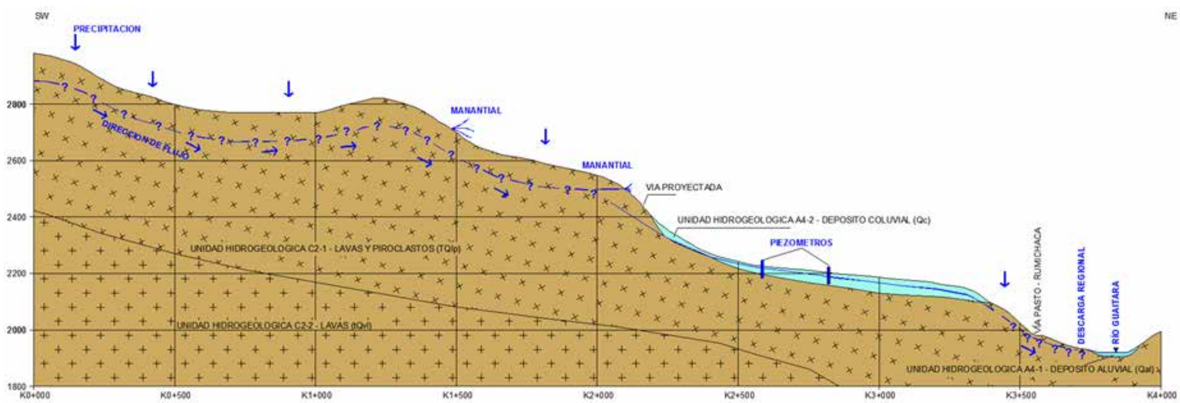
o **Section High Board.**

This sector is characterized by the presence of lavas and pyrotechnics, deposits of considerable thickness and variable extent, sometimes lava outcrops are isolated as windows under the pyroclastic deposits forming slopes of strong slopes, sometimes vertical, where It is common the formation of castades by drainage from the top of the slope. These fresh materials are considered with limited groundwater resources, that is, they have a "negligible" potentiality, although in some sectors there are occasional outcroppings of groundwater as springs, mainly occurring in the drastic slope changes of The slopes and in the high parts of the micro-basins where the drainage of the hillside is**Photo 5.92**). Some outcrops may also occur in fresh lava materials only due to secondary porosities and permeabilities due to fracturing and cracking caused by tectonic events.

In the lower and middle part of the slopes are Coluvial deposits (Qc) constituted by angular debris of different size, poorly selected and with low matrix content. In general, they are clastosoportados and predominates a unique lithology inside the deposit. In these materials is generally young groundwater, ie these local aquifers are generally recharged by direct precipitation over the outcrop area, however, the potentiality of the unit is

"Weak" to "Despicable", recording levels Is more than 5.0 meters deep (Figure 5.113). The general discharge of these aquifer systems occurs in the foot of the slope, fed the base flows of the Guaítara river.

Figure 5.112 Section Hydrogrologica Tablon Alto.

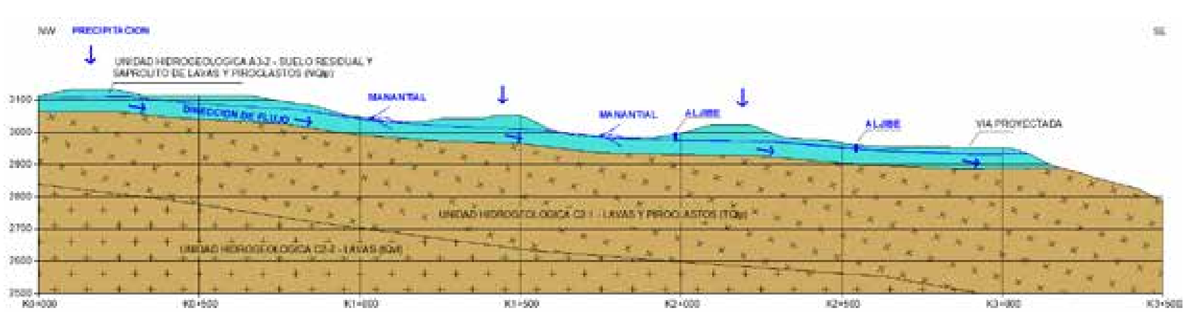


Source: GEOCOL CONSULTORES SA, 2017.

o **Section IP Ospina López.**

In this sector, the Lavas and pyroclastic unit of the neogene (NQlp), mainly formed by pyroclastic deposits of flow and fall, which are generally in an advanced state of weathering in the upland sector, generate clay, brown, gray and white soils; These materials form a hydrogeological unit of regional extension of weak potentiality, limited by the thickness of the meteorized horizons and granulometric constitution; In some sectors there are occasional outcroppings of groundwater as springs, mainly in the high parts of the microbasins where the drainage of the hillside is notched (**Photography 5.91**). It is also common to find surface catchments through wells with manual extraction and domestic and agricultural use.

Figure 5.113 Seccion Hidrogrologica IP Ospina Lopez.

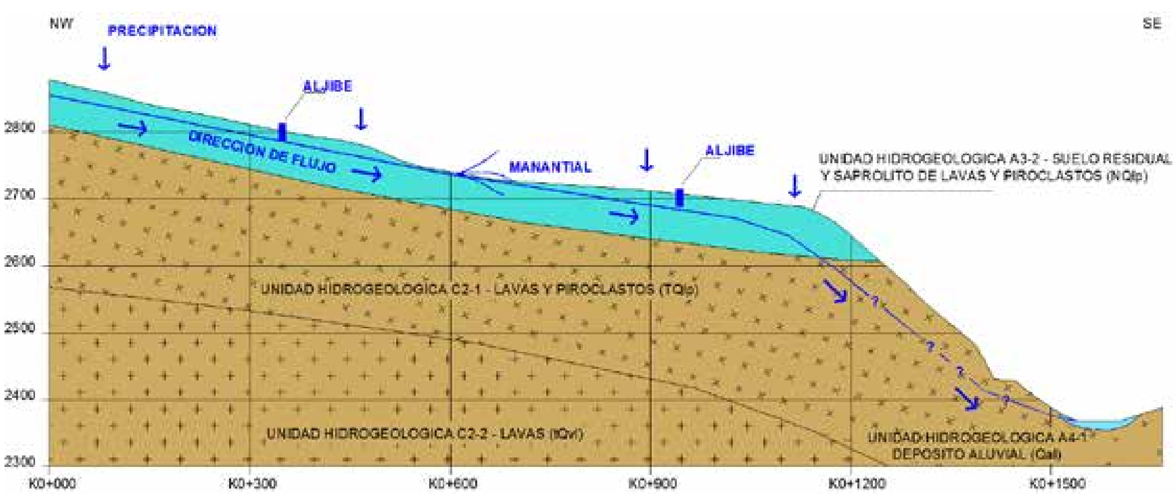


Source: GEOCOL CONSULTORES SA, 2017.

- **Section Aldea de María.**

Similar to the previous section, in this sector, the Lavas and pyroclasts unit of the neogene (NQlp) is mainly formed by pyroclastic deposits of flow and fall that are generally in an advanced state of weathering; These materials form a hydrogeological unit of regional extension of weak to negligible potentiality, limited by the thickness of the meteorized horizons and granulometric constitution; In some sectors there are occasional outcroppings of groundwater as springs, mainly to the middle slope. It is also common to find surface abstractions using wells with manual extraction and domestic and agricultural use in a smaller proportion. The general discharge of these aquifer systems occurs in the foot of the slope, fed the base flows of the Guaítara river.

Figure 5.114 Section Hidrogrologica Aldea de Maria.



Source: GEOCOL CONSULTORES SA, 2017.

- **Areas of recharge, transit and discharge.**

The recharge zones of the aquifer units are presented to the high mountainous areas, in rock outcrops of the Neogene belonging mainly to the Lavas and Piroclastos (TQlp) unit in weathered state; The direct recharge by precipitation of rainwater is possible mainly in the Nariñense Altiplanicie sector, where the characteristic morphology exhibits undulating terrain and residual slopes from mild to moderately inclined slopes (IP Section Ospina López). Other areas of local recharge are characterized by the direct outcropping of the different aquifer units, although the magnitude of this recharge is influenced mainly by slopes of the terrain, which especially favors surface runoff.

For the area of influence the transit zones are generally located on the slopes of the left slope of the Guáitara river; On these slopes, it is common to find groundwater outcrops on the surface in the form of stream (springs) giving rise to local discharge points. For evidences of field and characterization of the geological model in depth (maps and profiles of isoresistivity), it is concluded that generally in these microcuencas are generated local aquifers in many occasions not connected to each other, with flow lines towards the main slope drainage .

The discharge zones of the aquifers correspond to areas of high permeability and / or low slope where local rainfall is infiltrated by generating predominantly horizontal, subsurface flows or feeding free aquifers, which regulate the hydrological cycle, maintaining the water supply during periods of drought. According to the field survey, the regional discharge zones of the aquifers are presented on the units of recent alluvial deposits along the slope of the left bank of the Guáitara river on the eastern side of the area of influence and on both slopes of the Sapuyes , Boquerón and major tributaries. Locally, the discharge of aquifers manifests where the drainage is intersected by the formation of natural nacederos, and anthropic upwelling originated by the cut of part of the volume of the aquifer (cuts in drawer pathways).

· **Movement of groundwater.**

The piezometric levels present in the study area are controlled by direct infiltration by precipitation and have a constant recharge source due to surface outcrops.

The directions of the underground water flow are strongly influenced by the structural condition of the area, for the area of influence these directions are directed to topographically lower terrain, influenced by the action of the Guáitara river and larger tributaries; In this way, the directions of general flow have preferential orientation in the northwest → southeast direction.

5.1.9.6 Vulnerability Analysis to Groundwater Contamination - DRASTIC Method.

DRASTIC vulnerability analysis is a parametric method for assessing intrinsic or natural vulnerability to contamination (overlapping and indices), and assesses vulnerability to a surface pollutant load (downstream vertical flows). The DRASTIC (Aller et al 1987) is a scoring and weighting method (PCSM), in which in addition to assigning a score each parameter, is multiplied by a weight factor.

The DRASTIC method classifies and weighs intrinsic parameters, reflecting the natural conditions of the environment and is the most widespread to determine the vulnerability of aquifers as described in **Table 5.108** Y **Figure 5.116** For this analysis values as parameters:

D: Depth of groundwater.

A: Net Recharge: amount of annual water per unit area that contributes to the aquifer feed.

TO: Lithograph of the aquifer: characteristics of the nature of the aquifer.

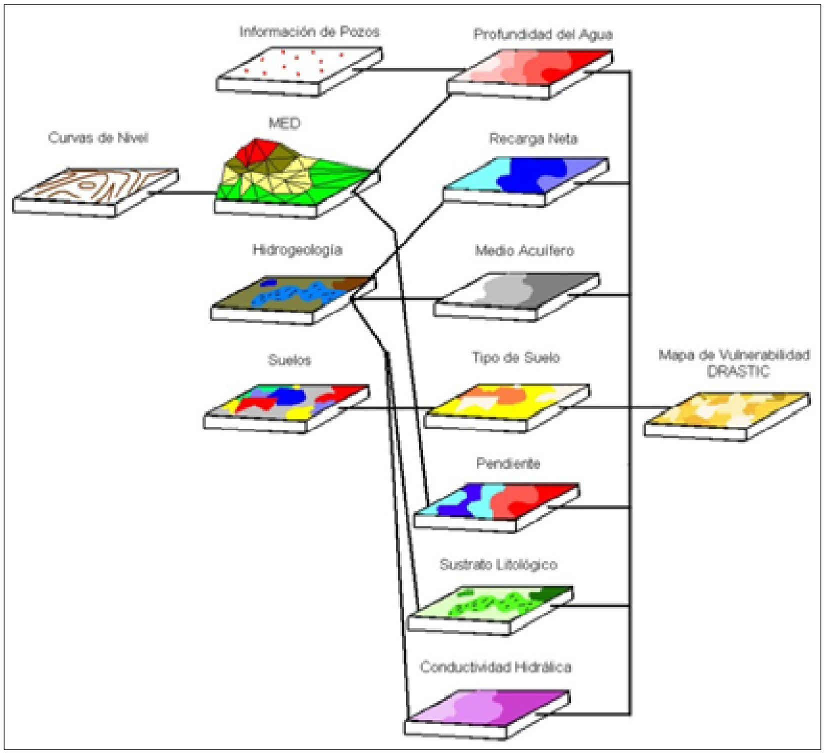
S: Type of soil: soil capacity to oppose the mobilization of pollutants.

T: Topography: slope of the topographic surface.

I: Unsaturated zone. Ability of the ZNS to obstruct vertical transport.

C: Hydraulic conductivity of the aquifer: amount of water that crosses the aquifer per unit of time and per unit of section.

Figure 5.115 Mathematical model for analysis of aquifer vulnerability using the DRASTIC method.



Source: Analysis of vulnerability to the contamination of a section of the aquifers of the Central Valley of Costa Rica, Http://proceedings.esri.com.

According to the characteristics and behavior, each parameter is assigned indexes ranging from 1.0 (minimum vulnerability) to 10.0 (maximum vulnerability) (Vargas Quintero 2010). In addition to the assessment of 1 to 10 given to each parameter, its influence is weighted within the vulnerability assessment by assigning weights from 1 to 5, which will vary if the contaminant in question is a pesticide, Less volatile and more persistent as indicated by **Table 5.109**. A limitation of this method is subjectivity in assessing the parameters, so to minimize this degree of subjectivity, homogeneous criteria must be used.

Table 5.108 DRASTIC parameter ranges and values.

DRASTIC METHOD PARAMETERS			
"D" Depth of Piezometric Level		"R" Net Recharge	
1.5 Depth (m)	Rating D_R	Recharge (mm)	R Rating$_R$
0-1,5	10	0-50	1
1,5-4,6	9	50-103	3
4,6-9,1	7	103-178	6
9,1-15,2	5	178-254	8
15,2-22,9	3	> 254	9
22,9-30,5	2		
> 30,5	1		

DRASTIC METHOD PARAMETERS

"A" Nature of the Aquifer			"S" Nature of Soil	
Lithograph of the aquifer	**Valuation A_R**	**Typical value A_R**	**Type of soil**	**S rating$_R$**
Big shit	1-3	2	Thin or absent	10
Metamorphic / Igneous	2-5	3	Gravel	10
Metamorphic / Weathered Igneous	3-5	4	Sand	9
Till glacial	4-6	5	Clay aggregate or compacted aggregate	7
Sequences of sandstone, limestone and shales	5-9	6	Marigold Sandstone	6
Massive sandstone	4-9	6	Loam	5
Bulk limestone	4-9	6	Marly slime	4
Arena or gravel	4-9	8	Marly clay	3
Basalts	2-10	9	Dried manure	2
Karst limestone	9-10	10	Non-compacted and non-aggregated clay	1

"T" Topography		"C" Hydraulic Conductivity		
Pending (%)	**Rating T_R**	**Hydraulic conductivity**		**Rating C_R**
0-2	10	**M / day**	**Cm / s**	
02-06	9	0,04-4,08	$4,6 \cdot 10^{-5}$-$4.7 \cdot 10^{-3}$	1
06-12	5	4,08-12,22	$4.7 \cdot 10^{-3}$-$1.4 \cdot 10^{-2}$	2
12-18	3	12,22-28,55	$1.4 \cdot 10^{-2}$-$3,4 \cdot 10^{-2}$	3
> 18	1	28,55-40,75	$3.4 \cdot 10^{-5}$-$4.7 \cdot 10^{-2}$	6
		40,75-81,49	$4.7 \cdot 10^{-2}$-$9.5 \cdot 10^{-2}$	8
		> 81.49	$> 9.5 \cdot 10^{-2}$	10

"I" Impact of the unsaturated zone		
Nature of the unsaturated zone	**Assessment I_R**	**Typical value I_R**
Conning layer	1	1
Cieno-clay	2-6	3
Lutita	2-5	3
Limestone	2-7	6
Sandstone	4-8	6
Sequences of sandstone, limestone and Lutita	4-8	6
Sand or gravel with silt and significant clay content	4-8	6
Metamorphic / Igneous	2-8	4
Gravel and sand	6-9	8
Basalt	2-10	9
Karst limestone	8-10	10

Source: Aller et al., 1987.

Table 5.109 Weighting factor of the DRASTIC method.

Contaminant type	Variable						
	D_W	R_W	TO_W	S_W	T_W	I_W	C_W
Pesticide	5	4	3	5	3	4	2
No pesticide	5	4	3	2	1	5	3

Source: Aller et al., 1987

Both indices are multiplied and the seven (7) results are added together to obtain a final valuation, as indicated in the following expression:

DRASTIC = (Dr · Dw) + (Rr · Rw) + (Ar · Aw) + (Sr · Sw) + (Tr · Tw) + (Ir · Iw) + (Cr · Cw)

Where:

R: indicates classification or rating factor

W: indicates weighting factor

The results can vary between 23 (minimum) and 230 (maximum), obtaining the ranges of vulnerability of the Table.

Table 5.110 Degree of vulnerability - DRASTIC method.

GENERAL VULNERABILITY	
GRADE	**VULNERABILITY**
Very low	23 - 64
Low	65 - 105
Moderate	106 - 146
High	147 - 187
Very high	188 - 230

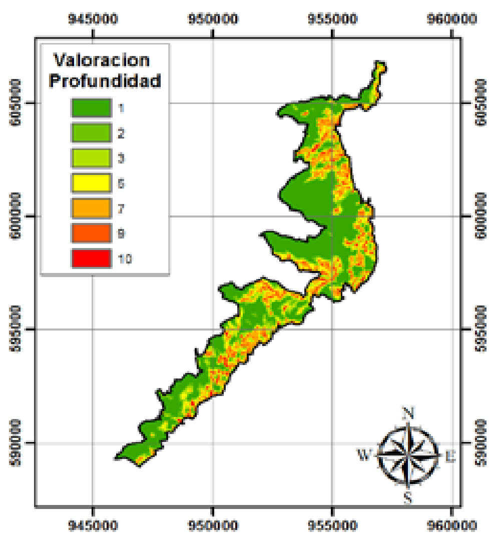
Source: Aller et al., 1987

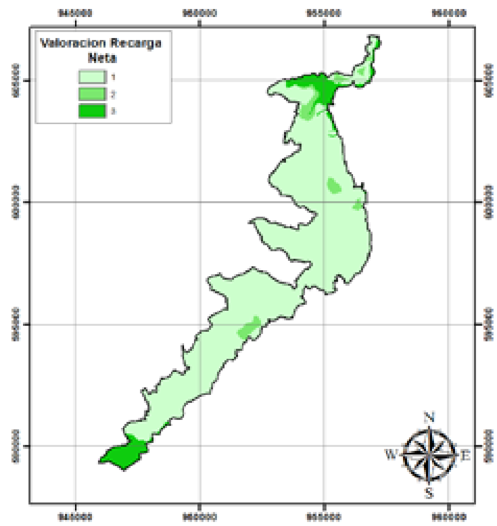
The maps of intrinsic vulnerability of aquifers to pollution represent sectors of homogeneous vulnerability to the work area, using the method described and must be updated periodically as the information that feeds the model is updated or expanded, as they involve many simplifications Geological and hydrogeological.

For the application of the DRASTIC method in the local context, two aquifers were considered one free and another confined as defined by the conceptual model of the present study, next the seven (7) factors are presented and finally the maps will be presented for each One of the analyzed aquifers (**Table 5.111**). In the **Figure 5.117** The reclassified final map of the vulnerability of the study area is presented.

Table 5.111 Evidence of intrinsic vulnerability of aquifers to contamination of the study area.

FACTOR D	FACTOR R

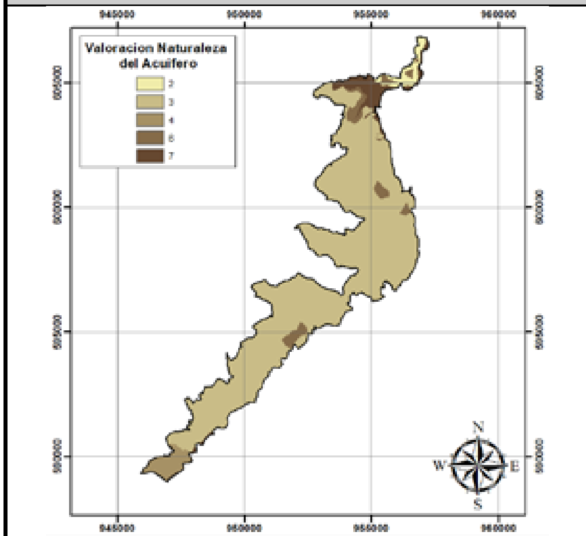




D: Depth of water table and piezometer: Corresponding to the thickness of the unsaturated zone, the assessment of this parameter is expressed as the estimation of the distance that a contaminating trace must travel to affect the water table. The titration of this parameter has been weighted for non-pesticidal contaminants. The data for the construction of the static level surfaces were obtained from the inventory of water points and analysis of water and piezometric surfaces.

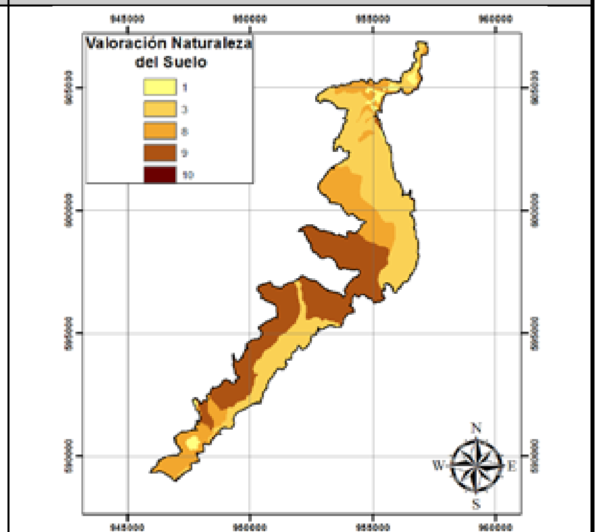
A: Net Recharge: Amount of annual water per unit area that contributes to aquifer feed. This factor corresponds to an indirect parameter taken from precipitation discounting evapotranspiration and surface water runoff. According to the hydroclimatological analyzes carried out in previous studies, the net recharge does not exceed 100 mm / year, being higher for classic units and recent sedimentary vulcan deposits.

FACTOR - A



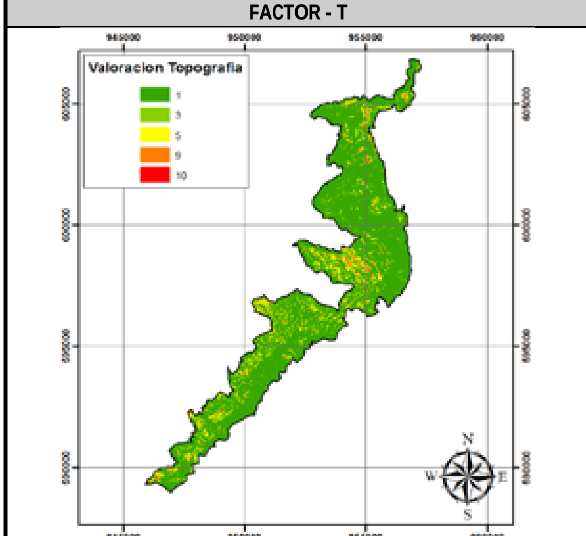
TO: Nature of the Aquifer: It represents the lithological characteristics of the hydrogeological units obtained from the analysis elaborated in the conceptual model. Materials varying from sands and gravel are observed in alluvial and colluvial deposits and igneous type materials for the other units.

FACTOR - S



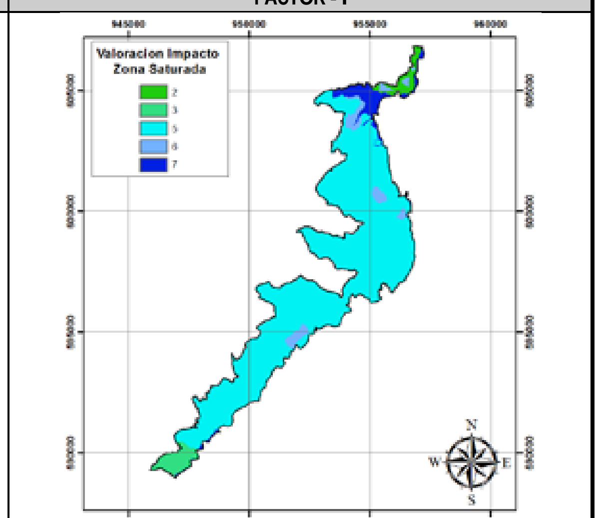
S: <u>Nature of the Soil:</u> It is the ability of the soil to oppose the mobilization of pollutants. These values are taken from the different types of soils that are recognized in the area as part of the soil component of the area, where it is observed that the highest values belong to gravels and coarse sediments, while the low values to fine sediments Like lavas.

FACTOR - T



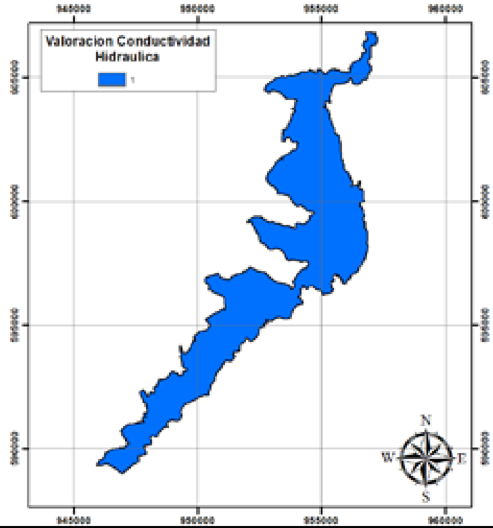
T: <u>Topography:</u> It represents the topographic variation according to the slopes of the terrain, reclassifying them according to the ranges established by the methodology from DEM with resolution of 12.5 m (ALOS-1 PALSAR | Alaska Satellite Facility - 2016). A smaller slope less surface water runoff and greater potential for infiltration-recharge, and therefore greater susceptibility to contamination.

FACTOR - I



I: <u>Nature of the Unsaturated Zone:</u> Capacity of the Unsaturated Zone to obstruct the vertical transport according to the characteristic lithology. In the categories of unsaturated zones, it is formed by sands with gravel and clay contents.

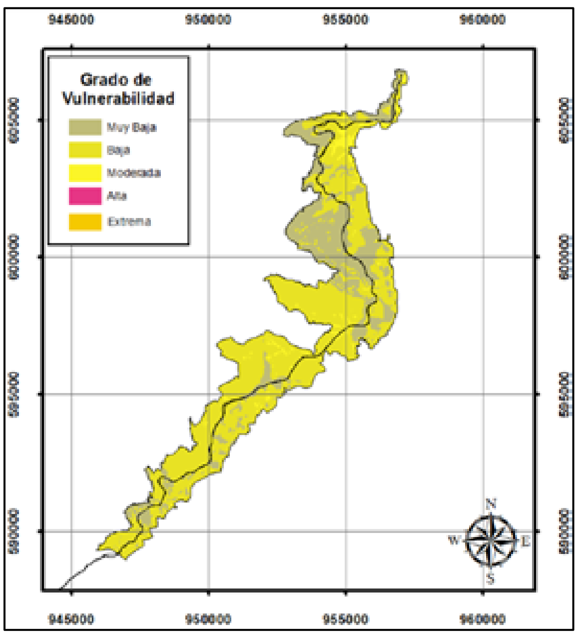
FACTOR - C



C: <u>Hydraulic Conductivity:</u> It determines the amount of water that the aquifer traverses per unit of time and per unit of section, ie the speed at which the groundwater moves. In general, conductivity values on the order of $1x10^{-2}$ To 1 m / day, which attributes an assessment of "1" according to the DRASTIC classification table.

Source: GEOCOL CONSULTORES SA, 2017.

Figure 5.116 Vulnerability Intrinsic to the contamination of aquifers.



Source: GEOCOL CONSULTORES SA, 2017.

5.1.10 Hydrogeochemical Model.

5.1.10.1 Monitoring and Analysis of Groundwater Quality.

In order to obtain groundwater quality parameters, a physical-chemical monitoring program was developed, including a sampling of eighteen (18) water points distributed as follows: seven (7) points for quality evaluation (complete test) and eleven 11) additional points for assessment of groundwater composition and distribution (partial test with cations and major anions); These results were analyzed in office and compared with the regulations established by the Ministry of Health (Resolution 2115 of 2007), which determines the characteristics of water for human consumption. Then, in **Table 5.112** Y **Table 5.113** The concentrations obtained from the laboratory analysis of each of the samples are related; The values that exceed the mentioned norm are highlighted in red color and analyzed later.

Table 5.112 Results of laboratory analysis for groundwater quality program for quality evaluation - complete analysis (Red values indicate that they exceed the limit of Resolution 2115/07).

SETTINGS	UNITS	Maximum Allowable Value Decree 2115/07	NACEDERO K 27,6	NECEDERO 40	ALJIBE K20,5	NECEDERO 28	NECEDERO 11	NECEDERO 23	NECEDERO 26
TEMPERATURE SAMPLE	° C		16,3	16,7	19,2	16,4	16,45	16,55	16,3
PH	UNITS		7,25	7,45	6,6	7,55	7,3	7,8	7,2
ELECTRIC CONDUCTIVITY	µS/cm		70	180	390	210	220	230	280
DISSOLVED OXYGEN	Mg / L O2		2,2	1,9	2,28	2,1	1,5	1,2	1,45
TURBIDITY	NTU	2	**12,7**	**16**	**2,97**	**3,19**	**50**	**15,7**	**37,4**
TOTAL ALKALINITY	Mg / l CaCO3	200	16,5	45,6	48,4	118	112	118	182
TOTAL HARDNESS	Mg / l CaCO3	300	25,2	53,6	108	102	85,2	68,4	100
CARBONATES	mg/L CaCO3		<2,00	<2,00	<2,00	<2,00	<2,00	<2,00	<2.00
BICARBONATES	Mg / l CaCO3		16,5	45,6	48,4	118	112	118	182
CHLORIDE	mg/L Cl-	250	10,2	24,3	46,9	7,55	<4,00	<4,00	<4,00
SULFATES	mg/L S04-2	250	<5,00	<5,00	13,4	10,4	<5,00	<5,00	<5,00
PHOSPHATES	mg/L P-PO4-3		<0,03	<0,03	<0,03	<0,03	<0,03	<0.03	<0.03
FLUORUROS	mg/L	1	<0,050	<0,050	0,115	0,095	0,066	0,06	0,075
NITRATES	mg/L N-NO3	10	2,7	2,14	2,31	2,71	0,406	1,17	0,546
NITRITES	mg/L N-NO2	0,1	0,0398	0,0188	0,0296	0,0295	0,0095	0,0283	0,0241
TOTAL CYANUR	mg/L CN	0,1	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2
TOTAL PHENOLS	mg/L	0,001	<0,002	<0,002	<0,002	<0,002	<0,002	<0,002	<0,002
TOTAL SUSPENDED SOLIDS	Mg / L		18	18	6	4	53	28	53
TOTAL SOLIDS	mg/L		76	122	210	162	180	166	248
DBO5	mg/L O2		<5	<5	<5	<5	<5	<5	<5
DQO	mg/L O2		<20	<20	<20	<20	<20	<20	<20
ANTIMONY	mg/L	0,005	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010
SELENIUM	mg/L	0,01	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010
ZINC	mg/L	3	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12
LEAD	mg/L	0,01	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05

SETTINGS	UNITS	Maximum Allowable Value Decree 2115/07	NACEDERO K 27,6	NECEDERO 40	ALJIBE K20,5	NECEDERO 28	NECEDERO 11	NECEDERO 23	NECEDERO 26
NICKEL	mg/L	0,02	<0,15	<0,15	<0,15	<0,15	<0,15	<0,15	<0,15
MOLYBDENUM	mg/L	0,07	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010
MERCURY	Mg / L	0,001	<0,002	<0,002	<0,002	<0,002	<0,002	<0,002	<0,002
ALUMINUM	mg/L	0,2	<0,54	<0,54	<0,54	<0,54	<0,54	<0,54	<0,54
ARSENIC	mg/L	0,01	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010	<0,10
BARIUM	mg/L	0,7	<0,60	<0,60	<0,60	<0,60	<0,60	<0,60	<0,60
BERYLLIUM	mg/L		<0,10	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10
BORON	Mg / L	0,3	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2
POTASSIUM	Mg / L		1,01	5,89	16,5	2,84	3,48	4,3	10,1
SODIUM	Mg / L		8,27	14,5	18,8	14,7	17,2	22,1	36
CALCIUM	Mg / L	60	5,27	5,79	12,8	7,12	4,48	3,87	6,11
MAGNESIUM	Mg / L	36	2,32	8,69	12,1	18,6	9,82	9,95	12,6
CADMIUM	Mg / L	0,003	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010
MANGANESE	mg/L	0,1	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12	<0,12
TOTAL CHROME	mg/L	0,05	<0,11	<0,12	<0,11	<0,11	<0,11	<0,11	<0,11
COPPER	mg/L	1	<0,15	<0,15	<0,15	<0,15	<0,15	<0,15	<0,15
FATS AND OILS	Mg / L	Missing	<1,40	<1,40	<1,40	<1,40	<1,40	<1,40	<1,40
TOTAL COLIFORMS	NMP/100 mL		1 300	1 078	567	890	830	810	870
FACIAL COLIFORMS	NMP/100mL	0	210	134	65	87	120	105	135

Source: GEOCOL CONSULTORES SA, 2017.

Table 5.113 Results of laboratory analysis for groundwater quality program for quality evaluation - Partial test with cations and major anions (Red values indicate that they exceed the limit of Resolution 2115/07).

SETTINGS	UNITS	Maximum Allowable Value Decree 2115/07	PZ 2UF 5Z2-8	NACEDERO 39	NACEDERO 52	NACEDERO 54	ALJIBE K26,1	NACEDERO K 21	NACEDERO 36	NACEDERO 21	PZVF 256	NACEDERO 47	NACEDERO 37
TEMPERATURE	°C		16,5	16,7	16,75	16,5	15,65	20,6	20,5	22,5	20,15	16,5	16,7
pH	UNITS		5,8	6,26	5,85	7,35	5,85	6,15	7,25	7,75	7,3	7,75	8,05
ELECTRIC CONDUCTIVITY	µS/cm		180	125	140	148	108	230	205	280	110	90	185
DISSOLVED OXYGEN	mg/L O2		2	1,9	2,05	1,95	2,15	1,7	1,9	1,95	2,15	2,15	2,35
TOTAL ALKALINITY	mg/L CaCO3	200	37,7	38,7	48,7	32,9	14,9	79,9	92,6	117,6	43.1	33,5	54,4
CARBONATES	mg/L CaCO3		<2,00	<2,00	<2,00	<2,00	<2,00	<2,00	<2,00	<2,00	<2,00	<2,00	<2,00
BICARBONATES	mg/L CaCO3		37,7	38,7	48,7	32,9	14,9	79,9	92,6	117,6	23,1	33,5	54,4
CHLORIDE	mg/L Cl-	250	17	4,18	10,9	14	8	11, 9	4,13	<4,00	2.81	6,09	12,2
SULFATES	mg/L S04-2	250	<5,00	<5,00	<5,00	<5,00	<5,00	<5,00	<5,00	<5,00	<5,00	<5,00	<5,00
NITRATES	mg/L N-NO3	10	2,45	2,63	2,34	1,98	2,43	2,66	0,8	1,76	2,81	2,66	1,53
POTASSIUM	mg/L		7,09	6,54	7,78	6,58	4,93	7,15	5,36	7,01	16	5,82	5,22
SODIUM	mg/L		11,7	11,8	14,5	15,2	7,47	19,3	18,8	20,8	12,91	14,1	19,3
CALCIUM	mg/L	60	4,85	3,07	4,51	2,25	3,48	5,07	4	11,2	4,96	0,6	0,8
MAGNESIUM	mg/L	36	4,97	3,57	3,68	2,02	3,1	7,32	7,73	8,89	1,21	1,32	5,03
REDOX POTENTIAL	Mv		165	140	120	117	98,4	185	120	150	96,4	65,2	165

Source: GEOCOL CONSULTORES SA, 2017.

According to the laboratory results it can be observed that for all the monitoring points only the Turbidity value has a high concentration compared to Resolution 2115/07, which indicates an existence of particles suspended in the water, which absorb light Solar, making them warmer, reducing the concentration of oxygen and therefore the survival of living beings; In addition, Fecal coliforms are present in high values, these concentrations of bacteria show that the waters are not suitable for human consumption, since they can generate epidemic outbreaks in the population.

5.1.10.2 Composition of groundwater.

This section presents a hydrochemical analysis of groundwater in the study area. The chemical analysis diagrams that were used correspond to Piper, and Stiff diagrams. Hydrogeochemical relationships and correlation of variables depend on the process that controls the dissolution or precipitation of the salts as base exchange, mixing of different types of water, salt intrusion, oxidation or reduction, etc.

The chemical and analytical results of the eighteen (18) water samples were processed and interpreted with the Aquachem 2011.1 program, and are described below:

- **Classification of sampled water.**

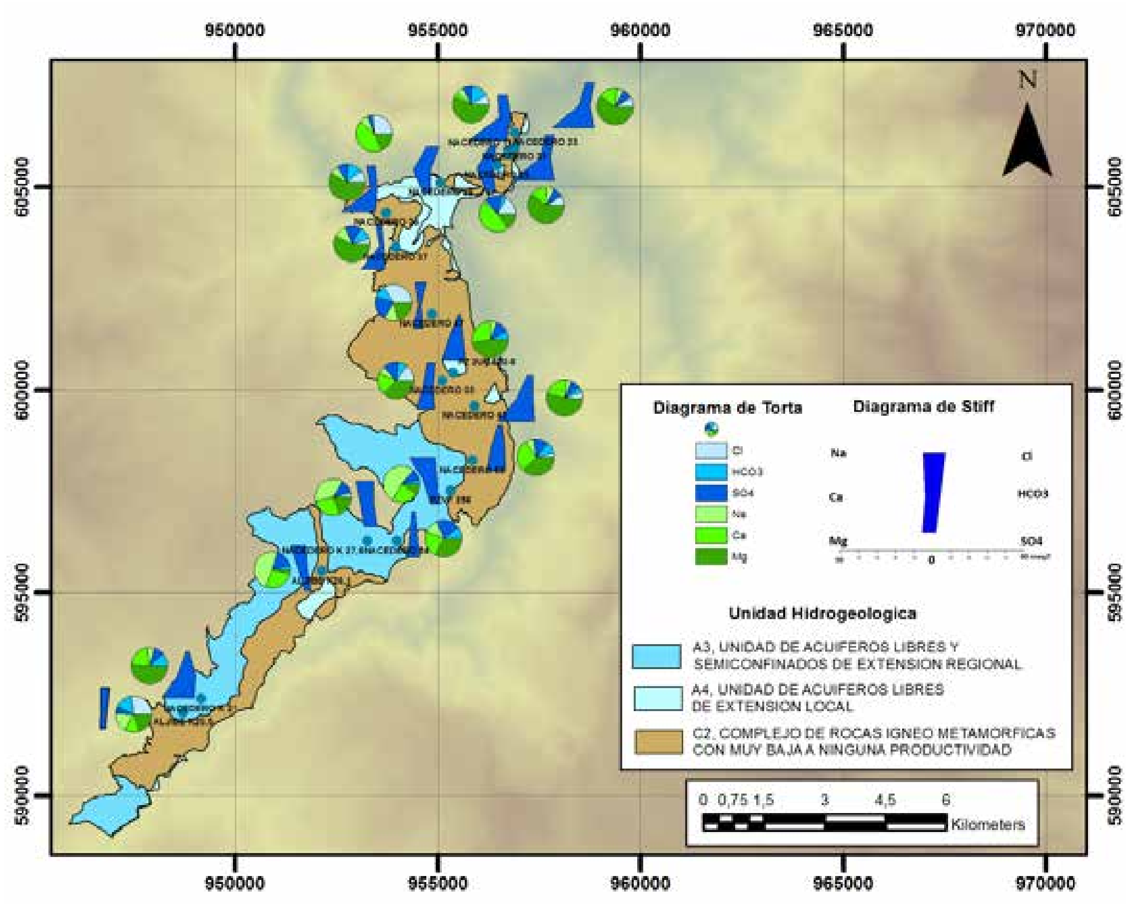
For the classification of sampled water, the Stiff diagrams were taken into account, corresponding to a graphic procedure with many advantages. This system presents a better image of total salt concentration than all other graphic methods as well as dissolution or concentration effects have been minimized and at the same time improve the distinction between different types of water (Donado Garzón 2010), So the classification was made in three groups, taking into account the catchment characteristics of each (**Table 5.114**) And the spatial distribution of the sampled points (**Figure 5.118**).

Table 5.114 Classification and types of water sampled

GROUP	Name Piezo / Fountain / Tank	X	Y	Type of Water
I	ALJIBE K20,5	948712	592062	Mg-Na-Ca-Cl-HCO3-CO3
	ALJIBE K26,1	952126	595533	Na-Ca-K-SO4
	NACEDERO 47	954852	601869	K-Mg-Cl-SO4
	NACEDERO K 27,6	953260	596280	Na-Ca-Mg
	PZVF 256	955317	597528	Na-Ca
II	NACEDERO 11	956897	606333	Mg-Ca
	NACEDERO 21	956890	605983	Mg-K-HCO3
	NACEDERO 23	956725	605835	Mg-Ca
	NACEDERO 36	953725	604372	Mg-K-HCO3
	NACEDERO 37	953962	603517	Mg-K-SO4
	NACEDERO 39	955107	600228	Mg-K-Ca-Cl-SO4
	NACEDERO 40	955901	599607	Mg-Ca
	NACEDERO 52	955849	598259	Mg-Ca-K
	NACEDERO 54	953981	596280	K-Mg-Ca-SO4
	NACEDERO K 21	949153	592393	Mg-Ca-K
	PZ 2UF 5Z2-8	955365	600420	Mg-Ca-K
III	NACEDERO 26	956461	605540	Ca-Mg-Cl-SO4
	NACEDERO 28	955066	605106	Ca-Mg-Cl

Source: GEOCOL CONSULTORES SA, 2017.

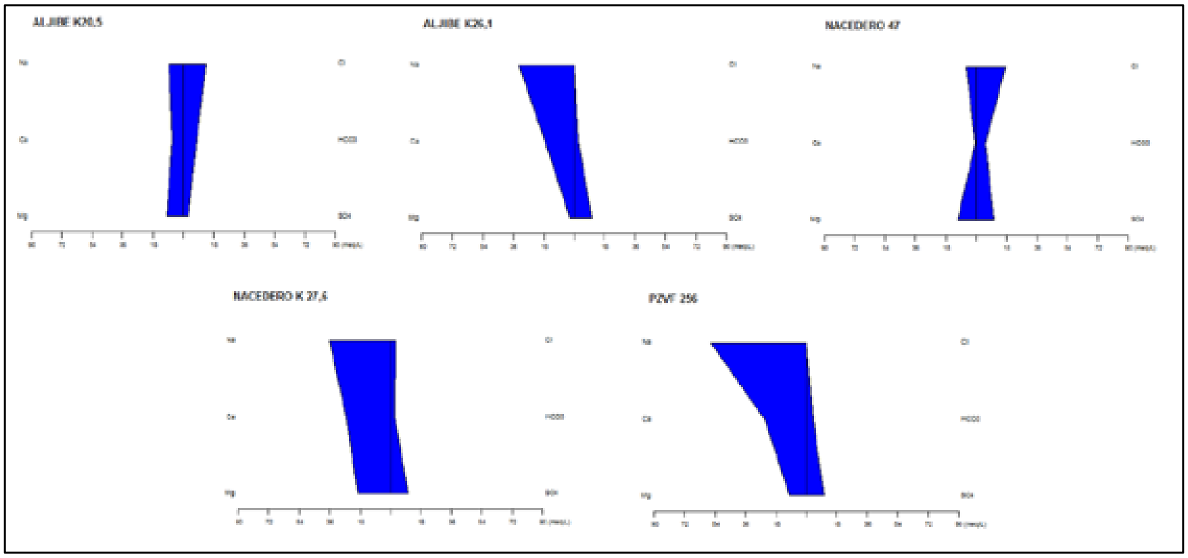
Figure 5.117 Spatial representation of groundwater composition using Stiff polygons and pie chart.



Source: GEOCOL CONSULTORES SA, 2017.

The points classified within Group I correspond to waters whose major ions belong to Calcium (Ca) Magnesium (Mg) and Sodium (Na), generally classified as calcium, magnesium, sodium, bicarbonate and sulfate and may also present Potassium) And Chlorine (Cl) (**Figure 5.119**). This type of water is mainly in the hydrogeological unit A3-2.

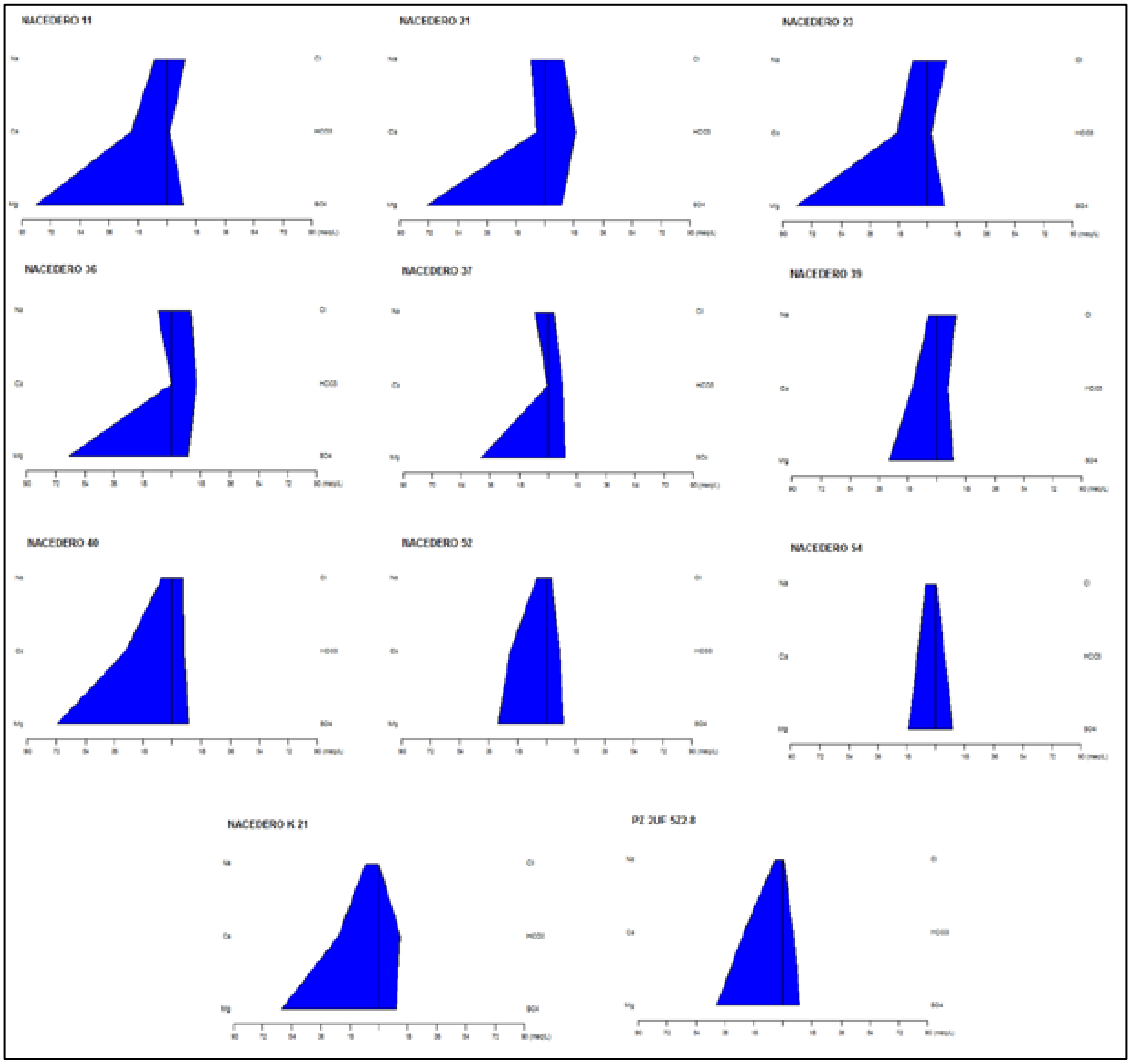
Figure 5.118 Polygons of Stiff, Group I.



Source: GEOCOL CONSULTORES SA, 2017.

At *Group II*, There are waters that are classified as Magnesic, Potassium and Calcic and to a lesser extent have concentrations of Sulphate, Chlorine and Bicarbonate (**Figure 5.120**). They are mainly found in the hydrogeological unit C2-1.

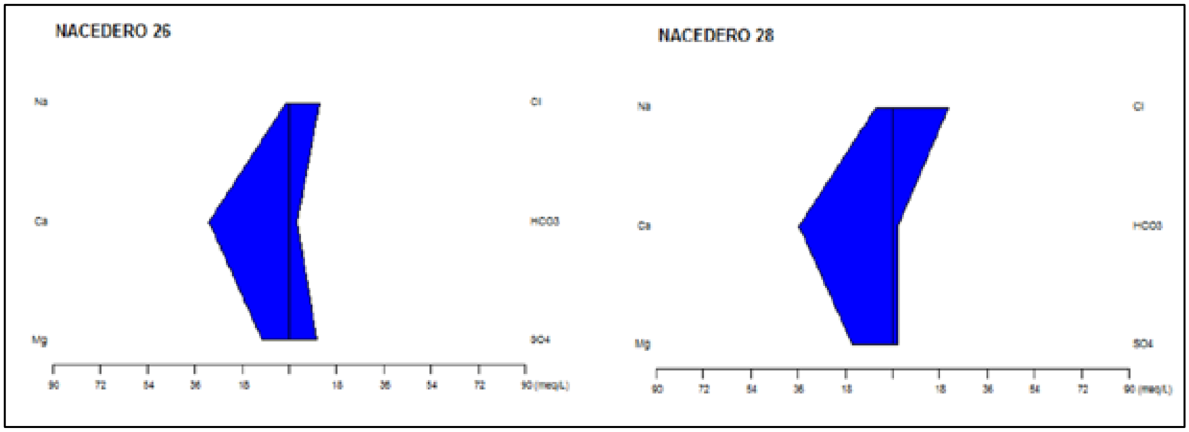
Figure 5.119 Stiff polygons, Group II.



Source: GEOCOL CONSULTORES SA, 2017.

Finally, in group III, waters whose major ions are calcium and magnesium are classified and, to a lesser extent, magnesium, chlorine and sulfate, mainly located in unit 4-1 (**Figure 5.121**).

Figure 5.120 Polygons of Stiff, Group III.



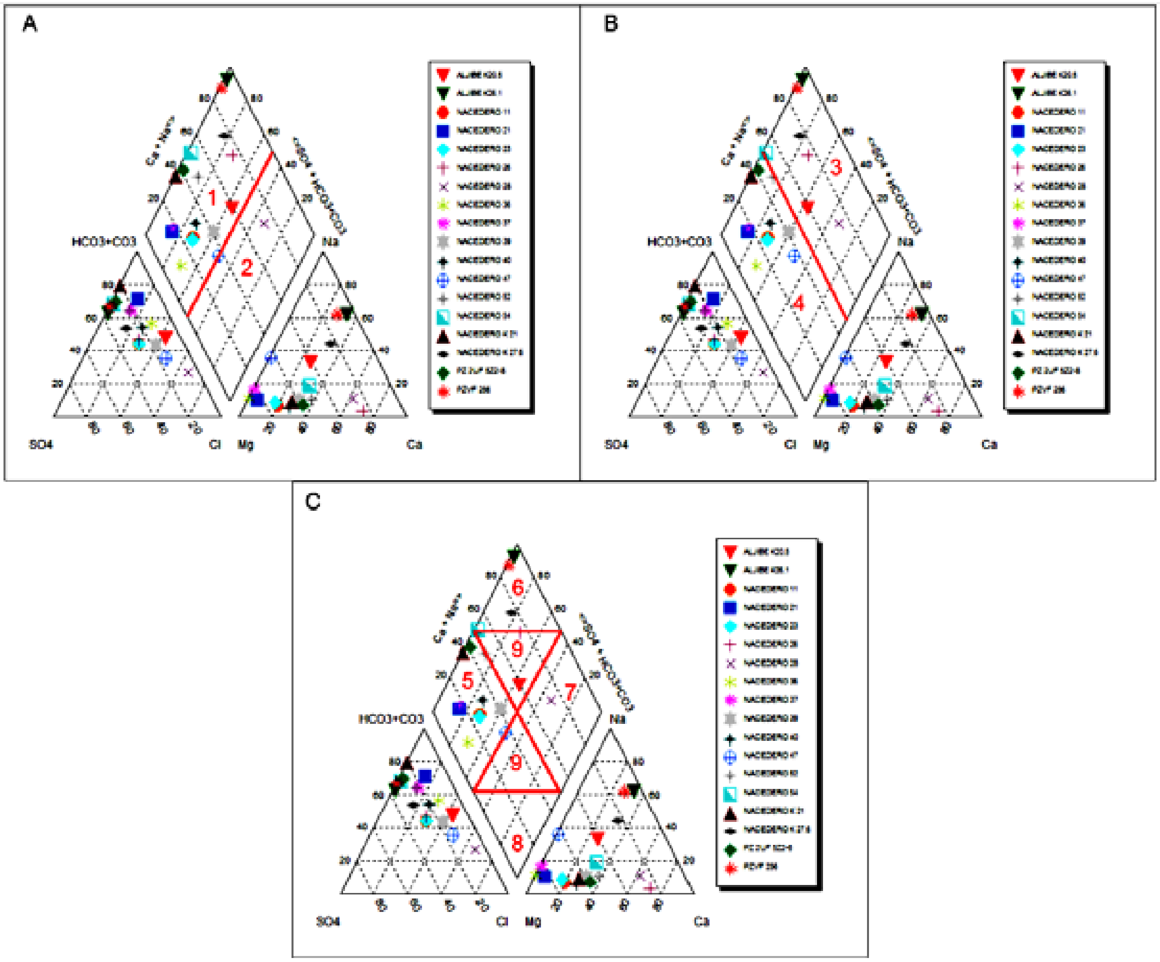
Source: GEOCOL CONSULTORES SA, 2017.

- **Piper's diagram.**

This graphical procedure is an effective tool in the analytical segregation of data for a critical study regarding the origins of constituents dissolved in waters, changes in the character of a water with passage through an area and related geochemical problems Donado Garzon 2010). It is based on the multiple triangular diagram shown and whose shape was gradually and independently developed over many years. Water contains dissolved constituents, cations (metals or bases) and anions (acid radicals) in chemical equilibrium with one another. Commonly the waters contain some silica, iron and aluminum, but these constituents are usually colloids like oxides and are not part of the chemical equilibrium with the ionized constituents.

Thus, in general, natural water can be treated in terms of variables, three cations and three anions, and because the subtotal of their cations and anions are each 50% of the total reactive value, the essential chemical character Of the water can be indicated graphically in the triangle. The analysis of the samples with respect to the Piper diagram (**Figure 5.122**).

Figure 5.121 Piper's diagram.



Source: GEOCOL CONSULTORES SA, 2017.

- **Triangle A:** It is evident in the samples that the alkaline earth metals (Magnesium, Calcium, sulphates and carbonates) exceed the alkaline (Na), in most samples "Region # 1"; On the other hand, the sample taken in Nacedero - 28, reflects that the alkaline (Na) exceeds the alkaline earth (Magnesium, Calcium, sulphates and carbonates) "Region # 2".
- **Triangle B:** It is reflected that in the majority of the samples the strong acids (chlorides and sulphates) exceed the weak acids, this indicates that there is a greater amount of acids that dissociate totally in the solution (strong) in contrast to those that are partially dissociated In water (weak) "Region # 4"; On the other hand, in the samples of Aljibe K 26.1 and K 20.5, PZVF - 256, and K 27.1, 54, 26, 28, the weak acids exceed the strong ones, indicating that there is a smaller amount of dissociating constituents Totally in the water "Region # 3".
- **Triangle C:** In the analyzed samples of most points, it can be concluded that the secondary alkalinity (carbonate hardness) is greater than 50% with chemical properties dominated by alkaline earths and

weak acids "Region # 5". In Aljibe K 26.1, PZVF 256 and Nacedero K 27.6 secondary salinity (non-carbonated hardness) exceeds 50% "Region # 6"; The primary salinity (non-carbonated alkalinity) exceeds 50% with chemical properties that are dominated by alkalis and strong acids in EL Nacedero 28 "Region # 7". Samples of Nabedero K 26 and Aljibe K 20.5 are located in the area that region "Region # 9", in which none of the cation anion pairs in the PALMER classification exceeds 50%.

5.1.11 Geotechnics.

For the development of the geotechnical component, it is necessary to carry out the analysis of susceptibility to the occurrence of mass removal processes involving, among others, the following aspects: Density of geological faults in the area of influence, distribution of geological and geomorphological units, intensity of morphodynamic processes, vegetation cover, intensity of rains, slopes and soil variability and earthquakes occurred in the area in recent decades. With the crossing of this information, the susceptibility map will be obtained, which will be the basis for the geotechnical zoning on the area of influence of the Rumichaca - Pasto dual carriageway project, San Juan - Pedregal section. In addition, a list of the morphodynamic processes identified during the field stage whose formats are related in the **Annex 3. Geomorphology.**

The following is a zoning according to the degree of susceptibility to mass removal processes along the area of influence

5.1.11.1 Susceptibility to mass removal processes.

The following is a description of the factors that were analyzed to obtain the zoning susceptibility by mass removal processes, such as geology, geomorphology, precipitation, degree of slope, roughness, fault density, morphodynamic processes and earthquakes.

- **Geology.**

The different types of rocks and surface formations present geomechanical properties indicative of their resistance to being disintegrated and later removed, the units composed of lavas materials and pyroclastic deposits of flow and fall, are propitious for erosion and detachment of materials.

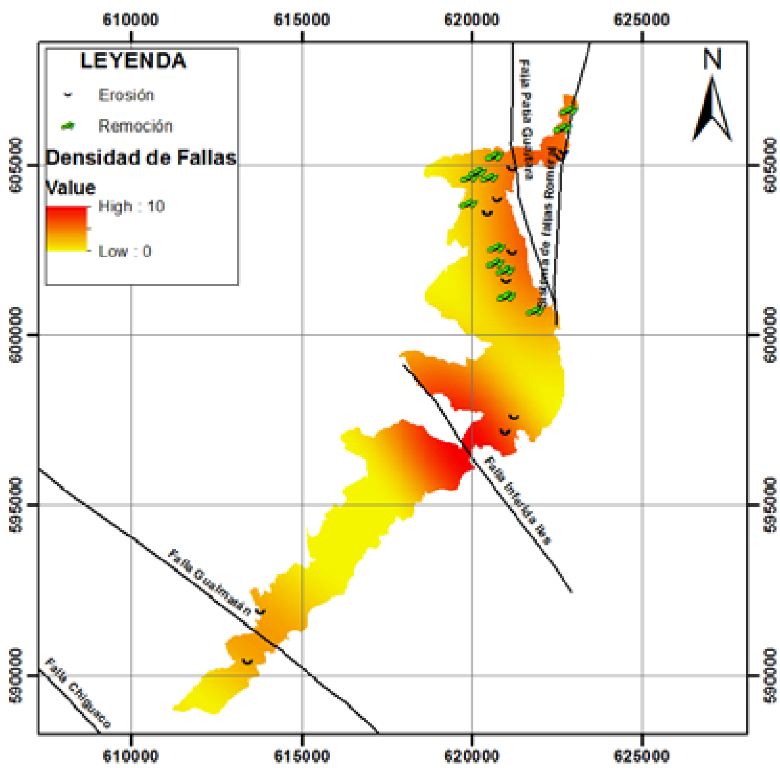
- **Density of Faults.**

The existence of planes of weakness or geological structures such as fault planes, diaclases, stratigraphic discontinuities or stratification planes, contribute to facilitate the detachment and subsequent displacement of the masses of land and / or rocks (González de Vallejo, 2002); It is detected that the greatest incidence in the genesis of the observed morphodynamic processes is the sectors where the greatest influence of geological faults is concentrated (**Figure 5.123**).

- **Geomorphology.**

Geomorphology has as main object the grouping of different landscape units, based on the origin of geoforms (morphogenesis), morphometry, morphostructure and denudatory processes that have shaped geoforms (morphodynamics). This allowed an analysis of the landscape units, surface formations, major and minor reliefs and on these were identified the geomorphodynamic processes, such as erosion, caracavamiento, flows and landslides, according to the component described previously.

Figure 5.122 EIA Fallas density map for the Rumichaca - Pasto dual carriageway project, San Juan Section - Pedregal.

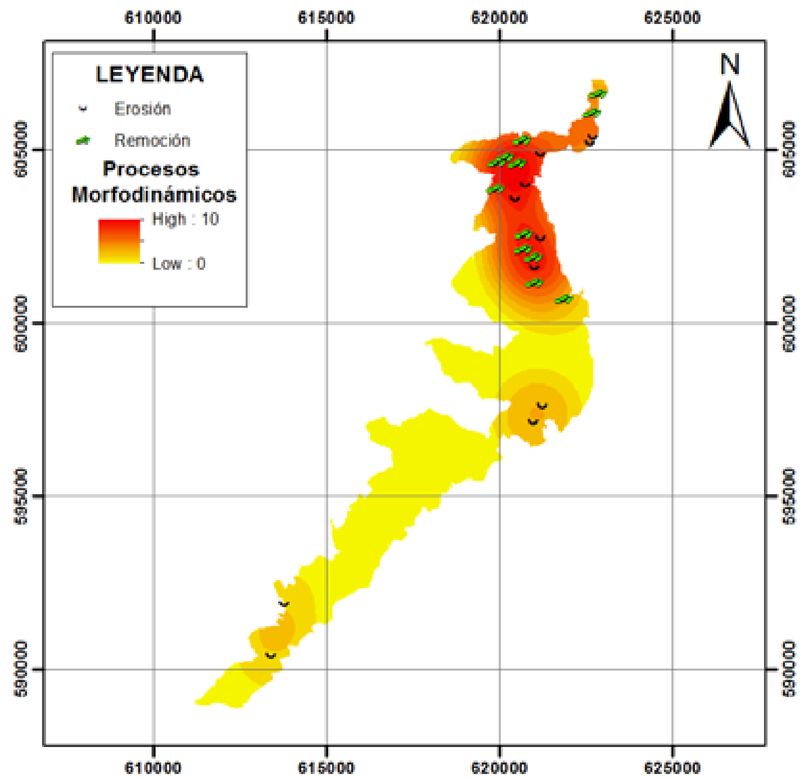


Source: GEOCOL CONSULTORES SA, 2017

· **Morphodynamic processes.**

It refers to the morphodynamic processes that have taken place in the area of influence, mainly related to soil deterioration processes such as erosion, carcavamiento and undermining, and mass removal processes, such as debris flow, block falls and landslides. Rotational and planar type (**Figure 5.124**). This factor, as input for the development of the susceptibility map, was taken as a sectoralization of the inventory of processes raised in the field.

Figure 5.123 Map of Morphodynamic processes identified in the field stage for the area of influence, dual carriageway project Rumichaca - Pasto, San Juan Section - Pedregal.



Source: GEOCOL CONSULTORES SA, 2017

- **Vegetable cover.**

It allows identifying the presence of vegetation on the surface and characterizing its spatial distribution, due to the fact that the vegetation cover affects the behavior of the surface soils and therefore favors the stability of the slopes and slopes.

- **Precipitation.**

Rainfall, besides being the active factor in the transport of the materials, adds water to the soil, causing an increase in the pore pressure, which generates a loss of cohesion of the materials; Most of the landslides that occur on slopes of mountainous areas occur after heavy rains (Suarez Díaz, 2009), So it is necessary to know the amount of rain to detonate them, which is often called critical rain, for this case must have the exact location of landslides, the date of occurrence, records of daily and monthly rainfall Preceded to the events obtained from the nearest stations.

For analysis purposes, precipitation ranges are grouped into five (5) categories, as follows: very low, with values lower than 1500 mm / year; Low, with values between 1501 - 2000 mm / year; Mean, with values between 2001 - 2500 mm / year; High, with values between 2501 - 2750 mm / year; And very high, with values greater than 2750 mm / year, noting that for the study area the rainfall is very low (<1500 mm / year). The information was obtained from the hydrology study elaborated for the present project, analyzing the annual precipitation regimes of the existing meteorological stations in the sector (**Table 5.115**).

Table 5.115 Annual precipitation regimes for the EIA area of influence for the Rumichaca - Pasto dual carriageway project, San Juan - Pedregal Section.

MES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Jan	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Feb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mar	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Apr	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Jun	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Jul	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Aug	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sep	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Oct	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nov	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dec	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Annual	1097.8	1121.2	1212.3	1326.0	993.6	1036.5	1156.1	1119.5	1308.6	1323.4	1030.3	1079.6	1148.2	1059.5	1099.7	1024.4	1087.9	1203.7	1071.0	1021.8	1207.2

Source: GEOCOL CONSULTORES SA, 2017.

- **Slopes.**

The slope is one of the most determinant factors in the origin of the landslides, since its increase directly affects the occurrence of this type of phenomena. For the case of the area of influence, the analysis of the slopes was generated from the topography (**Figure 5.125**), Defining nine slope intervals, in slope percentages, these are: 0- 1%, 1 to 3%, 3 - 7%, 7-12%, 12-25%, 25-50%, 50-75%, 75-100% and> 100%.

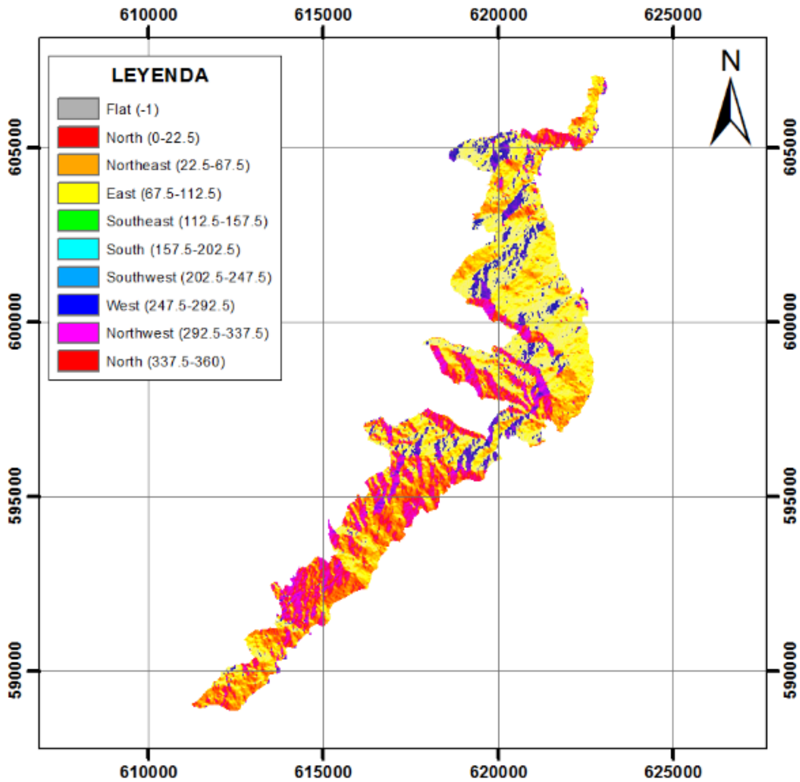
- **Variability of the terrain.**

The variability of the terrain, also known as "Roughness", is defined as a parameter obtained from slope variability and its orientations (**Figure 5.125**), In a defined spatial environment, the values obtained are qualitative and quite subjective, since they express the uniformity or geomorphological variability of a zone and are expressed as areas of roughness, low, medium and high. Fundamentally, the parameter allows to identify the morphometric discontinuities, such as slope ruptures, fluvial entrances and crest lines, related to lithological contacts or tectonic structures.

For the mapping of roughness, it is necessary to use a map of slopes and a map of orientation of the same, the multiplication of these, cell to cell, will result in a map with values that oscillate between 0 and a maximum value, that Will depend on the maximum values of the variations of the input maps that intervene in the calculation.

In the area of influence of this EIA, the variability of the relief represented by a map of roughness, allowed to contrast areas of strong topographic character, as well as homogeneous zones, in which defined relief features can be identified (**Figure 5.126**):

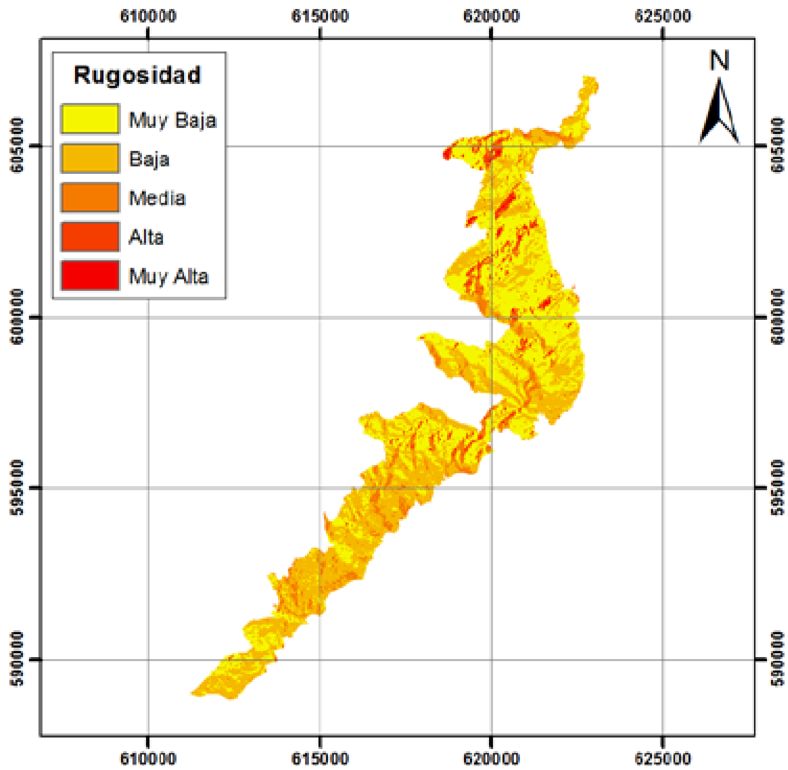
Figure 5.124 EIA Slope Guidance Map for the Rumichaca-Potosi dual carriageway project, San Juan Section - Pedregal.



Source: GEOCOL CONSULTORES SA, 2017

- Very low: Corresponds to areas where the slopes are very low, flat morphology and the orientation of the same form a direction East - Northeast, preferably.
- Low: This category corresponds to zones where the slopes are low, moderately flat morphology and the orientation of the same form a direction South and South-West.
- Half: They are zones where the slope of configuration is average, morphology slightly steep and whose orientation is preferred towards the West.
- High: They are zones where the slope is of high configuration and whose orientation has a preferential direction North to Northwest.
- Very high: They are zones where the slope of very high configuration, strongly steep morphology and a preferential direction Northwest.

Figure 5.125 RUSSIA EIA terrain map for the dual carriageway project Rumichaca - Pasto, San Juan Section - Pedregal.



Source: GEOCOL CONSULTORES SA, 2017

· **Seismicity.**

According to the Colombian NSR-10 seismic-resistant construction regulation, the area of influence of this EIA is in region 5, with a horizontal acceleration (Aa) of 0.25 assigned to the municipalities of Iles and Contadero, which is considered A high seismic hazard zone.

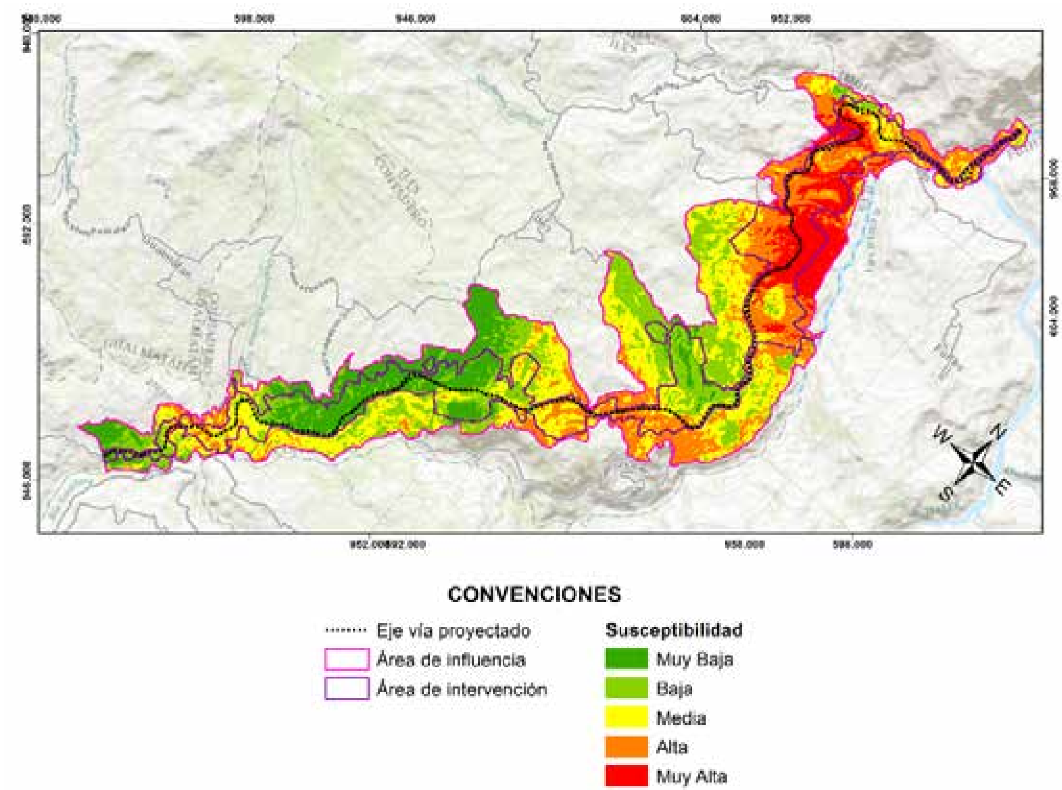
The previously described categories and their values are presented in the **Table 5.116,** Likewise, the susceptibility map resulting from the analysis is presented in the **Figure 5.127.**

Table 5.116 Factors used and qualification for the generation of the susceptibility map.

	Geología	Geomorfología	Pendientes	Precipitación	Rugosidad	Sismo	Cobertura Vegetal	Densidad de Fallas	Procesos Morfodinamicos
Calificacion	Unidad	Unidad	Rango en %	Rango en mm/año	Grado de Rugosidad	Valores de Aa	Unidad	Sectorizacion	Sectorizacion
1			0 -1%	< 1500	Muy Baja	0,05	Tejido urbano continuo, Ríos, Bosque de galería y ripario, Bosque denso altoandino	Menor influencia de fallas Geologicas	Menor Cantidad de procesos morfodinamicos identificados
2	Depositop Aluvial (Qal), Lavas (TQvl)	Altiplanicie volcánica, Cauce activo, Ladera denudacional residual	1-3%	1501-2000	Baja	0,15	Mosaico de pastos y cultivos, Tejido urbano discontinuo, Plantación forestal		
3	Depositos de Ceniza de Rumichaca (Qdcr)	Escarpe en lava, Terraza aluvial	3-7%	2001-2500	Media	0,2	Pastos limpios, Mosaico de cultivos, Vegetación secundaria alta		
4	Depostio Coluvial (Qco)	Ladera denudacional en cenizas, Ladera denudacional coluvial, Terraza antrópica	7-12%	2501-2750	Alta	0,25	Vegetación secundaria baja, Herbazal abierto rocoso,		
5		Ladera escarpada en piroclastos y lavas	12-25%	>2750	Muy Alta	0,3	Red vial y terrenos asociados, Explotacion de Materiales de		
6	Lavas y Piroclastos (NQlp)	Ladera denudacional abrupta en piroclastos	25-50%			0,35			
7			50-75%						
8			75-100%						
9			> 100%						
10								Mayor influencia de fallas Geologicas	Mayor Cantidad de procesos morfodinamicos identificados

Source: GEOCOL CONSULTORES SA, 2017.

Figure 5.126 Map of susceptibility by processes of mass removal in the area of influence, dual carriageway project Rumichaca - Pasto, San Juan - Pedregal Section.



Source: GEOCOL CONSULTORES SA, 2017

According to the susceptibility map for mass removal processes, in the area of influence defined for the environmental impact study, the Rumichaca - Pasto dual carriageway project, San Juan - Pedregal section can be divided into three homogeneous areas:

Between PK15 + 700 and PK26 + 600 there is an area of susceptibility to low to medium mass removal processes with little probability of occurrence of landslides, however, it is probable that erosive processes are generated in the projected cutting slopes and On the hillsides intervened by the man. Between PK 26 + 600 up to PK 34 + 200 an area with medium to high susceptibility was obtained by mass removal processes, finally between PK34 + 200 and PK45 + 00 there is a zone of high to very high susceptibility to the occurrence Of mass removal processes inducing a poor geotechnical behavior of the materials in front of the execution slopes of cut along the evaluated section, for this special attention must be given in this section because the processes of mass removal are more likely to develop .

5.1.11.2 Geotechnical zoning.

The geotechnical zoning obtained in the area of influence framed in the environmental impact study for the Rumichaca - Pasto dual carriageway project, San Juan - Pedregal stretch, was defined based on the analysis of susceptibility by mass removal processes, visits Recognition, geomechanical properties obtained in the geotechnical study for the detailed designs of foundation and slope stability (HMV -2016). As mentioned previously, the geotechnical zoning was obtained from the susceptibility analysis against the occurrence of mass removal processes, defining five geotechnically homogeneous areas assigning a qualification to the degree of stability. In the **Table 5.117** The categorization of defined geotechnical zones is presented.

Table 5.117 Categorization of homogeneous zones to be taken into account for the geotechnical zonification of the area of influence, dual carriageway project Rumichaca - Pasto, section San Juan - Pedregal.

Geotechnical Zone	Degree of stability	Main Features
V	Very high	Rocky materials, volcanic ash, low slopes, absence of morphodynamic processes and high values of cut resistance.
IV	high	Competent materials and volcanic ash, low slopes, presence of diffuse and specific morphodynamic processes
III	Half	Competent soils, moderate slopes and the presence of low intensity morphodynamic processes
II	Low	Moderate slopes, soft soils and presence of moderate to intense morphodynamic processes
I	Very low	Rocky materials, high slopes and presence of intense morphodynamic processes

Source: GEOCOL CONSULTORES SA, 2017

The following is a description of the geotechnically homogeneous units resulting from the zoning on the area of influence for the environmental impact study of the Rumichaca - Pasto dual carriageway project, San Juan - Pedregal section taking into account the degree of stability.

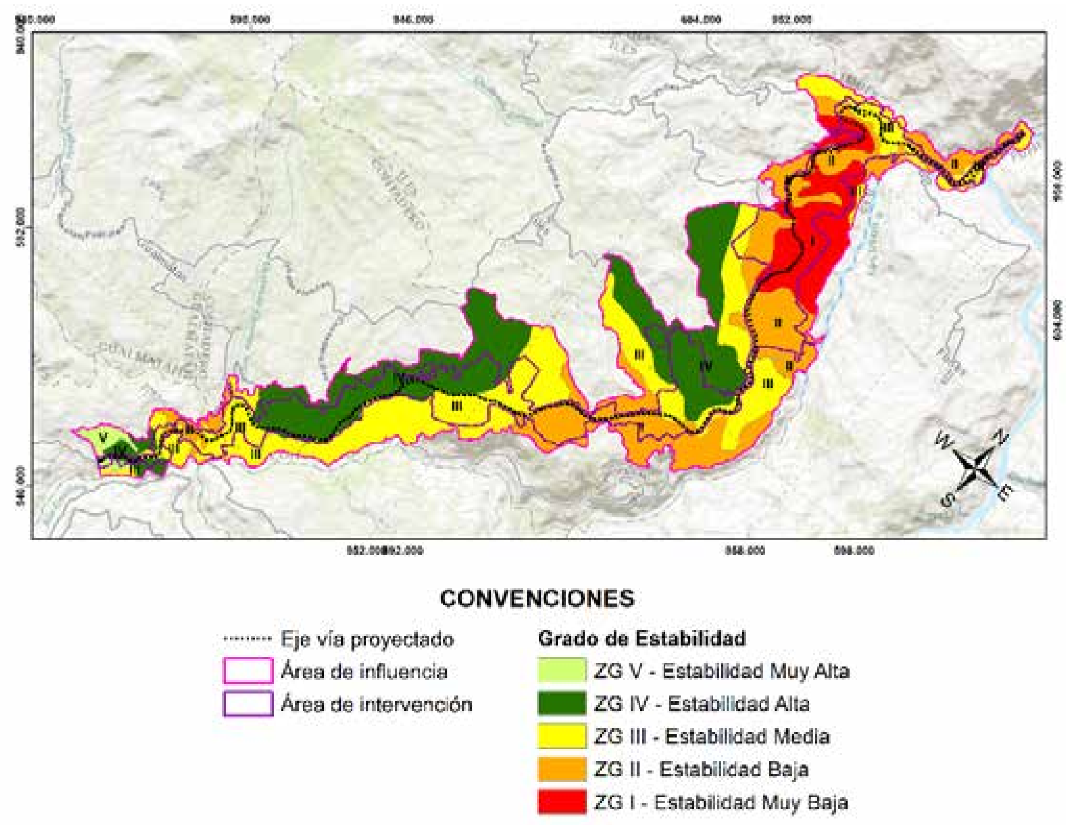
5.1.11.2.1 Zone of very high geotechnical stability (V).

The probability of occurrence of mass removal processes in this area is very low, implying a very high degree of stability according to the categorization of the related geotechnical zones in the area **Table 5.117**, The materials that make up this geotechnical unit correspond to supported pyroclastic deposits (60:40), silt ash tufa - very coarse-grained sand. Based on the Unified Soil Classification System (SUCS), the materials are classified as ML and SM, the plasticity index varies between NP and 30.10%, the natural humidity ranges between 32 and 54.6%, they offer a resistance to The unconfined compression between 8 and 20 ton / m^2. According to the lithostratigraphic columns, the thickness of these materials can reach 25 m. The slopes of moderately inclined to slightly flat predominate, there are occasional sporadic outcrops of subsurface water associated with springs that can influence the stability of the site. During the reconnaissance visits there were no morphodynamic processes acting on this area that could affect the stability of the slopes.

According to the designs of the road corridor, on this geotechnical unit is projected the formation of cut slopes with heights up to 35 m maintaining inclines 1H: 2V. During the execution of the geotechnical studies (HMV - 2016) values of the internal friction angle of the materials ranging from 33 ° to 42 ° were also obtained, the value of the cohesion varying between 65 and 89 Kpa. The stability analyzes for the projected slopes showed values of the safety factor varying between 1.49 and 1.51 for normal conditions and between 1.15 and 1.17

under extreme conditions respectively, thus fulfilling the required Colombian Construction Earthquake Resistant (NSR-10). In the **Figure 5.128 And in the Cartographic Annex, Map Nº19. Geotechnics,** The zones of geotechnical stability resulting from zoning are presented, this very high stability zone extends towards the southern end of the area of influence.

Figure 5.127 Map of geotechnical zoning in the area of influence, dual carriageway project Rumichaca - Pasto, Section San Juan - Pedregal.



5.1.11.2.2 Zone of high geotechnical stability (IV).

The probability of occurrence of mass removal processes in this area is low to very low, implying a high degree of stability, the materials that make up this geotechnical unit correspond to silt ash deposits, silt ash tuffs, very fine sand, Based on the Unified Soil Classification System (SUCS), the materials are classified as ML, SM and CH, the plasticity index varies between 17.2 and 89.60%, the natural humidity can range between 48.20 and 120.4%, offer an unconfined compressive strength between 2 and 20 t / m^2, For soil, for rock samples, the resistance to simple compression can reach values of 161,0 ton / m^2 With thicknesses ranging from 45 to 55m according to the lithostratigraphic columns of the perforations executed (HMV - 2016). The slopes moderately inclined to strongly inclined predominate, have associated erosive processes and smaller, punctual and incipient rotational landslides that do not represent a risk in the stability of the slopes and hillsides, there are occasional sporadic outcrops of subsurface water associated to springs that can Influence the stability of the site.

According to the designs of the road corridor, on this geotechnical unit is projected the formation of cut slopes with heights up to 35 m maintaining inclines 1H: 2V. During the execution of the geotechnical studies (HMV - 2016) values of the internal friction angle of the materials ranging from 33 ° to 42 ° were also obtained, the value of the cohesion was determined, which varies between 65 and 89 Kpa, corroborating the behavior Of existing soils. The stability analyzes for the projected slopes showed values of the safety factor varying between 1.49 and 1.51 for normal conditions and between 1.15 and 1.17 under extreme conditions respectively, thus fulfilling the required Colombian Construction Earthquake Resistant (NSR-10). Within the area of influence this geotechnical zone is located between the PK 16 + 00 - 16 + 700, parallel to the route of the track from the PK20 + 200 - PK25 + 700 covers the western sector, 100 m west of the line of the Is between PK30 + 300 - PK32 + 600 and between PK32 + 600 - PK36 + 400 (**Figure 5.128**).

5.1.11.2.3 Zone of medium geotechnical stability (III).

The probability of occurrence of mass removal processes in this area is average, implying an average degree of stability according to the categorization of the related geotechnical zones in the **Table 5.117**, The materials that make up this geotechnical unit correspond to silt-toasted ash tuffs, andesitic lavas and pyroclasts, colluvium deposits (gravel in 65% silt-sandy fine-grained matrix). Based on the Unified Soil Classification System (SUCS), the materials are classified as ML and SM and CH, the plasticity index varies between 13.3 and 46%, the natural humidity ranges from 0.3 to 88.4 %, Offer an unconfined compression strength between 1.4 and 20 ton / m^2 For soil, for rock samples the uniaxial resistance can reach values of 205,10 ton / m^2. According to the lithostratigraphic columns, the thickness of these materials can reach 55 m. Predominant slopes slightly flat and moderately inclined, with presence of moderate erosion processes laminar that do not represent risk in the stability of the slopes and slopes, are evident sporadic point outcrops of subsurface water associated to springs that can influence with the stability of the site. As shown in the **Figure 5.128**, This geotechnical zone is located between PK16 + 700 - PK17 + 500, bordering the geotechnical zone II between PK17 + 500 - PK18 + 500, on the side and side of the line between PK18 + 500 - PK20 + 200, on the eastern side Of the route in PK20 + 200 - PK25 + 700, between PK25 + 700 - PK26 + 600, west of PK29 + 800 - PK30 + 100, on the line at PK30 + 700 - PK33 + 00, north of the route Between the PK40 + 300-PK42 + 00, a strip to the east starting from the PK41 + 900, bordering to the geotechnical zone II between the PK43 + 300 - PK43 + 900 and finally, to the side E of the route until the river Guáitara between the PK43 + 300 - PK45 + 00.

According to the designs of the road corridor, on this geotechnical unit is projected the formation of cut slopes with heights between 62 and 92 m maintaining inclinations 1H: 2V. During the execution of the geotechnical studies (HMV-2016) values of the internal friction angle of the materials ranging from 33 ° to 37 ° were also determined, the value of the cohesion which varied between 50 and 80 Kpa was corroborated Of the existing soils, an average unit value of the materials of 1.8 ton / m^3. The stability analyzes for the projected slopes showed values of the safety factor varying between 1.40 and 1.45 for normal conditions and between 1.04 and 1.08 under extreme conditions respectively, thus fulfilling with the required Colombian Construction Earthquake Resistant (NSR-10).

5.1.11.2.4 Zone of low geotechnical stability (II).

According to the susceptibility map, the probability of occurrence of mass removal processes in this area is high to medium, implying a low degree of stability, the materials that make up the area correspond to deposits of colluvium (gravel in sandy matrix very Thin-thick), andesitic sludge, slime-sand ash, pyroclastic deposits with medium to coarse sandy silt matrix. Based on the Unified Soil Classification System (SUCS), materials are classified as ML, SM, the plasticity index can vary between 2.2 and 45.98%, the natural humidity can range between 2.07 and 78 , 5%, offer an unconfined compression strength between 3 and 110 t / m^2, With thicknesses that can exceed 45 m according to the lithostratigraphic columns obtained in the perforations. Predominant slopes slightly flat and moderately inclined, during the reconnaissance visits showed moderate morphodynamic processes acting on this area associated mainly minor rotational landslides and rock fall, punctually manifest areas of laminar erosion and in furrows, there are also outcrops of water Subsurface associated with springs that negatively influence the stability of the slopes.

According to the designs of the road corridor, on this geotechnical unit is projected the formation of cut slopes with heights between 60 and 79 m maintaining slopes during 1H: 3V excavations. In the execution of the geotechnical studies (HMV-2016) values of the internal friction angle of the materials that oscillate between 33 ° and 37 ° were also determined the value of the cohesion that varies between 50 and 80 Kpa corroborando the behavior Of the existing soils, an average unit value of the materials is estimated at 1.8 to 20 ton / m^3. The stability analyzes for the projected slopes showed values of the safety factor varying between 1.40 and 1.74 for normal conditions and between 1.05 and 1.25 under extreme conditions respectively, thus fulfilling the required Colombian Construction Earthquake Resistant (NSR-10). Within the area of influence this area is located (**Figure 5.128**) Between PK17 + 500 - PK18 + 500, northwest of PK18 + 800 - PK19 + 00, towards the southeast of the line in PK26 + 600 - PK30 + 600, between PK33 + 00 - PK34 + 400, a Northwest from the PK36 + 400, between the PK36 + 900 - PK37 + 900, between the PK38 + 00 - PK38 + 500, in the PK33 + 900 - PK40 + 200 is a sector that is thinning to the east, from the PK41 +800 an area extending southeast, between PK42 + 00 - PK43 + 300 and from PK44 + 00 - PK45 + 00.

5.1.11.2.5 Zone of very low geotechnical stability (I).

According to the susceptibility map, the probability of occurrence of mass removal processes in this area is very high, implying a very low degree of stability, the materials that make up the zone correspond to pyroclastic deposits with medium to coarse sandy matrix deposits Colluvium of chondrosporous composition. Based on the Unified Soil Classification System (SUCS), the materials are classified as ML, SM, the plasticity index can vary between NP and 10.4%, the natural humidity can vary between 2.90 and 33.5 %, Offer an unconfined compression strength between 113.4 and 639.8 ton / m^2, With thicknesses that can exceed 38 m according to the lithostratigraphic columns obtained in the perforations. Predominant slopes ranging from strongly sloping to strongly steep, evidence of the presence of morphodynamic processes acting on this area associated mainly with rotational, translational landslides, debris flow and rockfall and erosion processes. As can be seen in the **Figure 5.128**, The very low stability geotechnical zone is located between PK34 + 400 - PK36 + 300, PK36 + 500 - PK36 + 900, east of the line between PK37 + 600 - PK38 + 00 and in PK38 + 600 - PK39 +900.

According to the designs of the road corridor, on this geotechnical unit is projected the formation of cut slopes with heights between 46 and 56 m maintaining slopes during 1H: 3V excavations. In the execution of the geotechnical studies (HMV-2016) values of the internal friction angle of the materials that oscillate between

33 ° and 37 ° were also determined the value of the cohesion that varies between 50 and 80 Kpa corroborando the behavior Of the existing soils, an average unit value of the materials is estimated at 1.8 to 20 ton / m^3. The stability analyzes for the projected slopes showed values of the safety factor varying between 1.57 and 2.015 for normal conditions and between 1.19 and 1.53 under extreme conditions respectively, thus fulfilling the required Colombian Construction Regulation Resistant (NSR-10).

5.1.12 Atmosphere.

5.1.12.1 Meteorology.

Climate is the set of atmospheric phenomena that characterize the environment of a given region, which is determined by the time space analysis of the elements that define it and the factors that affect it. In this section we analyze the climatic elements of the area, such as precipitation, temperature, atmospheric pressure, relative humidity, wind, solar brightness, cloudiness, mixing height, atmospheric stability and others. The first two are the most important because they allow defining, classifying and zoning the climate of the given region, while the others are presented as attributes characterizing the units already defined. The factors of the climate, slope, altitude, relief forms, generate climatic changes at regional or local level, while the vegetal cover is cause and effect of the climate.

From the physical-biotic point of view, the climate is important because of its direct intervention in the evolution of the soils and the landscape. In addition, it is one of the elements or inputs necessary for the determination of natural and socio-economic threats because of its influence on the decision to use the land for certain uses.

The analysis of climatology was based on the collection and analysis of secondary information as follows:

- Consult the meteorological information in the area, where the Rumichaca - Pasto dual carriageway project area is located, San Juan - Pedregal section. (Information available at IDEAM until 2016).
- Climatic characterization for each of the analyzed parameters, based on the different histograms that allow to define their temporal distributions throughout the year, for each one of the stations analyzed; As well as their respective spatial distributions that allow to characterize the study area.
- Classification and climatic zoning by means of the methodology proposed by IDEAM in its document "Continental, coastal and marine ecosystems of Colombia"[2].
- Estimation of the water balance, following the methodology proposed by Thornthwaite; Which allowed generating the temporal and spatial analysis of the availability of the water resource that is presented in the study area.

For the climatic analysis of the area of influence of the project, meteorological information was used in the stations closest to the zone of influence and that are operated by the Institute of Hydrology, Meteorology and Environmental Studies - IDEAM (See **Annex 8. Climate**); Stations are presented in the **Table 5.118**, While its location is presented in the **Figure 5.129**.

[2] IDEAM. Inland, marine and coastal ecosystems of Colombia. Institute of Hydrology, Meteorology and Environmental Studies (IDEAM). December 2007.

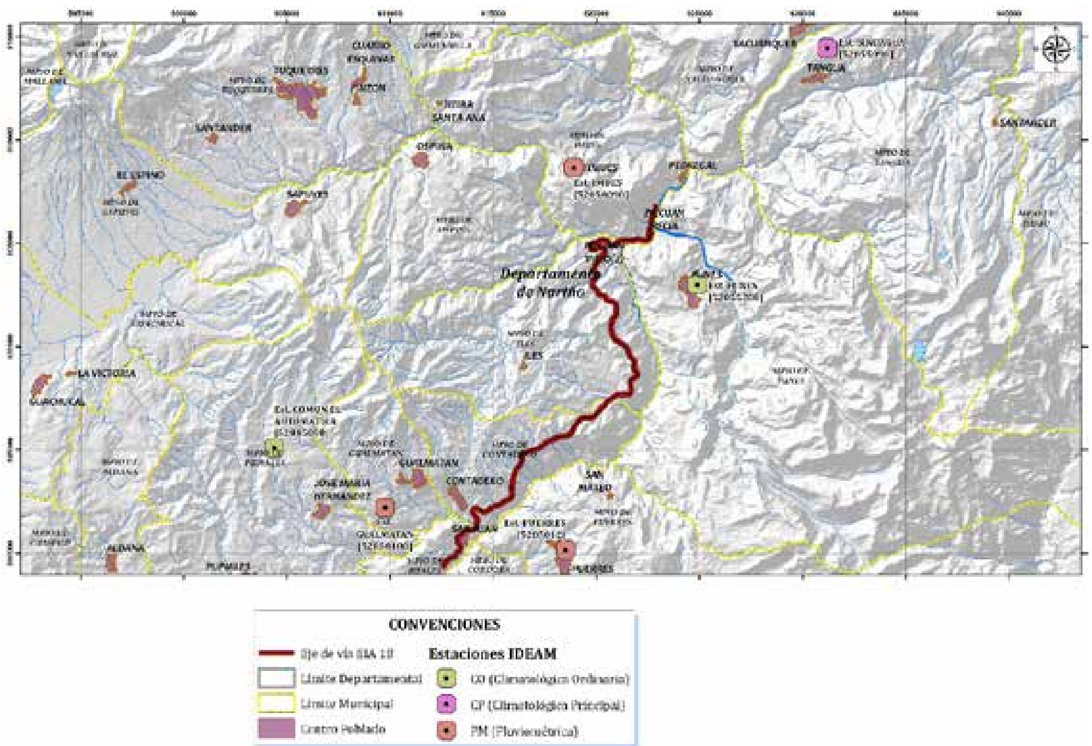
Table 5.118 Meteorological stations used to characterize the area of influence of the Rumichaca - Pasto, San Juan - Pedregal section.

CODE	KIND	STATION	CURRENT	DEPARTMENT	MUNICIPALITY	ELEVATION (MSNM)	DATA PERIOD		COORDINATES MAGNA SIRGAS ORIGIN WEST	
									EAST	NORTH
52050090	P.M	Imues	Guáitara	Nariño	Imues	2550	1991	2016	953025	608454
52055200	CO	Funes	Guáitara	Nariño	Funes	2181	2009	2016	959007	602811
52055090	CP	Sindagua	Guáitara	Nariño	Tangua	2800	1991	2016	965290	614239
52045090	CO	El Común - Automatica	Guáitara	Nariño	Pupiales	3141	2007	2016	938550	594898
52050100	PM	Gualmatan	Guáitara	Nariño	Gualmatan	2830	1991	2016	943914	592025
52050120	PM	Puerres	Guáitara	Nariño	Puerres	2764	1991	2016	952648	589987
52055010	SP	Apto. San Luis*	Guáitara	Nariño	Aldana	2961	1991	2016	933187	586544

P.M: Pluviometric CO: Climatological Ordinary CP: Climatológica Principal SP: Main Synoptic
* Station used for wind characterization and mixing height

Source: National Stations Catalog. IDEAM, 2017.

Figure 5.128 Spatial location of the meteorological stations used to characterize the area of influence of the Project Area.



Source: GEOCOL CONSULTORES SA, 2017.

The results of the statistical analyzes of the meteorological parameters used for the climatic characterization of the area of influence of the project are presented below.

5.1.12.1.1 Precipitation.

Precipitation is understood to mean any and all forms of water, in a liquid or solid state, falling from the clouds to the earth[3]. The volume is measured in millimeters which in turn equals liters of water per square meter.

- **Temporal Distribution.**

The area of influence of the project is located in the hydrographic area of the Pacific. According to the results obtained from the histograms of the analyzed stations, it was possible to establish that in the area of influence of the project, the pluviometric regime is bimodal; In which two rainy seasons are presented on average, separated by mid-year by a season of low rains called summer and a summer in early January. (See **Figure 5.130**).

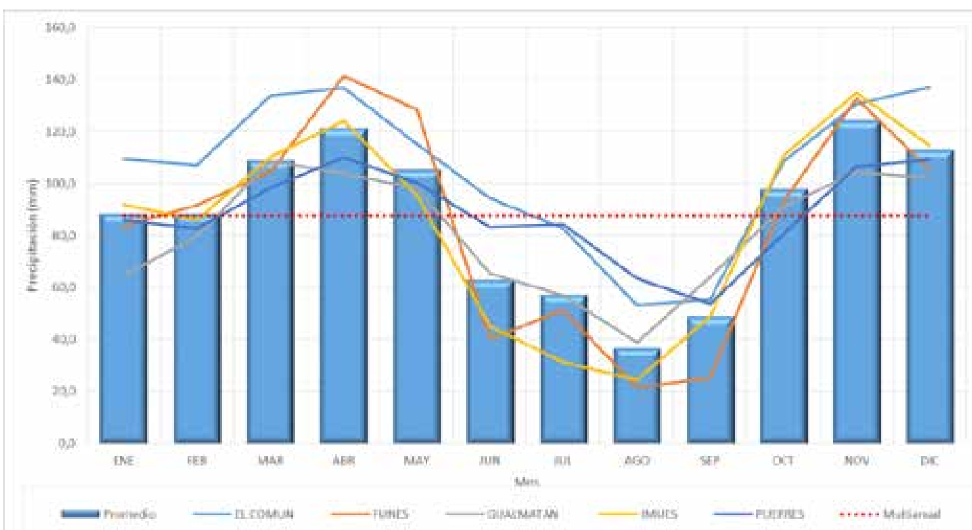
[3] University of Chile Taken from http://www.atmosfera.cl/HTML/glosario/glosario_02.html

In general, in the area of influence of the project, total monthly rainfall of the order of 21.6 mm to 141.5 mm is recorded, as can be **Figure 5.130**. On average, the month with the highest rainfall is November with mean monthly mean values of 124.4 mm, while in August, it is classified as the least rainy month, with monthly mean values of 36.7 mm, as can be seen in **Figure 5.131.**

An average monthly multiannual precipitation of 87.8 mm was obtained, a value that divides the values of the main dry season and the rainy season of the area, it is observed that the El Común station presents the highest rainfall record, moving away from the trends Of the other stations. In the summer season (August) values of 21.6 mm from the Funes station are recorded up to 63.5 mm from the Puerres station. In the first two months of the year values are obtained from 64 mm (*Est. Gualmatan*) Up to 109 mm (*Est. El Común*), Showing a great difference between the summer and the summer of the area (see **Figure 5.130** Y **Figure 5.131**).

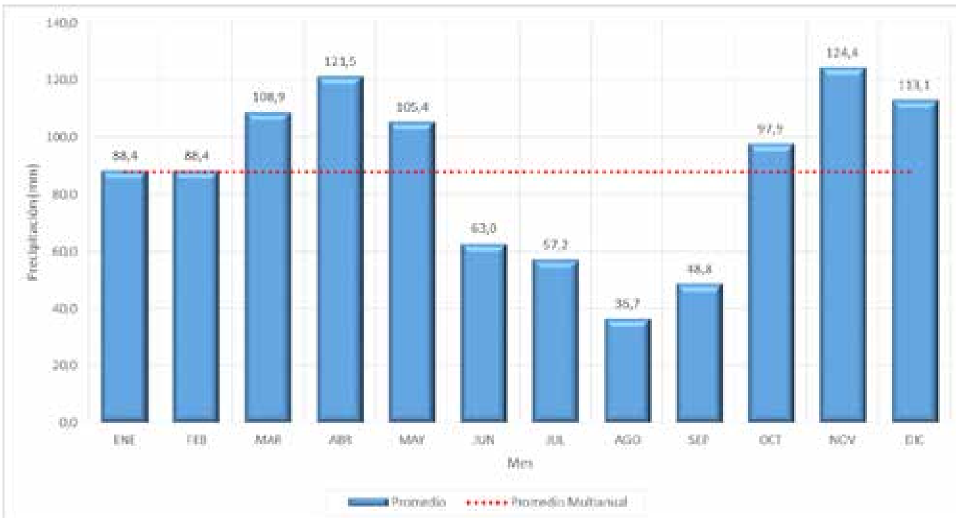
The two precipitation peaks of the area occur in April and November, the first peak with average values of 121.5 mm and the second with average values of 124.4 mm, very similar values, which is expected to find Two peaks of precipitation of similar trends during those months.

Figure 5.129 Temporal distribution of the monthly average multi-year rainfall in the area of influence of the draft.



Source: GEOCOL CONSULTORES SA, 2017.

Figure 5.130 Estimated average histogram - Temporal distribution of precipitation in the area of influence of the project.



Source: GEOCOL CONSULTORES SA, 2017.

In the **Table 5.119** The records of the maximum, average and monthly multi-annual monthly precipitation of the stations used in the characterization of the area of influence of the project are presented.

Table 5.119 Multi-annual monthly maximum, mean and minimum values of precipitation (mm) in the meteorological stations used to characterize the area of influence of the project.

STATION		JAN	FEB	SEA	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	HALF	ANNUAL
THE COMMON	MIN	35,3	40,8	81,0	72,9	36,8	65,7	33,3	30,1	23,7	55,0	56,0	33,5	47,0	564,1
	Med	109,5	106,9	133,9	136,9	115,2	94,2	82,8	53,2	55,4	108,4	130,4	137,0	105,3	1263,8
	MAX	246,7	217,1	189,0	218,7	186,3	142,1	160,2	62,2	110,5	145,3	234,9	275,4	182,4	2188,4
FUNES	MIN	1,4	18,9	39,6	50,8	27,4	10,2	20,0	7,4	8,6	49,2	82,5	6,0	26,8	322,0
	Med	83,8	91,7	104,6	141,5	128,5	40,2	51,3	21,7	25,4	93,1	132,8	105,5	85,0	1020,1
	MAX	177,9	164,6	142,8	252,7	274,9	84,9	88,3	41,8	53,5	137,4	219,9	219,9	154,9	1858,6
GUALMATAN	MIN	5,5	15,1	36,2	34,0	33,9	8,3	23,5	13,8	12,6	13,5	30,5	15,4	20,2	242,3
	Med	64,6	79,7	108,7	103,9	98,0	65,4	57,0	39,0	64,1	91,1	104,2	102,0	81,5	977,8
	MAX	162,1	229,3	351,8	243,4	459,5	170,8	122,0	96,3	411,3	184,1	181,0	353,9	247,1	2965,5
IMUES	MIN	1,0	11,6	19,7	49,5	17,3	6,9	1,2	0,0	4,4	32,3	43,7	16,1	17,0	203,7
	Med	91,8	85,9	110,3	124,1	95,5	45,1	31,4	24,4	49,0	110,5	134,9	114,5	84,8	1017,5
	MAX	209,2	214,3	213,7	244,3	228,3	101,2	86,2	226,0	123,0	188,3	251,7	232,7	193,2	2318,9
You can	MIN	14,6	15,7	46,7	59,4	40,4	40,3	37,5	20,9	10,6	9,3	31,2	34,9	30,1	361,5
	Med	85,9	82,8	98,4	109,9	100,3	83,1	84,4	63,5	53,8	80,5	106,5	109,1	88,2	1058,3
	MAX	189,8	200,4	144,1	184,8	242,6	151,3	155,7	116,7	136,9	183,0	226,0	275,3	183,9	2206,6
SI N	MIN	13,7	18,8	26,2	45,8	34,9	6,0	6,7	0,5	2,2	33,3	47,2	4,6	20,0	239,9

STATION		JAN	FEB	SEA	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	HALF	ANNU AL
	Med	94,7	83,2	97,6	112,6	95,2	49,7	36,3	18,5	45,0	103,9	137,8	110,3	82,1	984,7
	MAX	228,4	235,6	182,6	184,5	187,1	122,4	103,2	39,0	135,9	191,8	257,3	233,5	175,1	2101,3
AVERAGE	MIN	11,9	20,2	41,6	52,1	31,8	22,9	20,4	12,1	10,4	32,1	48,5	18,4	26,9	322,2
	Med	88,4	88,4	108,9	121,5	105,4	63,0	57,2	36,7	48,8	97,9	124,4	113,1	87,8	1053,7
	MAX	202,4	210,2	204,0	221,4	263,1	128,8	119,3	97,0	161,9	171,7	228,5	265,1	189,4	2273,2

Source: GEOCOL CONSULTORES SA, 2017.

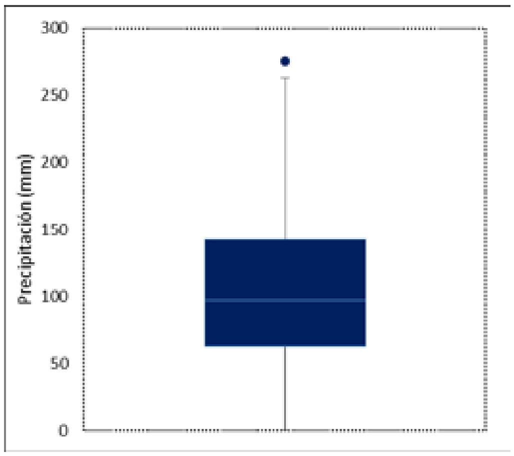
In the **Figure 5.132** The distribution of the precipitation of the El Común station is presented throughout the year, in the **Annex 8. Weather - extreme values,** The temporal distribution for each of the stations used in the climatic characterization of the area of influence of the project is presented. In the **Figure 5.132** It is observed that the extreme values of precipitation can vary from 275.4 mm and 33.5 mm for the same month of the year (December), which is why there are values that stretch precipitation values that are usually 87.8 mm as mentioned above.

Figure 5.131 Temporary rainfall for different statistics (Min / Med / Max) at the station The Common.

Source: GEOCOL CONSULTORES SA, 2017.

In the **Figure 5.133** It is shown the Box-Plot diagram of the El Común station in which it is sought to characterize these extreme values that do not represent the reality of the phenomenon, for the station it is observed that the average value of precipitation is 105 mm while the values Of the upper limit reach 260 mm leaving the values *Outliers* Higher than the 275 mm. At **Annex 8. Climate - extreme values** The Box-Plot diagrams are presented for each of the stations used in the climatic characterization of the area of influence of the project.

Figure 5.132 Diagram of Box-Plot station The Common.



Source: GEOCOL CONSULTORES SA, 2017.

o **Spatial Distribution.**

Spatially, the Isoyetas are the graphical representation of precipitation values in a cartographic plane, which illustrates the spatial distribution of rainfall in the region.

To obtain the precipitation field, the "inverse of the weighted distance" (IDW) methodology is used, in which the value of each cell is estimated by weighting the values of the different available stations. This method is ideal to represent the great spatial variability that precipitation can have, since the value of each point depends on all precipitation stations, relative to the weighted distance, using the following formula.

$$P_i = \sum_{j=1}^{n} \beta_j \times P_j$$

Where:

B_J: Calculated weight of cell i with respect to station j

P_J: Precipitation at the registration station

The weights with respect to each station for each cell are calculated by the following formula:

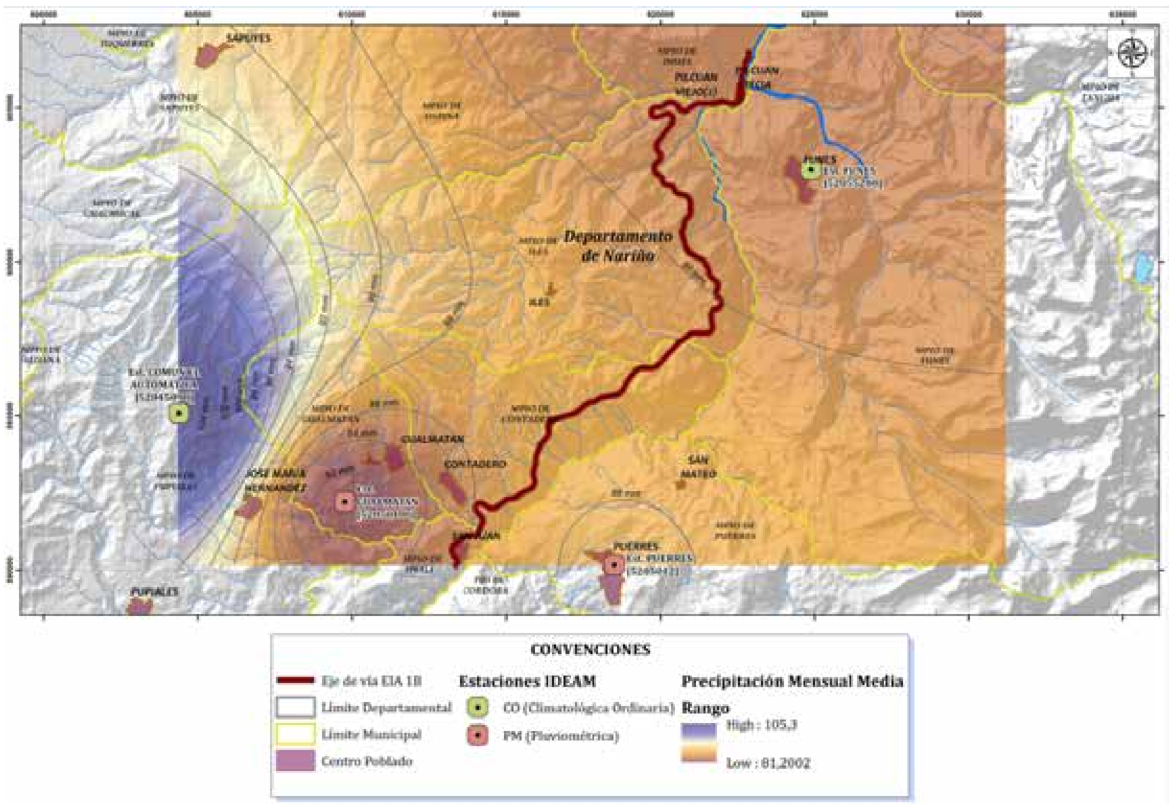
$$B_j = \frac{\frac{1}{D_j}}{D_{acum}}$$

The precipitation distribution (**Figure 5.134**) Is obtained using the multiyear mean precipitation values, estimated in the analysis of precipitation series.

The spatial distribution of monthly rainfall in the area of influence of the project; Allows to observe that the rainfall has a very similar behavior along the road, being on average between 84 to 88 mm, a precipitation peak is observed near the municipality of Pupiales and a decrease in the municipality of Gualmatan (See **Figure**

5.134 And Cartographic Annex, Map N ° 16. Isoyetas). At **Annex 8. Climate - Extreme values** The spatial distribution of the maximum and minimum values by means of isoyetas of the project area is presented.

Figure 5.133 Isoyetas Monthly average multi-annual precipitation of the project.

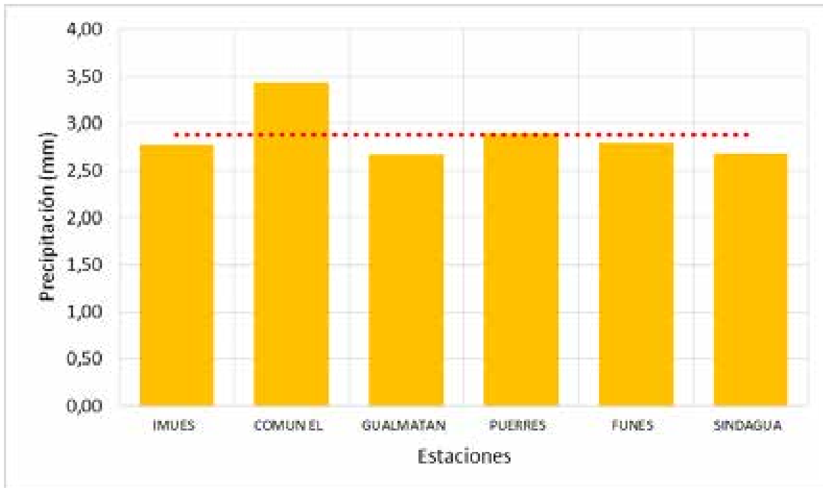


Source: GEOCOL CONSULTORES SA, 2017.

· **Average daily precipitation, maximum, minimum.**

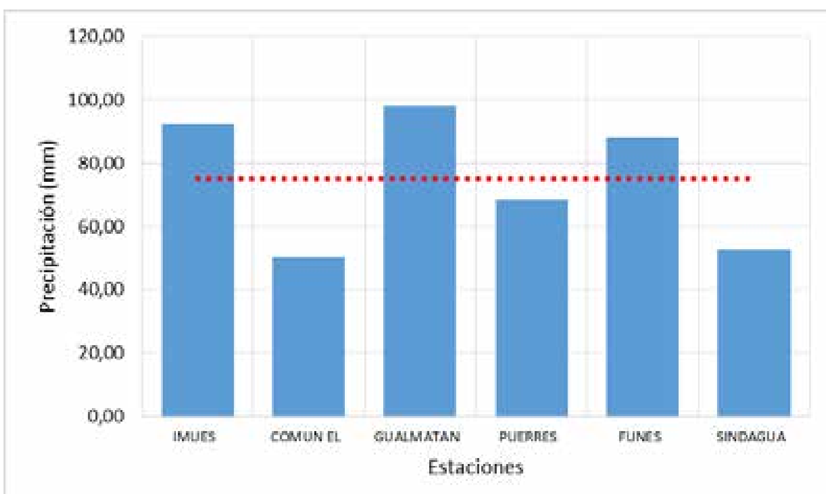
In the **Figure 5.135** Daily multiyear precipitation is presented for a time series from 1991 to 2016, where a daily average of 2.88 mm is shown for the nearest stations used in the climatic characterization of the project, in the **Figure 5.136** The maximum extreme values for the stations are presented, where an average of 74.97 mm of daily precipitation is presented, a difference of up to 97.2% with respect to the average precipitation, which shows a very high variability between precipitation Of the different days, the minimum values of precipitation for being daily will be of zero.

134 Multi-year daily average precipitation for the project's weather stations.



Source: GEOCOL CONSULTORES S.A, 2017.

.135 Multi-year maximum daily maximum precipitation for the project's weather stations.



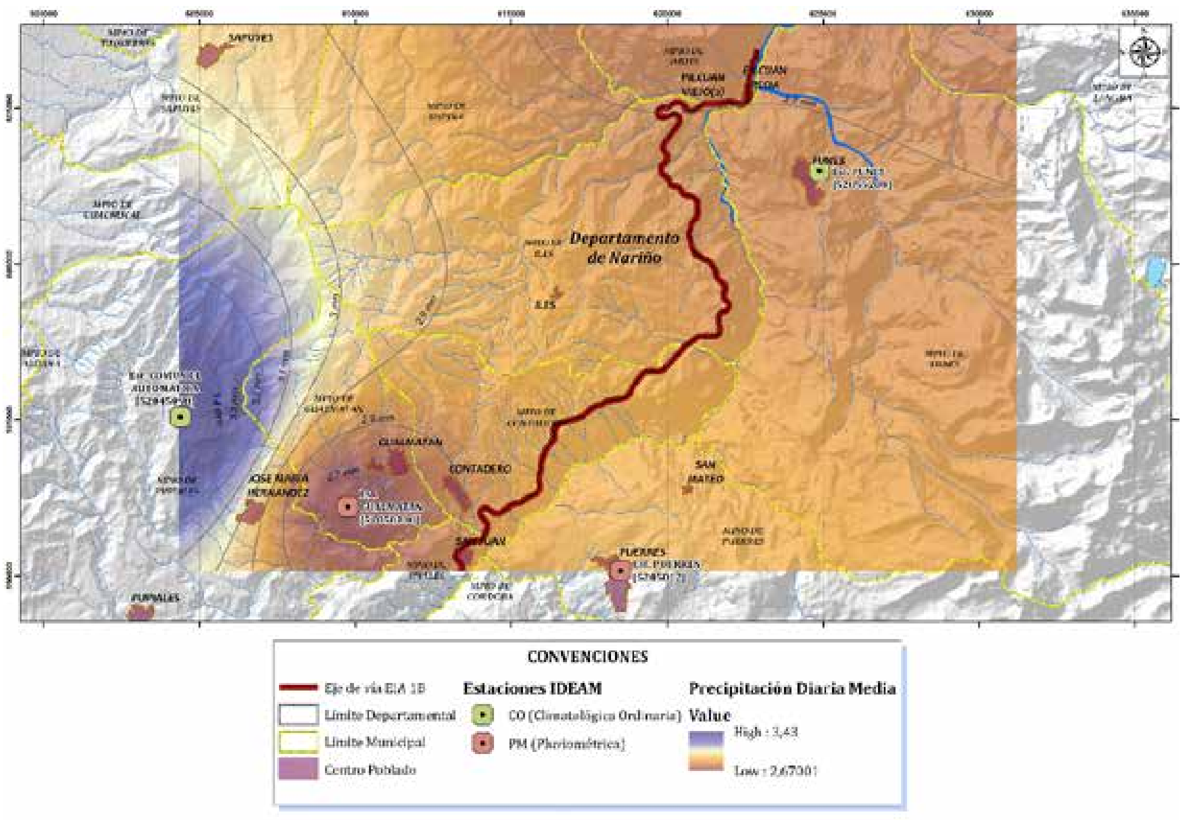
Source: GEOCOL CONSULTORES S.A, 2017.

- **Spatial Distribution**

The spatial distribution of daily precipitation in the area of influence of the project shows that the precipitation has a very similar behavior along the route, with average values between 2.8-3.0 mm, a with precipitation peak near the municipality of Pupiales and a decrease in the municipality of Gualmatan (See Figure Error! **No**

text of specified style in document.3). Annex 8. Climate - Extreme values shows the spatial distribution of the maximum and minimum values through isohyets in the project area.

Figure 5.136 Isohyets Multi-year daily average precipitation in the project

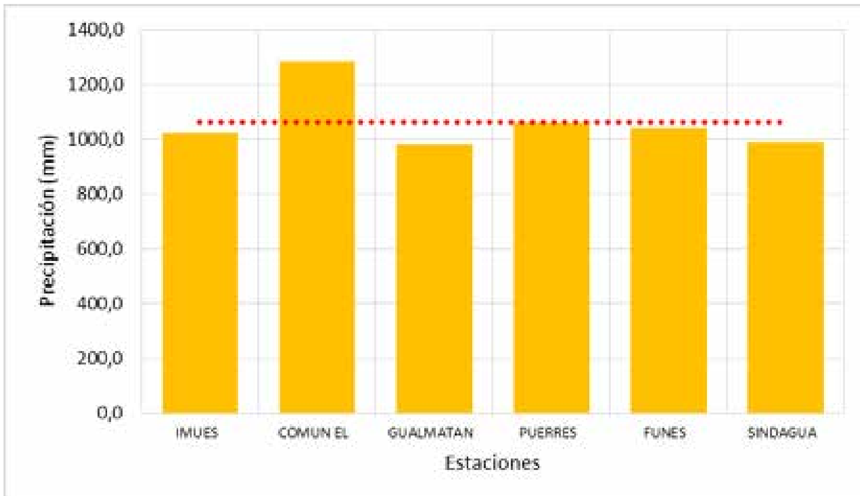


Source: GEOCOL CONSULTORES S.A, 2017.

- **Average annual precipitation, maximum, minimum**

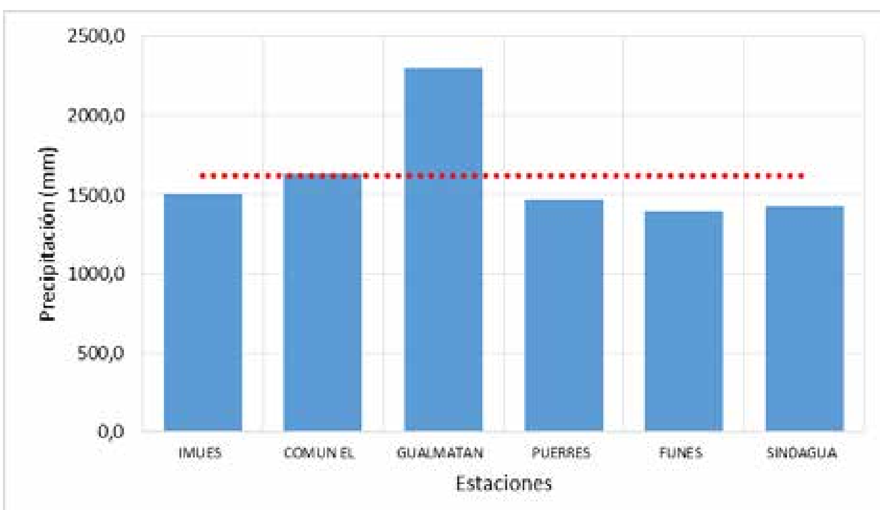
Figure Error! No text of specified style in document .4 shows the annual multi-year precipitation for a time series from 1991 to 2016, which shows an annual average of 1063.4 mm for the stations used in the climatic characterization of the project. The **Figure 5.138** shows the maximum extreme values for the stations, with an average of 1621.5 mm of annual precipitation, with a difference of up to 34.2% with respect to the average precipitation, which shows a very high year-to-year variability in precipitation. The minimum precipitation values are shown in **Figure 5.139** with an average value of 691.4 mm.

Figure 5.137 Multi-year annual average precipitation for the project's weather stations.



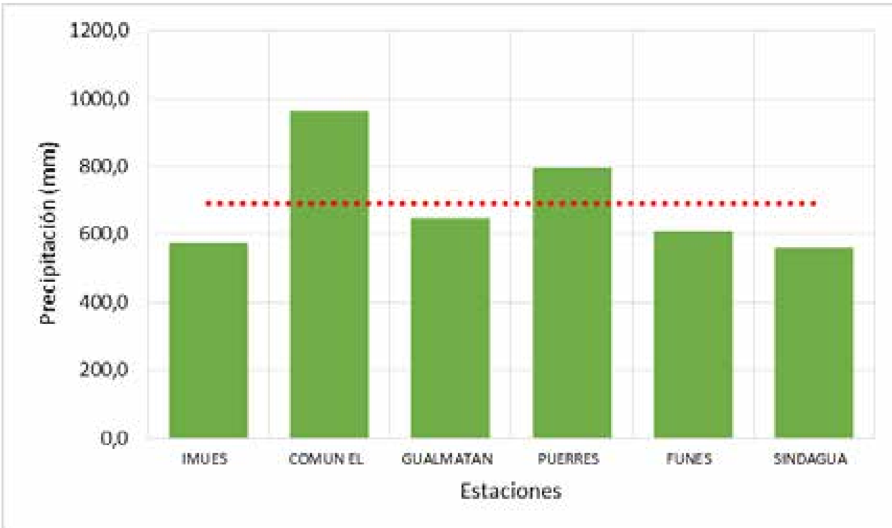
Source: GEOCOL CONSULTORES S.A, 2017.

Figure 5.138 Multi-year maximum annual precipitation for the project's weather stations.



Source: GEOCOL CONSULTORES S.A, 2017.

Figure 5.139 Multi-year annual minimum precipitation for the project's weather stations.



Source: GEOCOL CONSULTORES S.A, 2017.

Figure 5.140 shows the graphical analysis of the total annual precipitation values recorded in the meteorological stations used to characterize the area of influence of the project. This graph shows the behavior of the precipitation variable, in relation to the wet, normal and dry years, as well as the influence of El Niño and La Niña phenomena, during a 25-year recording period.

The Oceanic Niño Index (ONI) is the standard used to determine warm events (El Niño Phenomenon) and cold weather events (La Niña Phenomenon) in the tropical Pacific Ocean[4]:

- ONI values above 0.5 indicate a warm event (El Niño).
- ONI values below -0.5 indicate a cold event (La Niña).

Table 5.120 shows the ONI indexes calculated by the climate forecast center. It shows that Niña years, e.g. 1999, 2000 or 2011, have most or all months with ONI values below -0.5, and years like 1992, 2002 or 2015 are Niño years, since most of their months have ONI values above 0.5. This is consistent with the precipitation analysis carried out, where the years mentioned above present a decrease of precipitation in the warm (Niño) years and an increase of precipitation in the cold (Niña) years (See **Figure 5.140**).

Figure 5.140 shows that there is no upward or downward trend in precipitation since an average annual rainfall in the order of 1011 mm is expected in the 25-year analysis period.

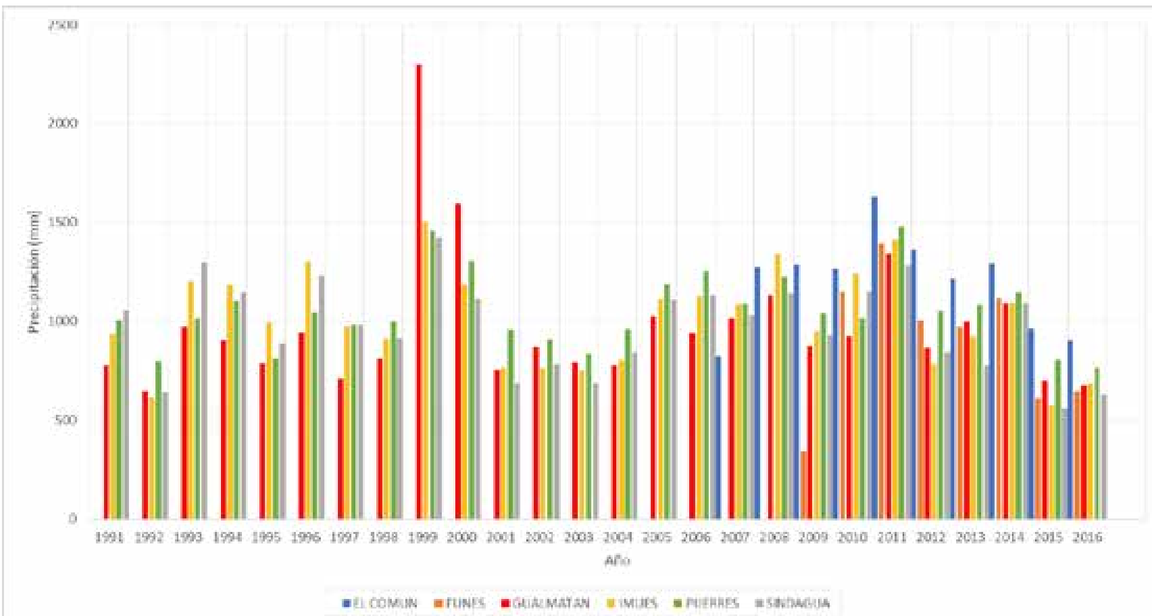
Table 5.120. Oceanic Indices Values for the Years Under Study

[4] NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION. Taken from: http://www.cpc.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1991	0,4	0,3	0,2	0,2	0,4	0,6	0,7	0,7	0,7	0,8	1,2	1,4
1992	1,6	1,5	1,4	1,2	1,0	0,8	0,5	0,2	0	-0,1	-0,1	0
1993	0,2	0,3	0,5	0,7	0,8	0,6	0,3	0,2	0,2	0,2	0,1	0,1
1994	0,1	0,1	0,2	0,3	0,4	0,4	0,4	0,4	0,4	0,6	0,9	1,0
1995	0,9	0,7	0,5	0,3	0,2	0	-0,2	-0,5	-0,7	-0,9	-1,0	-0,9
1996	-0,9	-0,7	-0,6	-0,4	-0,2	-0,2	-0,2	-0,3	-0,3	-0,4	-0,4	-0,5
1997	-0,5	-0,4	-0,2	0,1	0,6	1,0	1,4	1,7	2,0	2,2	2,3	2,3
1998	2,1	1,8	1,4	1,0	0,5	-0,1	-0,7	-1,0	-1,2	-1,2	-1,3	-1,4
1999	-1,4	-1,2	-1,0	-0,9	-0,9	-1,0	-1,0	-1,0	-1,1	-1,2	-1,4	-1,6
2000	-1,6	-1,4	-1,1	-0,9	-0,7	-0,7	-0,6	-0,5	-0,6	-0,7	-0,8	-0,8
2001	-0,7	-0,5	-0,4	-0,3	-0,2	-0,1	-0,1	-0,1	-0,2	-0,3	-0,4	-0,3
2002	-0,2	0,0	0,1	0,2	0,4	0,6	0,8	0,8	0,9	1,1	1,2	1,1
2003	0,9	0,7	0,4	0	-0,2	-0,1	0,1	0,2	0,2	0,3	0,3	0,3
2004	0,3	0,3	0,2	0,1	0,2	0,3	0,5	0,6	0,7	0,7	0,6	0,7
2005	0,7	0,6	0,5	0,5	0,3	0,2	0	-0,1	0	-0,2	-0,5	-0,7
2006	-0,7	-0,6	-0,4	-0,2	0,0	0,0	0,1	0,3	0,5	0,7	0,9	0,9
2007	0,7	0,4	0,1	-0,1	-0,2	-0,3	-0,4	-0,6	-0,9	-1,1	-1,3	-1,3
2008	-1,4	-1,3	-1,1	-0,9	-0,7	-0,5	-0,4	-0,3	-0,3	-0,4	-0,6	-0,7
2009	-0,7	-0,6	-0,4	-0,1	0,2	0,4	0,5	0,5	0,6	0,9	1,1	1,3
2010	1,3	1,2	0,9	0,5	0,0	-0,4	-0,9	-1,2	-1,4	-1,5	-1,4	-1,4
2011	-1,3	-1,0	-0,7	-0,5	-0,4	-0,3	-0,3	-0,6	-0,8	-0,9	-1,0	-0,9
2012	-0,7	-0,5	-0,4	-0,4	-0,3	-0,1	0,1	0,3	0,3	0,3	0,1	-0,2
2013	-0,4	-0,4	-0,3	-0,2	-0,2	-0,2	-0,3	-0,3	-0,2	-0,3	-0,3	-0,3
2014	-0,5	-0,5	-0,4	-0,2	-0,1	0,0	-0,1	0,0	0,1	0,4	0,5	0,6
2015	0,6	0,5	0,6	0,7	0,8	1,0	1,2	1,4	1,7	2,0	2,2	2,3
2016	2,2	2,0	1,6	1,1	0,6	0,1	-0,3	-0,6	-0,8	-0,8	-0,8	-0,7

Source: NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, 2017.

Figure 5.140 Temporal distribution of total multi-year annual precipitation in the meteorological stations used to characterize the area of influence of the project

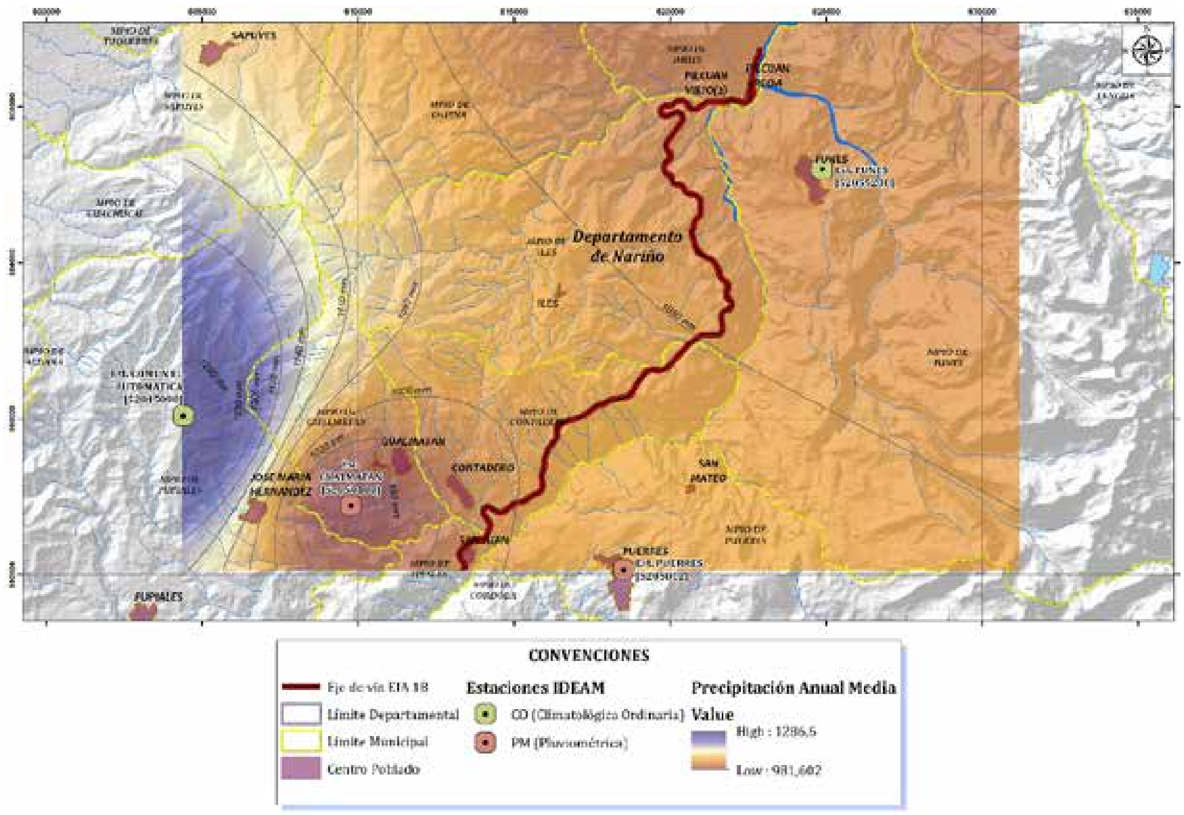


Source: GEOCOL CONSULTORES S.A, 2017.

o **Spatial Distribution**

The spatial distribution of annual rainfall in the area of influence of the project shows that rainfall has a very similar behavior along the route, with values averaging between 1020 and 1050 mm, with a precipitation peak near the municipality of Pupiales (1280 mm) and a decrease in the municipality of Gualmatan (980 mm) (See **Figure 5.136**). **Annex 8. Climate - Extreme values** shows the spatial distribution of the maximum and minimum values through of isohyets in the area of the project.

Figure 5.141 Isohyets. Multi-year annual average precipitation of the project.



Source: GEOCOL CONSULTORES S.A, 2017.

5.1.12.1.2 Temperature

Temperature is a physical magnitude that characterizes the average random motion of molecules in a physical body. In particular, the term air temperature refers to the measurement of the thermal state of the air with respect to its ability to yield heat around it. The average temperature observed during a given time interval (hour, day, month, year, decade, etc.) is called mean temperature, while the highest (maximum) and lowest (minimum) values in the course of such an interval are known as extreme temperatures5.

In addition, it is worth mentioning that temperature is one of the most important factors in climate analysis, because this parameter affects directly the evapotranspiration processes and conditions the existence of certain plant species.

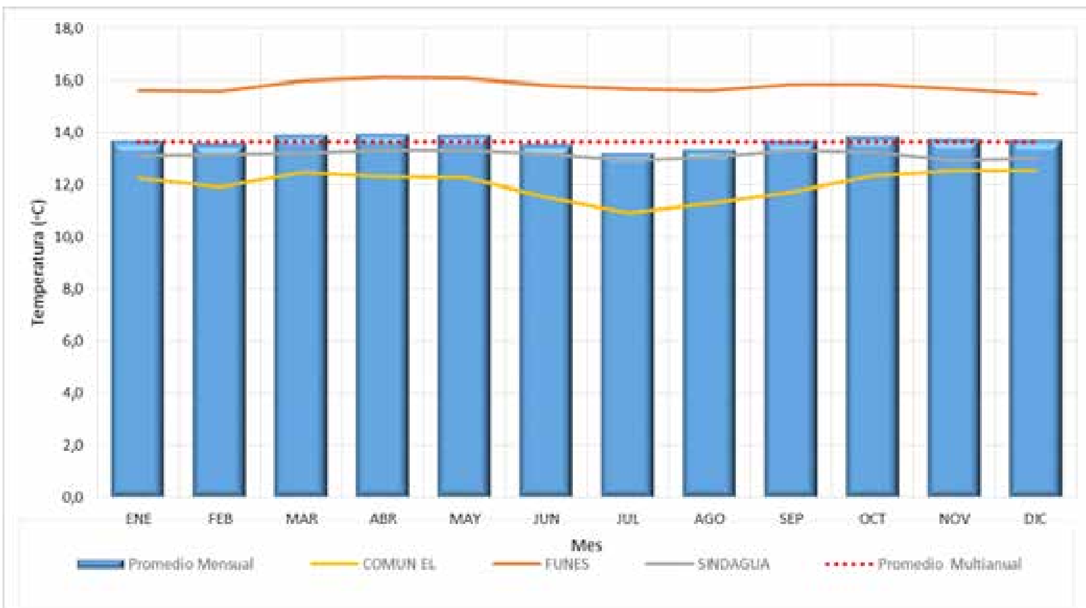
[5] Climatological Atlas of Colombia – IDEAM. Taken from http://www.ideam.gov.co/atlas/mclima.htm

- **Temporal Distribution**

In general, in the area of influence of the project, the average monthly temperature varies between 10.9 °C and 16.1 °C. The records of the analyzed stations show an average temperature of 13.6 °C, as seen in **Figure 5.142**.

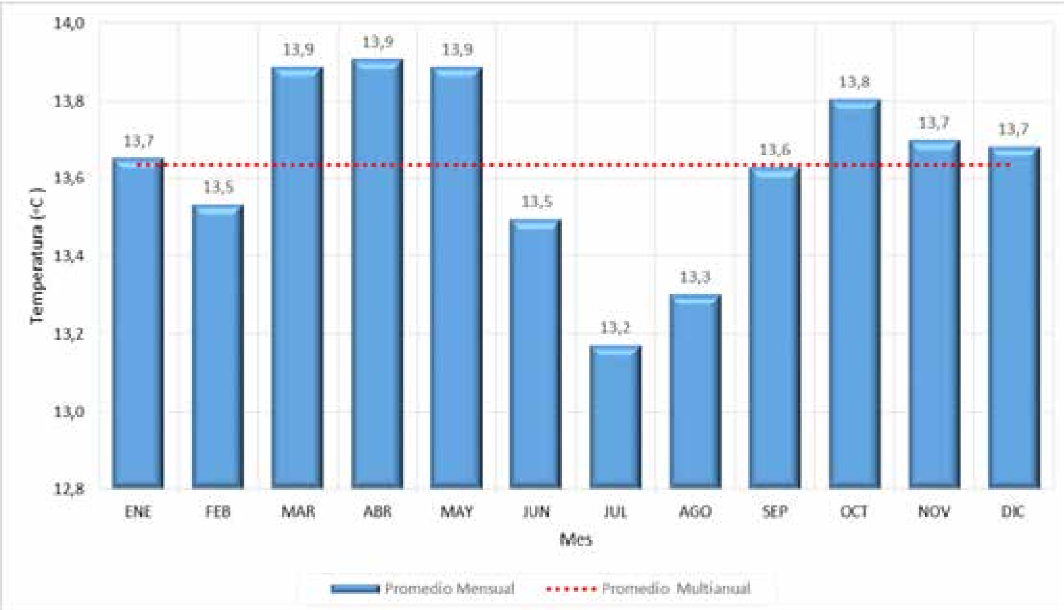
On average, low temperatures in the area are present during low-rainfall periods (July-August), which is associated with cold winds, with values from 13.2 °C to 13.3 °C, according to the estimated average temperatures for the area. In addition, we observe that the highest temperatures occur during the month of April, with 13.91 °C. (See **Figure 5.142** and **Figure 5.143**). It also shows the Funes station presents on average the highest temperature records (see **Figure 5.142**).

Figure 5.142 Temporal Distribution of multi-year average monthly temperature in the area of influence of the project.



Source: GEOCOL CONSULTORES S.A, 2017.

Figure 5.143 Estimated Average Histogram - Temporal Distribution of the average temperature in the area of influence of the project.



Source: GEOCOL CONSULTORES S.A, 2017.

Table 5.121 shows records of monthly average, maximum, and minimum temperature of stations used to characterize the area of the project.

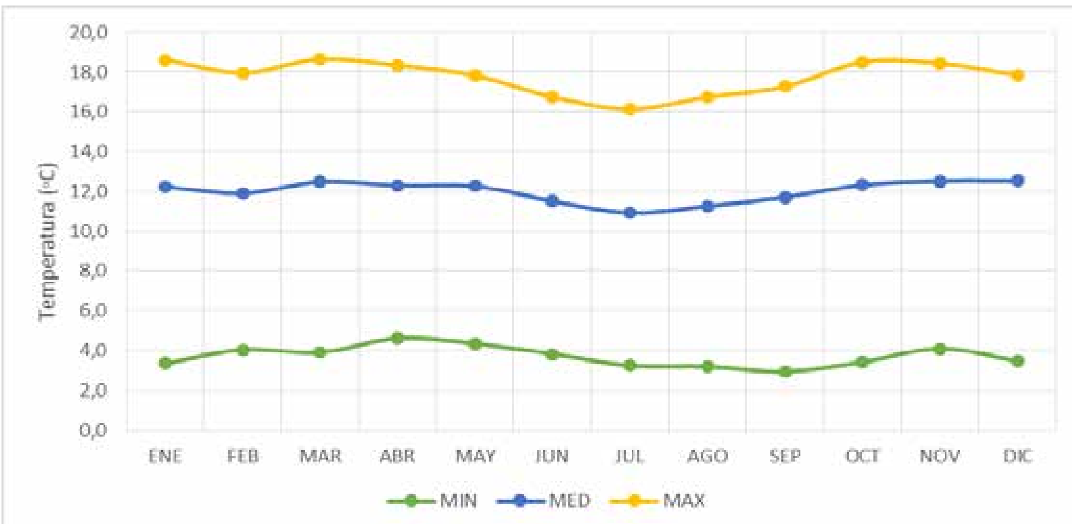
Table 5.121 Multi-year monthly average, maximum and minimum temperature (°C) values in the meteorological stations used to characterize the area of influence of the Project

STATION		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG/ YEAR
EL COMÚN	MIN	3,4	4,0	3,9	4,6	4,4	3,8	3,2	3,2	3,0	3,4	4,1	3,5	3,7
	MEA	12,2	11,9	12,5	12,3	12,3	11,5	10,9	11,3	11,7	12,3	12,5	12,5	12,0
	MAX	18,6	18,0	18,6	18,3	17,8	16,8	16,1	16,7	17,3	18,5	18,4	17,8	17,8
FUNES	MIN	9,5	10,1	10,5	10,6	10,5	10,5	10,1	9,4	9,1	9,6	10,2	10,1	10,0
	AVG	15,6	15,6	16,0	16,1	16,1	15,8	15,7	15,6	15,9	15,8	15,7	15,5	15,8
	MAX	25,4	25,2	24,7	24,9	24,8	24,5	23,4	23,9	26,2	25,0	25,7	24,0	24,8
SINDAGUA	MIN	7,2	7,3	7,7	7,8	8,1	7,6	6,7	6,9	6,8	7,2	7,4	7,5	7,4
	AVG	13,1	13,1	13,2	13,3	13,3	13,2	12,9	13,0	13,3	13,2	12,9	13,0	13,1
	MAX	20,3	20,8	20,4	20,5	20,1	20,0	19,7	20,5	21,7	21,3	20,2	20,0	20,5
AVERAGE	MIN	6,7	7,1	7,4	7,7	7,6	7,3	6,7	6,5	6,3	6,8	7,2	7,0	7,0
	AVG	13,7	13,5	13,9	13,9	13,9	13,5	13,2	13,3	13,6	13,8	13,7	13,7	13,6
	MAX	21,4	21,3	21,3	21,3	20,9	20,4	19,7	20,4	21,7	21,6	21,4	20,6	21,0

Source: GEOCOL CONSULTORES S.A, 2017.

Figure 5.144 shows the distribution of temperature of the El Común station throughout the year. **Annex 8. Climate - Extreme Values** shows the temporal distribution for each of the stations used in the climatic characterization of the project. **Figure 5.144** shows that extreme temperature values can vary from 18.6 °C and 3.4 °C for the same month of the year (January), suggesting a high thermal variability in the area, with a variation of more than 15 degrees Celsius. There is also an average temperature for El Común station of 12.5 °C.

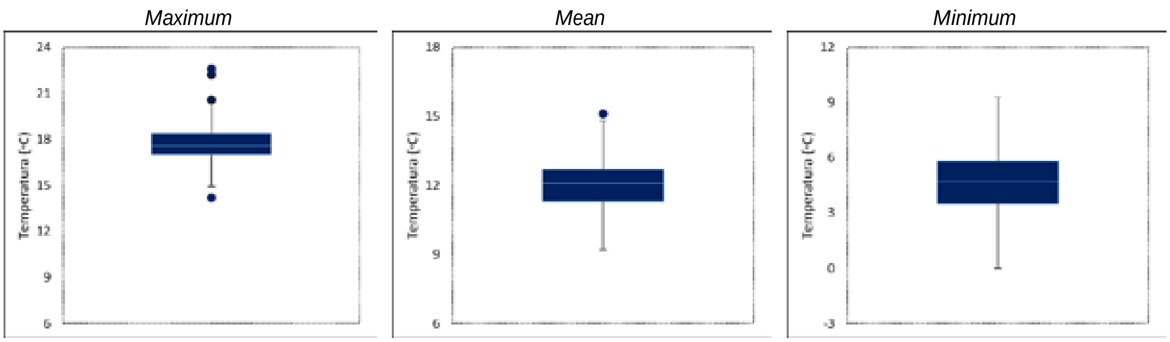
Figure 5.144 Temperature for Different Statistics (Min/Mean/Max) in El Común Station.



Source: GEOCOL CONSULTORES S.A, 2017.

Figure 5.145 shows the Box-Plot diagram of El Común station, which seeks to characterize these extreme values that do not represent the reality of the phenomenon. Station A shows that for mean temperatures the average temperature value is 12 °C while upper limit values reach 14.8 °C and lower limit values reach 9.2 °C leaving out the upper outlier of 15.1 °C. It is observed that the maximum temperature values are in the order of 17.6 °C and the minimum values around 3,9 °C. No outliers were identified for the minimum temperature scenario, indicating that in the lower temperature values in the area are always within the given range. **Annex 8. Climate - Extreme Values** shows the Box-Plot diagrams for the mean and extreme values for each of the stations used in the climate characterization of the project.

Figure 5.145 Box-Plot diagram of El Común Station, maximum/mean/minimum.

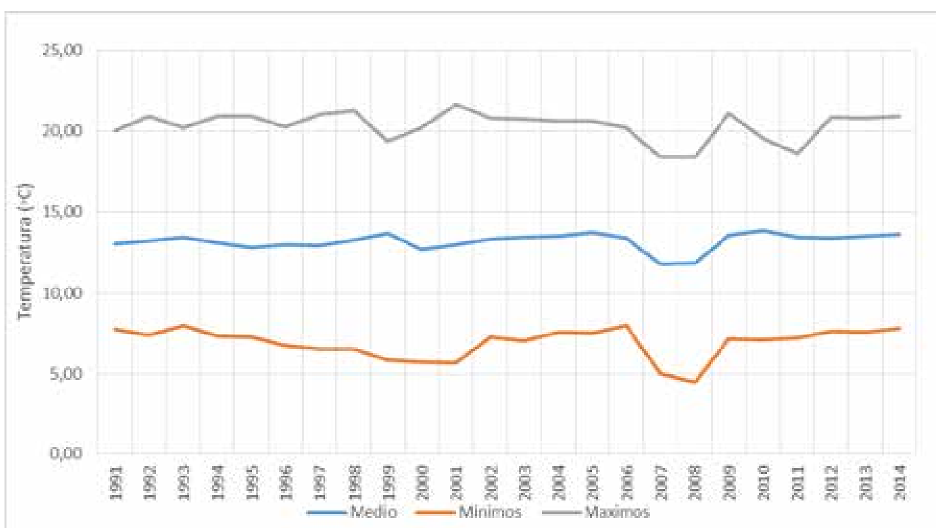


Source: GEOCOL CONSULTORES S.A, 2017.

Figure 5.146 shows the graphical analysis of the total annual values of the mean, minimum and maximum temperature recorded in the meteorological stations used to characterize the project area. This graph shows the behavior of the temperature variable, in relation to the wet, normal and dry years, as well as the influences of the El Niño and La Niña phenomena, during a 25-year recording period.

Based on the analysis conducted with **Figure 5.146, it** is possible to determine that there are no upward or downward trends in the period under analysis in the different stations used to characterize the temperature of the project area. It shows that the lowest temperature values occurred during 2007 and 2008.

Figure 5.146 Temporal Distribution of multi-year monthly temperature in meteorological stations used to characterize the area of the project.



Source: GEOCOL CONSULTORES S.A, 2017.

- **Spatial Distribution**

From a spatial perspective, the isotherms are the graphical representation on a map of the Temperature values, which illustrate the spatial distribution of temperature in the region.

In order to obtain the mean temperature distribution, we adopted the inter-institutional methodology developed by IDEAM, IAvH, Invemar, I.Sinchi, IIAP and IGAC in the document entitled Inland, Coastal and Marine Ecosystems of Colombia, which developed the Ecosystem Map and a set of thematic maps at an updated 1:500000 scale including the temperature map.

For the distribution of temperature in the Project Area, a 30 m digital elevation model (DEM) was used, with which the spatial distribution of temperature was obtained, by means of the equation determined in the cited study, to relate the air temperature with the height above the level of the sea:

$$T = 28.1926 - (0.00561473\, x\, H)$$

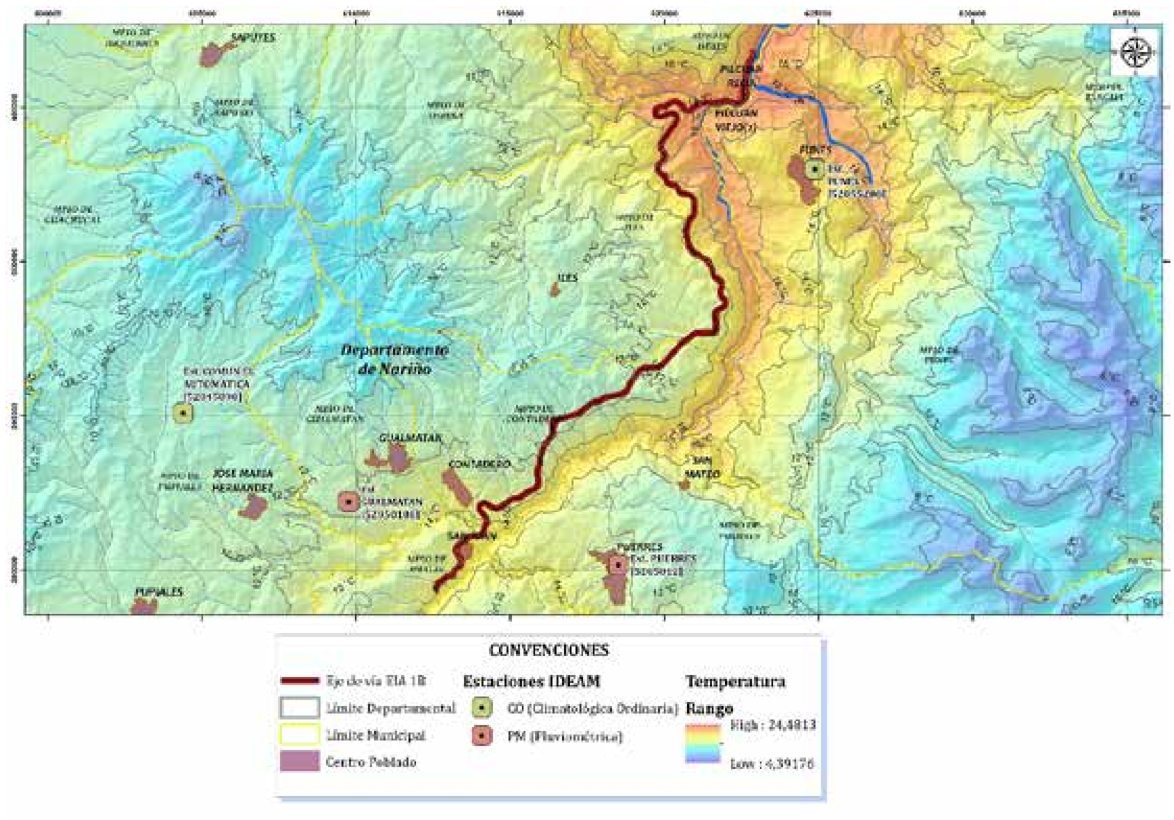
Where:

T = Mean Temperature [°C].

H = Elevation above sea level [AMSL].

These values were calibrated through the average temperature values determined by the IDEAM stations in the project area. The spatial distribution of temperature in the area of influence of the project shows that the highest temperature values are towards the north side of the project near the Pedregal headwaters, with temperatures around 18 °C. Towards the South, temperature begins to decrease, with temperatures of 14 °C near the San Juan headwaters. Generally, the area of influence of the project has a temperature between 13 °C to 15 °C (See **Figure 5.147**) and **Cartographic Annex, Map No. 17. Isotherms**).

Figure 5.147 Isotherms. Multi-annual monthly average temperature of the project area



Source: GEOCOL CONSULTORES S.A, 2017.

5.1.12.1.3 Relative Humidity. USB flash drives

Relative humidity is the ratio expressed as a percentage of the actual water vapor stress and the saturation stress at the same temperature. The relative humidity-temperature ratio is the reverse: when the temperature increases, the air's capacity to retain water vapor increases and the relative humidity decreases, while when the temperature decreases, the retention capacity decreases and the relative humidity increases.

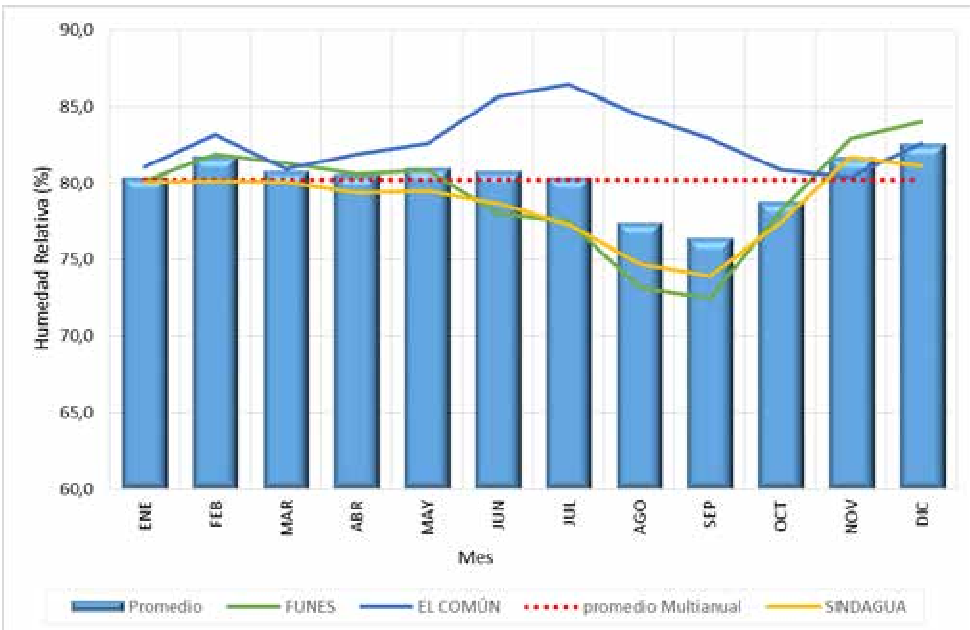
In addition, relative humidity and temperature allow vegetation and fauna to acquire physiognomic differences from one area to another.

- **Temporal Distribution**

According to the records of the stations under analysis for the area of influence of the project, the average monthly relative humidity ranges from 73% to 86%. (See **Figure 5.148**).

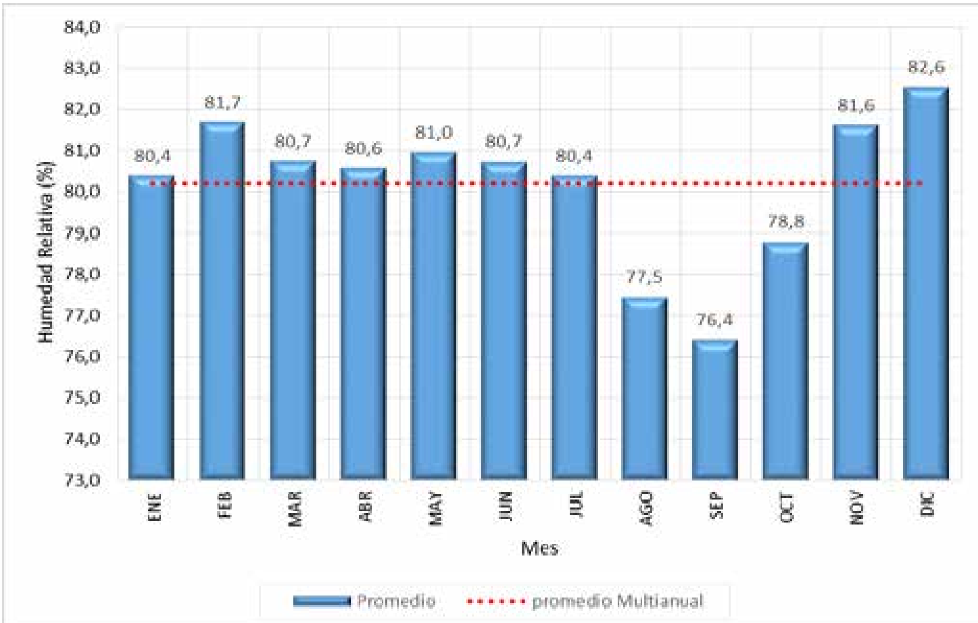
On average, the highest relative humidities are recorded during low temperature periods, with mean monthly values of 82.6%, with December being on average the month with the maximum relative humidity values. The lowest relative humidity values on average are recorded during September and August, with mean values ranging from 76.4% to 77.5% respectively, with August being the month with the lowest relative humidity in the Project Area. (See **Figure 5.149**).

Figure 5.148 Temporal Distribution of the multi-year monthly average relative humidity in the area of influence of the Project



Source: GEOCOL CONSULTORES S.A, 2017.

Figure 5.149 Estimated average histogram - Temporal Distribution of relative humidity in the area of influence of the project



Source: GEOCOL CONSULTORES S.A, 2017.

Table 5.122! shows the records of the mean, maximum and minimum monthly relative humidity of the stations used in the characterization of the area of influence of the project.

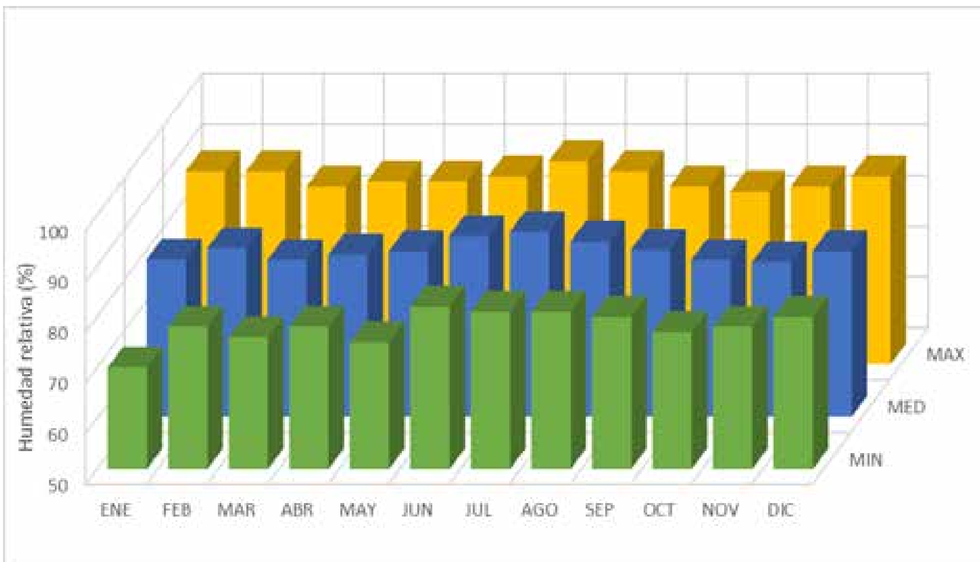
Table 5.122 Multi-year monthly mean, maximum and minimum relative humidity values (%) in the meteorological stations used to characterize the area of influence of the project.

STATION		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG / YEAR
FUNES	MIN	72	76	72	74	74	75	71	69	68	74	76	68	72
	AVG	80	82	81	81	81	78	78	73	73	78	83	84	79
	MAX	88	90	90	93	88	83	83	79	80	85	91	91	87
EL COMÚN	MIN	70	78	76	78	75	82	81	81	80	77	78	80	78
	AVG	81	83	81	82	83	86	86	84	83	81	80	83	83
	MAX	88	88	85	86	86	87	90	88	85	84	85	87	87
SINDAGUA	MIN	68	71	72	71	76	74	65	65	58	65	75	66	69
	AVG	80	80	80	79	80	79	77	75	74	77	82	81	79
	MAX	91	86	86	84	84	84	83	84	81	84	88	87	85
AVERAGE	MIN	70	75	73	74	75	77	72	72	69	72	76	71	73
	AVG	80	82	81	81	81	81	80	77	76	79	82	83	80
	MAX	89	88	87	88	86	85	85	84	82	84	88	88	86

Source: GEOCOL CONSULTORES S.A, 2017.

Figure 5.150 shows the distribution of relative humidity of the El Común Station throughout the year. **Annex 8. Climate - Extreme Values** shows the temporal distribution for each of the stations used in the climate characterization of the area of influence of the project. **Figure 5.150** shows that extreme values of relative humidity can range from 70% to 88% for the same month of the year (January). A very similar distribution is shown for the evaluated statistics.

Figure 5.150 Relative humidity for different statistics (Min/Mean/Max) at El Común Station.



Source: GEOCOL CONSULTORES S.A, 2017.

o **Spatial Distribution**

Spatially, Isohumes are the graphical representation of relative humidity values on a map, which illustrate the spatial distribution of relative humidity in the region.

Based on the information on heights and temperatures obtained from the DEM, relative humidity is calculated through the following equation, since there is not enough information in the region covering the area under study as a whole.

$$H_r = \left(\frac{P_v}{P_{vs}}\right) * 100$$

Where:

Hr= relative humidity ,

Pv = the vapor pressure of the air, which is obtained with the following formula

$$P_v = 6.11 * e^{(T_r*17.27)/(237.3+T_r)}$$

Where:

Tr = the dew temperature estimated through the following formula

$$T_r = 26.061 - (H * 0.0060)$$

Pvs = the saturation vapor pressure of the air, which is calculated using the following formula

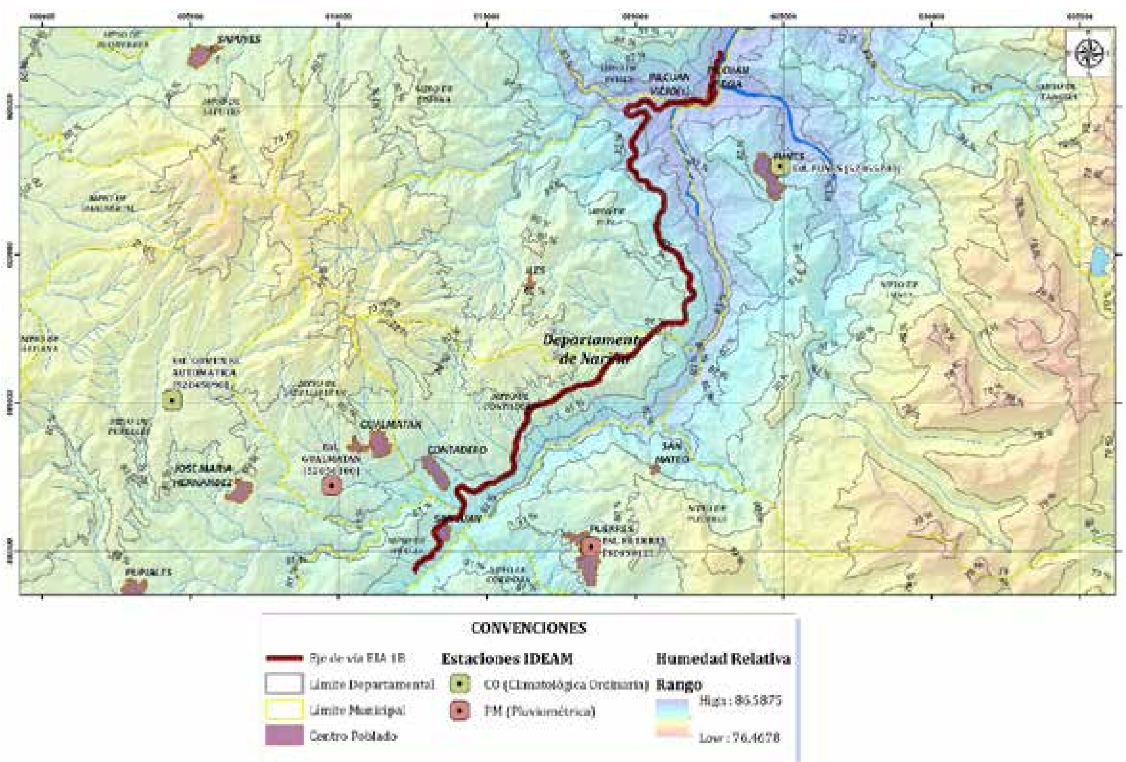
$$P_{vs} = 6.11 * e^{(T*17.27)/(237.3+T)}$$

Where:

T = the annual average temperature that was previously calculated

The spatial distribution of relative humidity in the area of influence of the project shows that the highest values of relative humidity are in the area of influence of the project, with relative humidity values of 81%. In the north vertex of the area, the highest relative humidity is recorded, with 83%. In general, the area of influence of the project has a relative humidity between 80% and 83%. (**Figure 5.151**).

Figure 5.151 Isohumes – Multi-year mean monthly relative humidity in the Project Area.



Source: GEOCOL CONSULTORES S.A, 2017.

5.1.12.1.4 Evaporation

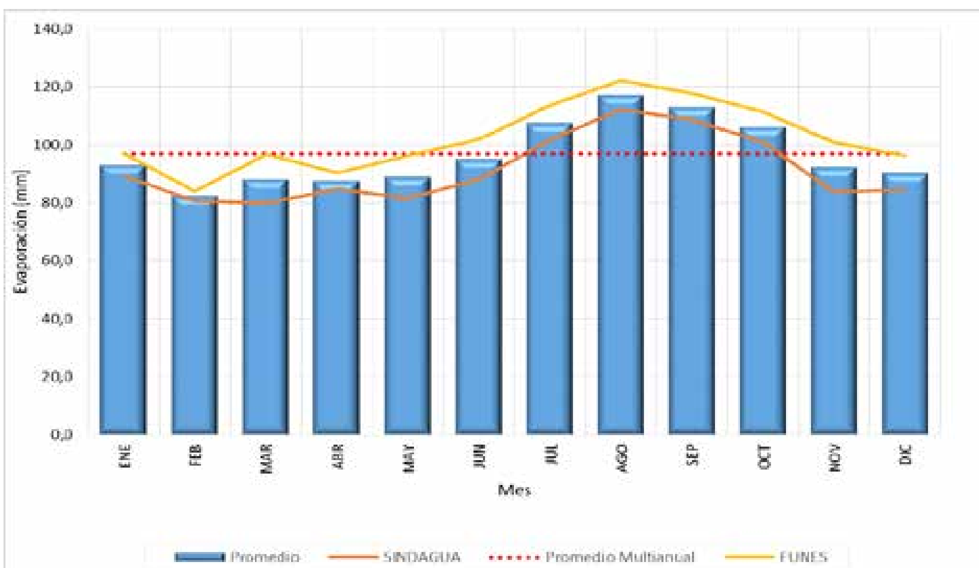
Evaporation is the emission of water vapor into the atmosphere from a humid surface at a temperature below the boiling point. It is directly related to several factors, such as the type of soil and climatic factors such as temperature, wind speed, atmospheric pressure, insolation, as well as the amount of water contained on the surface.

o **Temporal Distribution**

According to records of the station analyzed in the area of influence of the Project, mean monthly evaporation ranges from 79.9 mm to 122.1 mm; therefore, total average evaporation in the area is around 96.8 mm per month. (See **Figure 5.152**).

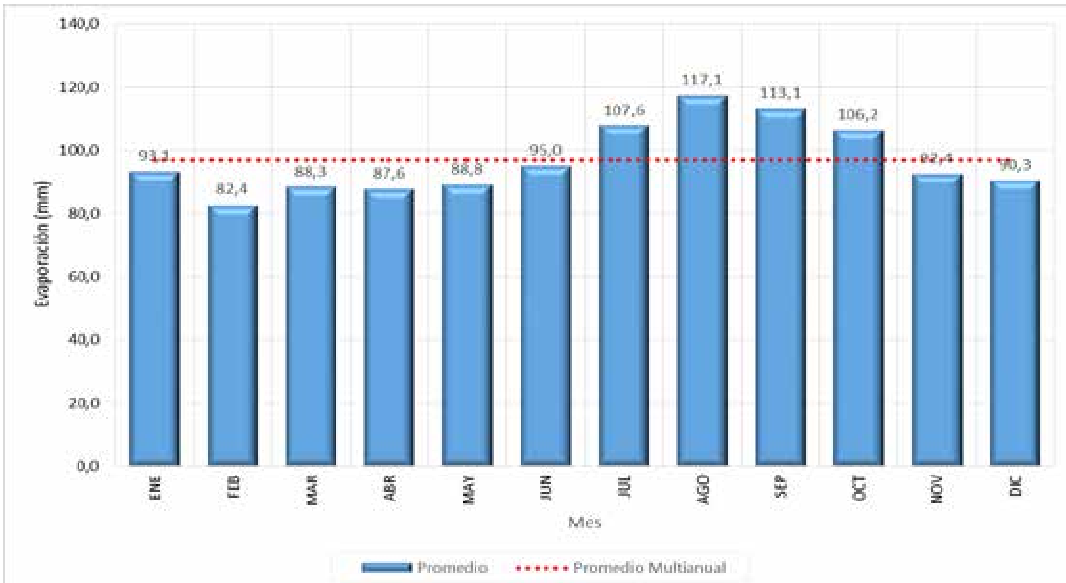
According to the estimated average histogram of evaporation for the area of influence of the project, the periods with the largest evaporations are in August, with average monthly values of 117.1 mm. The lowest values evaporation occurred in February, with a value of 82.44 mm.

Figure 5.152 Temporal Distribution of the mean monthly evaporation (mm) in the area of influence of the project



Source: GEOCOL CONSULTORES S.A, 2017.

Figure 5.153 Estimated Average Histogram - Temporal Distribution of Evaporation in the area of influence of the project.



Source: GEOCOL CONSULTORES S.A, 2017.

Table 5.123 below shows records of mean, maximum and minimum monthly evaporation from the station used in the characterization of the area of influence of the project.

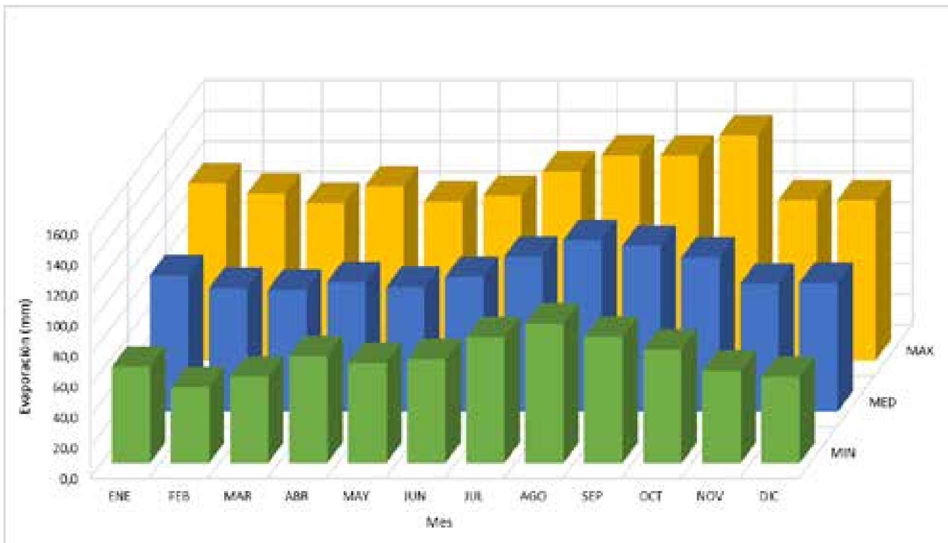
Table 5.123 Mean, maximum and minimum evaporation values (mm) in the meteorological stations used to characterize the area of influence of the Project.

STATION		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG	YEAR
SINDAGUA	MIN	63,1	49,6	56,4	70,0	65,5	68,0	82,3	91,4	82,5	74,2	60,2	56,3	68,3	819,5
	AVG	89,2	80,8	79,9	84,8	81,4	88,1	101,6	112,2	108,5	100,9	83,8	84,5	91,3	1095,7
	MAX	115,7	109,0	103,0	114,1	104,0	107,8	123,6	134,2	134,0	147,3	104,9	104,8	116,9	1402,4
FUNES	MIN	77,5	67	86,2	65,9	73,3	93	97,4	106,7	96,5	103	85,7	83,8	86,3	1036,0
	AVG	97,0	84,1	96,6	90,4	96,3	101,9	113,6	122,1	117,7	111,5	100,9	96,2	102,4	1228,2
	MAX	133,1	105,9	102,9	109,6	119,5	109,8	131,8	141,9	137,2	123,3	130,5	119,4	122,1	1464,9
AVERAGE	MIN	70,3	58,3	71,3	68,0	69,4	80,5	89,9	99,1	89,5	88,6	73,0	70,1	77,3	927,8
	AVG	93,1	82,4	88,3	87,6	88,8	95,0	107,6	117,1	113,1	106,2	92,4	90,3	96,8	1161,9
	MAX	124,4	107,5	103,0	111,9	111,8	108,8	127,7	138,1	135,6	135,3	117,7	112,1	119,5	1433,7

Source: GEOCOL CONSULTORES S.A, 2017.

Figure 5.154 shows the distribution of the evaporation from the Apt. San Luis Station throughout the year. **Annex 8. Climate Extreme Values** shows the temporal distribution for the station used in the characterization of the area of influence of the project. **Figure 5.154** shows that the extreme evaporation values can range from 74.2 mm to 147.3 mm for the same month of the year (October). A very similar distribution is shown for the evaluated statistics.

Figure 5.154 Evaporation for different statistics (Min/Mean/Max) at the Sindagua Station.



Source: GEOCOL CONSULTORES S.A, 2017.

5.1.12.1.5 Sunshine

Sunshine represents the total time during which direct sunlight irradiates on an area, between dawn and dusk, i.e. the number of hours of sunshine (hours/day) on a given area. Taking this into account, brightness is directly dependent on the existing cloudiness in a certain area. Thus, at lower cloudiness, the greater the sunshine, and vice versa.

o **Temporal Distribution**

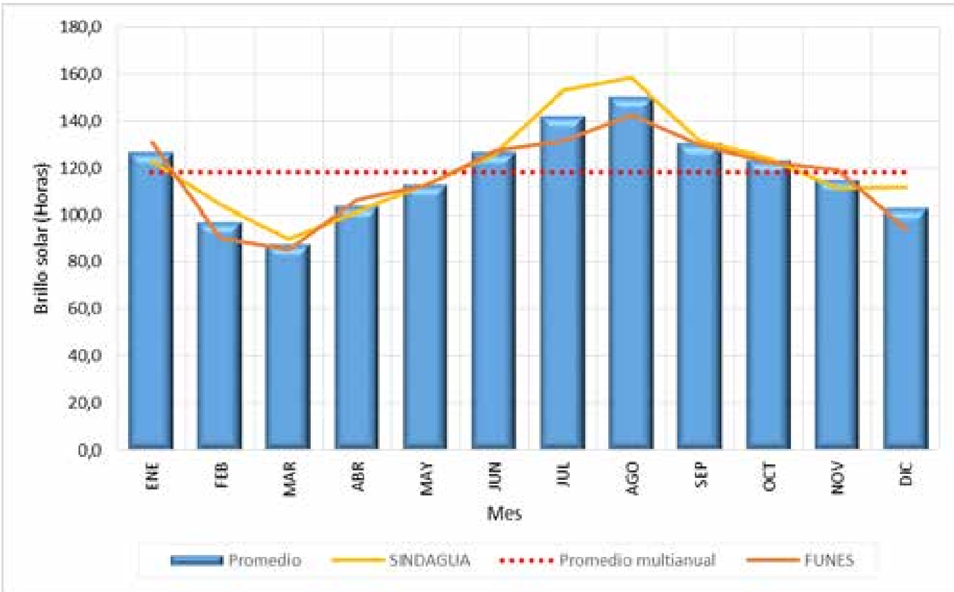
The number of hours of sunshine is influenced in the area by the temporal distribution of precipitation across the months of the year. The low precipitation periods are also those with the highest insolation, while the wet season is characterized by the lowest sunshine values.

The records of solar radiation or sunshine at the stations analyzed in the project area show that it varies monthly from 85.3 hours to 158.6 hours, so that on average, the total radiation for the area is on the order of 118.3 hours per month. (See **Figure 5.155**).

On average, the lowest solar radiation occurs during rainy periods (February-April), with monthly variations from 87.6 hours to 104 hours. The month with the lowest average radiation is March, considered one of the rainiest months. (See **Figure 5.155** and **Figure 5.156**).

On the other hand, it is evident that the highest radiation or insolation occurs during summer periods, with an average from 126.6 hours to 150.7 hours. The month with the highest average radiation is August, considered the least rainy month. (See **Figure 5.155** and **Figure 5.156**).

Figure 5.155 Temporal Distribution of multi-year monthly solar radiation in the area of influence of the project.



Source: GEOCOL CONSULTORES S.A, 2017.

Figure 5.156 Estimated Average Histogram - Temporal Distribution of solar radiation in the area of influence of the project.

Source: GEOCOL CONSULTORES S.A, 2017.

Table 5.124 below shows records of mean, maximum and minimum multi-year monthly sunshine at the stations used in the characterization of the area of influence of the project.

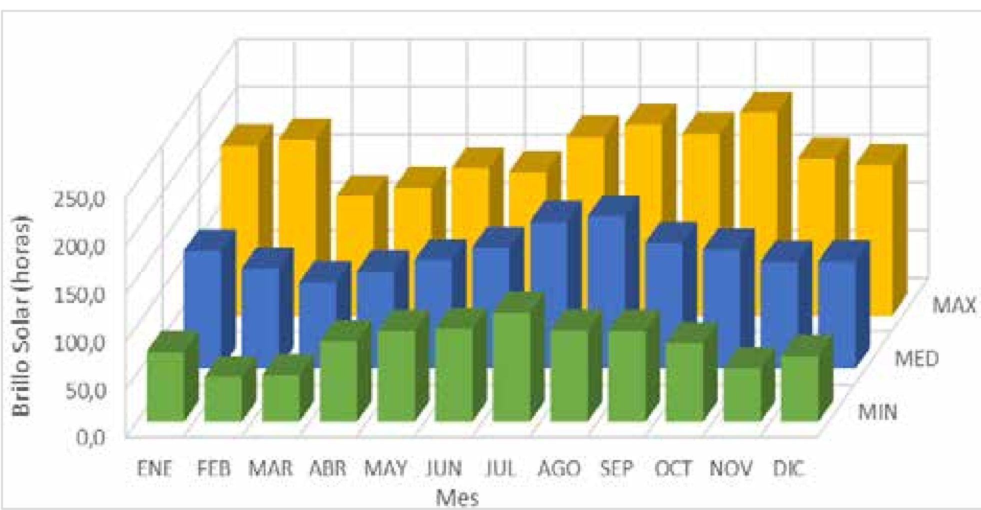
Table 5.124 Mean, maximum and minimum values of monthly sunshine (hours) at meteorological stations used to characterize the area of influence of the project

STATION		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG	YEAR
SINDAGUA	MIN	73,2	46,8	48,8	83,8	94,8	97,0	113,9	95,4	95,0	81,8	55,6	69,0	79,6	955,1
	AVG	123,0	104,3	90,0	101,6	113,1	126,2	153,1	158,6	131,4	124,2	111,3	111,8	120,7	1448,6
	MAX	177,3	183,9	124,7	133,3	153,6	149,9	186,3	199,1	189,8	211,8	163,7	157,2	169,2	2030,6
FUNES	MIN	79,6	56,1	76,1	80,1	107,1	105,2	123,1	124,3	106,2	106,4	81,0	68,1	92,8	1113,3
	AVG	130,8	90,2	85,3	106,5	112,7	127,1	131,2	142,7	129,7	122,5	119,4	94,2	116,0	1392,3
	MAX	182,0	113,6	100,4	122,9	119,5	142,8	148,5	155,2	150,6	134,0	157,2	135,9	138,6	1662,6
AVERAGE	MIN	76,4	51,5	62,5	82,0	101,0	101,1	118,5	109,9	100,6	94,1	68,3	68,6	86,2	1034,2
	AVG	126,9	97,2	87,6	104,0	112,9	126,6	142,2	150,7	130,5	123,3	115,3	103,0	118,4	1420,5
	MAX	179,7	148,8	112,6	128,1	136,6	146,4	167,4	177,2	170,2	172,9	160,5	146,6	153,9	1846,6

Source: GEOCOL CONSULTORES S.A, 2017.

Figure 5.157 shows distribution of sunshine at the Sindagua Station throughout the year. **Annex 8. Climate - Extreme Values** shows the temporal distribution for the station used in the climatic characterization of the area of influence of the project. **Figure 5.157** shows that extreme sunshine values have a high variability, since there is no clear upward or downward trend. The mean values show an even trend with a slight decrease of sunshine hours in the third month of the year, with the highest sunshine value occurring in October (211.8 hours) and the lowest in February (46.8 hours).

Figure 5.157 Sunshine for different statistics (Min/Mean/Max) at the Sindagua Station.



Source: GEOCOL CONSULTORES S.A, 2017.

5.1.12.1.6 Cloud cover

Cloud cover is the fraction of the sky that is covered by clouds. To perform the measurement of cloudiness the sky is divided in 8 parts or oktas. The number of oktas in the sky that are covered determines the level of cloudiness. **Table 5.125** shows the classification established by the World Meteorological Organization (WMO) to interpret cloudiness[6].

Table 5.125 Interpretation of cloudiness – WMO.

OKTAS	DEFINITION	CATEGORIES
0	Clear	Clear/good weather
1	1/8 of sky covered, more than zero	Clear/good weather
2	2/8 of sky covered	Clear/good weather
3	3/8 of sky covered	Partially cloudy
4	4/8 of sky covered	Partially cloudy
5	5/8 of sky covered	Partially cloudy
6	6/8 of sky covered	Cloudy
7	7/8 of sky covered, but not completely	Cloudy
8	8/8 of sky covered, fully cloudy	Covered

Source: WMO.

- **Temporal Distribution**

Based on the records of the stations analyzed for the area of influence of the project, the average monthly cloud cover varies from 3 to 6 oktas, with an average annual value of 5 oktas. (See **Figure 5.158**).

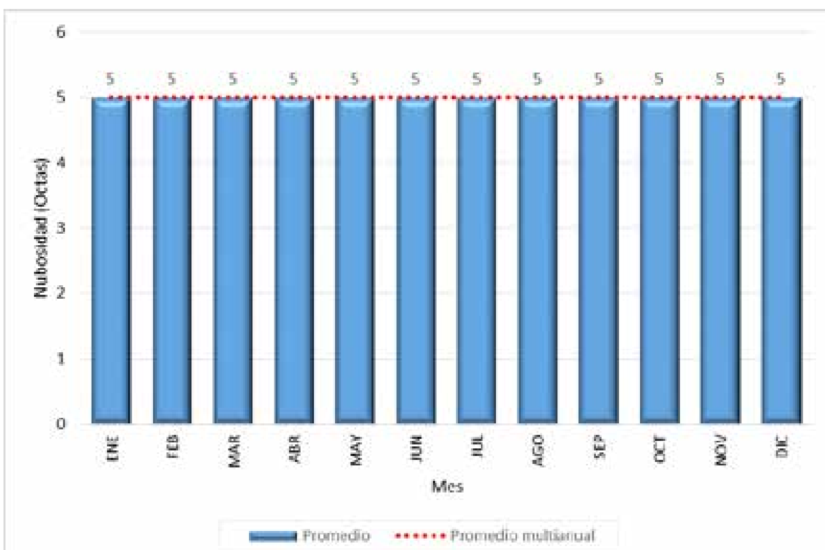
According to the Estimated Average Histogram for the area of influence of the project, there is a permanent average cloud cover trend of 5 oktas, which means that a partially cloudy sky is expected in the project area. (See **Figure 5.159**).

[6] World Meteorological Organization (WMO). Taken from http://wwis.inm.es/cloud/

Figure 5.158 Temporal Distribution of multi-year mean monthly cloud cover in the area of influence of the project.

Source: GEOCOL CONSULTORES S.A, 2017.

Figure 5.159 Estimated Average Histogram - Temporal Distribution of cloud cover in the area of influence of the project.



Source: GEOCOL CONSULTORES S.A, 2017.

Table 5.126 below shows the mean, maximum and minimum monthly cloud cover values of the stations used in the characterization of the area of influence of the project.

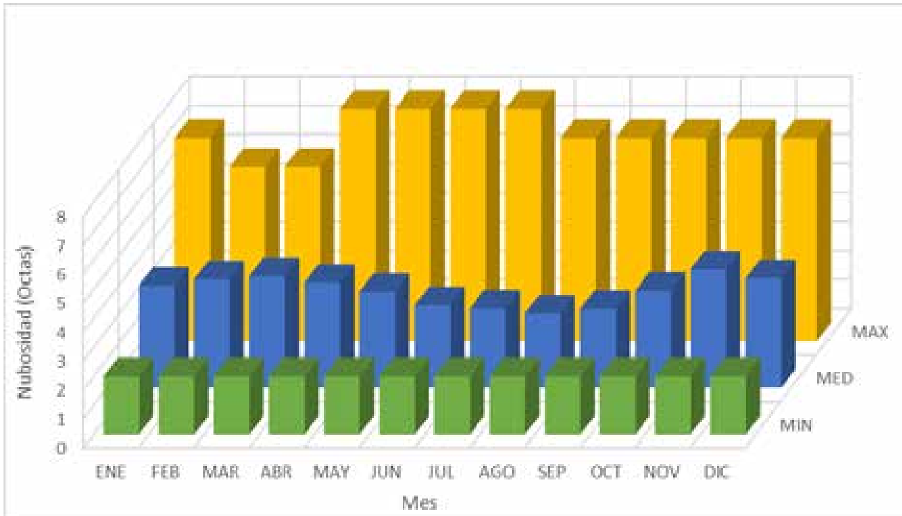
Table 5.126 Monthly mean, maximum and minimum cloud cover values (Oktas) at the meteorological stations used to characterize the area of influence of the project.

STATION		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG / YEAR
SINDAGUA	MIN	2	2	2	2	2	2	2	2	2	2	2	2	2
	AVG	4	4	4	4	3	3	3	3	3	3	4	4	3
	MAX	7	6	6	8	8	8	8	7	7	7	7	7	7
EL COMÚN	MIN	5	6	6	5	6	6	5	6	6	6	6	6	6
	AVG	6	6	6	6	6	6	6	6	6	6	6	6	6
	MAX	6	6	6	6	6	7	6	6	6	6	6	6	6
FUNES	MIN	4	5	5	4	5	4	5	5	4	4	5	4	5
	AVG	5	6	6	5	5	5	5	5	5	5	6	6	5
	MAX	6	6	7	6	6	6	6	6	6	6	7	7	6
AVERAGE	MIN	4	4	4	4	4	4	4	4	4	4	4	4	4
	AVG	5	5	5	5	5	5	5	5	5	5	5	5	5
	MAX	6	6	6	7	7	7	7	6	6	6	7	7	7

Source: GEOCOL CONSULTORES S.A, 2017.

Figure 5.160 shows the distribution of cloud cover at the Sindagua Station throughout the year. **Annex 8 Climate - Extreme Values** shows the temporal distribution for each of the stations used in the climatic characterization of the area of influence of the project. **Figure 5.160** shows that extreme cloud cover values are always between 6 and 8 oktas, which shows that there are high probabilities to find covered skies in the area. The same applies for minimum values, with an average 2 oktas, i.e. a clear sky/good weather

Figure 5.160 Cloud cover for different statistics (Min/Mean/Max) at Sindagua Station.



Source: GEOCOL CONSULTORES S.A, 2017.

5.1.12.1.7 Wind

The wind is the natural movement of the air. It is determined by the direction or point of the horizon where it blows from and by its speed, which the greater or lesser force depends on. For meteorological purposes, wind direction is defined as the direction where the wind blows from, and is measured in degrees clockwise from true north. A methodology useful to know some characteristics of the wind is the one called Wind Rose, which determines graphically the direction and speed of the wind at a particular location. The wind rose is based on information collected in a weather station equipped with devices necessary to perform wind measurements, usually an anemometer. In addition, to establish the wind force, the Beaufort scale can be used (See **Table 5.127**).

Table 5.127 Beaufort scale for wind speeds.

SCALE	AVERAGE SPEED m/s	CLASSIFICATION	CHARACTERISTICS
0	0.1	Calm	Smoke rises vertically.
1	0.9	Light air	Smoke drift indicates wind direction, still wind vanes.
2	2.4	Light breeze	Wind felt on face, leaves rustle, vanes begin to move.
3	4.4	Gently breeze	Leaves and small twigs constantly moving, light flags extended.
4	6.7	Moderate breeze	Dust, leaves, and loose paper lifted, small tree branches move.
5	9.4	Fresh breeze	Small trees in leaf begin to sway; waves in still waters.
6	12.3	Strong breeze	Larger tree branches moving; umbrellas are difficult to keep straight.
7	15.5	Near gale	Whole trees moving; resistance felt walking against wind.
8	19	Gale	Twigs breaking off trees, generally impedes progress.

SCALE	AVERAGE SPEED m/s	CLASSIFICATION	CHARACTERISTICS
9	22,6	Strong gale	Chimney pots and slates removed; bushes fall; plantations are strongly damaged.
10	26,4	Storm	Seldom experienced inland; trees uprooted; considerable structural damage
11	30,5	Violent storm	
12	32,7	Hurricane	

Source: VENTDEPOT, 1996.

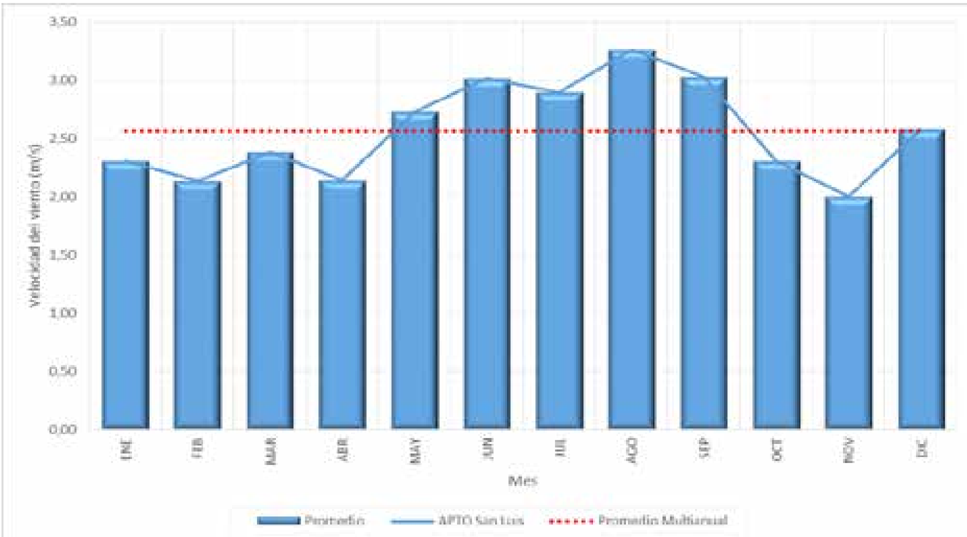
- **Temporal Distribution.**

The wind analysis for the study area was conducted based on the information of the Apto. San Luis station, taking into account that the other stations used in the climatic characterization of the Project Area do not have the parameter measurement. Therefore, and based on the historical records of the stations, it was possible to collect wind reliable information at a regional scale.

According to the records of the station analyzed in the area of influence of the project the average monthly wind speed varies from 2 m/s to 3.2 m/s, so that, on average, the average monthly wind speed in the area is about 2.5 m/s, which according to the Beaufort Scale is a gently breeze. (See **Figure 5.161** y **Figure 5.162**).

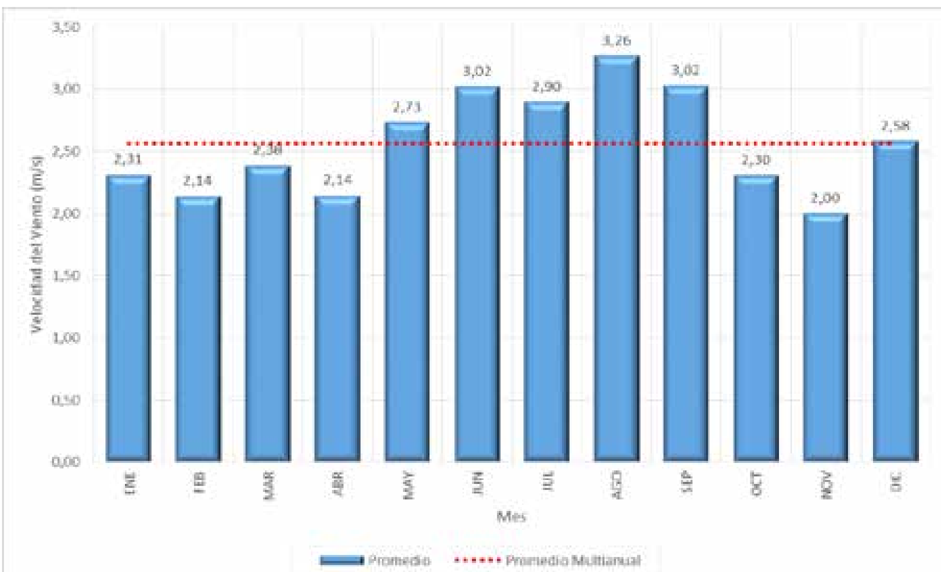
It was estimated that in average, in the area of direct influence of the project, the periods where the highest wind speeds occur are the low precipitation and low temperatures periods, which are associated also with cold winds (July to September). Monthly mean values were found to be between 2.96 m/s and 3.26 m/s, with August being the month with the highest average speed. On the other hand, in the periods of high precipitation and high temperature wind speeds are lower per month, with mean values of 2.0 m/s and 2.3 m/s during October and November, and 2, 14 m/s to 2.38 m/s during the first quarter of the year. November was found to be in average the month with the lowest wind speed. (See **Figure 5.161** and **Figure 5.162**).

Figure 5.161 Temporal distribution of multiannual and monthly wind speed in the area of influence of the project.



Fuente: GEOCOL CONSULTORES S.A, 2017.

Figure 5.162 Estimated average histogram – Temporal Distribution of the wind speed in the area of influence of the project.



Source: GEOCOL CONSULTORES S.A, 2017.

Table 5.128 below shows the average maximum and minimum wind speed records of the stations used in the characterization of the Project's area of influence.

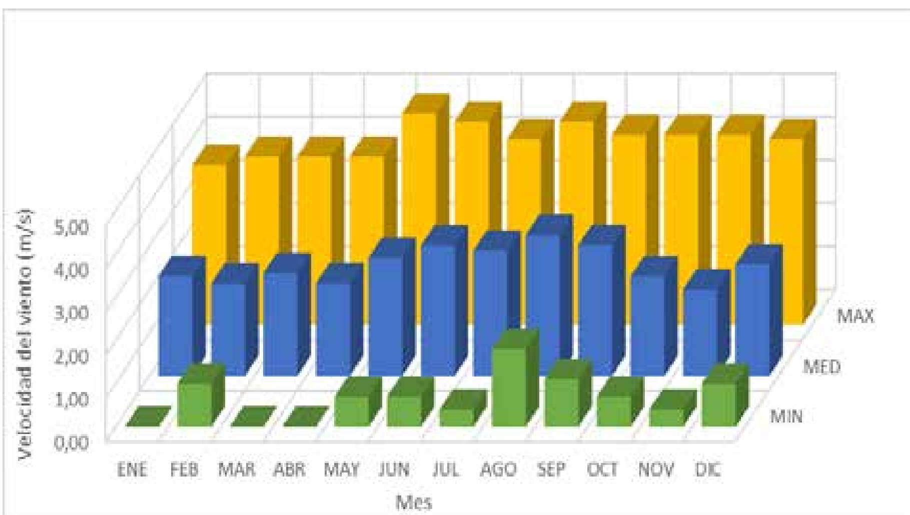
Table 5.128 Average monthly maximum and minimum wind speed values (m/s) in the meteorological stations used to characterize the area of influence of the project.

SEASON		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL/ MEAS
APTO. SAN LUIS	MIN	0,00	1,00	0,00	0,00	0,70	0,70	0,40	1,80	1,10	0,70	0,40	1,00	0,65
	MID	2,31	2,14	2,38	2,14	2,73	3,02	2,90	3,26	3,02	2,30	2,00	2,58	2,57
	MAX	3,70	3,90	3,90	3,90	4,90	4,70	4,30	4,70	4,40	4,40	4,40	4,30	4,29

Source: GEOCOL CONSULTORES S.A, 2017.

Figure 5.163 shows the distribution of wind speed in Apto San Luis station throughout the year. **Annex 8 Climate extreme values** shows the temporary distribution for the station used in the climate characterization of the area of influence of the project. **Figure 5.163** shows that extreme values of wind speed behave similarly throughout the year. Nevertheless, they show a strong variability of 0.4 m/S to 4.4 m/s, entailing a more than 100 % increase for the same month (November).

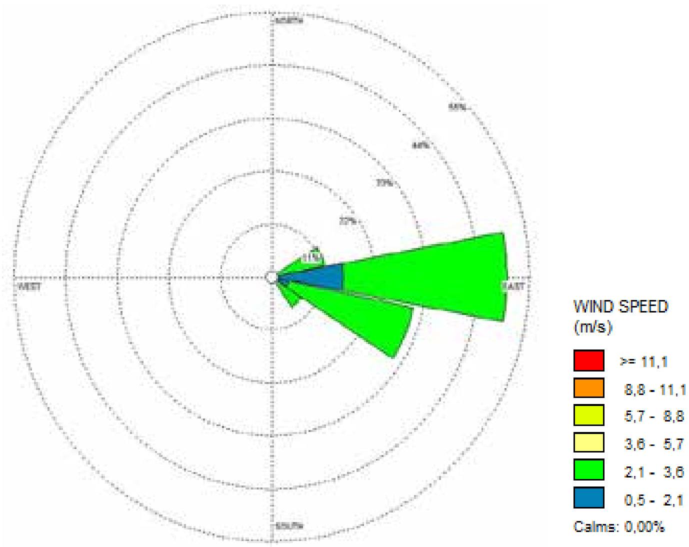
Figure 5.163 Temporal Distribution of wind speed in the various statistics (Min/Mid/Max) in Apto. San Luis station.



Source: GEOCOL CONSULTORES S.A, 2017.

Annual and monthly wind roses of the Apto. San Luis were made using the WRPLOT software developed by Lakes Environmental. **Figure 5.164**, shows the annual wind rose obtained for the season. **Figure 5.164** shows that in the Apt. San Luis station the wind predominantly goes eastward, and 50 % of the recorded data show wind speeds between 0.5 to 3.6 m/s.

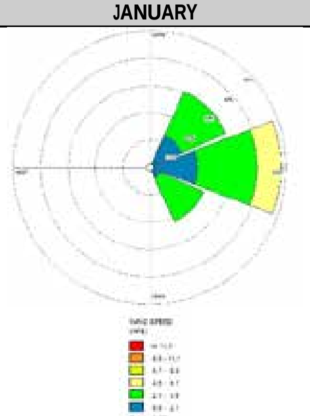
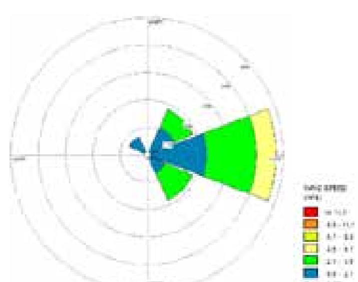
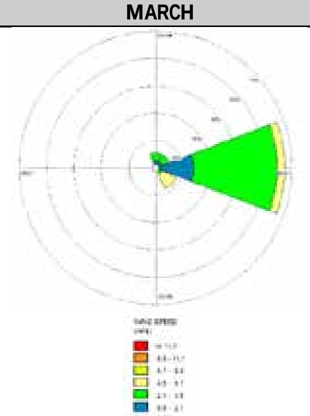
Figure 5.164 Annual wind rose for Apto San Luis station.

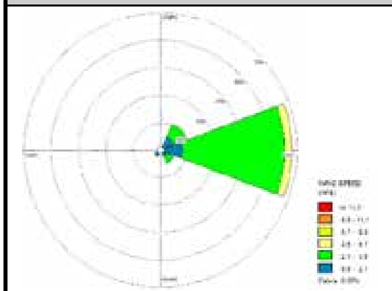
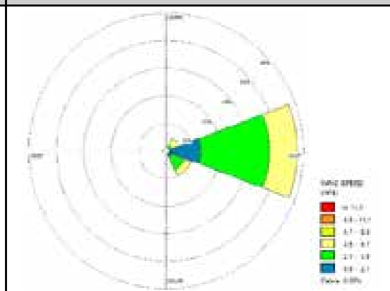
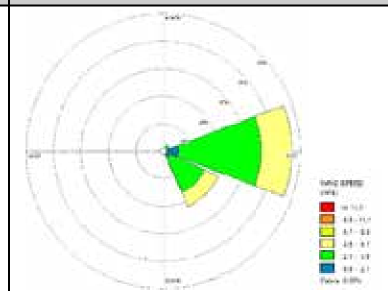
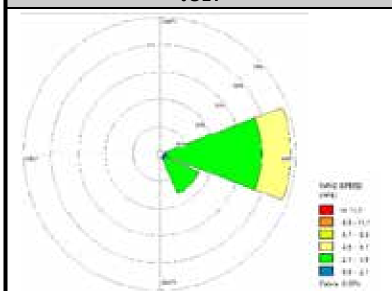
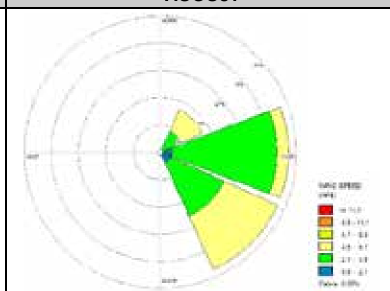
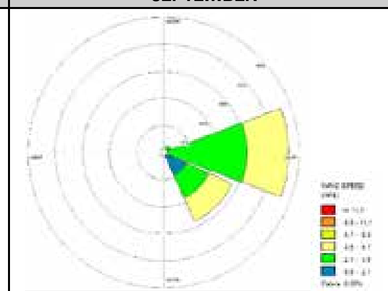
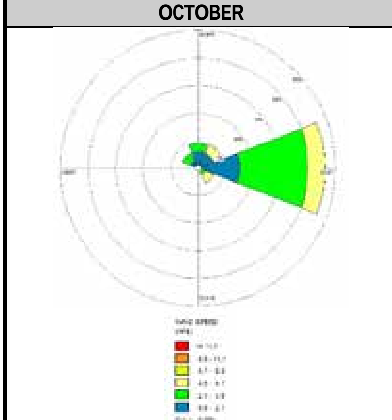
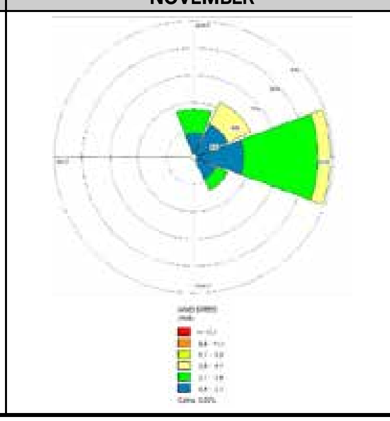
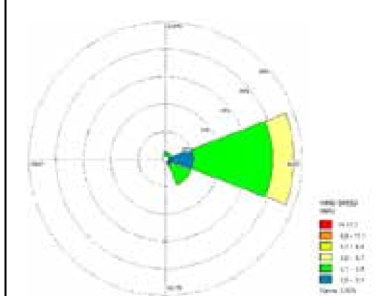


Source: GEOCOL CONSULTORES S.A, 2017.

Wind roses were made also for each month in the Apto. San Luis station, in order to see the wind behavior per season. Wind roses shown in **Table 5.129** indicate that the wind blows predominantly eastward throughout the year. In some months, like August, the wind blows from the southwest. It is also observed that the wind speeds are faster from May to September, which is in line with the previously described temporal distribution.

Table 5.129 Monthly wind roses of Apt. San Luis station.

JANUARY	FEBRUARY	MARCH
		

APRIL	MAY	JUNE
		
JULY	**AUGUST**	**SEPTEMBER**
		
OCTOBER	**NOVEMBER**	**DECEMBER**
		

Source: GEOCOL CONSULTORES S.A, 2017.

5.1.12.1.8 Mixing height and Atmospheric Stability.

Atmospheric stability refers to the atmosphere stratification as per hydrostatic equilibrium, i.e., when the cold air (heavier) is below the warmer air, that is called a stable atmosphere because the vertical movements are inhibited. If the opposite happens, i.e. the cold air is over the warmer air, the atmosphere tends to reduce such imbalance by pushing the cold air downwards and raising the warmer air.[7].

[7]Universidad de Chile Modificado de http://www.atmosfera.cl/HTML/glosario/glosario_02.html

Table 11

As shown in the **Table 5.130** below, 6 types of atmospheric stability are identified according to the Pasquill classification, which are calculated according to the meteorological information of wind temperature, direction and speed and solar radiation. For unstable atmosphere conditions the stability classes can be A, B or C, and D for neutral conditions; for stable conditions classes can be either E or F. For fully covered skies, both daytime and nighttime, class D stability must be chosen.

Table 5.130 Pasquill Stability Classification.

PASQUILL STABILITY CLASSIFICATION	
DAY TIME	A: Very unstable
	B: Unstable
	C: Slightly unstable
DAY/NIGHT TIME	D: Neutral
	E: Slightly stable
NIGHT TIME	F: Stable

Source: PASQUILL, 1961.

The mixing height is defined as the height of the layer adjacent to the soil where the contaminants undergo the mixing process as a result of turbulence on an about one hour or less time scale. The vertical depth of the atmosphere where the mixing takes place is called the mixing layer. The top of this layer is known as the mixing height, which defines the vertical extent of the dispersion process of the pollutants released below it. The mixing layer thickness depend on the conditions of the atmosphere, mainly the stability class, the solar radiation, the wind speed and the type of terrain.

Since the IDEAM does not perform 24 hour measurements of atmospheric stabilities, the classes of atmospheric stabilities were conservatively estimated applying the Pasquill criteria shown in **Table 5.131**.

Table 5.131 Simplified criteria to estimate the class of atmospheric stability and the mixing height from the wind speed and the sunshine degree.

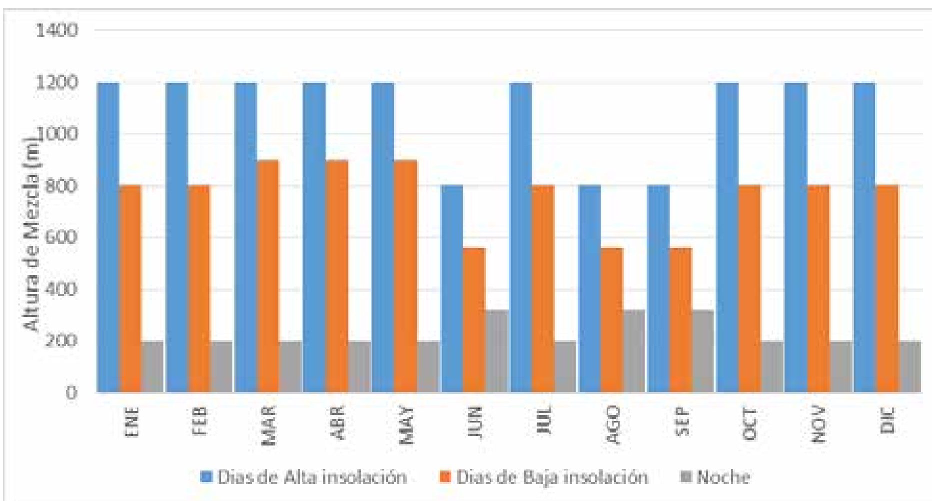
TIME	WIND SPEED (m/s)	PASQUILL CLASS	MIXING HEIGHT (m)
High sunshine days	0 - 2	A (Very unstable)	1600
	2 - 3	B (Unstable)	1200
	3 - 5	C (Slightly unstable)	800
	> 5	D (Neutral)	560
Low sunshine days	0 - 2	B	200
	2 - 3	C	800
	3 - 5	D	560
	> 5	D	560
Night time	0 - 2	F (Stable)	200
	2 - 3	F	200
	3 - 5	E (Slightly stable)	320
	> 5	D (Neutral)	560
	Cloudy	D	560

Source: SPADARO, 1991.

This is a very general classification of stabilities. To perform the valuation at different hours of the day, high sunshine was assumed to occur between 9:00 a.m. and 4:00 p.m., low sunshine between 7:00 p.m. - 9:00 p.m. and also between 14:00 - 18 hours.

The atmospheric stability and the mixing height were estimated in a simplified way using the wind speed and the sunshine degree (Spadaro, 1991). **Figure 5.165** shows the behavior of the mixing height for the Apto San Luis station throughout the year. It is observed that for the high sunshine days the mixing height occurs at 1200 m. A slight variation is observed during low precipitations seasons in mid-August, while during low sunshine days the mixing height may occur at around 800 m. A decrease in the mixing height is observed in mid-August, where the mixing height can be at 560 m. At nighttime when the thermal layers are inverted, the mixing height is usually at around 200 m and in the low precipitation season it can reach 320 m.

Figure 5.165 Temporal average distribution of the mixing height in Apto San Luis station.



Source: GEOCOL CONSULTORES S.A, 2017.

5.1.12.1.9 Atmospheric Pressure.

Atmospheric pressure is the pressure exerted by the atmosphere at a specific point as a result of the effect of gravity on the air column above such point[4]. Therefore, the atmospheric pressure decreases with altitude while the amount of air in the atmosphere also decreases. In order to obtain representative values, the atmospheric pressure estimates were made under the hypothesis of a standard atmosphere for each of the stations used in the climatic characterization of the area of influence of the project, the results of which are shown in **Figure 5.166**.

According to the Food and Agriculture Organization of the United Nations (FAO) the Atmospheric Pressure at different elevations can be calculated using the following equation:

$$P = 101,3\left(\frac{293 - 0,006z}{293}\right)^{5,26}$$

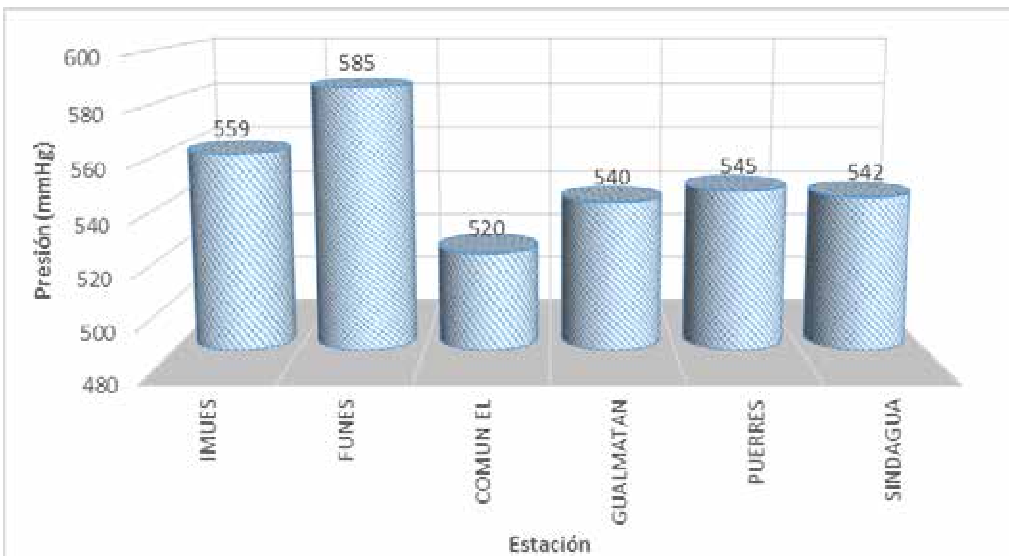
Where:

P = Atmospheric pressure [kPa].

z = Meters above sea-level [MASL].

The atmospheric pressure calculated in the zone, and making the conversion to mmHg, ranges between 520 and 585 mmHg, being the meteorological stations of the Común and Funes the points of smaller and greater pressure respectively. The average of this variable with respect to the stations analyzed in the area of influence of the project is approximately 549 mmHg. (See **Figure 5.166**).

Figure 5.166 Atmospheric pressure calculated at the weather station of the area of the project.

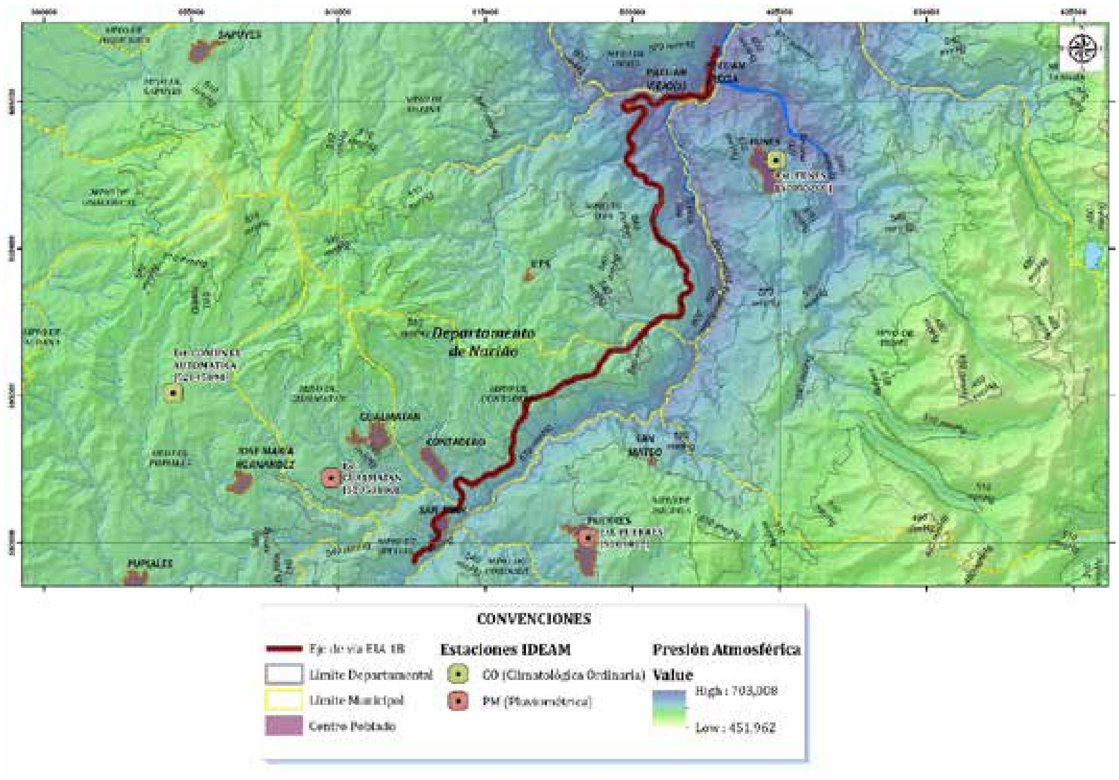


Source: GEOCOL CONSULTORES S.A, 2017.

- **Spatial Distribution.**

Atmospheric pressure areas are depicted by the isobar curves, which represent the cartography of the points of the earth with equal atmospheric pressure at a given time. The project pressures are observed to be of 570 mmHg towards south of the area of influence of the project, and towards the northern area near Pilcuan, pressures show to be of 600 mmHg. Sharp variations in pressure are observed, which are associated to topographic variations found in the area of the project. The average atmospheric pressure estimated in the area of influence of the project ranges between 540 - 600 mmHg, as shown in **Figure 5.167.**

Figure 5.167 Spatial distribution of atmospheric pressure in the area of influence of the project.



Source: GEOCOL CONSULTORES S.A, 2017.

5.1.12.1.10 Water Balance.

The water balance was calculated according to the Thornthwaite methodology that establishes the amount of water entering the ecosystem by means of precipitation, the one returning to the atmosphere by evapotranspiration and the one stored in the soil to be used by vegetation, excess or runoff and percolation waters.

"Evapotranspiration is the sum of the amounts of water evaporated from the soil and transpired by plants, while potential evapotranspiration (ETP) refers to the maximum amount of water that might be lost by a continuous vegetation layer covering the land. It is measured and estimated in millimeters per time unit time."[8]

The procedure for calculating ETP in the study area was carry out according to the Thornthwaite method, which is shown below:

- A "monthly heat index" (i) is calculated from the monthly average temperature (t):

[8] La atmosfera, el tiempo y el clima. Taken from http://www.ideam.gov.co/publica/medioamb/cap3-i.pdf

$$i = \left(\frac{t}{5}\right)^{1,514}$$

- An annual heat index (I) is calculated by adding the 12 heat monthly values:

$$I = \sum i$$

- The "uncorrected" monthly ETP is calculated using the following formula:

$$ETP_{\text{un}\,corrected} = 16\left(10\frac{t}{I}\right)^{a}$$

Where: **ETP uncorrected =** Monthly ETP mm/month, for 30 days months and 12 sunshine hours (theoretically)

t = Mean monthly temperature, °C

I = Annual heat index from point 2

a = $(675 * 10^{-9} * I^{3}) - (771 * 10^{-7} * I^{2}) + (1792 * 10^{-5} * I) + (0{,}49239)$

- Evapotranspiration correction

$$ETP = ETP_{\text{un}\,corrected} * F$$

- Where:

ETP = Corrected Evapotranspiration

F = Thornthwaite correction factor, the number of days of the month (Ndi) and the astronomical duration of the day (Ni-sunshine hours)

$$F = \frac{Ndi}{30} * \frac{Ni}{12}$$

To make the water balance, it is important to establish the system inputs and outputs, so that mean monthly precipitations of the stations assessed in the study area are the inputs. **Table 5.132**, shows the results of the calculation of potential evapotranspiration (ETP) and water balance.

Table 5.132 Water Balance in the project area.

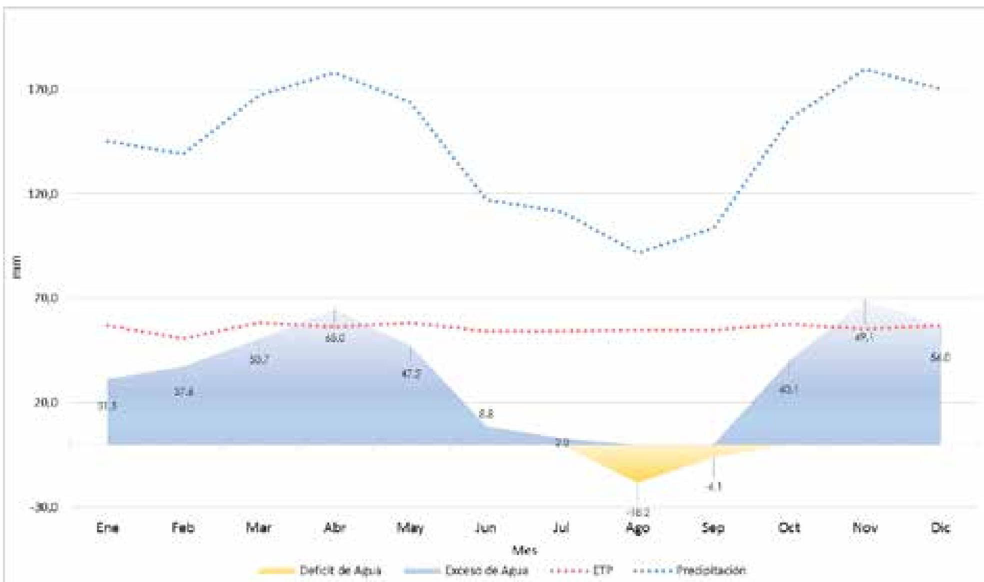
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Temperature	13,7	13,5	13,9	13,9	13,9	13,5	13,2	13,3	13,6	13,8	13,7	13,7	13,6
ETP Corrected	56,9	50,8	58,2	56,4	58,2	54,2	54,2	54,9	54,9	57,7	55,3	57,1	668,8
Precipitation	88,4	88,4	108,9	121,5	105,4	63,0	57,2	36,7	48,8	97,9	124,4	113,1	1053,7
Excess water	31,5	37,6	50,7	65,0	47,2	8,8	3,0	0	0	40,1	69,1	56,0	409,2
Water deficit	0	0	0	0	0	0	0	-18,2	-6,1	0	0	0	-24,3

Source: GEOCOL CONSULTORES S.A., 2017.

The results show that the annual potential evapotranspiration is 668.8 mm in the study area. Such a value is below 1053.7 mm of average annual precipitation recorded by the stations in that area. Based on the results obtained it is possible to conclude that during ten of the twelve months of the year there are excesses; the months where there are no excesses are August and September, nevertheless the deficit is low in those months.

Figure 5.168, shows a comparison between the excesses and deficits found in the study area throughout the year, based on the data of precipitation and potential evapotranspiration.

Figure 5.168 Water Balance in the project area.



Source: GEOCOL CONSULTORES S.A., 2017.

Figure 5.168, shows that surpluses are recorded during most of the year. Excesses surpass deficits, indicating that in the rainy season the soil recovers the total storage until saturation, enough to hold a quantity of water on the earth surface during 10 months of the year. In summary, it is observed that excesses are drained as runoff towards the surface water body during most of the year.

5.1.12.1.11 Climate Classification.

In order to establish the climatic classification of the area of influence of the project, the climatological information described in the previous paragraphs is taken and the inter-institutional methodology that IDEAM, IAvH, Invemar, I. Sinin, IIAP and IGAC developed in a document entitled Inland, Coastal and Marine Ecosystems of Colombia is adopted. Such document developed the Ecosystem Map as well as a set of thematic maps to an updated scale of 1: 500,000 within which is the map of precipitation, temperature and climate zoning.

The methodology applied in the elaboration of the climatic zoning map, classifies the territory as per the variables of temperature and precipitation typical of the Colombian geography. Such meteorological elements are relevant for a climate characterization.

The climatic zoning map is elaborated based on the source maps of temperature and precipitation. The main characteristics of each source maps are described below.

o **Climate Classification - Average Annual Temperature Map.**

This classification is based on the adaptation of the methodology proposed by Caldas in 1802.

The categorization by climate area is the delimitation of zones according to the average annual temperature (° C) and altitude (MASL), therefore five categories or thermal denominations are defined.

This methodology classifies the extremely cold and nival climate areas into a single one since there are few polygons above 4,500 m. And it changes the following original Caldas climate areas denominations: The system named "high moor" changed to very cold and the system "low moor" changed to the extremely cold.

Table 5.133 shows the temperature and altitude ranges of each category:

Table 5.133 Climate areas denomination.

DENOMINATION	ALTITUDE RANGE (MASL)	TEMPERATURE RANGE
Warm	0 to 800	T > 24° C
Tempered	801 to 1800	Between 18° C and 24°C
Cold	1801 to 2800	Between 12° C and 18° C
Very cold	2801 to 3700	Between 6° C and 12° C
Extremely cold and / or Nival	3701 to 4500 and 4500 onwards up to nival	Between 1.5° C and 6° C, and under 1,5 to nival

Source: INLAND, COASTAL AND MARINE ECOSYSTEMS OF COLOMBIA, 2007.

For the classification of the climate areas in the area of the project, a 30 m digital elevation model was used to obtain the spatial distribution of the temperature using the equation defined in the quoted study, to relate the Temperature of the air with the height above the sea-level:

$$T = 28.1926 - (0.00561473 \, x \, H)$$

Where:

T = Average Temperature [° C].

H = Meters above Sea-Level [MASL].

Then, the climate area denomination present in the study area was crossed and determined.

o **Climate classification by precipitation ranges.**

The precipitation map classifies the territory in zones based on the estimation of ranges of annual precipitation applying the methodologies of Caldas-Lang, Holdridge and those suggested by the IGAC.

Tabla 5.134 describes the type of denomination and the annual precipitation ranges of each zone.

Tabla 5.134 Denomination by precipitation.

DENOMINATION	ANNUAL PRECIPITATION RANGE (mm/year)
Arid	0-500
Very Dry	500-1.000
Dry	1.001-2.000
Humid	2.001-3.000
Very humid	3.001-7.000
Pluvial	>7.000

Source: INLAND, COASTAL AND MARINE ECOSYSTEMS OF COLOMBIA, 2007.

In the elaboration of the annual precipitation map of the project, data provided by IDEAM for the stations were used and as established by the methodology of the map of inland, coastal and marine ecosystems of Colombia, a geostatistical multivariate interpolation was carried out using the Cokriging method, in order to obtain a continuous surface for the precipitation field, where variations ranging from 981 mm to 1286 mm of total annual precipitation occurred.

- **Map of Climate Zoning.**

The climatic zoning map results from the spatial intersection of the two previous maps. This map relates the precipitation ranges to the temperature ranges, also taking into account the elevation to determine the climatic zone.

Table 5.135 describes the 25 categories which the Colombia Climate zoning Map refers to.

Table 5.135 Climate zoning map key.

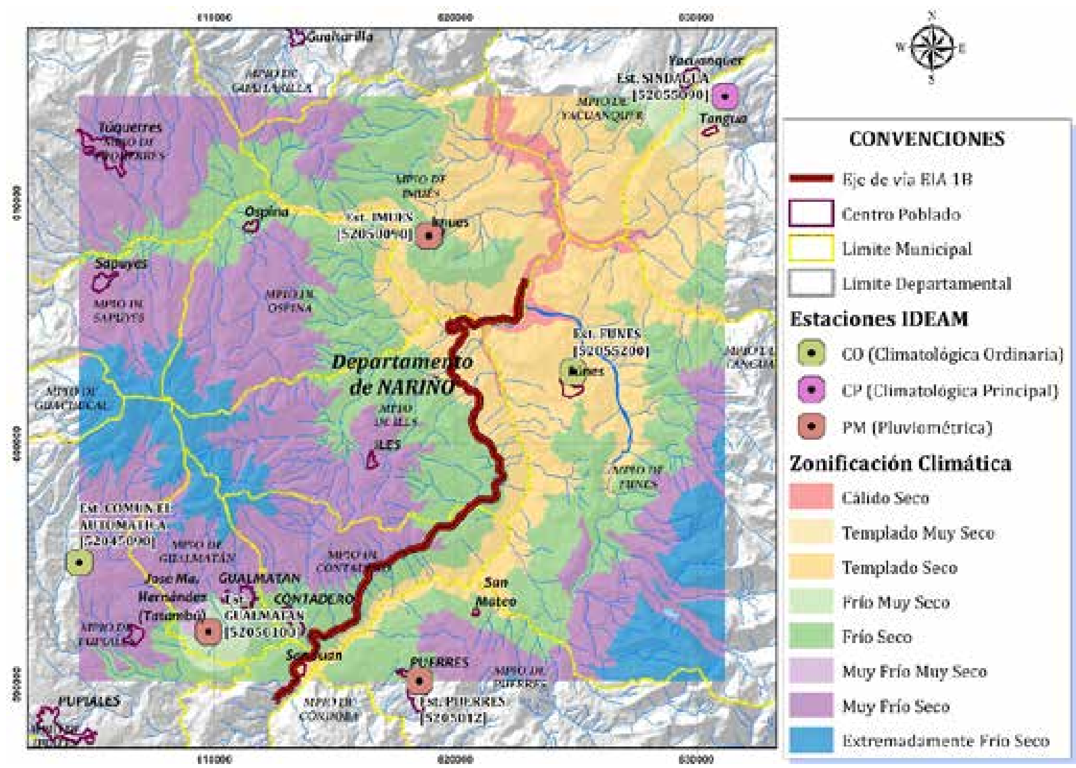
WARM (0-800 MASL) TEMPERATURES ABOVE 24° C	
DENOMINATION	**DENOMINATION**
Arid	Arid
Very Dry	Very Dry
Dry	Dry
Humid	Humid
Very humid	Very humid
Pluvial	Pluvial
TEMPERED (800-1.800 MASL) TEMPERATURES BETWEEN 18° C AND 24° C	
DENOMINATION	**DENOMINATION**
Very dry	Very dry
Dry	Dry
Humid	Humid
Very humid	Very humid
Pluvial	Pluvial
COLD (1.800-2.800 MASL) TEMPERATURES BETWEEN 12° C AND 18° C	
DENOMINATION	**DENOMINATION**
Very dry	Very dry
Dry	Dry
Humid	Humid

Very humid	Very humid
VERY COLD (2.800-3.700 MASL) TEMPERATURES BETWEEN 6° C AND 12° C	
DENOMINATION	**DENOMINATION**
Very dry	Very dry
Dry	Dry
Humid	Humid
Very humid	Very humid
EXTREMELY COLD (3.700-4.500 MASL) TEMPERATURES BETWEEN 1.5° C AND 6° C	
DENOMINATION	**DENOMINATION**
Very dry	Very dry
Dry	Dry
Humid	Humid
Very humid	Very humid
NIVAL (> 4.500 MASL) TEMPERATURES ABOVE 1.5° C	
DENOMINATION	**DENOMINATION**
Very dry	Very dry
Dry	Dry

Source: INLAND, COASTAL AND MARINE ECOSYSTEMS OF COLOMBIA, 2007.

According to the above proposed methodology, the climatic classification was established for the study area. **Figure 5.169** shows the spatial location and parameters found for the area of the project, according to the climate zoning map.

Figure 5.169 Climate zoning.



Source: GEOCOL CONSULTORES S.A, 2017.

According to the analysis of temperature, the main climate area denomination in the area of the project is Cold, while in some areas near to Pedregal there are tempered and warm areas. Regarding the precipitation denomination the rainfall analysis showed that the area is within the dry range since is between 1020 to 1050 mm/year.

The two previous classifications together define the classification of the project area as predominantly Dry-Cold

5.1.12.2 Identification of Emission Sources.

Clean air is considered to be a basic requirement for human health and well-being, yet its contamination continues to pose a significant threat to health around the world. In order to establish the impact, the sources of emission of atmospheric pollution are identified and characterized under the current Colombian legislation, which set forth the following types of polluting sources. See Error! Not a valid bookmark self-reference..Table 5.136 **Current types of sources of atmospheric pollution**

<table>
<tr><th>APPLICABLE LEGISLATION</th><th colspan="3">SOURCE CLASSIFICATION</th><th>DESCRIPTION</th></tr>
<tr><td rowspan="2">Resolution 909/2008
Resolution 910/2008
Resolution 1309/2010</td><td rowspan="2">Fixed</td><td colspan="2">Precise</td><td>The source emits pollutants to the air by ducts or chimneys.</td></tr>
<tr><td colspan="2">Disperse</td><td>It is the area where focal points of emission from fixed sources are dispersed in an area, due to the movement of the source of emission, as in the case of open controlled burns in rural settings.</td></tr>
<tr><td rowspan="4">Resolution 909/2008
Resolution 910/2008
Resolution 1309/2010</td><td rowspan="4">Fixed</td><td rowspan="4">Area source: it is a specific zone or region, urban, suburban or rural, that having multiple fixed sources of emission, is considered as a special generating of pollutants on the air area</td><td>Class I – Areas of high pollution</td><td>Areas where the concentration of pollutants, given natural or background and ventilation or dispersion conditions, exceed with a frequency equal or greater than seventy five percent (75%) the cases of annual quality regulation.</td></tr>
<tr><td>Class II – Areas of moderated pollution</td><td>Areas where the concentration of pollutants, given natural or background and ventilation and dispersion conditions, exceed with a frequency of fifty percent (50%) and under seventy percent (75%) the cases of annual quality regulation.</td></tr>
<tr><td>Class III – Areas of mild pollution</td><td>Areas where the concentration of pollutants, given natural or background and ventilation or dispersion conditions, exceed with a frequency greater than twenty five percent (25%) and under fifty percent (50%) the cases of annual quality regulation.</td></tr>
<tr><td>Class IV – Areas of marginal pollution</td><td>Areas where the concentration pollutants, given natural or background and ventilation and dispersion conditions, exceed with a frequency greater than ten percent (10%) and under twenty five percent (25%) the cases the annual quality regulation.</td></tr>
<tr><td rowspan="4">Resolution 909/2008
Resolution 910/2008
Resolution 1309/2010</td><td rowspan="4">Mobile</td><td colspan="2">Air</td><td rowspan="4">They are the source of emissions that because of their use or purpose, is prone to move: automobiles, airplanes or motor transportation vehicles of any kind.</td></tr>
<tr><td colspan="2">Land</td></tr>
<tr><td colspan="2">River</td></tr>
<tr><td colspan="2">Sea</td></tr>
</table>

Source: GEOCOL CONSULTORES S.A., 2017.

In the project area, we identified three types of atmospheric emission sources, namely: fixed, precise, dispersed and mobile.

5.1.12.2.1 Fixed sources

It is the source of emission from a specific place or unmovable, even when the discharge of pollutants is dispersed.

In the project area, fixed sources come from agro-industrial activity typical of plantation crops of potato (Photograph error! No text of specified style in document.-1), cabbage, onion, etc. (Photograph error! No text of specified style in document.-2), due to dusting carried out in crops mainly.

Photograph error!-109 Potato crop "*Solanum tuberosum* of Project area E: 955766; N 598044.

Photograph 5-110 Crops in the Project area. E: 948454; N 591477.

Source: GEOCOL CONSULTORES S.A., 2017.

Likewise, open air controlled burns, which is a common practice of agriculture and burn of solid waste as means of disposal (Photograph Error!**Photograph 5-111**), are fixed sources of atmospheric pollutants, this activity is periodic and extensive; therefore its effect is moderate.

It was also found that domestic activities in rural areas, such as cooking food, are fixed sources of emissions, due to use of wood as source of heat; however, because of its disperse generation and few population, the impact is light.

Photograph 5-111 Source of emission due to burning of waste E: 954388; N 596850.

Source: GEOCOL CONSULTORES S.A., 2017.

Another common fixed source of emission in the project area pertains to quarries, in Table Error! **Table 5.137** it is a relation of this type of fixed sources that are present in the project area. **Figure 5.170** it is the location of identified fixed sources. It is important to point out that even when source 1 seems out of the project area, it is within, and the effect occurs due to size of the object used to represent it.

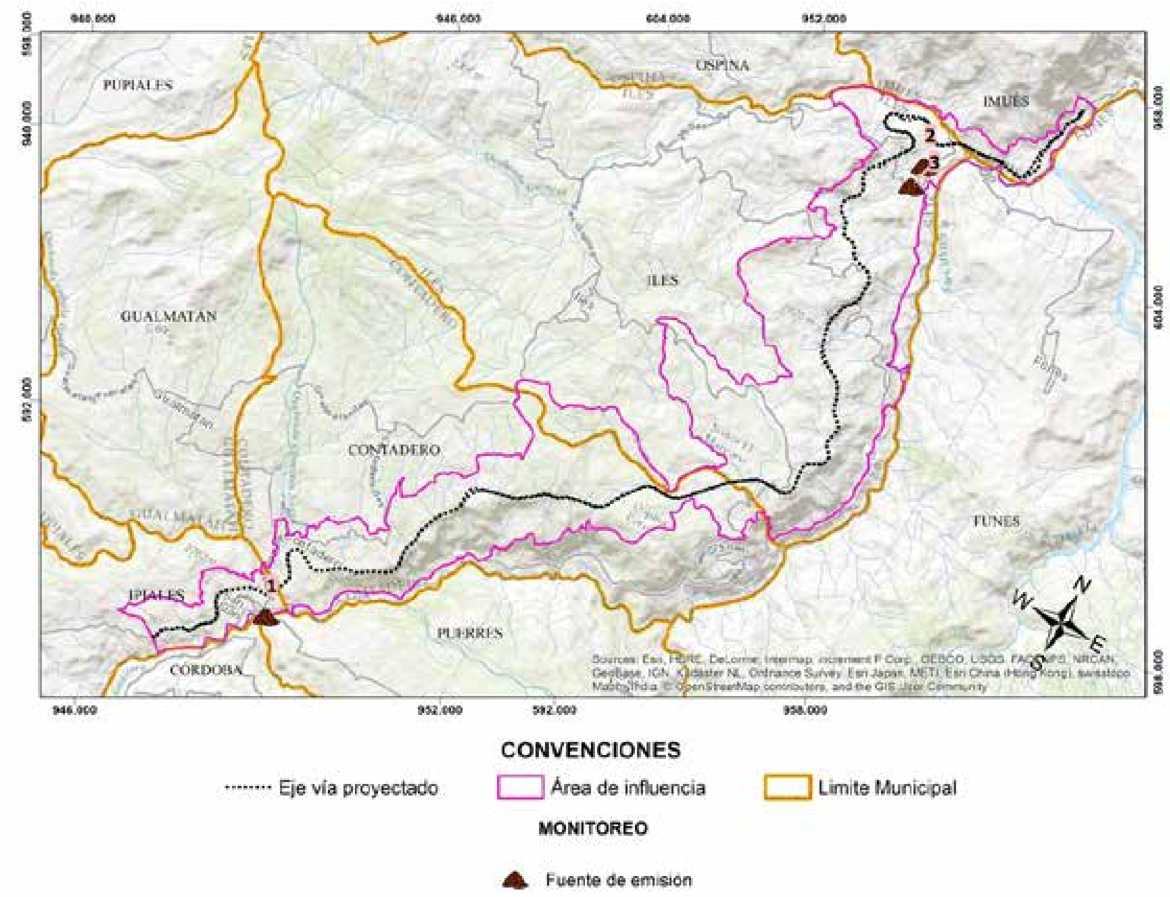
Table 5.137 Relation of Fixed Sources in Project area Rumichaca-Pasto double-lane road, San Juan – Pedregal segment.

ID	INDUSTRIAL ACTIVITY	LOCATION	COORDINATES RELATED TO MAGNA SIRGAS (GEOCENTRIC REFERENCE SYSTEM FOR THE AMERICAS) WEST		PICTURE
			EAST	NORTH	
1	Quarry	**Path:** San Juan **Municipality**: Ipiales	948385	590581	

ID	INDUSTRIAL ACTIVITY	LOCATION	COORDINATES RELATED TO MAGNA SIRGAS (GEOCENTRIC REFERENCE SYSTEM FOR THE AMERICAS) WEST		PICTURE
			EAST	NORTH	
2	Quarry	**Path:** Porvenir **Municipality**: Iles	954922	604213	
3	Quarry	**Path:** Porvenir **Municipality:** Iles	954898	603765	

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 5.170 Fixed sources of emission in the Rumichaca – Pasto divided highway project, San Juan – Pedregal segment.



Source: GEOCOL CONSULTORES S.A., 2017.

- **Description of fixed sources**
  - **Quarries and recrusher plant.**

Quarries are places accepted by the environmental entity for the extraction or exploitation of rocky materials, where the main pollutant emitted is particulate matter. The components of a recrusher plant and the description of productive process are:

- Reception Hopper: storage where raw material of exploitation zone is poured.
- Primary crushing: it is where the first fragmentation is carried out, reducing the size of mineral pieces to the desired size.

- Sieve: products are filtered in a vibrating sieve with the purpose of separating those pieces whose size is fine enough, in order to increase the capacity of the secondary crushing.

Generally, primary crushing is carried out by means of an earth grinder, which has two steel plates (jaws), placed one in front of the other, one is fixed while the other is mobile. It spins over an axis located in the upper or lower part; by means of a device it can displace forward or backward. The mineral is placed in the space between the plates moving forward, pieces are crushed with the fixed plate; when the mobile plates go backwards, the crushed minerals fall by the hole in the lower part formed by plates.

- Secondary crushing: in secondary crushing, the size of pieces coming from primary crushing are reduced to an interval between 3" and 2", taking into account the relevant considerations to continue with crushing or with the preliminary concentration.
- Conveyors: these gather up fragmented material coming from primary crushing or coming from the last processes, then elevate and transport them to storages or to new process stages. The system uses rubber and canvas conveyors that spin in cycles over rollers with electric traction.

5.1.12.2.2 Mobile sources

These can move autonomously, emitting pollutants along their path. The main source of emission in the project area were vehicles that ride over the San Juan-Pedregal road, which are automobiles, trucks, tractor-trailer trucks, motorcycles and buses designed to operate in public highways. Said vehicles are sources of CO, NOx, Sox and particulate material emissions mainly, and, to a lesser extent, vehicles that ride over roads that lead to municipal heads of Contadero and Iles and path roads between these two municipalities.

The inventory of mobile sources that ride over the main road corridor was extracted from study of Volume of traffic 2010, 2011, of National Institute of Roads-INVIAS (by its acronym in the Spanish language) (See **Table 5.138**).

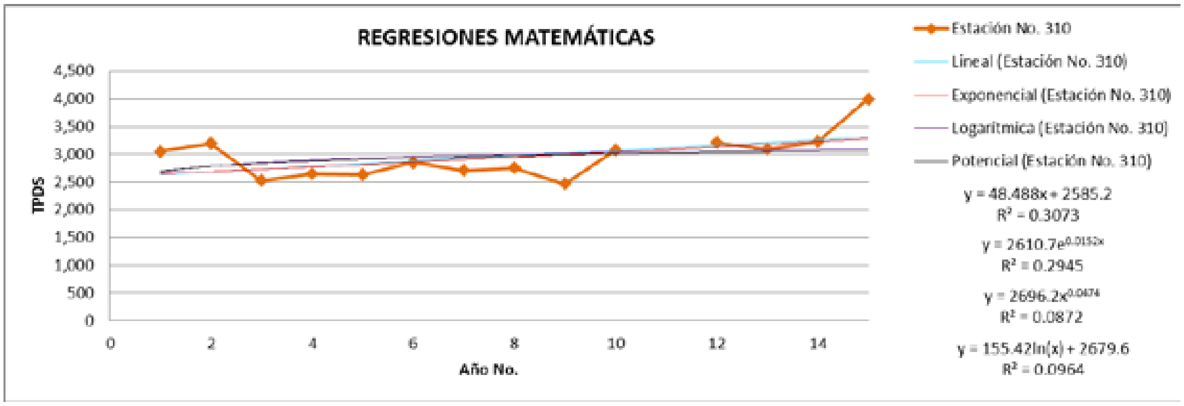
Table 5.138 historic record and composition of Average Daily Traffic (ADT)

STATION No.	SECTOR	HISTORIC RECORD AND COMPOSITION OF AVERAGE DAILY TRAFFIC - ADT															
		TERRITORIAL NARIÑO															
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	STANDARD DEVIATION
310	SAN JUAN - PEDREGAL	3053	3198	2529	2652	2637	2855	2710	2758	2466	3076	---	3214	3094	3232	4004	399

Source: traffic volumes INVIAS, 2010 - 2011.

When analyzing the data to determine the projection of ADT for 2017, we concluded that the linear function which suits better for historic data of road Graphic Error! No text of specified style in document 38, which resulted in an ADT of 3603 vehicles for 2017.

Graphic 5.171 Adjustment of distribution of likelihood for San Juan-Pedregal road



Source: GEOCOL CONSULTORES S.A., 2017.

Table 5.139 Projections of ADT in Ipiales San Juan – Pedregal road for 2017.

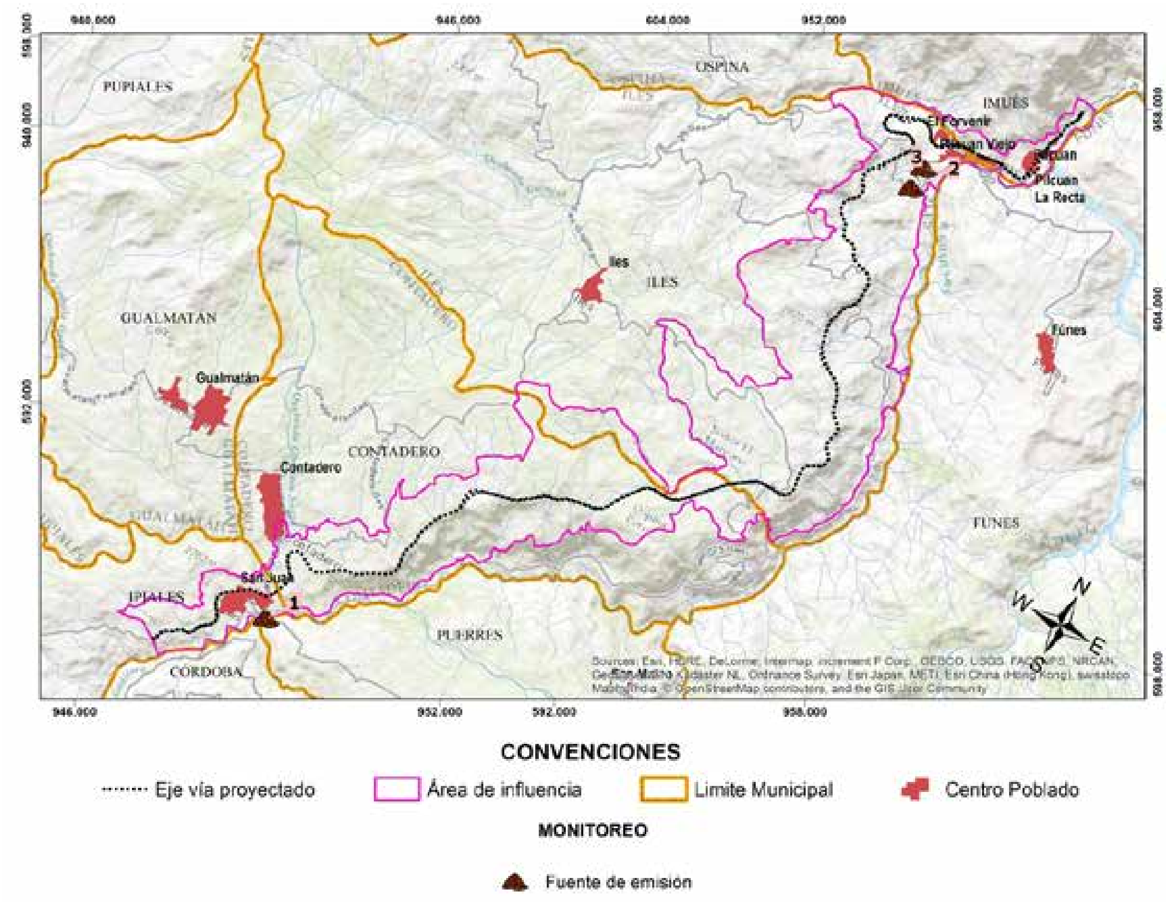
YEAR	YEAR No.	ADT	TDA
1997	1	3053	21371
1998	2	3198	22386
1999	3	2529	17703
2000	4	2652	18564
2001	5	2637	18459
2002	6	2855	19985
2003	7	2710	18970
2004	8	2758	19306
2005	9	2466	17262
2006	10	3076	21532
2007	11	---	---
2008	12	3214	22498
2009	13	3094	21658
2010	14	3232	22624
2011	15	4004	28028
2012	16	3361	23527
2013	17	3409	23866
2014	18	3458	24206
2015	19	3506	24545
2016	20	3555	24885
2017	21	3603	25224

Source: GEOCOL CONSULTORES S.A., 2017.

5.1.12.2.3 Potential receivers

Potential receivers of sources of emission determined in the San Juan-Pedregal road pertain to the settled and floating population, as well as facilities with people working in the vicinity. In Graphic Error! No text of specified style in document...39 has location of identified sources. It is important to mention that even when source 1 seems out of the project area, it is inside, and the effect is due to the size of the object used to represent it.

Graphic 5.172 Potential receivers of the Rumichaca – Pasto divided highway project, San Juan – Pedregal segment.



Source: GEOCOL CONSULTORES S.A., 2017.

Among the main towns identified in the area of study, classified as potentials receivers, we found downtown of Contadero, the small villages of San Juan, El Porvenir, Pilcuan Viejo and Pilcuan La Recta, as well as small towns dispersed in the path of the project area, such as: Boquerón, La Providencia, San Francisco, Aldea de María, El Capulí, El Culantro, Las Cuevas, San Andrés, Ospina Pérez, El Manzano, San José de Quis Namuez, Alto del Rey, Urbano, Tablón Alto, Tablón Bajo and El Rosario.

5.1.12.3 Air quality.

Air quality of the Environmental Impact Assessment for the Rumichaca – Pasto divided highway project - San Juan – Pedregal segment, was determined by taking into account 6 representative aspects of the project's area of influence, where the following samples were taken: total suspended particles (TSP), particulate material equal or lower than 10 micras (PM10), particulate material equal or lower than 2.5 micras (PM2.5), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), with daily samples every 24 hours, measuring direct Carbon Monoxide (CO) in continuous sampling and total hydrocarbons reported as methane (HCTM) in intervals of one hour a day for 18 days. Results obtained allowed us to know the current conditions and characteristics of air quality and the main sources of emission that release pollutants to the atmosphere.

Air quality monitoring tasks were carried out for ten and eighteen (18) calendar day for each monitoring station, from February 19 to March 13 of 2017 by the Lab Gestión & Medioambiente, which is accredited by the IDEAM, under Resolution 2307, dated October 13, 2016, as a competent lab to conduct analysis in the air matrix, from which the aforementioned parameters were taken; therefore, high-volume equipment calibration was made for PM10, PM2.5 and TSP, gas bubblers for NO_2 and SO_2, automatic CO analyzers, low-flow sampling pump for HCTM, flow meters and portable meteorological station.

In order to assess air quality, the behavior of meteorological variables was taken into account, as well as the climatological analysis within the context of this study, which is aimed to describe the atmospheric time and the general dynamics of climatic parameters in the area of influence of the project during the sampling period. All of these are changing conditions. Therefore, data and logs from a portable meteorological station were gathered. See **Annex 15. Air monitoring**.

The equipment, equipment calibration and the methodology followed to determine the concentrations of each parameter is presented in **Annex 15. Air Monitoring**.

Sites defined to determine air quality were located taking into account the areas identified as being the most sensitive areas as a result of the previous field works, including among them several inhabited areas such as the urban area of Contadero, the hamlets of San Juan, El Porvenir and Pilcuán La Recta, and considering also the location of the existing emission sources described in the preceding numeral, which need to be characterized in the closest inhabited areas in order to monitor the emissions that may generate within the project during the construction as compared to the existing sources; similarly, the whole area was covered with the purpose of generating air quality maps.

These six monitoring sites also enable the characterization of camps San Juan, 31+100, Picapiedra, 35+600 and Mikel that correspond to the main emission sources that the project will have and for which the emissions permit is requested.

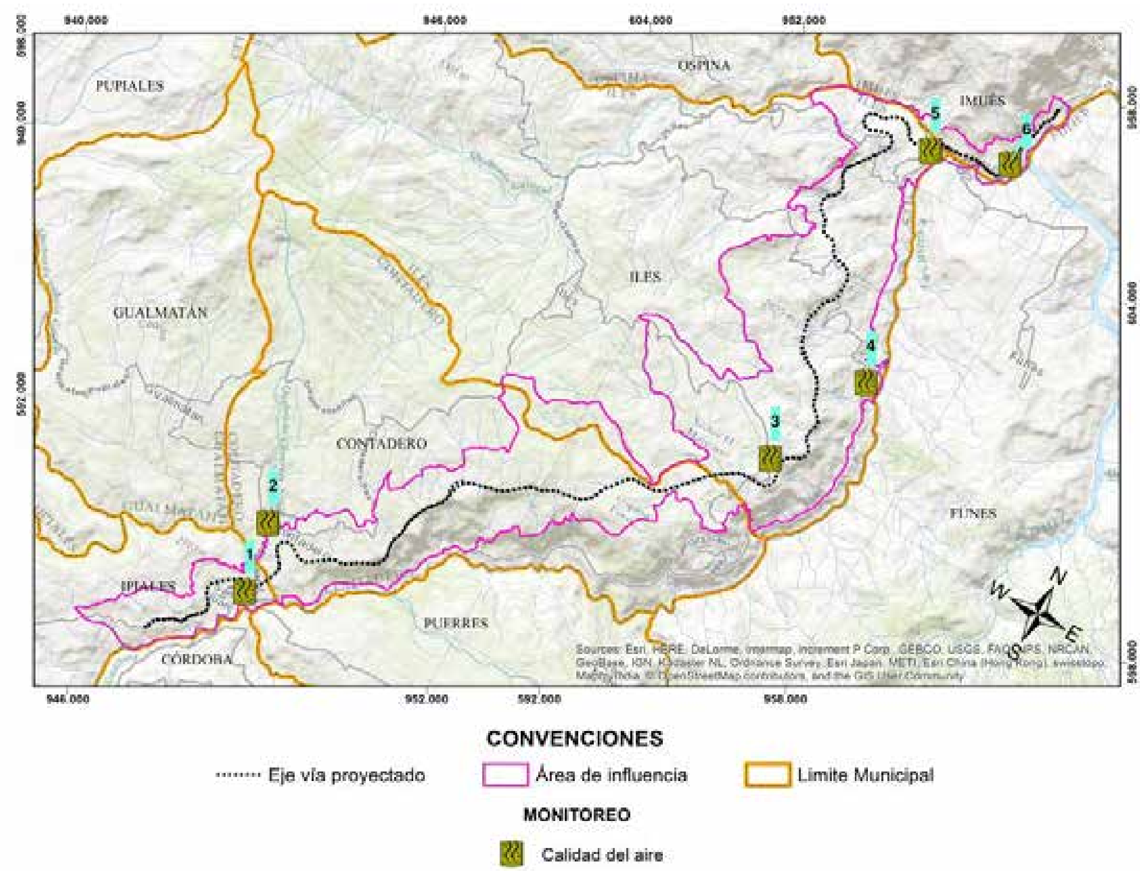
Table 5.140 shows the name of stations, along with their coordinates and sampling dates. The spatial distribution of the stations concerning the Rumichaca – Pasto divided highway project, San Juan – Pedregal segment is presented in **Figure 5.173**.

Table 5.140 Air quality sampling stations for the Rumichaca – Pasto divided highway project, San Juan – Pedregal segment.

STATION	NAME OR LOCATION	RURAL DISTRICT	MAGNA SIRGAS COORDINATES WEST ORIGIN		SAMPLING DATE
			EAST	NORTH	
1	San Juan	San Juan	948033.6	590759.6	February 19 to March 09 of 2017
2	Contadero	Casco urbano Contadero	947761.9	592132.9	February 22 to March 12 of 2017
3	31+100 Camp	Casco urbano Iles	955537.9	598054.0	February 23 to March 13 of 2017
4	Picapiedra Camp	La Esperanza	956411.5	600246.9	February 19 to March 09 of 2017
5	Mikel Camp	El Porvenir	955244.4	604753.0	February 23 to March 13 of 2017
6	Pilcuán	Pilcuán	956709.4	605294.5	February 23 to March 13 of 2017

Source: Field work, GESTIÓN & MEDIOAMBIENTE S.A.S, 2017.

Figure 5.173 Location of air quality sampling stations.



Source: GEOCOL CONSULTORES S.A., 2017.

- **Description of monitoring stations.**

The air quality monitoring area was located in the area of the Rumichaca – Pasto divided highway project, San Juan – Pedregal segment, in the department of Nariño (municipalities of Ipiales, Contadero, Iles and Imúes). The places assigned to determine air quality were located taking into account the areas identified as being the most sensitive ones during the previous field works (inhabited or industrial areas). The air quality monitoring stations are identified and described below:

- ***Station (01)- San Juan***: the village of San Juan is located north of the municipality of Ipiales, over the Pasto roadway, 15 km away from the municipal seat and close to the Guáitara river. It is located southwest of the surveyed area. Station was located 2.5 m high over a terrace house.
- ***Station (02) –Contadero****:* located in the municipal seat of Contadero, southwest of the surveyed area. The municipality is located in an area dominated by broken relief, that mixes small plateaus and hills. Station was located 2.5 m high over a terrace house, on the margins of a non-paved street.
- ***Station (03) –31+100 Camp****:* located in the rural area of the municipality of Iles in the rural district of Urbano, east of the surveyed area. It was located at 1.5 m high over a scaffold, in an area of wavy ground.
- ***Station (04) –Picapiedra Camp***: located in the municipality of Iles, rural district of La Esperanza, east of the surveyed area, on the margins of the Pasto roadway. It was located at 1.5 m high over a scaffold.
- ***Station (05) –Mikel Camp***: located in the rural district of El Porvenir of the municipality of Iles, in the northwest area of the area of study. It was locate on the margin of a non-paved roadway, in the vicinities of the Pasto roadway, at 2.5 m high over a terrace house.
- ***Station (06) –Pilcuán***: located in the rural district of Pilcuán of the municipality of Imúes, in the northeast area of the surveyed area. It was located close to the Pasto roadway, at 2.5 m high over a terrace house.

o **Results.**

The following section presents the results obtained from the determinations of PST, PM10, PM2.5 , NO2, SO2, CO and HCT in the six monitoring stations located in the area of the Rumichaca – Pasto divided highway project, San Juan – Pedregal segment.

Annex 15. Air Monitoring contains the reports submitted by the labs, which include details on the daily behavior of each of the pollutants and which establish the climatological conditions of precipitation and wind speed under which the monitoring was carried out. Similarly, this annex presents the air quality maps for each of the parameters monitored in the area.

The degree of pollution is determined upon verification of the parameters monitored versus the requirements set forth in Resolution 610 of 2010, issued by the Ministry of Environment, Housing and Territorial Development (MAVDT), referred to today as Ministry of Environment and Sustainable Development (MADS).

Article 2 of the said Resolution sets the maximum allowable levels of pollutants, as well as the criteria and exposure time of each pollutant, See **Table 5.141**.

Table 5.141 Maximum allowable levels of pollutants

PARAMETER	UNIT	ALLOWABLE LIMIT AS PER RESOLUTION 610 OF 2010
PARTICULATE MATERIAL (PST)		
Daily Average (24 Hours)	$\mu g/m^3$	300

PARAMETER	UNIT	ALLOWABLE LIMIT AS PER RESOLUTION 610 OF 2010
Annual Geometrical Average	µg/m³	100
PARTICULATE MATERIAL (PM10)		
Daily Average (24 Hours)	µg/m³	100
Annual Arithmetical Average	µg/m³	50
PARTICULATE MATERIAL (PM2.5)		
Daily Average (24 Hours)	µg/m³	50
Annual Arithmetical Average	µg/m³	25
NITROGEN OXIDES (NO_X)		
Daily Average (24 Hours)	µg/m³	150
Annual Arithmetical Average	µg/m³	100
SULFUR DIOXIDES (SO_2)		
Daily Average (24 Hours)	µg/m³	250
Annual Arithmetical Average	µg/m³	80
CARBON MONOXIDE (CO)		
1 Hour	mg/m³	40 (40000 µg/ m³)
8 Hours	mg/m³	10 (10000 µg/ m³)

Source: Resolution 610 of 2010.

Data correction to reference conditions: with the aim of comparing data obtained in field with the allowable limits contained in Resolution 610 of 2010 of the MAVDT, which are presented under reference conditions for temperature and pressure, namely, 25 °C and 760 mm Hg, respectively, the equation referred to in NTC 3704 will be used as follows:

$$DR = \frac{DL * 760 * (273 + TL°C)}{PbL * 298K}$$

Where:

DL=Data collected in field under local conditions.

DR=Data collected in field under reference conditions.

P.b.L=Local barometric pressure.

T L=Local average room temperature.

- **Total suspended particles.**

Table 5.142 and **Figure 5.174** provide a summary of the geometrical averages and the maximum and minimum daily levels of particulate suspended material such as PST, from each of the monitoring stations.

Table 5.142 Average PST concentration in the area of the Rumichaca – Pasto divided highway project

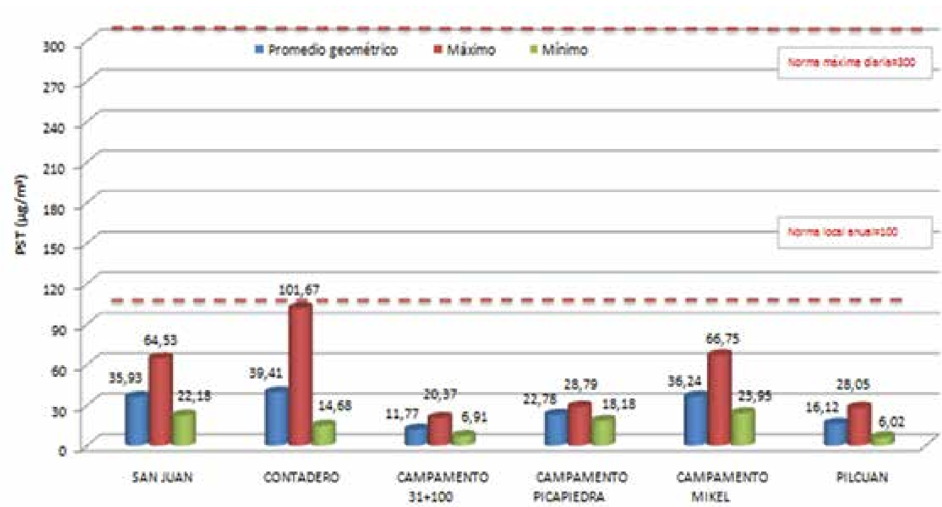
	PST Concentration					
	01 - San Juan	02 - Contadero	03 - 31+100 Camp	04 - Picapiedra Camp	05 - Mikel Camp	06 - Pilcuán
Geometrical average (µg/m³std)	35,93	39,41	11,77	22,78	36,24	16,12
Maximum (µg/m³std)	64,53	101,67	20,37	28,79	66,75	28,05
Minimum (µg/m³std)	22,18	14,68	6,91	18,18	23,95	6,02

Source: GESTIÓN & MEDIOAMBIENTE S.A.S, 2017

According to the results obtained from the monitoring of total suspended material or PST, the concentration of suspended particulate material is low for all the monitoring period as compared to the daily maximum standard of 300 µg/m3 provided in resolution 610 of 2010.

Some differences can be observed among the monitoring stations, mainly for stations 01, 02 and 05, where a higher concentration of suspended particulate matter is recorded compared to other stations, due to the greater influence of the identified sources (mobile sources mainly), since this accounts for the main traffic levels of vehicles going from Ipiales to Pasto. Concentration peak was noted in station 02, on the first monitoring day, with a concentration of 101,67 µg/m3. Geometrical averages determined in the six (6) monitoring stations are below the annual standard of 100 µg/m3, being station 02 of Contadero the one with the highest average of concentrations obtained, possibly, as a result of being located at a non-paved urban roadway.

Figure 5.174 Comparison of PST concentrations * in each of the sites being monitored.



Source: GESTIÓN & MEDIOAMBIENTE S.A.S 2017.

*Geometrical averages of concentrations

- **Particulate matter PM2.5.**

In the **Table 5.143** and in the **Figure5.175**, summarizes the arithmetic averages and the daily maximum rate of particulate matter as PM 2.5 determined at each of the monitored points. The results obtained from the concentration of particulate matter as PM2.5 show a uniform dispersion of the pollutant at stations 01, 06 and 05, contrary to the other stations where there are significant fluctuations during the 18 days. The highest average concentrations are registered in stations 02, 04 and 05, and are influenced by emissions from mobile sources circulating on the Ipiales-Psto road, and the activities in populated zones.

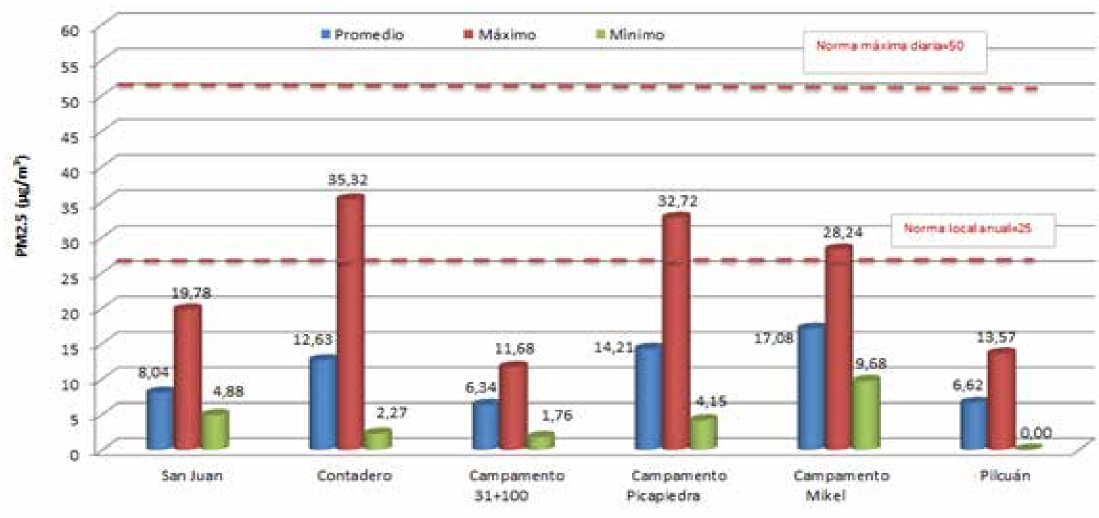
The 02 Contadero monitoring station registered the highest value of PM2.5in all measurements, with a value of 35.32 μg / m^3. In none of the monitoring days is the permissible limit of 50 μg / m limit exceeded a 24-hour exposure period and the arithmetic averages for the monitoring time neither exceeded the annual standard of 25 μg / m^3.

Table 5.143 Average concentration of PM 2.5 in the area of the Rumichaca - Pasto Divided Highway Project.

Monitoring point	Arithmetical average µg/m^3	Daily maximum rate µg/m^3	Maximum daily Res.610 / 2010 (µg / m^3)	Percentage of daily norm
01 - San Juan	8,04	19,78	**50**	16,08
02 - Contadero	12,63	35,32		25,26
Campamento 31 + 100	6,34	11,68		12,68
04 - Campamento Picapiedra	14,21	32,72		28,42
05 - Campamento Mikel	17,08	28,24		34,16
06 - Pilcuán	6,62	13,57		13,24

Source: GESTIÓN & MEDIOAMBIENTE S.A.S 2017

Figure5.175 Comparison of concentrations of PM 2.5 in each of the monitored points.



Source: GESTIÓN & MEDIOAMBIENTE S.A.S 2017

o **Nitrogen dioxide (NO_2).**

In the **Table 5.144** and in the **Figure5.176**, summarizes the average result and the daily maximum rates of nitrogen dioxide detected at each of the monitored points.

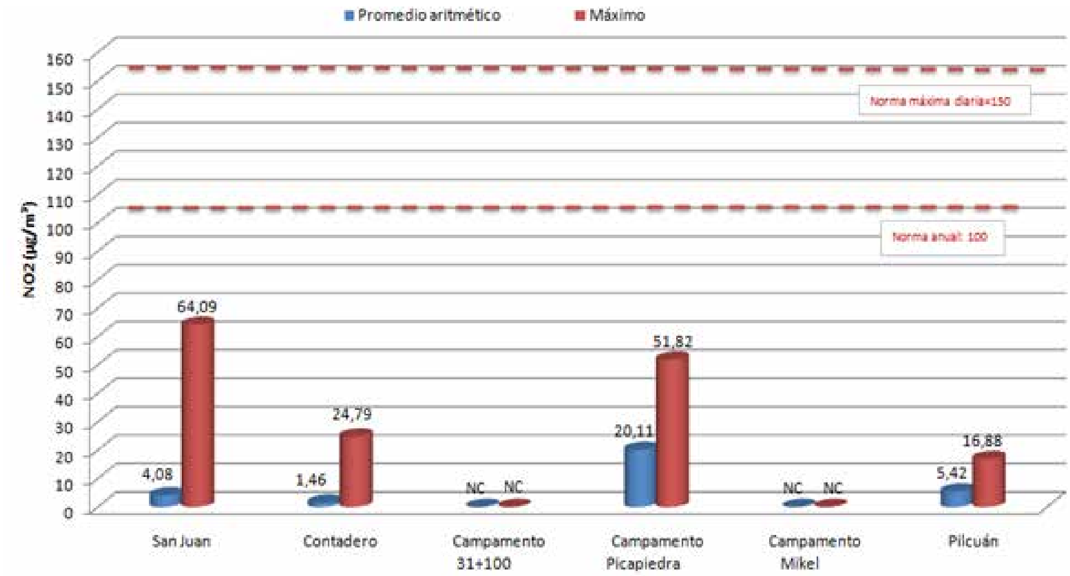
The concentrations obtained at each station show that no day exceeded the maximum permissible value of 150 µg / m³std and the average of none of the stations is above the annual permissible limit of 100 µg / m3std. Station 04, located in Campamento Picapiedra, registers the highest average concentration, which can be explained by its location close to the road that connects Ipiales with the city of Pasto, used by vehicles that generate emissions of this compound through their combustion processes. The values reported as "Non-quantifiable" are due to the fact that the concentration does not exceed the quantification limit established by the laboratory, which in this case is 0.027 µg NO2.

Table 5.144 Average concentration of NO2 in the area of the Rumichaca - Pasto Divided Highway Project

Monitoring point	Arithmetical average Mg NO / m³Std 2	Daily maximum rate Mg NO / m³Std 2	Daily maximum rate Res.610 / 2010 (Mg / m³Std)
01 - San Juan	4,08	64,09	150
02 - Contadero	1,46	24,79	
Campamento 31 + 100	-	-	
04 - Campamento Picapiedra	20,11	51,82	
05 - Campamento Mikel	-	-	
06 - Pilcuán	5,42	16,88	

Source: GESTIÓN & MEDIOAMBIENTE S.A.S 2017

Figure5.176 Comparison of NO2 concentrations at each monitoring st ation.



Source: GESTIÓN & MEDIOAMBIENTE S.A.S 2017

- **Sulfur dioxide (SO_2).**

In the **Table 5.145** and in the **Figure5.177**, summarizes the average result and the daily maximum rates of sulfur dioxide detected at each of the monitored points. As shown in the above table, quantifiable values were obtained only on days 01, 15, 16 and 18 of the monitoring, at stations 01, 05, 06 and 03, respectively, near the main road in the area. This indicates a very low presence of this pollutant given the few industrial activities in the area.

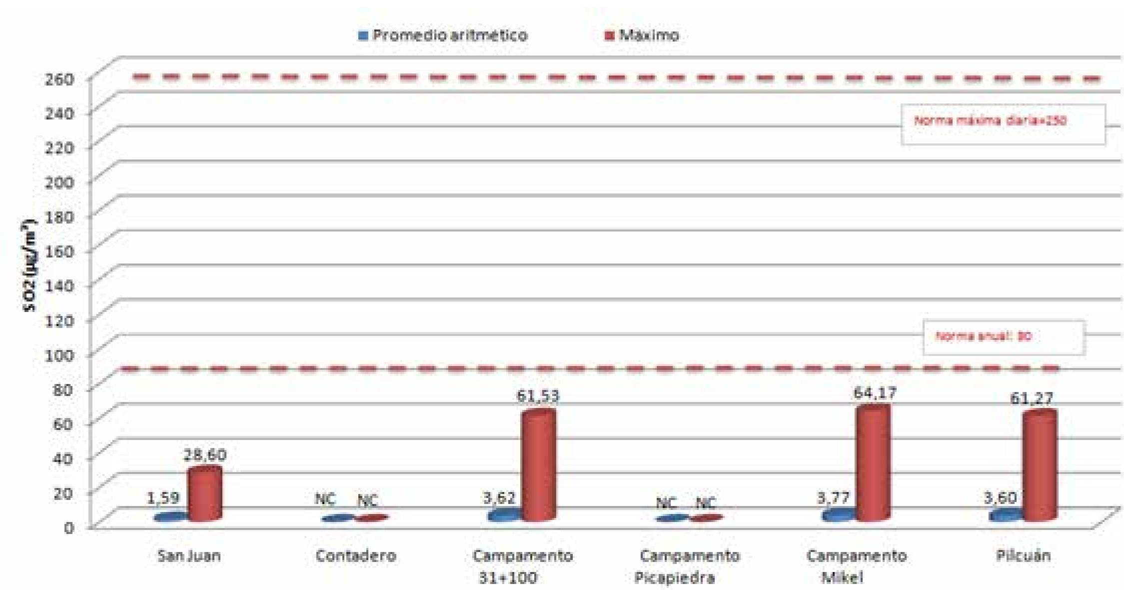
Table 5.145 Average concentration of SO2 in the road project area.

Monitoring point	Arithmetical average Mg SO2 / m³Std	Daily maximum rate Mg SO2 / m³Std	Daily maximum rate Res.610 / 2010 (Mg / m³Std)
01 - San Juan	1,59	28,60	250
02 - Contadero	-	-	
Campamento 31 + 100	3,62	61,53	
04 - Campamento Picapiedra	-	-	
05 - Campamento Mikel	3,77	64,17	
06 - Pilcuán	3,60	61,27	

Source: GESTIÓN & MEDIOAMBIENTE S.A.S 2017

According to the above results, the daily concentrations of SO2 obtained for the six (6) monitoring stations comply with the maximum standard of 250 µg / m3 for a 24-hour measurement period. Most of the results are presented as "Non-detectable", because the concentrations tested are below the reagent blank used and "Not quantifiable" when the concentration does not exceed the l quantification limit established by the laboratory, which in this Case is 1,010 µg SO2-.

Figure5.177 Comparison of SO2 concentrations in each monitoring station.



Source: GESTIÓN & MEDIOAMBIENTE S.A.S 2017

o **Carbon monoxide (CO).**

In the **Table 5.146** and in the **Figure5.178**, summarizes the average result of hourly measurements of the CO concentration detected at each of the monitored points and is compared to the maximum 1-hour permissible level.

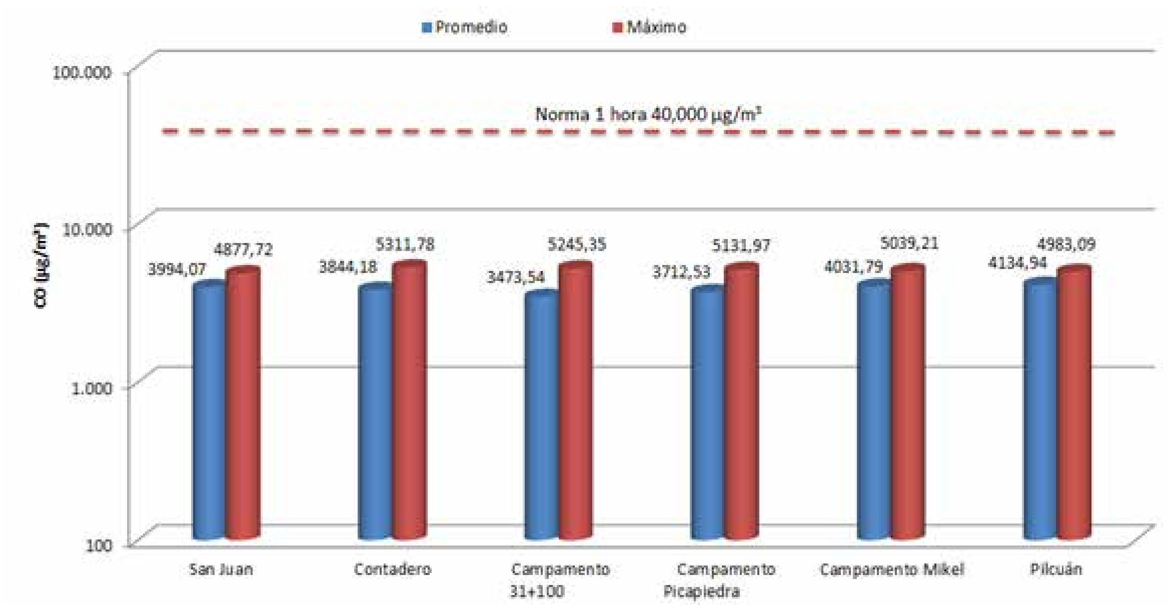
Table 5.146 Average concentration of CO in the road project area.

Monitoring point	Arithmetical average Mg NO / m³Std	Maximum Mg NO / m³Std	Maximum hourly rate³Std)
01 - San Juan	3994,07	4877,72	40 000
02 - Contadero	3844,18	5311,78	
Campamento 31 + 100	3473,54	5245,35	
04 - Campamento Picapiedra	3712,53	5131,97	
05 - Campamento Mikel	4031,79	5039,21	
06 - Pilcuán	4134,94	4983,09	

Source: GESTIÓN & MEDIOAMBIENTE S.A.S 2017

As explained in **Table 5.146** and in the **Figure5.178,** It is observed that the average of the hourly daily concentrations obtained at each measurement site are similar, but with some peaks and a downward trend. The highest average concentration was obtained in station 06 - Pilcuán with 4134.94 μg CO / m3std, which is located on the Troncal de Occidente that communicates with the cities of Ipiales and Pasto and through which heavy and light vehicles transit, which this gas in their internal combustion processes, but the value is below the regulatory limit of 40.000 μg CO / m3std.

Figure5.178 Comparison of the hourly averages of CO concentrations in each station



Source: GESTIÓN & MEDIOAMBIENTE S.A.S 2017

o **Total hydrocarbons (HCT).**

In the **Table 5.147** and in the **Figure5.179,** summarizes the average result and the daily maximum rates of sulfur dioxide detected at each of the monitored points. It should be noted that the daily concentrations of HCT obtained for the six (6) monitoring stations are mostly below quantification limit established by the analysis laboratory, which in this case is 30μg HCRO DRO / sample, indicating a low presence of the pollutant assessed.

Table 5.147 Average concentration of CO in the road project area.

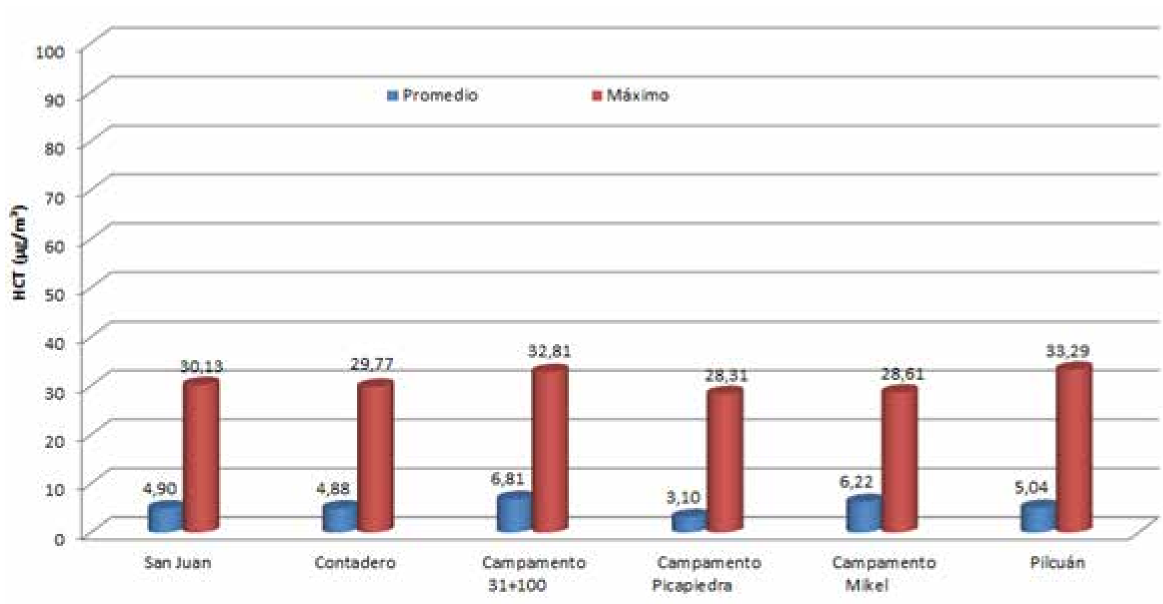
Monitoring point	Average Mg HCT / m^{3}Std	Daily maximum rate Mg HCT / m^{3}Std
01 - San Juan	4,90	30,13
02 - Contadero	4,88	29,77
Campamento 31 + 100	6,81	32,81
04 - Campamento Picapiedra	3,10	28,31

Monitoring point	Average Mg HCT / m³Std	Daily maximum rate Mg HCT / m³Std
05 - Campamento Mikel	6,22	28,61
06 - Pilcuán	5,04	33,29

Source: GESTIÓN & MEDIOAMBIENTE S.A.S 2017

Of the quantifiable values, those of greater magnitude were those presented in the Pilcuán and Campamento 31 + 100 e stations, although with very low concentrations, despite the fact that there is no permissible maximum limit established in environmental regulations.

Figure5.179 Comparison of HCT concentrations at each monitoring station.



Source: GESTIÓN & MEDIOAMBIENTE S.A.S 2017

- **Conclusions.**

- Concentrations of total suspended particulate matter (PST), particulate matter as PM10 and as PM2.5, obtained at each monitoring station, are below the permissible limits set forth by the national air quality standard; therefore, these pollutants do not represent a risk factor for people's health in the populated areas within the Rumichaca - Pasto Divided Highway Project, San Juan - Pedregal stretch. This is considering their average values. The highest concentrations determined at the monitoring stations located in San Juan (for PM10), Contadero (for PST) and Campamento Mikel (for PM2.5) are related to their spatial location in populated areas and their proximity to the main road in the region.
- In the six (6) stations, the results of the concentrations obtained are in line with the fact that the quantity of suspended particles is greater as compared with particulate matter of less than 10 µ (PM 10). The high

PM10 / TSP ratio indicates that the largest proportion of total particles comes from vehicular traffic, pavement and civil works.

- The concentrations of PM 2.5 do not exceed the standard maximum limit, for both daily and annual assessments; however, the high PM2.5 / PM10 ratio indicates that a significant proportion of these fine particles make up the particulate matter of less than 10 microns. According to the ICA calculation for this pollutant criterion, some days of monitoring registered moderate and harmful air quality for sensitive groups.
- In the area of the road project, pollution by particulate matter is more representative than that caused by gases (NO_2, SO_2 And CO). Although traces of these compounds were evident in air, their concentrations do not exceed the maximum permissible limits.
- The highest concentrations of NO_2 are present in station 04, located in the Campo Picapiedra, possibly because of the emissions from the combustion of vehicles that transit through the Ipiales - Pasto road. For SO_2, most records are below the quantification limit; there were quantifiable values mainly in stations 01, 03, 05 and 06, mostly of which were close to the main road
- The levels of carbon monoxide, whose origin is related to vehicle combustion, are higher in the areas closest to the Troncal de Occidente, i.e. in stations 01, 05 and 06; however, these levels are safe for the exposed population.
- The absence of quantifiable levels of total hydrocarbons in most of the monitoring shows that there is no impact by specific emissions from the petrochemical industry or the like. In the Pilcuán 06 station, the highest quantifiable value was presented, although at a concentration that remains low.

5.1.12.3.1 Multitemporal analysis of the air quality in the study area.

To analyze the temporary variations of air quality in the area, information was collected from the monitoring carried out by the SH Consortium in the study area, through the contracting of the ASOAM SAS Agrosoluciones Ambientales (laboratory accredited by IDEAM under Resolution 1556 of August 14, 2015, modified by Resolution 2191 of October 7, 2015 for the performance of air quality monitoring), a study in which 6 stations were located in the San Juan - Pedregal stretch. These monitoring are compared with the current ones in coinciding locations.

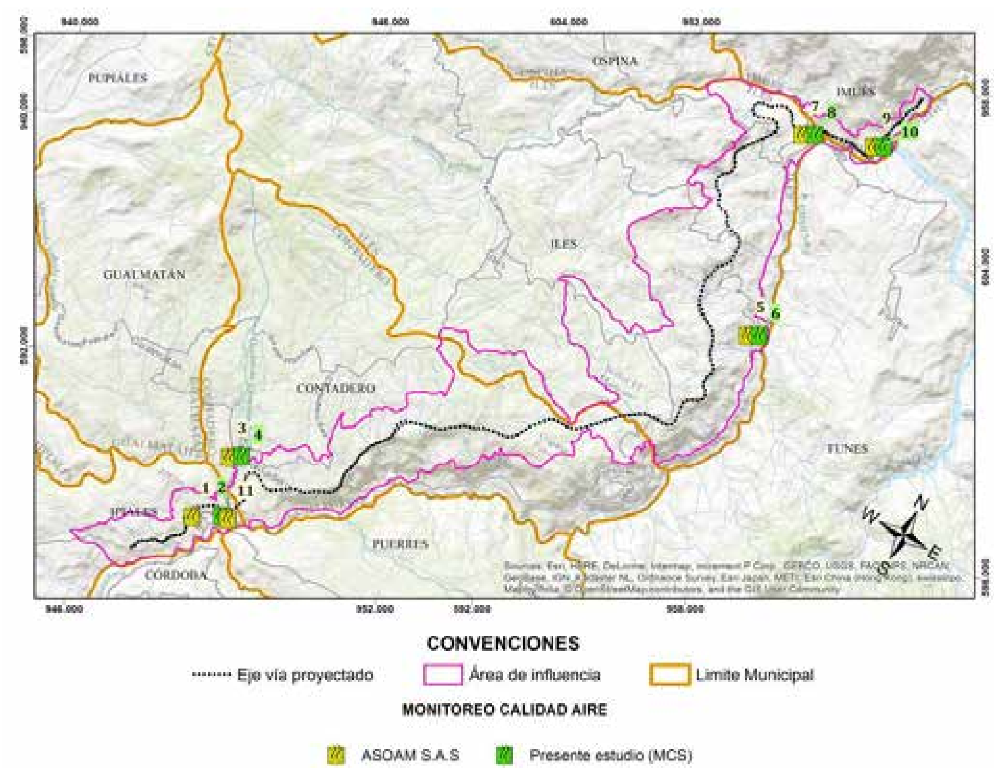
The names of the stations with their respective coordinates and the date of the monitoring were found in **Table 5.148** and in the **Figure5.180** spatial distribution.

Table 5.148 Monitored points for multitemporal analysis of air quality.

STATION	ID	NAME OF THE STATION WHERE STUDY WAS CONDUCTED	WEST ORIGIN MAGNAS SIRGAS COORDINATES		FECHA DE MONITOREO	SOURCE
			EAST	NORTH		
1	A1	San Juan	947724	590571	21 Apr - 09 May 2016	ASOAM SAS
	A2	San Juan	948033	590759	19 Feb - 09 Mar 2017	Present study
2	A3	Contadero	947775	592127	21 Apr - 09 May 2016	ASOAM SAS
	A4	Contadero	947761	592132	22 Feb - 12 Mar 2017	Present study
3	TO 5	Campamento Picapiedra	956428	600250	07 Aug - 2014 2016	ASOAM SAS
	A6	Campamento Picapiedra	956411	600246	19 Feb - 09 Mar 2017	Present study
4	A7	El Porvenir Rural District	955244	604753	21 Apr - 09 May 2016	ASOAM SAS
	A8	Campamento Mikel	955244	604753	23 Feb - 13 Mar 2017	Present study
5	A9	Pilcuán	956757	605314	21 Apr - 09 May 2016	ASOAM SAS
	A10	Pilcuán	956709	605294	23 Feb - 13 Mar 2017	Present study
6	A11	Camp San Juan	948437	590913	07 Aug - 24 Aug 2016	ASOAM SAS

Source: GEOCOL CONSULTORES S.A., 2017.

Figure5.180 Location of monitored points for multi-temporal analysis of air quality.



Source: GEOCOL CONSULTORES S.A., 2017.

The behavior of the pollutants at the stations described in the **Table 5.148** are analyzed temporarily over the years of the monitoring in order to confirm if they have decreased or if, on the contrary, they have increased. This comparison is possible because the spatial location of the monitoring points is the same for different years. As regards the San Juan camp, the specific value of the monitoring is presented for the year 2016, which suggest the air quality at that point. In the **Table 5.149 and in the** Figure Error! No text of specified style in document..32, The values to be compared in the multi-temporal analysis of the air quality are presented.

Table 5.149 Results of Air Quality in different periods.

STATION		A1. San Juan	A2. San Juan	A3. CONTADERO	A4. CONTADERO	TO 5. Campamento Picapiedra	A6. Campamento Picapiedra
SAMPLING DATE		21 Apr - 09 May 2016	19 Feb - 09 Mar 2017	21 Apr - 09 May 2016	22 Feb - 12 Mar 2017	07 Aug - 24 Aug 2016	19 Feb - 09 Mar 2017
PST (µg / m 3)	Average	N.R.	35,93	N.R.	39,41	N.R.	22,78
	Daily maximum rate	N.R.	64,53	N.R.	101,67	N.R.	28,79
PM10 (µg / m 3)	Average	32,33	24,82	11,31	23,99	15,9	14,44
	Daily maximum rate	51,38	39,78	19,49	40,03	56,1	20,33
PM2.5 (µg / m3)	Average	N.R.	8,04	N.R.	12,63	N.R.	14,21
	Daily maximum rate	N.R.	19,78	N.R.	35,32	N.R.	32,72
SO2 (µg / m 3)	Average	8,07	1,59	8,63	-	4,46	-
	Daily maximum rate	12,91	28,6	15,09	-	9,76	-
NOX (µg / m^3)	Average	2,11	4,08	2,43	1,46	2,05	20,11
	Daily maximum rate	2,42	64,09	4,1	24,79	2,23	51,82
CO (ppm)	Average	1020	3994,07	1060	3844,18	1590	3712,53
	Daily maximum rate	1580	4877,72	1600	5311,78	1620	5131,97
CH4 (ppm)	Average	N.R.	4,9	N.R.	4,88	N.R.	3,1
	Daily maximum rate	N.R.	30,13	N.R.	29,77	N.R.	28,31

N.R. Not reported Parameters not analyzed in the Monitoring.

Source: GEOCOL CONSULTORES S.A., 2017.

Table 5.150 Results of Air Quality in different periods (Continuation).

STATION		A7. EL PORVENIR RURAL DISTRICT	A8. CAMPAMENTO MIKEL	A9. PILCUÁN	A10. PILCUÁN	A11. SAN JUAN CAMP
SAMPLING DATE		21 Apr - 09 May 2016	23 Feb - 13 Mar 2017	21 Apr - 09 May 2016	23 Feb - 13 Mar 2017	07 Aug - 24 Aug 2016
PST (µg / m 3)	Average	N.R.	36,24	N.R.	16,12	N.R.
	Daily maximum rate	N.R.	66,75	N.R.	28,05	N.R.
PM10 (µg / m 3)	Average	16,06	23,74	11,2	12,05	8,76
	Daily maximum rate	29,3	42,49	22,13	24,01	15,12
PM2.5 (µg / m3)	Average	N.R.	17,08	N.R.	6,62	N.R.
	Daily maximum rate	N.R.	28,24	N.R.	13,57	N.R.
SO2 (µg / m 3)	Average	5,87	3,77	7,16	3,6	5,54
	Daily maximum rate	13,64	64,17	15,41	61,27	16,05
NOX (µg / m³)	Average	2,12	-	2,09	5,42	2,05
	Daily maximum rate	2,76	-	2,17	16,88	2,33
CO (ppm)	Average	1250	4031,79	1170	4134,94	1490
	Daily maximum rate	1660	5039,21	1690	4983,09	1520
CH4 (ppm)	Average	N.R.	6,22	N.R.	5,04	N.R.
	Daily maximum rate	N.R.	28,61	N.R.	33,29	N.R.

N.R. Not reported Parameters not analyzed in the Monitoring. "-" Not quantifiable.

Source: GEOCOL CONSULTORES S.A., 2017.

To determine the behavior over time of air quality in a sector, it is fundamental to carry out monitoring with variations in time and space in order to show changes, compare them with each other and with the current air quality standards. In Colombia, such standards are based mainly on Resolution 610 of 2010 issued by the Ministry of Environment, Housing and Territorial Development, now the Ministry of Environment and Sustainable Development.

As a fully comparative measure not representing current air quality regulations, Resolution 601 of 2006 was used, in which a limit of 1500 µg / m³ of the total hydrocarbons expressed as methane was set as a reference for the values found in the Monitoring.

- **Analysis of Results**

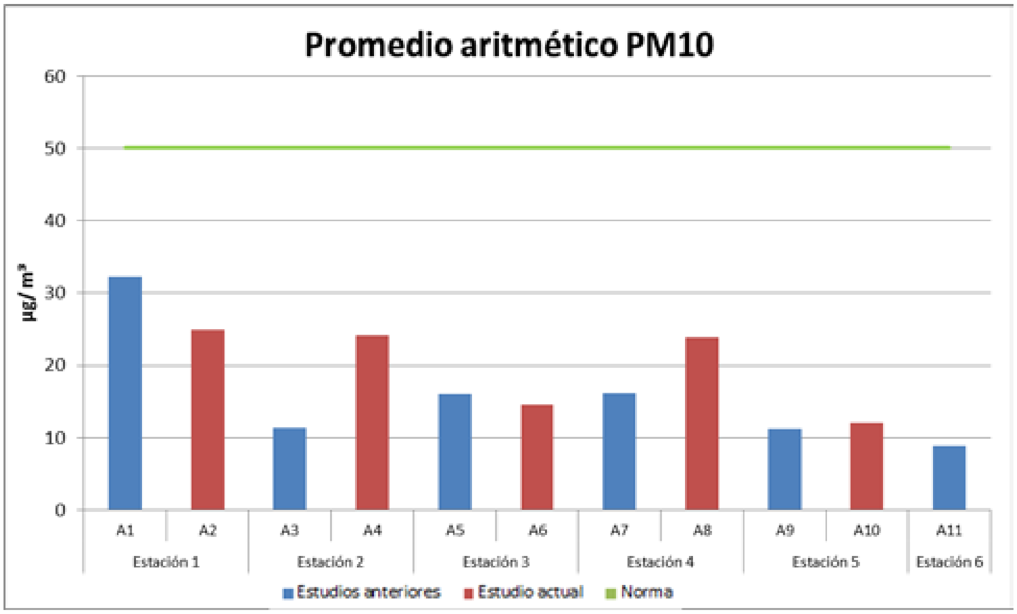
Presented below are the results of the multi-temporal analyses performed taking into account the selected stations and periods. It should be noted that the parameters PST, PM2.5, and HCT were not taken into account in this analysis because they are not recorded in the study conducted in 2016.

o **Particulate matter (PM10).**

If the geometric average in the two monitored periods are compared, there is an evident varied behavior. For stations 1 (San Juan) and 3 (Campamento Picapiedra), mean PST values were higher in the previous study, with a maximum values of 32.33 µg / m³ and 15.9 µg / m³, respectively, while in stations 2 (Contadero), 4 (El

Porvenir) and 5 (Pilcuán), the results of the present study register higher values, bwith 23.99 µg / m³, 23.79 µg / m³ and 12.05 µg / M³ being the highest, respectively. In the **Figure5.181** The above facts are presented in a graphic manner, and furthermore, it is observed that all the measurements of this parameter are within the maximum established by the current regulations.

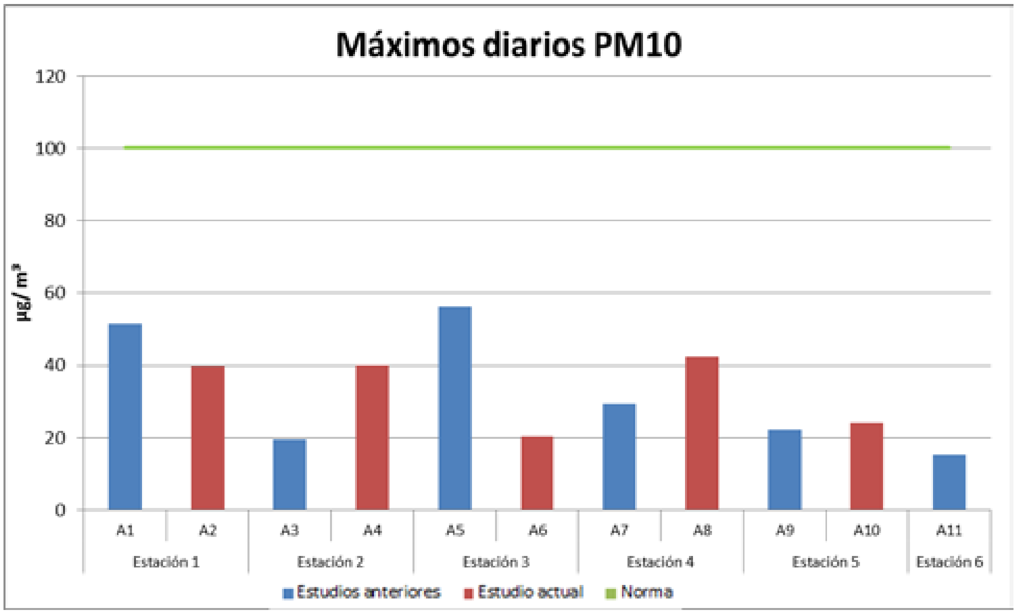
Figure5.181 Multi-temporal comparison of the arithmetic average of CO.



Source: GEOCOL CONSULTORES S.A., 2017.

When comparing the maximum values in the two monitored moments in time, a very varied behavior is evident. For stations 1 (San Juan) and 3 (Campamento Picapiedra), mean PST values were higher in the previous study, with a maximum values of 51.38 µg / m³ and 56.1 µg / m³, respectively, while in stations 2 (Contadero), 4 (El Porvenir) and 5 (Pilcuán), the results of the present study register higher values, with 40.03 µg / m³, 42.49 µg / m³ and 24.01 µg / M³ being the highest, respectively. In the **Figure5.182 The above facts are reflected in a graphic manner and, furthermore, it is observed that all the measurements of this parameter are within the maximum established by the current regulations.**

Figure5.182 Multi-temporal comparison of daily CO maximum rates.

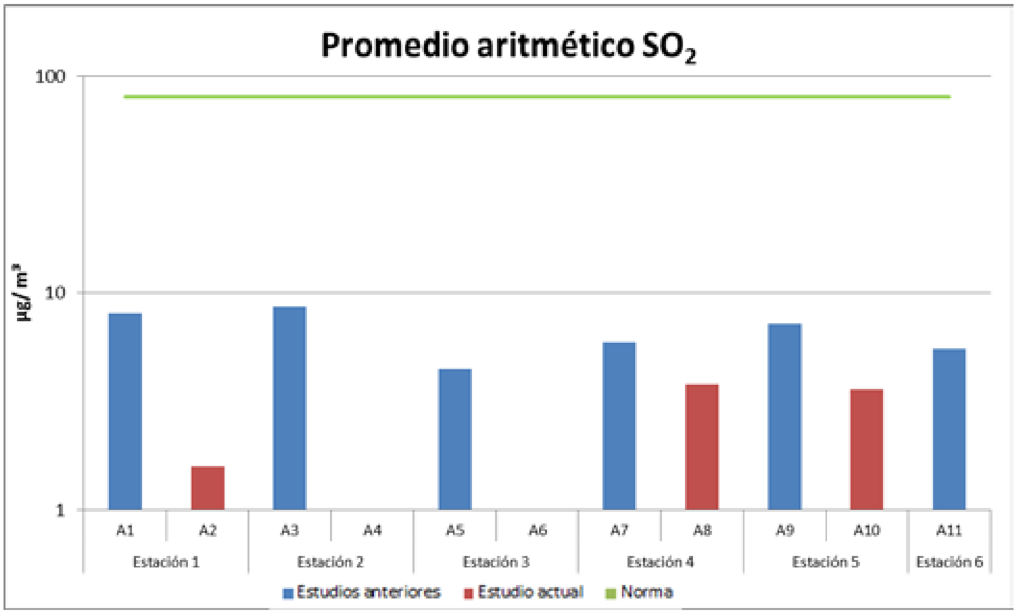


Source: GEOCOL CONSULTORES S.A., 2017.

o **Sulfur dioxide (SO_2).**

If the arithmetic average is compared in the two points in time that were monitored, a clear behavior is evident: all the values found in 2016 are higher than those determined in the present study. Thus, the highest recorded figure was 8.63 μg / m³, corresponding to record A5 (Campamento Picapiedra, 2016). In the **Figure5.183 The above facts are reflect in a graphic manner, and furthermore, it is observed that all the measurements of this parameter are within the maximum** established by the current regulations.

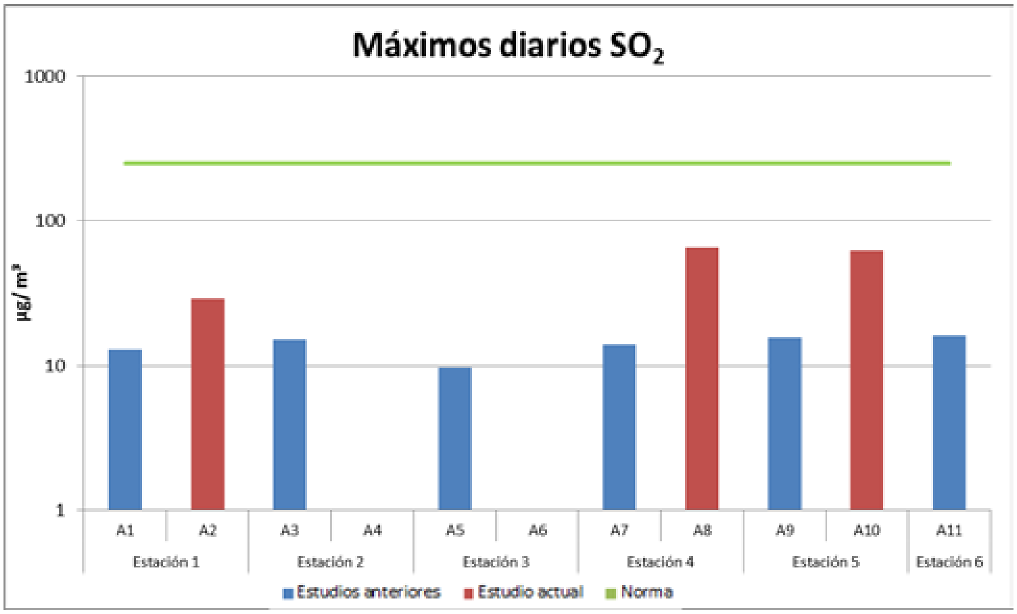
Figure5.183 Multi-temporal comparison of the arithmetic average of SO_2.



Source: GEOCOL CONSULTORES S.A., 2017.

When comparing the maximum values in the two monitored moments in time, a very disperse behavior is evident. While for stations 1 (San Juan), 4 (El Porvenir) and 5 (Pilcuán), the maximum values of SO2 were higher in the present study, in stations 2 (Contadero) and 3 (Campamento Picapiedra) the previous analysis registered higher value, as this parameter was below the quantifiable range of the analysis method used. The maximum value was recorded at point A8 (Campamento Mikel) and it was 64.17 µg / m³. In the **Figure5.184 The above facts are reflect in a graphic manner, and furthermore, it is observed that all the measurements of this parameter are within the maximum** established by the current regulations.

Figure5.184 Multitemporal comparison of daily maximum rates oof SO_2.

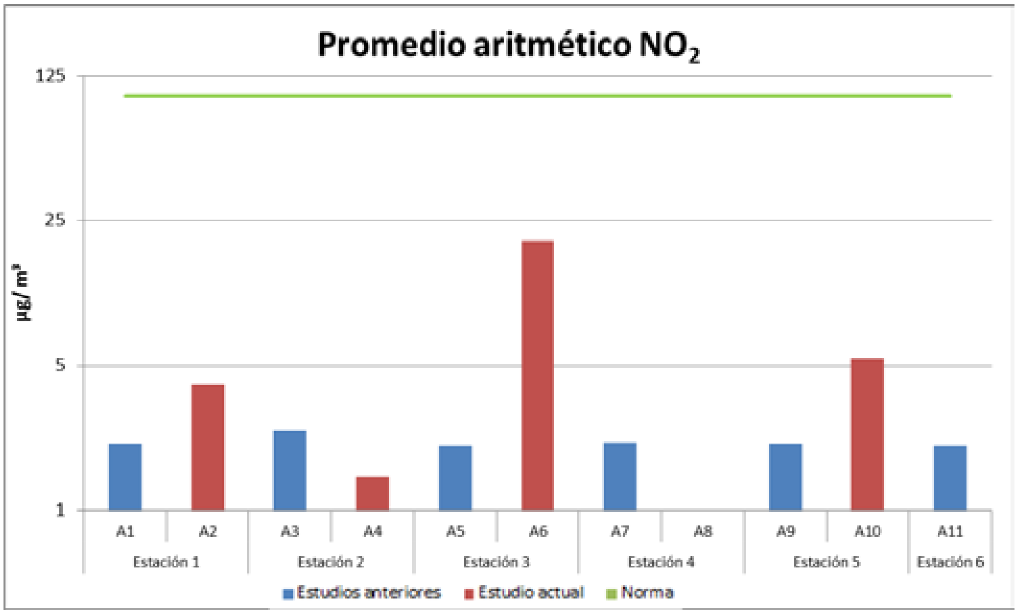


Source: GEOCOL CONSULTORES S.A., 2017.

- **Nitrogen Oxides (NOx).**

If the arithmetic average is compared in the two monitored moments in time, a very unstable behavior is evident. For stations 1 (San Juan), 3 (Campamento Picapiedra) and 5 (Pilcuan), the mean values of NOx were higher in the current study, with maximum values of 4.8 µg / m³, 20.11 µg / m³ And 5.42 µg / m 3, respectively, while in stations 2 (Contadero) and 4 (El Porvenir), the results of the previous study show higher values due to the fact that in these points it was not possible to quantify this pollutant. In the **Figure5.185** The above facts are reflected in a graphic manner and, furthermore, it is observed that all the measurements of this parameter are within the maximum established by the current regulations.

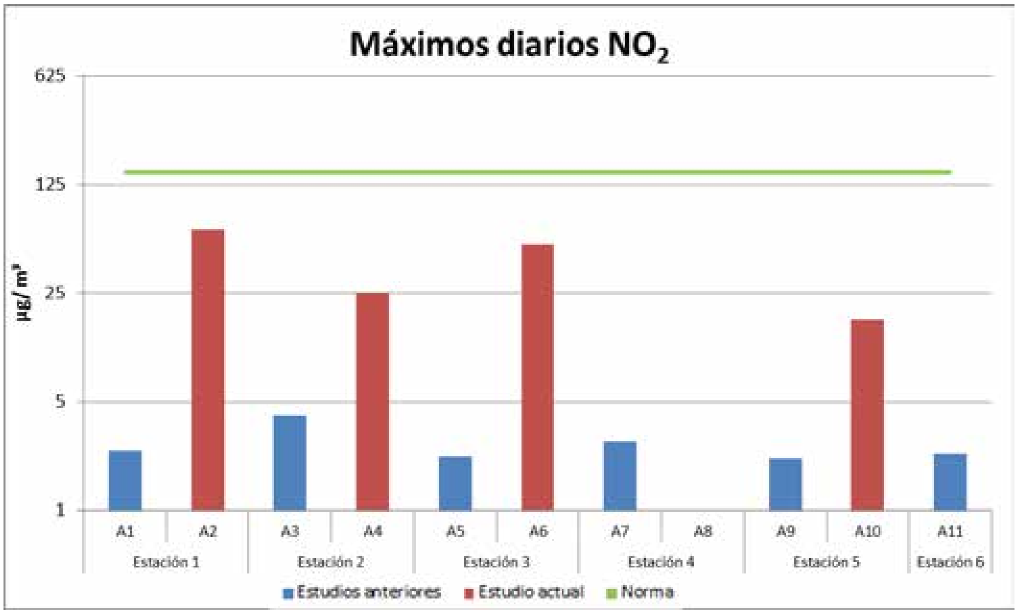
Figure5.185 Multi-temporal comparison of the arithmetic average of NO_2.



Source: GEOCOL CONSULTORES S.A., 2017.

As evidenced by the **Figure5.186**, The maximum values of this pollutant were determined in the current study for all stations except for number 4 (El Porvenir) in which the NOx value could not be determined in the 2017 monitoring, as it is below the limit of quantification. The maximum value was registered at point A2 (San Juan, 2017) and corresponds to 64.09 µg / m³.

Figure5.186 Multi-temporal comparison of daily maximums of NO_2.



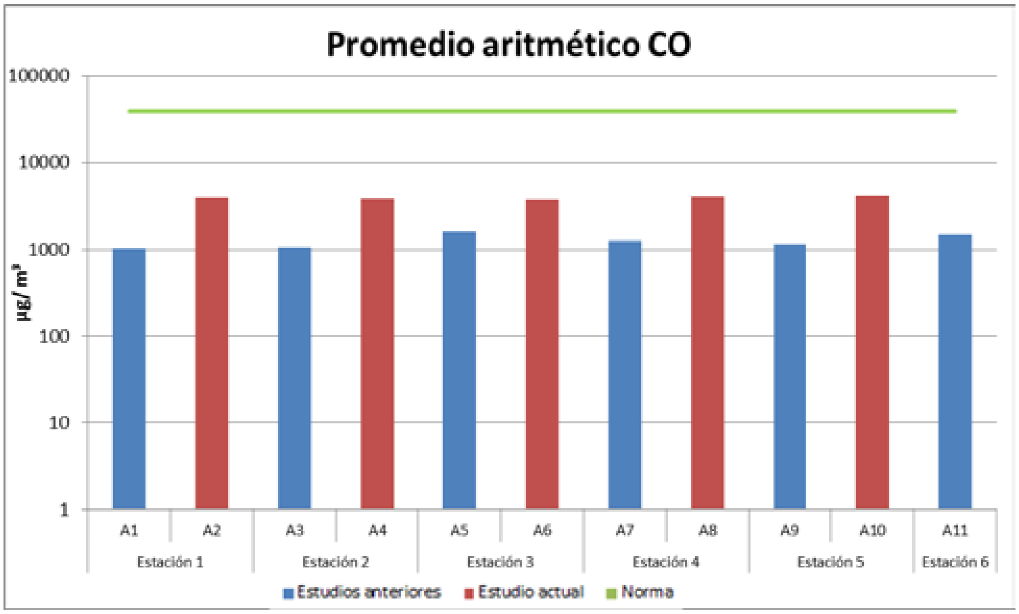
Source: GEOCOL CONSULTORES S.A., 2017.

In the **Figure5.186** It is observed also that all the measurements of this parameter are within the maximum established by the current regulations.

o **Carbon Monoxide (CO).**

If the arithmetic average is compared in the two monitored moments in time, a quite constant behavior is evident. In all the stations taken into account, the values found for CO were higher in the present study, registering a maximum of 4134.94 µg / m³ at point A10 (Pilcuán, 2017). In the **Figure5.187** The above facts rare reflected in a graphic manner, and furthermore, it is observed that all the measurements of this parameter are within the maximum established by the current regulations.

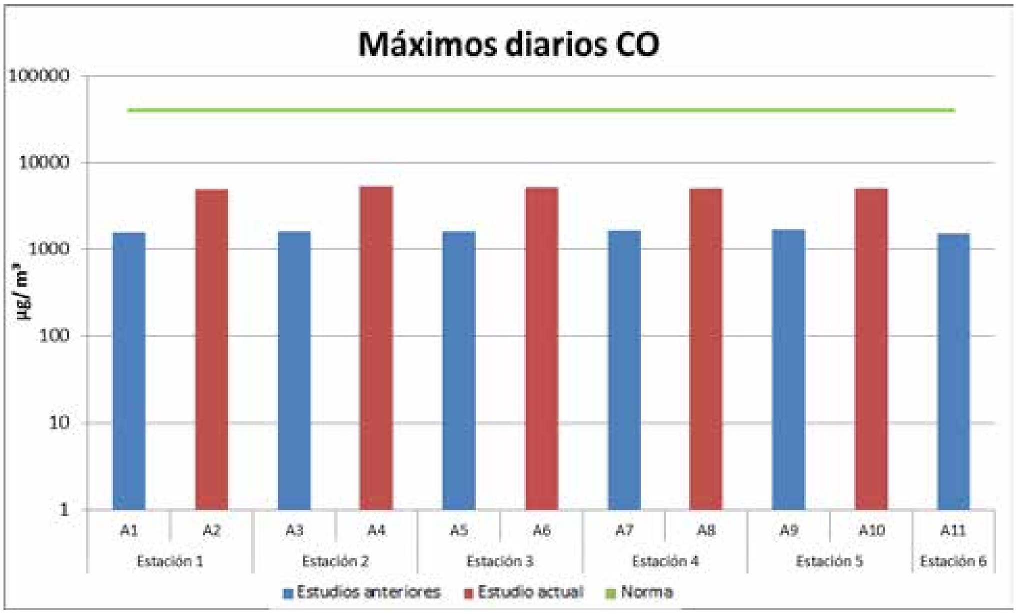
Figure5.187 Multi-temporal comparison of the arithmetic average of CO.



Source: GEOCOL CONSULTORES S.A., 2017.

If the arithmetic average is compared in the two monitored moments in time, a quite constant behavior is evident. At all stations taken into account, the maximum values found for CO were higher in the present study, above the previous one, registering a maximum of 5311.78 µg / m³ in point A4 (Contadero, 2017). In the **Figure5.188** The above facts are reflected in a graphic manner, and furthermore, it is observed that all the measurements of this parameter are within the maximum established by the current regulations.

Figure5.188 Multitemporal comparison of daily CO maximum rates.



Source: GEOCOL CONSULTORES S.A., 2017.

· **Conclusions.**

- It was determined that for most parameters considered for the analysis, a clear trend of increase or decrease over time was not evidenced and the only one that had a marked behavior was the CO, which always registered higher values in this study bvis-a-vis the previous one, reaching 4134,94 µg / m³ (average value) and 5311,78 µg / m³ (daily maximum value).
- It was identified that, unlike the previous study, at present, values of some parameters (SO2 and NOx) were below the quantifiable limit of the analysis method used, which indicates that air conditions (as related to said parameters), are good quality.
- It was evidenced that none of the previously analyzed parameters exceeds the limits established by Colombian regulations, for both average and maximum values, which indicates that the pollutants studied, in the concentrations found, do not represent a danger to human health.

5.1.12.4 Noise.

The noise consists in a set of undesired, loud, unpleasant or unexpected sounds that can produce physiological and psychological effects that are harmful to a person or group of people.

The environmental noise control is established because it is considered one of the most significant environmental problems at present, and in its great majority it is produced by human activities such as industry and urban growth. Control is performed to prevent and mitigate noise that may affect the health of the population, the balance of ecosystems, which disrupts public peace or affects the right of people to enjoy public goods and the environment at ease(IDEAM, 2006).

- **Sources of noise generation.**

Through the road corridor that is the object of the project, different sources of environmental noise were identified, as well as population settlements and social infrastructure.

The most significant sources of noise in the study area are represented by commercial activities of the municipalities of the area of influence, both formal and informal, street vending (using loudspeakers), etc.

Vehicular traffic also represents one of the main sources of noise emission. The widespread use of motorcycles as a means of transport for urban and rural residents generates noise from the engine and excessive use of horns.

Natural sources of noise are the sound of birds, insects and amphibians mainly during night time.

Among the potential recipients are mainly populated centers corresponding to San Juan, Contadero, El Porvenir and Pilcuán. In terms of social infrastructure, there are educational centers, churches, health centers and sports venues.

The following table shows the main receivers and noise emitters identified during performance of environmental noise monitoring. (Ver **Table 5.151**.

Table 5.151 Sources generating noise and potential receivers in the area of influence of the dual carriageway project Rumichaca - Pasto, section San Juan - Pedregal.

POTENTIAL RECEPTORS	ENVIRONMENTAL NOISE SOURCE
Corregimiento of San Juan - Ipiales	Heavy vehicles Lightweight vehicles Motorcycle Traffic Pedestrian traffic
Municipal Seat - Contadero	Heavy vehicles Lightweight vehicles Motorcycle Traffic Pedestrian traffic Domestic animals
El Porvenir Rural District	Crushing activities Heavy vehicles Lightweight vehicles Domestic animals Wildlife fauna Motorcycle traffic
Township of Pilcuan	Heavy vehicles Lightweight vehicles Domestic animals Guáitara River Current
Campamento Picapiedra	Heavy vehicles Lightweight vehicles Motorcycle Traffic

Source: GEOCOL CONSULTORES S.A., 2017.

- **Vehicle noise.**

Directly or indirectly all of the above contribute to the generation of environmental noise. The large masses of people who travel daily through the Pan-American Highway and secondary roads covering greater distances, also promote an increasing use of collective or individual transport units in circulation, which produce noise in various forms.

It has been demonstrated that motor vehicles in circulation are the ones that pollute the environment with noise, which is associated with the sound produced by the contact of the tires with the pavement. (Territorial, 2016).

The noise from the vehicles circulating on the roads depends on factors such as the characteristics of the vehicle, the speed, the driving regime, and the road conditions. From an acoustic point of view, the noise of an automobile depends on the type of vehicle, its mass, engine power, combustion technology, its state of conservation, etc. With respect to their sound emission, the vehicles can be classified in:

- Light vehicles, those with a light weight of less than 3.5 tons
- Vehículos pesados, con peso en carga mayor de 3,5 toneladas
- Motorizados de dos ruedas (Echazarreta, 2016).

- **Urban noise.**

It is the predominant background noise in a community. It is comprised by sounds coming from distant and near sources, associated to the habits of the inhabitants; there are social trends that are irreversible, as the population growth, the densification of certain spaces at the expense of others that lose population, and the increase of urban concentrations, creating, in contrast, scattered spaces and with very few inhabitants. (Territorial, 2016). In an urban center, the noise varies significantly from the quietest suburban areas to the sectors bordered by routes of intense traffic and commercial establishments. The noise varies according to the hours of the day and according to the predominant activities. The annoyance caused by the noise is the main cause of complaint by the citizenship. (Cauca, 2016).

- **Industrial noise**

The noise generated by civil works is another frequent source of urban and rural noise, and it has great local impact for the nearest residents. In general, noise is emitted by processing machinery and moving cargo vehicles; some machines such as pile drivers and pneumatic hammers, generate high levels of acoustic pressure accompanied by mechanical vibrations that affect the areas surrounding the works. There are also works under construction in areas interspersed in residential and office areas, which are often grounds for complaints about the generation of noise, vibration, and pollutant emissions to the atmosphere. Noise from construction works generally can be constant for long periods or fluctuate considerably, and increase at certain times. (Territorial, 2016).

5.1.12.4.1 Sampling of sound pressure levels.

Para el análisis de la contaminación acústica se tiene en cuenta lo establecido en la Resolución 627 de 2006 del MAVDT hoy MADS, la cual establece la norma nacional de ruido ambiental (**Table 5.152**) y emisión de ruido, donde se definen los límites diurnos y nocturnos, según la actividad y el uso del suelo.

Table 5.152 Permissible maximum standards of ambient noise levels.

SECTOR	SUBSECTOR	DAY (dB)	NIGHT (dB)
Sector A. Tranquility and Silence	Hospitals, libraries, nurseries, sanatoriums, geriatric homes.	55	45
Sector B. Tranquility and Moderate Noise	* Residential areas or exclusively destined for housing development, hotels and lodging.	65	50
	Universities, colleges, schools, research and study centers.		
	Parks in different urban areas other than outdoor mechanical parks		
(*) Sector C. Restricted Intermediate Noise	Zones with permitted industrial use, such as general industry, port zones, industry parks, free trade zones, which levels must not exceed the following:	75	70
	Areas with commercial allowed uses, such as shopping malls, warehouses, commercial premises or facilities, automotive and industrial mechanic shops, sports and recreational centers, gyms, restaurants, bars, taverns, discos, bingos, casinos.	70	55
	Areas with institutional uses.	65	50
	* Areas with other related uses, such as outdoor mechanical parks, areas for outdoor public shows, trunk roads, highways, main roads.	80	70
(*) Sector D. Suburban or Rural Area of Tranquility and Moderate Noise	Residential suburban.	55	45
	* Rural, inhabited and destined to agricultural exploitation.		
	Recreation and rest areas, such as natural parks and natural reserves.		

Source: Resolution 627 of 2006.

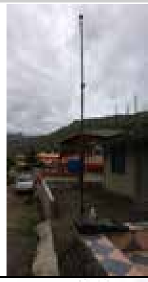
In order to meet the requirements established in Resolution 627 of 2006, six (6) monitoring points were located along the area of influence of the Rumichaca - Pasto divided highway project, San Juan - Pedregal segment. Due to the relation between current and projected emission sources (for installation of camps and crushing plants, concrete and asphalt) and noise receivers. At each point, measurements of ambient noise were taken in both daytime and night time, including measurements during public holidays.

Then in the **Table 5.153** It indicates the specific conditions under which these measurements were taken.

Table 5.153 Location of environmental noise measurement points In the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan - Pedregal segment.

ID	PHOTOGRAPHS	NOISE RESTRICTION SECTOR	MONITORING POINT LOCATION	COORDINATES DATUM MAGNAS SIRGAS ORIGEN WEST		DATE OF MEASUREMENT
				EAST	NORTH	
Noise 1. San Juan		D Suburban or Rural Area of Tranquility and Moderate Noise	**Sidewalk**: San Juan **Municipality** Ipiales	948033.6	590759.6	**Daytime Business Day:** 13 - Mar -2017
						Daytime Business: 11 - Mar - 2017

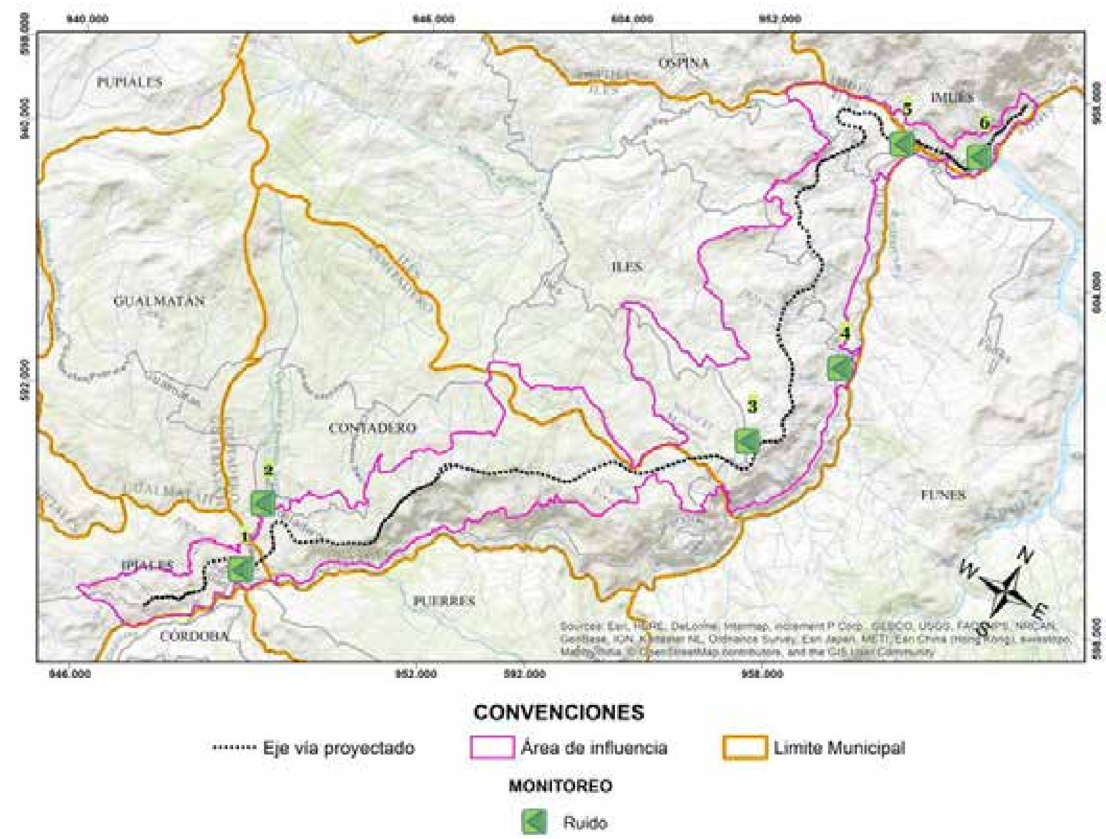
ID	PHOTOGRAPHS	NOISE RESTRICTION SECTOR	MONITORING POINT LOCATION	COORDINATES DATUM MAGNAS SIRGAS ORIGEN WEST		DATE OF MEASUREMENT
				EAST	NORTH	
		Suburban Residential Subsector 55 dB (A) Day, 45 dB (A) night.				**Daytime Holiday:** 12 - Mar-2014
						Night Holiday: 12 - Mar - 2017
Noise 2. Contadero		Tranquility and moderate noise Subsector residential areas 65 dB (A) Day, 50 dB (A) night.	Contadero Urban Zone **Municipality**: Contadero	947761.9	592132.9	**Daytime Business Day:** 13-Mar-2017
						Daytime Business: 11 - Mar -2017
						Daytime Holiday: 12 - Mar-2014
						Night Holiday: 12 - Mar - 2017
Noise 3. Camp 31 + 100		Suburban or rural area of tranquility and moderate noise 55 dB (A) day, 45 dB (A) night	Iles urban zone **Municipality** Iles	955537.9	598054.0	**Daytime Business Day:** 11-Mar-2017
						Daytime Business: 11 - Mar -2017
						Daytime Holiday: 12-Mar-2017
						Night Holiday: Not done
Noise 4. Campamento Picapiedra		Intermediate restricted noise: Subsector trunk roads, highways and main roads. 80 dB (A) Day, 70 dB (A) night.	**Sidewalk**: La Esperanza **Municipality** Iles	956411.5	600246.9	**Daytime Business Day:** 11 - Mar - 2017
						Daytime Business: 13 - Mar - 2017
						Daytime Holiday: 12 - Mar - 2017
						Night Holiday: 12 - Mar - 2017
Noise 5. Campamento Mikel		Suburban or rural area of tranquility and moderate noise. 55 dB (A) day,	**Sidewalk**: El Porvenir **Municipality** Iles	955244.4	604753.0	**Daytime Business Day:** 11 - Mar - 2017
						Daytime Business: 13 - Mar - 2017

ID	PHOTOGRAPHS	NOISE RESTRICTION SECTOR	MONITORING POINT LOCATION	COORDINATES DATUM MAGNAS SIRGAS ORIGEN WEST		DATE OF MEASUREMENT
				EAST	NORTH	
	 	45 dB (A) night.				**Daytime Holiday:** 12 - Mar - 2017
						Night Holiday: 12 - Mar - 2017
Noise 6. Pilcuán	 	Intermediate restricted noise: Subsector trunk roads, highways and main roads. 80 dB (A) day, 70 dB (A) night.	**Sidewalk**: Pilcuan **Municipality** Imúes	956709 .4	605294.5	**Daytime Business Day:** 11 - Mar - 2017
						Daytime Business: 13 - Mar - 2017
						Daytime Holiday: 12 - Mar - 2017
						Night Holiday: 12 - Mar - 2017

Source: FIELD WORK, MANAGEMENT & ENVIRONMENT SAS, 2017.

The location of the monitoring performed for the present study is shown in the **Figure5.189**.

Figure5.189 Location of environmental noise measurement points in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan - Pedregal segment.



Source: GEOCOL CONSULTORES S.A., 2017.

The execution of the monitoring was carried out by the Laboratory Gestión & Medioambiente SAS, which is accredited by IDEAM under Resolution 2307 dated October 13, 2016, as the laboratory competent to carry out the analyses in the noise matrix.

The sound level meter was set up in such a way that the sonometer mode measurements were made with a frequency weighting filter A and slow response mode (S or Slow) for 5 minutes to then take measurements in third octave analyzer mode also for 5 minutes (First of 3 evenly spaced intervals). These measurement intervals were carried out for 1 hour, on a tripod four meter high (unit measurement time interval, Article 5 Resolution 627 of 2006).

Based on records stored in the sound level meter, a single value was obtained with the measurements of each time interval for the equivalent continuous sound pressure level, residual equivalent continuous sound pressure level and percentile 90 and the adjustments per tone (KT) pulses (KI) and low frequencies (KS) to obtain the corrected levels.

Los resultados fueron llevados a mapas de ruido (ver **Anexo 15.** The results were transferred to maps (see Annex 15. Monitoring) to graphically represent the results obtained, which allow visualizing the reality in terms of environmental noise, identifying critical areas and possible sources of pollution by noise emission, as well as the noise generated by project activities.

· **Results of night noise monitoring.**

In the Error! Reference source not found. It shows compared results of the measurements made with respect to the maximum permissible limit of the daytime period established in table 2 of article 17 of Resolution 627 of 2006 issued by the MAVDT for the corresponding restriction sector is presented. Igualmente se presentan los ajustes calculados para las mediciones.

Table 5. Comparison of the results of noise measurements carried out in the area of influence of the Rumichaca - Pasto Divided Highway, San Juan - Pedregal segment. Regarding the daytime standard.

IDENTIFICATION OF THE MONITORING POINT	RURAL DISTRICT	COORDINATES DATUM MAGNAS SIRGAS ORIGEN WEST		Day	L_{R90}	$L_{RAeq,T}$	Max Level (dB)	Complies (Yes / No)
		EAST	NORTH					
01 - San Juan	San Juan	948033.6	590759.6	Business Day	42,3	58,4	55	No
				Holiday	46,8	55,3		No
02 - Contadero	Contadero Urban Zone	947761.9	592132.9	Business Day	40,7	55,9	65	Yes
				Holiday	44,1	94,4		No
Campamento 31 + 100	Iles urban center	955537.9	598054.0	Business Day	32,8	98,8	55	Yes
				Holiday	31,7	47,1		Yes
04 - Campamento Picapiedra	La Esperanza	956411.5	600246.9	Business Day	40,4	68,3	80	Yes
				Holiday	43,2	68,9		Yes
05 - Campamento Mikel	El Porvenir	955244.4	604753.0	Business Day	41,9	50,3	55	Yes
				Holiday	46,9	64,0		No
06 - Pilcuán	Pilcuan	956709.4	605294.5	Business Day	50,5	68,6	80	Yes
				Holiday	50,7	64,1		Yes

Source: GEOCOL CONSULTORES S.A., 2017.

· **Results of night noise monitoring.**

In the Error! Reference source not found. presents the compared results of the measurements made with respect to the maximum permissible limit of the night period, as the adjustments calculated for each one of them.

Table 5. Comparison of the results of noise measurements carried out in the area of influence of the Rumichaca - Pasto Divided Highway, San Juan - Pedregal segment. Regarding the night norm.

IDENTIFICATION OF THE MONITORING POINT	RURAL DISTRICT	COORDINATES DATUM MAGNAS SIRGAS ORIGEN WEST		Day	L_{R90}	$L_{RAeq,T}$	Max Level (dB)	Complies (Yes / No)
		EAST	NORTH					
01 - San Juan	San Juan	948033.6	590759.6	Business Day	41,0	62,3	45	No
				Holiday	40,7	62,7		No
02 - Contadero	Contadero Urban Zone	947761.9	592132.9	Business Day	46,6	67,8	50	No

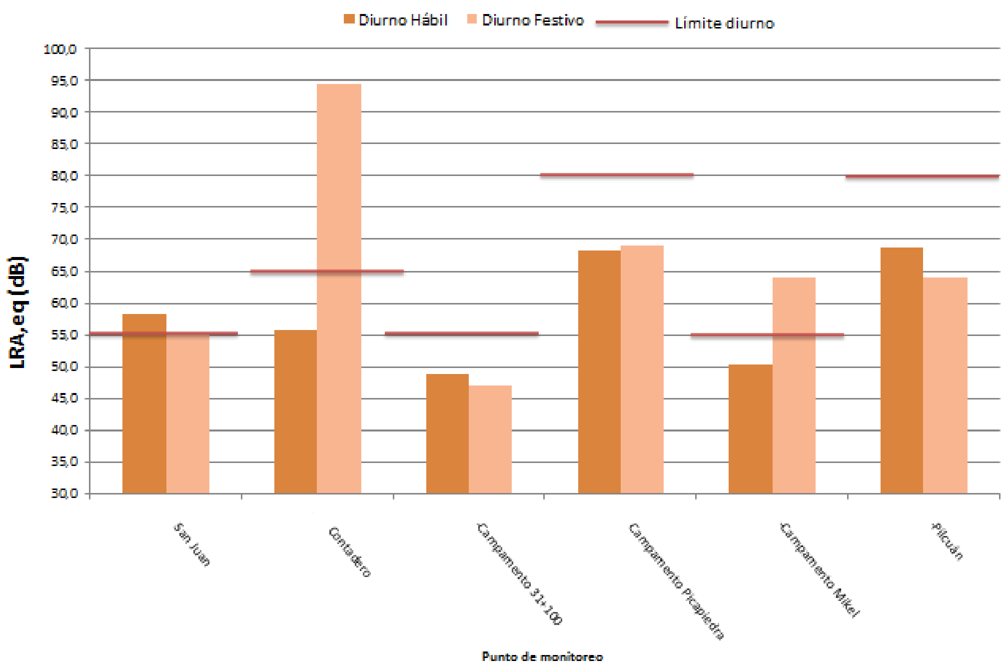
IDENTIFICATION OF THE MONITORING POINT	RURAL DISTRICT	COORDINATES DATUM MAGNAS SIRGAS ORIGEN WEST		Day	L_{R90}	$L_{RAeq,T}$	Max Level (dB)	Complies (Yes / No)
		EAST	NORTH					
				Holiday	43,2	45,7		Yes
Campamento 31 + 100	Iles urban center	955537.9	598054.0	Business Day	31,8	37,7	45	Yes
				Holiday	-	-		-
04 - Campamento Picapiedra	La Esperanza	956411.5	600246.9	Business Day	38,2	61,6	70	Yes
				Holiday	42,7	63,2		Yes
05 - Campamento Mikel	El Porvenir	955244.4	604753.0	Business Day	53,1	55,4	45	No
				Holiday	42,9	55,3		No
06 - Pilcuán	Pilcuan	956709.4	605294.5	Business Day	38,9	63,0	70	Yes
				Holiday	44,6	63,5		Yes

Source: GEOCOL CONSULTORES S.A., 2017.

In the **Figure5.190** Datyme results are resented of the corrected levels of weighted equivalent continuous sound pressure A, LR (A) and their respective comparison with the maximum permissible standards established for the daytime.

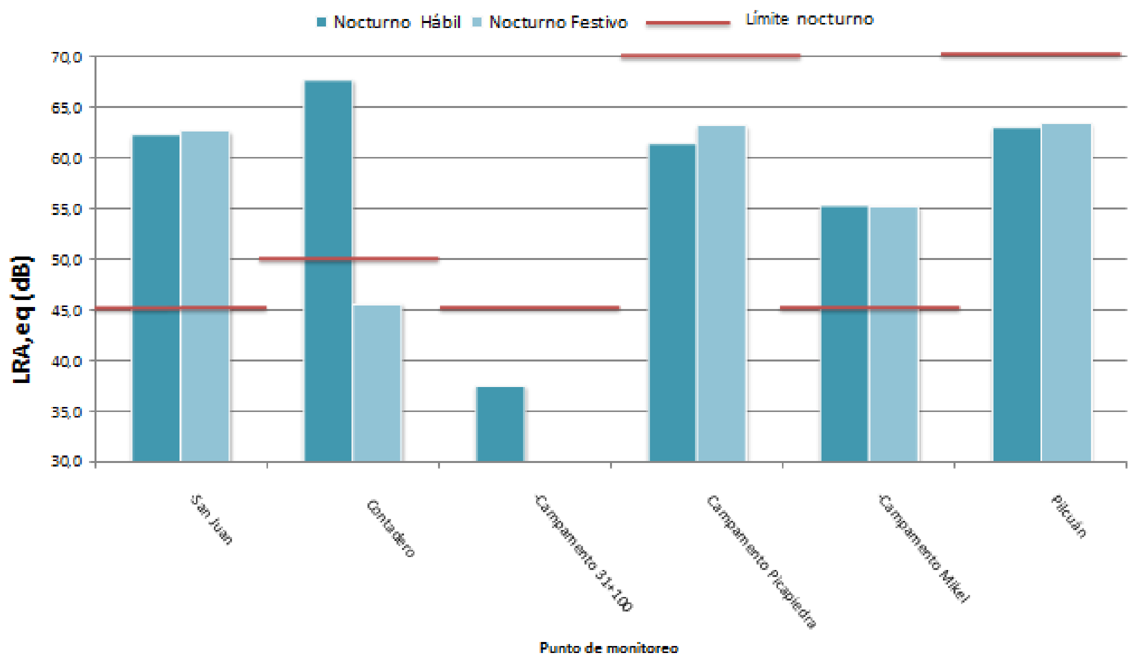
Similarly, in the **Figure5.191** Daytime results are presented of the corrected levels of weighted equivalent continuous sound pressure A, LR (A) and their respective comparison with the maximum permissible standards established for the daytime.

Figure5.190 Daytime sound pressure levels for business days and holidays compared to the daytime standard.



Source: GESTIÓN & MEDIOAMBIENTE S.A.S 2017

Figure5.191 Daytime sound pressure levels for business days and holidays compared to the daytime standard.



Source: GESTIÓN & MEDIOAMBIENTE S.A.S 2017

- **Analysis of Results**

The analysis of the information presented in the previous numerals shows that in the area of influence of the Rumichaca-Pasto divided highway project, San Juan - Pedregal segment, measurements were made in suburban or rural areas of the municipalities of Ipiales, Iles, Contadero and Imués . The highest daytime noise levels occurred at the measurement sites near the San Juan-Pedregal roadway (R3-San Juan, R6-Campo Picapiedra and R8-Pilcuan). At the metering points of the Campamento Picapiedra and Pilcuan, similar values were registered of 68.3 dB and 68.6 dB during the day and 61.6 dB and 63.0 dB in the night, respectively, representing noise levels associated with constant vehicular traffic between Ipiales and Pedregal, which decreases to some extent in the night. However, these noise levels comply with the allowable limits for the noise restriction sector applicable to main roads on both business days and holydays.

The metering point located in San Juan is classified within the D suburban residential zone with very restrictive limits according to the anthropic activities and noisy sources identified (mainly vehicular traffic by the current route between San Juan and Pedregal) with values of 58.4 dB in the day and 62.3 dB in the night, which exceeded the limits of 55 dB in the day and 45 dB in the night. However, the 90 percentile levels show that values of 42.3 dB occur in the day and 41.0 dB in the night, which indicate that during 90% of the measurement time, the permissible limits are met and only specific events like Passing motorcycles or natural noises made by pets generate higher noise levels.

The measurement point known as Camp 31 + 100 in the village of Porvenir de Iles is the most remote site of the San Juan - Pedregal segment, classified within the sector D inhabited rural area for agricultural exploitation, presented the lowest levels of noise associated mainly to natural noises with 48.8 dB in the day and 37.7 dB in the night and with 90th percentiles of 32.8 dB in the day and 31.8 dB in the night. Obviously, the applicable permissible standards are complied with at this site.

The measurement point located in the urban area of the municipality of Contadero recorded a working day 55.9 dB in the daytime period and 67.8 dB in the night period complying with the standard for the day but not for the night. This is due to the traffic of motorcycles that generate moments of high noise. The analysis of percentile 90 showed this is 46.6 dB at night, which is below the allowable limit. In the daytime during a holiday, the highest level was recorded with 94.4 dB but also the 90th percentile only reached 44.1 dB, so that only specific events give rise to such high value. At night on a holiday, 45.7 dB were reached, a level that is also below the allowable limit.

The results of the noise measurements carried out at the site called Campamento Mikel in the village of El Porvenir in the municipality of Iles show that only the daytime limit (55 dB) with 50.3 dB is observed; in a holiday, the regisiter was 64.0 dB. At night, both on a business day and on holidays, values above 45 dB are recorded, reaching 55.4 dB and 55.3 dB respectively. This can be explained by the natural noises of nocturnal fauna. Percentile 90 levels show that in this site, 90% of the measurement time the allowable daytime limit is met, both on business day and holidays and at night on holidays. At night on a business day, percentile 90 was 53.1 dB, above the 45 dB limit.

- **Conclusions.**

  - According to the classification issued by the Ministry of Environment, Housing and Territorial Development in Resolution 627 of 2006 and in accordance with the location of the measurement points for the area of influence of the Rumichaca - Pasto divided highway project, San Juan - Pedregal segment, the activities observed and the identification of human settlements, there are several noise restriction sectors in the area including restricted intermediate noise sector C applicable to the main road between Ipiales and Pedregal, sector B of quiet and moderate noise applicable to residential areas and Sector D rural area of tranquility and moderate noise applicable to residential suburban and rural residential areas intended for agricultural exploitation.
  - During the daytime, at all the measuring points, during 90% of the measurement period, the noise levels were below the thresholds established in the current environmental regulations for each noise restriction sector identified. The foregoing indicates the low noise impact of the anthropogenic activities of the inhabitants of the area and low noise emission of small industries and linear sources.
  - During night time, at all the measuring point (except at the site called Campamento Mikel in the rural district of El Porvenir de Iles), during 90% of the measurement period, the noise levels were below the thresholds established in the current environmental regulations for each noise restriction sector identified.
  - In daytime hours, the highest levels of noise are associated with vehicular traffic along the route between Ipiales and Pedregal, reaching levels between 64.1 dB and 68.9 dB; the lowest levels were recorded in the most distant area to populated centers and main roads, reaching values only between 47.1 dB and 48.8 dB specifically at the site denominated camp 31 + 100 in the rural district Urbano of the municipality of Iles.

5.1.12.4.2 Multitemporal analysis of the quality of sound pressure level in the study area.

To analyze the temporary variations of sound pressure level in the area, information was collected from the monitoring carried out by the SH Consortium in the study area, through the contracting of the ASOAM SAS Agrosoluciones Ambientales (laboratory accredited by IDEAM under Resolution 1556 of August 14, 2015, modified by Resolution 2191 of October 7, 2015 for the performance of noise monitoring), a study in which 6 stations were located in the San Juan - Pedregal segment. Said monitoring results are compared with the current ones in coinciding sites; in addition, air quality results in camp 31 + 100 are presented.

The names of the stations with their respective coordinates and the date of the monitoring were found in **Table 5.154.**

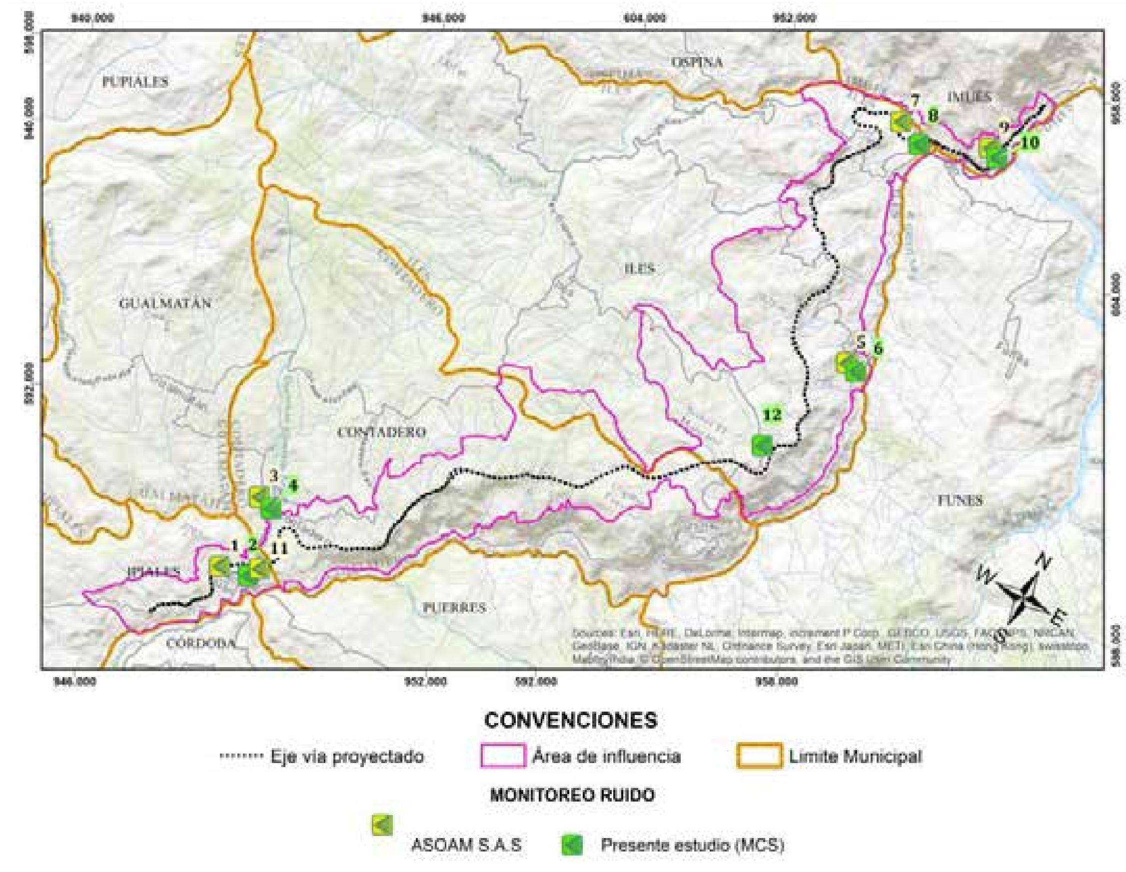
Table 5.154 Ubicación de los Puntos Monitoreados.

STATION	DATE		POINT	NAME OF THE STATION WHERE STUDY WAS CONDUCTED	COORDINATES		SOURCE
	Working day	Holiday			EAST	NORTH	
1	27 Apr 2016	27 Aug 2016	R1	P.2 San Juan	947724	590571	ASOAM SAS
	13 Mar 2017	12 Mar 2017	R2	San Juan	948033	590759	Present study
2	27 Apr 2016	27 Aug 2016	R3	P. 3 Contadero	947714	592143	ASOAM SAS
	13 Mar 2017	12 Mar 2017	R4	Contadero	947761	592132	Present study
3	24 Aug 2016	27 Aug 2016	R5	04 - Campamento Picapiedra	956431	600232	ASOAM SAS
	11 Mar 2017	12 Mar 2017	R6	Campamento Picapiedra	956411	600246	Present study
4	27 Apr 2016	27 Aug 2016	R7	p. 4 El Porvenir Rural District	954976	604892	ASOAM SAS
	11 Mar 2017	12 Mar 2017	R8	Campamento Mikel	955244	604753	Present study
5	27 Apr 2016	27 Aug 2016	R9	P. 5 Pilcuán	956757	605314	ASOAM SAS
	11 Mar 2017	12 Mar 2017	R10	Pilcuán	956709	605294	Present study
6	24 Aug 2016	27 Aug 2016	R11	P.13 Campamento San Juan	948427	590916	ASOAM SAS

Source: GEOCOL CONSULTORES S.A., 2017.

The behavior of sound pressure level in the stations described in **Table 5.154** are analyzed temporarily over the years of the monitoring in order to confirm if they have decreased or if, on the contrary, they have increased. This comparison is possible because the spatial location of the monitoring points is the same for different years. As regards the San Juan camp, the specific value of the monitoring is presented for the year 2016, which suggests the air quality at that point. This is also the case with Campamento 31+100, which was monitored in this study.

Figure5.192 Monitored points for multi-temporal analysis of air quality.



Source: GEOCOL CONSULTORES S.A., 2017.

· **Analysis of Results**

The maximum levels of environmental noise depend on the sector and the activity where the monitoring is performed; these were performed both day and night on business days and holidays; these were conducted in areas where there were commercial and industrial activities and in rural areas where noise activities were minor, An analysis was then presented on each of the stations identified with a code for each station and for each point, both in camps and in roads where sound pressure levels were identified and showing the maximum permissible level according to current regulations.

o **Daytime business day.**

As can be seen in the **Table 5.155** and in the **Figure5.193**, Most of the points monitored comply with the regulations regarding maximum sound pressure levels and only a points R1 (P.2 San Juan), R2 (San Juan) and R11 (P. 13 San Juan Camp) are above the regulatory limits. In all the cases **Table 5.155** Both points of the same station show the same behavior: both meet the norm or both exceed it.

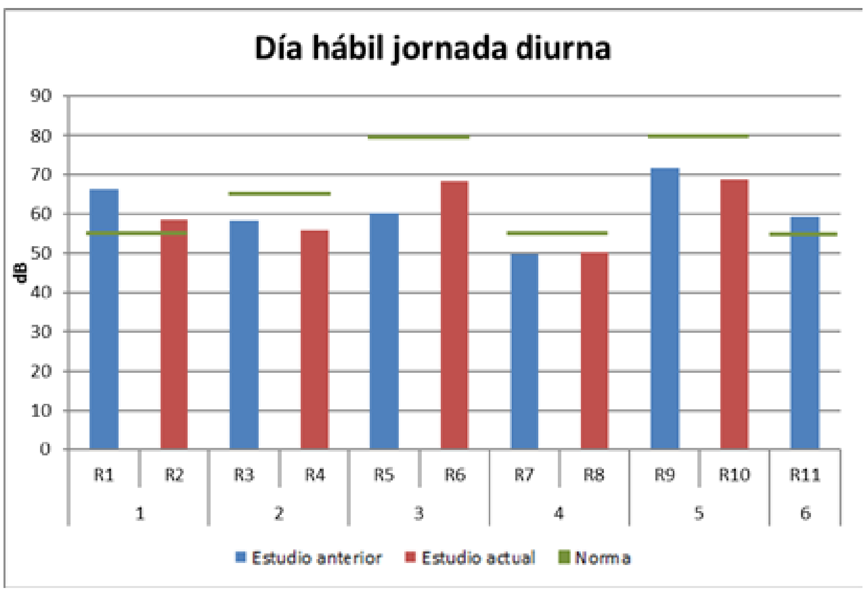
Table 5.155 Comparison of results of noise measurements with respect to daytime standard - Business day

DAYTIME BUSINESS DAY					
STATION	STATION	POINT	$L_{RAEQ,T}$	MAX LEVEL (DB)	MEETS (YES / NO)
P.2 San Juan	1	R1	66,3	55	No
San Juan		R2	58,4	55	No
P. 3 Contadero	2	R3	58,2	65	Yes
Contadero		R4	55,9	65	Yes
04 - Campamento Picapiedra	3	R5	60,3	80	Yes
Campamento Picapiedra		R6	68,3	80	Yes
p. 4 El Porvenir Rural District	4	R7	49,7	55	Yes
Campamento Mikel		R8	50,3	55	Yes
P. 5 Pilcuán	5	R9	71,5	80	Yes
Pilcuán		R10	68,6	80	Yes
P.13 Campamento San Juan	6	R11	59,2	55	No

Source: GEOCOL CONSULTORES S.A., 2017.

As evidenced by the **Figure5.193**, The behavior of noise levels registered during the monitoring is quite varied for the two analyzed moments of time. While in stations 1 (San Juan), 2 (Contadero) and 5 (Pilcuán), noise levels were higher in the previous study, stations 3 and 4 showed higher sound pressure levels in the present study.

Figure5.193 Multi-temporal comparison of noise measurement results with respect to daytime standard - Daytime Business Day



Source: GEOCOL CONSULTORES S.A., 2017.

- **Business Day at night.**

As can be seen in the **Table 5.156** and in the **Figure5.194**, There are some monitoring points that comply with the regulations regarding maximum sound pressure levels, such as points R5 (P.14 Campamento Picapiedra) and R6 (Campamento Picapiedra), R9 (P.5 Pilcuán) and R10 (Pilcuán), while others are above the permissible limit. In the **Table 5.156** It can also be observed that, for both the previous and the present study, there were no variations regarding compliance with the standard, i.e., stations that were above the regulatory limit in the previous study, are also above in the current study.

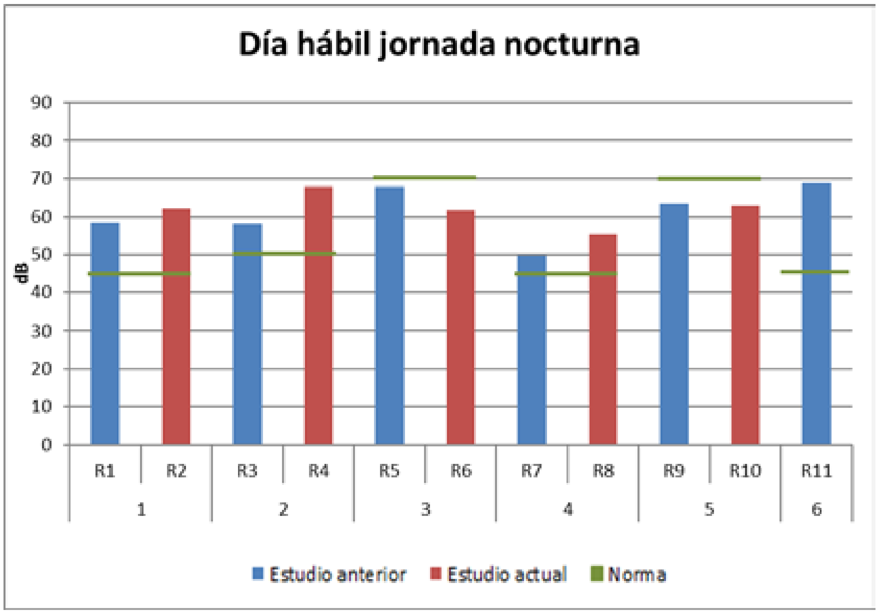
Table 5.156 Comparison of results of noise measurements with respect to night standard - Holiday

NIGHT BUSINESS DAY					
STATION	**STATION**	**POINT**	**$L_{RAEQ,T}$**	**MAX LEVEL (DB)**	**MEETS (YES / NO)**
P.2 San Juan	1	R1	58,3	45	No
San Juan		R2	62,3	45	No
P. 3 Contadero	2	R3	58,2	50	No
Contadero		R4	67,8	50	No
04 - Campamento Picapiedra	3	R5	67,8	70	Yes
Campamento Picapiedra		R6	61,6	70	Yes
p. 4 El Porvenir Rural District	4	R7	49,7	45	No
Campamento Mikel		R8	55,4	45	No
P. 5 Pilcuán	5	R9	63,5	70	Yes
Pilcuán		R10	63	70	Yes
P.13 Campamento San Juan	6	R11	68,9	45	No

Source: GEOCOL CONSULTORES S.A., 2017.

As evidenced by the **Figure5.194**, The results of noise measurements are higher in the present study for three of the five stations analyzed: 1 (San Juan), 2 (Contadero) and 4 (El Porvenir). On the other hand, the records of the previous study were higher in stations 3 (Camp Flintstone) and 5 (Pilcuan).

Figure5.194 Multi-temporal comparison of noise measurement results with respect to the standard - Business Day at Night



Source: GEOCOL CONSULTORES S.A., 2017.

- **Daytime Business Day**

As can be seen in the **Table 5.157** and in the **Figure5.195**, There are some monitoring points that comply with the regulations regarding maximum sound pressure levels, such as points R5 (P.14 Campamento Picapiedra) and R6 (Campamento Picapiedra), R9 (P.5 Pilcuán) and R10 (Pilcuán), while others are above the permissible limit: R1 (P.2 San Juan), R2 (San Juan), R4 (Contadero), R8 (Camp Mikel) and R11 (P.13 Campamento San Juan). In the **Table 5.157** It can be observed that in station 2 (Contadero), it went from being below the regulatory maximum limit in the previous study, to being above it according to the current records; it is also the case of station 4 (Campamento Mikel).

Table 5.157 Comparison of results of noise measurements with respect to daytime standard - Holiday

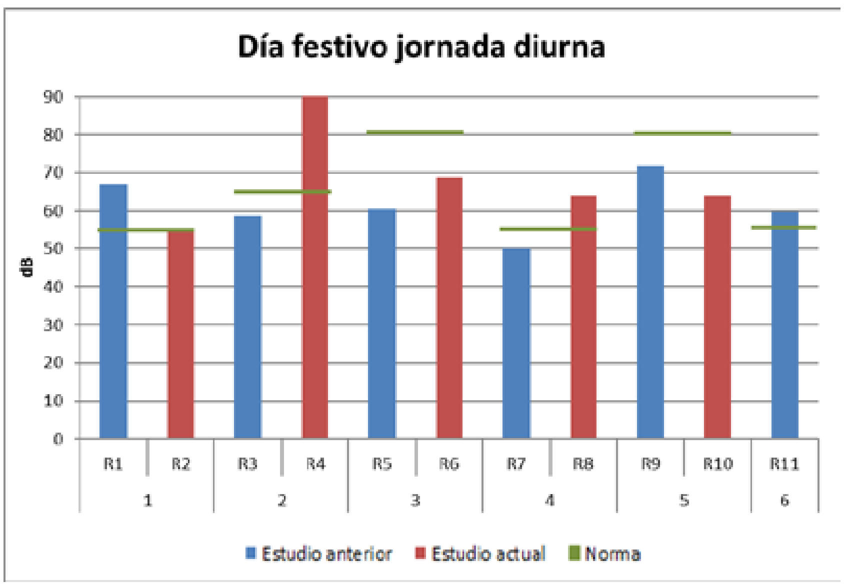
DAYTIME HOLIDAY					
Station	STATION	POINT	$L_{RAEQ,T}$	MAX LEVEL (DB)	MEETS (YES / NO)
P.2 San Juan	1	R1	67	55	No
San Juan		R2	55,3	55	No
P. 3 Contadero	2	R3	58,6	65	Yes
Contadero		R4	94,4	65	No
04 - Campamento Picapiedra	3	R5	60,5	80	Yes
Campamento Picapiedra		R6	68,9	80	Yes
p. 4 El Porvenir Rural District	4	R7	50,1	55	Yes
Campamento Mikel		R8	64	55	No
P. 5 Pilcuán	5	R9	71,9	80	Yes
Pilcuán		R10	64,1	80	Yes

DAYTIME HOLIDAY					
Station	STATION	POINT	LRAEQ, T	MAX LEVEL (DB)	MEETS (YES / NO)
P.13 Campamento San Juan	6	R11	59,6	55	No

Source: GEOCOL CONSULTORES S.A., 2017.

As evidenced by the **Figure5.195**, The behavior of noise levels registered during the monitoring is quite varied for the two analyzed moments in time. While in stations 1 (San Juan) and 5 (Pilcuán), noise levels were higher in the previous study, in stations 2 (Contadero), 3 (Camp Flintstone) and 4 (El Porvenir) sound pressure levels ere higher in the present study.

Figure5.195 Multi-temporal comparison of noise measurement results with respect to daytime standard - Daytime Holiday



Source: GEOCOL CONSULTORES S.A., 2017.

o **Night Holiday.**

As can be seen in the **Table 5.158** and in the **Figure5.196**, There are some monitoring points that comply with the regulations regarding maximum sound pressure levels, such as points R5 (P.14 Campamento Picapiedra) and R6 (Campamento Picapiedra), R9 (P.5 Pilcuán) and R10 (Pilcuán), while others are above the permissible limit: R1 (P.2 San Juan), R2 (San Juan), R4 (Contadero), R8 (Camp Mikel) and R11 (P.13 Campamento San Juan). In the **Table 5.158** It can be observed that in station 2 (Contadero), it went from being below the regulatory maximum limit in the previous study, to being above it according to the current records.

Table 5.158 Comparison of results of noise measurements with respect to night standard - Holiday

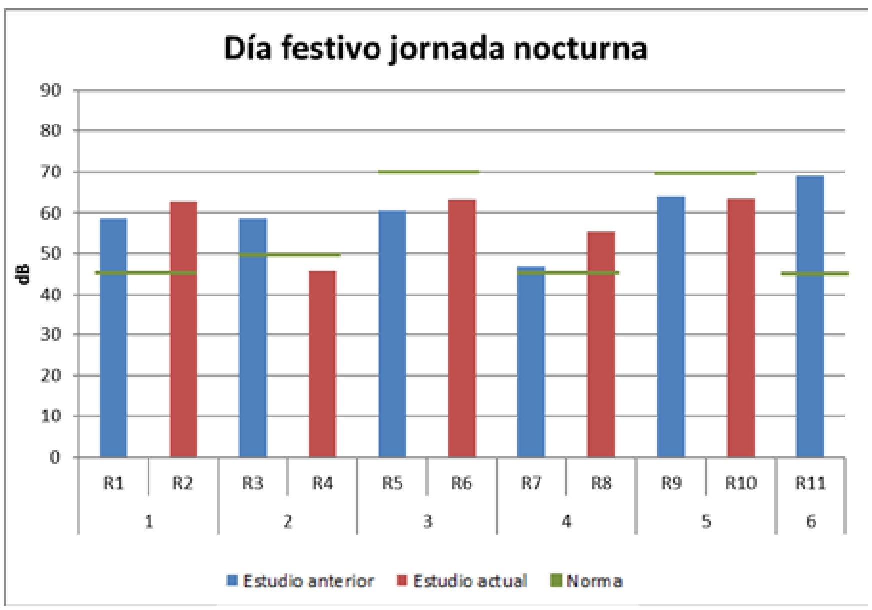
HOLIDAY NIGHT					
Station	Station	Point	LRAeq, T	MAX LEVEL (dB)	MEETS (YES / NO)
P.2 San Juan	1	R1	58,8	45	No

HOLIDAY NIGHT					
Station	Station	Point	$L_{RAeq,T}$	MAX LEVEL (dB)	MEETS (YES / NO)
San Juan		R2	62,7	45	No
P. 3 Contadero	2	R3	58,6	50	No
Contadero		R4	45,7	50	Yes
04 - Campamento Picapiedra	3	R5	60,5	70	Yes
Campamento Picapiedra		R6	63,2	70	Yes
p. 4 El Porvenir Rural District	4	R7	47	45	No
Campamento Mikel		R8	55,3	45	No
P. 5 Pilcuán	5	R9	64	70	Yes
Pilcuán		R10	63,5	70	Yes
P.13 Campamento San Juan	6	R11	69,1	45	No

Source: GEOCOL CONSULTORES S.A., 2017.

As evidenced by the **Figure5.196**, The behavior of noise levels registered during the monitoring is quite varied for the two analyzed moments in time. While in stations 1 (San Juan) and 5 (Pilcuán), noise levels were higher in the previous study, in stations 2 (Contadero), 3 (Camp Flintstone) and 4 (El Porvenir) sound pressure levels were higher in the present study.

Figure5.196 Multi-temporal comparison of noise measurement results with respect to the standard - Holiday at Night



Source: GEOCOL CONSULTORES S.A., 2017.

- **Conclusions.**

o After performing the multi-temporal analysis, it was evidenced that there are no clear trends in the variations of sound pressure in the compared stations, since registers increase and decrease in all the stations and scenarios compared (daytime business day, daytime holiday, night business day, and night holiday).

- In relation to the maximum norm allowed for the day, it was evidenced that non-fulfillment of this is more frequent during holidays in stations 1 (San Juan), 2 (Contadero), 4 (El Porvenir) and 6 (P .13 Campamento San Juan), with a maximum value of 94.4dB (point R4 (Contadero), holiday, daytime)., while at stations 3 (Camp Flintstone) and 5 (Pilcuan), it complies with the standard for both working and holidays.
- Regarding the maximum limits for night work, the non-compliance occurs in stations 1 (San Juan), 2 (Contadero), 4 (El Porvenir) and 6 (P.13 Campamento San Juan), with a maximum value of 67.8dB (point R4 (Contadero), business day, at night). In turn, in stations 3 (Campamento Picapiedra) and 5 (Pilcuan), the norm is complied with in the two analyzed moments in time.