OBJECTIVES AND GENERALITIES

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1 OBJECTIVES

1.1 General

Present the information that allows to evaluate and give feasibility to the request of modification of the environmental license for the "Construction and Operation of a Port Terminal of Solid Bulk of Great Depth in Bahia Colombia" so that it is a Port Terminal Multipurpose, with base The Reference requirements (MM-INA-05), taking into account the information requirements established in Resolution 0032 of 2012 and in the request for minor modifications within the ordinary course of activity and following the guidelines established in the general methodology for the presentation of environmental studies, the environmental guidelines, the current environmental regulations, the previous studies for the area.

1.2 Specific

- Describe the new activities to be developed, subject to modification of the environmental license.
- Establish the area of influence of the project, based on the conditions of the area, the new characteristics of the project and the identified environmental impacts.
- Update the abiotic, biotic and socioeconomic environmental baseline, in cases that apply, for new activities in accordance with the provisions of the Terms of Reference
- To add the demand, use, exploitation and / or affectation of the natural resources, necessary for the construction and operation of the port terminal.
- Identify the potential impacts, positive and negative, generated by the new project activities.
- Redefine environmental and environmental management zoning for the defined area of influence.
- Complement the different management and monitoring measures in order to prevent, mitigate, control and compensate for the environmental impact that new activities may generate.
- Update the Contingency Plan based on a risk analysis for the new project activities.
- Establish the dismantling and abandonment plan in harmony with the surrounding environment and the final use of the land.

2 GENERAL

2.1 Background

Port Concession

In January 2010 Puerto Bahía of Colombia of Urabá S.A. presented the Port concession request before the National Institute of Concessions (INCO), for the occupation and temporary and exclusive use of an area of public use located in

Colombia, Municipality of Turbo, for the construction and operation of a Port Terminal of Solid Bulk of Great depth.

Through Resolution 898 of December 21, 2012, the National Infrastructure Agency - ANI, granted a port concession to the company PUERTO BAHÍA COLOMBIA DE URABÁ SA, for temporary and exclusive occupation of the public use area that includes the beach sectors , low tide lands and marine zones accessory to those found in Bahía Colombia, Gulf of Urabá.

The ANI through Resolution 939 of August 26, 2013, extended in six (6) months the term indicated in the twenty-second article of Resolution 898 of December 21, 2012.

Subsequently, Resolution 507 of March 21, 2014 issued by the Vice Presidency for the Structuring of the ANI, modified the tenth article of Resolution 898 of December 21, 2012, referring to the value and form of payment of the contract, and the article Twenty-second of the same resolution, in the sense of indicating that the concession contract will be signed within a term of six (6) following months counted from the execution of this resolution.

Finally, the ANI through Resolution 606 of April 14, 2015 granted feasibility to the request for modification of the conditions under which the port concession was granted to the company PUERTO BAHÍA COLOMBIA DE URABÁ SA, through Resolution 898 of December 21, 2012 and modified by resolutions 939 of August 26, 2013 and 507 of March 21, 2014.

Alternative Diagnosis of Alternatives

The Puerto Bahía of Colombia Company of Urabá S.A through communication 4120-E1-50880 of April 2010, requested the then Ministry of Environment, Housing and Territorial Development - MAVDT, pronouncement on the need for Environmental Diagnosis of Alternatives for the Port Terminal. The MAVDT through Auto 2417 of June 28, 2010, stated that the project did not require the presentation of environmental diagnosis of alternatives and set the terms of reference for the preparation of the Environmental Impact Study and made specific requirements.

Environment Effect Investigation

By Order No. 4120-E1-89762 of July 16, 2010 and supplemented by the filings No. 4120-E1-97290 of August 5, 2011, No.4120-E1-104997 of August 19 and No. 4120 -E1-1074721 of August 25, 2011, the Puerto Bahía of Colombia Company of Urabá SA presented an application for an environmental license for the project "Construction and Operation of a Port Terminal of Solid Bulk of Great Depth in Bahia Colombia"

The National Authority of Environmental Licenses - ANLA - granted by Resolution 0032 of january 25, 2012 the environmental license for the project of Construction and Operation of a Port Terminal of Solid Bulk of Great Depth in Bahía Colombia, in the Municipality of Turbo, department of Antioquia, with a capacity of 2.2 million tons / year , of imported grains.

The environmental license authorized the following works and / or activities both on land and at sea:

a. Projects:

- Open dock composed of a platform of 200m x 20m
- Loading and unloading the bride of solid bulk which supports the conveyor belt with a length of 3.75 km.
- Cable bridge that will support a bridge on the León River with a central light of 100 m and gauge of 15 m.
- Marginal services dock.
- Vertical silos 40m high x 9m diameter. Composed of three batteries of 8x4 = 32 silos each (total 96 silos), each with capacity to store 1,500 tons of bulk.
- 21 between silos with a capacity of 400 t each one.
- Physical plant composed of:
    - Administration building, billing, restaurant, cafeteria and meeting rooms, toilets, dressing rooms for operators.
    - Maintenance workshop for the port equipment, metalworking workshop.
    - Warehouse for storage of safety supplies, spare parts and lubricants.
    - Booth to protect the fire control equipment, emergency power plant and electrical substation in the service area.
    - Booth for gatehouse
- Internal roads, parking area and patios.

- Closing of the operations areas and the rest of the port land
- Drainage system, sewage and effluent treatment, revegetation and trunking of areas, collectors and drainage channels, sand trap, grease trap.
- Installation of a domestic wastewater treatment plant.
- Existing storage warehouse, as a storage center during the construction phase. It must be defined six months prior to the end of the construction stage, if the warehouse will be part of the construction port infrastructure.
- Camping installation for the construction stage.
- Improvement of the road access to port facilities.
- Storage tank for water pumped from the León River with a capacity of 30 m3.
- Tank or pool for water storage for fire control.

b. Ground construction activities:

- Land clearing and cleaning (extension of at least 70% of the land)
- Adaptation and construction of locative facilities
- Disposal, excavations, fillings and affirmed.
- Civil works on land and assembly of equipment.
- Demolition of administrative module and existing pier on the banks of the León River. It must be done before the start of the operation.

c. Construction activities at sea:

- Manufacture and driving of piles (located every 20 m)
- Armed and cast of heads and beams
- Embedment of the supports of the conveyor belt, bits and fenders.
- Armed and cast from the bridge plate and the dock.
- Installation of the conveyor belt, hoppers and unloader.

- Wiring link-ups dock services.
- Civil works at sea and assembly of equipment.

Finally, by means of ANLA 2015008528-1-000 dated February 20, 2015, the corporation Puerto Bahía Colombia de Urabá S.A. requested a ruling related to minor modifications or normal adjustment within the ordinary course of activity licensed in Resolution 0032 of January 25, 2012.

To which the National Authority of Environmental Licenses - ANLA, through the filing 2015008528-2-001 of March 13, 2015, authorized as ordinary turn of the activity licenses the construction of a viaduct as connection between the dock and the port terminal, this authorization does not imply changes in the structure of the hanging bridge over the León River, approved in the environmental license; nor the variation in the conditions of use, exploitation, and impact of renewable natural resources.

In reference to the inclusion of additional charges (containers, general cargo and vehicles) and works within the port terminal, said authority determined that Puerto Bahía Colombia de Urabá must present additional information related to the cargoes so that said authority can issue a declaration on the matter.

The proposal to build and operate a new maritime dock is not authorized within the ordinary course of business of the licensed activity, and therefore the procedure for modification of environmental license must be carried out in accordance with the provisions of Sectoral Decree 1076 of 2015

2.2 Scopes

The scope of this study is the modification of the Environmental License granted by Resolution 0032 of January 25, 2012, meeting all the legal requirements of the current environmental regulations and the terms of reference M-M-INA-05 issued by the ANLA; by means of the construction of the baseline corresponding to the abiotic, biotic and socioeconomic means, defining the activities of the extension of the platform in the marine area, the dredging of deepening of the access channel and maneuver area, realignment of the access road , changes in the type and capacity of cargo and cargo, and construction of the dock for the terminal on land; where the new environmental impacts identified and the adjustments to the management measures contemplated in the environmental management plan are evaluated.

The following is a list of the chapters included in this document:

Chapter 1. Objectives: The objectives of the project are defined considering the scope of the study.

Chapter 2. General: This chapter relates the content of the document, the objectives, background, normative framework and scope; describes the methodologies used for the construction of the baseline, the evaluation of environmental impacts, management zoning and other items requested by the terms of reference.

Chapter 3. Project description: It describes in a general way the current status of the project and the additional activities that are part of the modification of the Environmental license.

Chapter 4. Definition Influence Area: This chapter defines and delimits the influence areas of the project for the different components (abiotic, biotic and socioeconomic). Considering the potential impacts of the project on the different factors.

Chapter 5. Characterization of the Area of Influence: It is constructed from the definition of the areas of influence and is developed following the requirements of the terms of reference. For the characterization, primary and secondary information is used. From the analysis of the information, the elements of each of the three characterized factors (abiotic, biotic and socioeconomic) are described, following the methodologies established by the current environmental regulations and the methodology for presentation of environmental studies of the Ministry of Environment, Housing and Territorial Development, today Ministry of Environment and Sustainable Development.

Finally, an analysis of ecosystem services is presented.

Chapter 6. Environmental zoning: Environmental zoning is carried out, which determines the environmental sensitivity of the most relevant elements in each characterized environment, before the alterations of its current condition by any anthropic intervention.

Chapter 7. Demand, Use, Exploitation and / or Affectation of Natural Resources: It presents the summary of the status of the permits and concessions granted in force or in the process of being updated. Additionally, the need for the use and / or exploitation of additional natural resources is estimated for the activities subject to modification and the processing of associated environmental permits.

Chapter 8. Environmental Assessment: Identification and assessment of environmental impacts that may affect the area of influence, taking into account the activities subject to the modification of the Environmental license.

Chapter 9. Zoning of Environmental Management: According to the results of environmental zoning and impact assessment, the management zoning is spatially identified, in which the areas with environmental exclusion restriction, intervention with restriction or simply intervention are defined.

Chapter 10. Environmental economic evaluation: An analysis of the potential environmental costs and benefits generated by the project is presented.

Chapter 11. Plans and Programs: includes the Environmental Management Plan and the Monitoring and Monitoring Plan. This chapter establishes the programs and measures for prevention, mitigation, correction and / or compensation to be carried out in the abiotic, biotic and socioeconomic factors, considering the impact that may be generated during the execution of the Projects own activities.

In this chapter, **follow-up and monitoring measures** are also formulated to guarantee compliance with environmental management measures and follow-up programs to the environment impacted.

Additionally, the **risk management plan** is presented adjusted to the new characteristics of the project, where the plan is structured for prevention, attention and evaluation of unexpected events; following the risk analysis scheme identifying threats and vulnerabilities; so that later the strategic plans of the **contingency plan.**

Dismantling and abandonment plans The final use proposals and the morphological management and restructuring measures of the infrastructure areas directly intervened by the project they apply will be presented through the approach.

And finally, an update to the **1% investment plan** following the guidelines of Decree 1900 of 2006 and the **compensation plan for loss of biodiversity** according to the compensation allocation manual (Resolution 1517 of 2012)

2.3 Methodology

Below is the methodology of each of the means, abiotic, biotic and socioeconomic for the conduct of environmental studies of the Modification of Environmental License of the Project "Construction and Operation of a Port Terminal of Solid Bulk of Great Depth in Bahia Colombia ", So that it is a Multipurpose Port Terminal.

2.3.1 Abiotic environment

The methodology used for the development of the abiotic environment, generally consisted of:

1) Collection and review of secondary information of the area where the project will be located.

2) Generating of new information and update and complement the existing information of the Environmental Impact Study that supports the environmental license granted by Resolution 0032 of 2012 through field visits and corresponding samplings of marine and continental water, marine and continental sediments and environmental noise , among others.

3) Processing of the information.

The following is the methodology by component used for the competion of the environmental characterization of the abiotic environment:

2.3.1.1 *Geology*

The geology for the study area of the project was carried out taking into account the following items and was represented in maps with working scale 1: 10,000.

- ✓ *Lithology*

A geological survey was made to the project area through field trips, and with the help of aerial photographs, the regional geology was taken from geological studies that have been carried out in the region, while the description of the lithological units was taken from the POT of the municipality of Turbo, referencing its age, origin, thickness, distribution of the different units that emerge both in the area of influence and in the regional area. The spatial distribution of the lithological units was presented in a properly georeferenced plane and in an adequate scale.

- ✓ *Structural.*

The information on geological structures was obtained from geological studies carried out in the region, complemented by digital elevation models

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1 COLOMBIA. NATIONAL AUTHORITY OF ENVIRONMENTAL LICENSES - ANLA. Resolution 0032 (January 25, 2012). By means of which an environmental license is granted. Bogotá, D.C. 135 p.
2 NATIONAL HYDROCARBONS AGENCY -ANH. Geological Cartography and Structural Modeling of the Urabá and Sinú-San Jacinto Basins based on the Interpretation of Remote Sensing Images and Seismic Monitoring. 2009
3 GONZALEZ, H. Geological Map of the Department of Antioquia. Explanatory Memory INGEOMINAS, Map scale 1: 400,000. 2001
4 COLOMBIA. MUNICIPAL ADMINISTRATION OF TURBO. Territorial Planning Plan Municipality of Turbo. Turbo, 2000.
5 NATIONAL HYDROCARBONS AGENCY - ANH. 2009 Op. Cit.
6 GONZÁLEZ H. 2001. Op. Cit.

(DEM). The cartographic information obtained from the structural study was presented together with the lithological units indicated in the previous item, to generate in this way a geological map.

- ✓ *Geo threats*

An analysis was made of the possible threats that may affect the area where the project is proposed to be implemented. The threat analysis addressed the dynamic processes that are present in the geomorphological units (mentioned below), it was possible to establish the intensity with which they act in the natural environment and the possible effects that these processes could cause to the infrastructure. . The document International Strategy for Disaster Reduction - ISDR was consulted.

Regarding the seismic threat present in the region, information on seismicity was consulted.

2.3.1.2 *Geomorphology*

The geomorphological analysis was mainly approached from the photointerpretation, interpretation of remote sensors, this interpretation was verified with field visits, the geomorphological study included a characterization of the geoforms present in the study area, its spatial distribution was represented on a map with working scale 1: 10,000.

- ✓ *Dynamics of the processes*

In order to establish the dynamics of the morphosedimentary processes (erosive and sedimentary) that act on the different geoforms, a multi-temporal analysis was carried out with the help of aerial photographs (Table No. 2.1) obtained from different dates, from an aerial photograph of the IGAC of the year 1983, until the most recent of 2014 acquired by the project, with the purpose of observing the evolution of the geoforms during the last 30 years.

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7 INTERNATIONAL STRATEGY FOR DISASTER REDUCTION IN THE AMERICAS. [Online] <http://www.eird.org/esp/terminologia-esp.htm> [Accessed July 19, 2015].
8 TECTOCLUB2011. [Online] <https://tectoclub2011.wikispaces.com/Tectonica+de+Placas+Aplicada+a+Colombia> [Consulted 18, July, 2015].

Tabla No. 2.1 Recurso fotográfico para el área de estudio

Flight	Photo	Date	Scale
R – 1148	308	22/03/1989	1:12.000
R – 1148	446	22/03/1989	1:12.000
R – 973	293	09/08/1983	1:30.000

Source: Prepared by Aqua & Terra Consultores Asociados S.A.S, 2015.

- ✓ *Coastal and fluvial erosion processes*

To know the intensity with which the processes of erosion and / or coastal and fluvial sedimentation are presented, we proceeded in the first instance to define the coastlines of different dates:

For the lines of coast and margins of the Leon river of the years 1983 and 2014, they were traced digitally superimposed on corresponding aerial photographs properly georeflected.

For the coast lines corresponding to the years 1994, 2004 and 2009, the information in Shape format that AUGURA (Colombian Bananeros Association) owns was taken as a product of the multiple studies that it has carried out in the area (This information was obtained of surveys with GPS)

Once the tracings of the shorelines were acquired, they were deployed spatially using the ArcMap software in order to compare them to know the evolution they have followed.

- ✓ *Evolution of the León River Delta*

The evolution of this sediment body was made possible through the multitemporal analyzes carried out on the bathymetric surveys carried out by AUGURA in 2007 and 2013. This information was complemented with the interpretation of the aforementioned aerial photographs.

- ✓ *Morphology of funds*

In order to know the morphology of the seabed in the area of influence of the project, an analysis of the shapes of the isobaths obtained from the bathymetric survey carried out in May 2014 was carried out.

2.3.1.3 *Landscape*

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9 It is a proprietary spatial data file format developed by the company ESRI, who creates and markets software for Geographic Information Systems.

To determine the landscape of the area of influence of the project, it was evaluated from various points of view both ecological (abiotic and biotic) and sociocultural. In the first instance, the basic cartography and POT mapping information of the municipality of Turbo 2000 and 2012, Atlas of the Gulf of Urabá and the use of the available geographic information portals contained in the IGAC website, SIG-OT, were identified. INVEMAR

Additionally, for the assessment of the visibility and landscape quality analysis, the landscape units were carried out in the first phase with the methodology used by Peralta and Landscape Aesthetics A Handbook for Scenery Management, in the second phase the criteria for assessing the landscape are described the landscape in terms of models of visual quality of the landscape where several methodologies were used, among which are those defined by Montoya et al based on the models of the authors such as Aguiló (1981) and Aramburo (1994) and by Cañas en the introduction: main considerations to take into account in landscape-constructions. For the analysis of the information, the Geographical Information System - GIS with the superposition of layers was used.

Below are the criteria defined for the determination of the unity of the landscape, analysis of landscape visibility, visual quality of the landscape and sites of scenic interest, according to the characteristics of the study area and the information available.

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10 COLOMBIA. MUNICIPALITY OF TURBO. Land Management Plan: physical-environmental diagnosis. Turbo: 2000
11 MUNICIPALITY OF TURBO. Agreement 022 (2012) Land Management Plan - POT. Turbo, 2012.
12 INSTITUTE OF MARINE AND COASTAL INVESTIGATIONS JOSÉ BENITO DE ANDREÍS (INVEMAR) and GOVERNMENT OF ANTIOQUIA. Atlas of the Gulf of Urabá: a look at the Caribbean of Antioquia and Chocó. Series of special publications No. 12. Santa Marta: 2007. 180 pages. ISBN 978-958-98104-3-9.
13 GEOGRAPHIC INSTITUTE AGUSTÍN CODAZZI -IGAC. [Online] <http://www.igac.gov.co/igac> [Accessed 28, July, 2015]
14 GEOGRAPHICAL INFORMATION SYSTEM FOR PLANNING AND TERRITORIAL ORDINATION-SIG-OT. [Online] <http://sigotn.igac.gov.co/sigotn/> [Accessed 28, July, 2015]
15 INSTITUTE OF MARINE AND COASTAL INVESTIGATIONS JOSÉ BENITO DE ANDREÍS- INVEMAR; MARINA AND COASTAL ENVIRONMENTAL INFORMATION SYSTEM - SIAM. [Online] <http://siam.invemar.org.co/siam/index.jsp> [Accessed 28, July, 2015]
16 PERALTA, Eduardo. Model to determine landscape units for environmental impact studies of hydroelectric projects. The case of the Savegre-Costa Rica river basin. In: XII Meeting of geographers of Latin America Montevideo - Uruguay [Online]. http://observatoriogeograficoamericalatina.org.mx/egal12/ Procesosambientales / Geomorfologia / 34.pdf [Quoted 22, July, 2015]
17 UNITED STATES DEPARTMENT OF AGRICULTURE. Landscape Aesthetics A Handbook for Scenery Management. Agriculture Handbook Number 701. 1995. 104 p.
18 MONTOYA, Raymundo., PADILLA, Jorge., STANFORD, Sergio. Assessment of the quality and visual fragility of the landscape in the Valley of Zapotitlán de las salinas, Puebla (Mexico), 2003. In: Bulletin of A.G.E. No. 35, p. 123 - 136.

19 CAÑAS GUERRERO, Ignacio. Introduction: Main considerations to take into account in buildings - Landscape. [online] <http://www.grupoinvestigacionpadoc.com/upload/presenta%20impacto_paisajistico.pdf> [Accessed 23, July, 2015]

- Landscape units

To restrict the units of the landscape, a methodology of Ian Mc-Harg used by Peralta, also known as overlap, was used, which consists of the development of a series of thematic maps, one for each environmental variable, presenting the data organized by category , they are superimposed and a synthesis map of the landscape units in the study area is generated. The variables used for the definition of landscape units were based on the methodology mentioned above and the one proposed in Landscape Aesthetics A Handbook for Scenery Management, and a spatial distribution of the dominant ecological factors affecting the structure and functional attributes of the ecosystem was carried out:

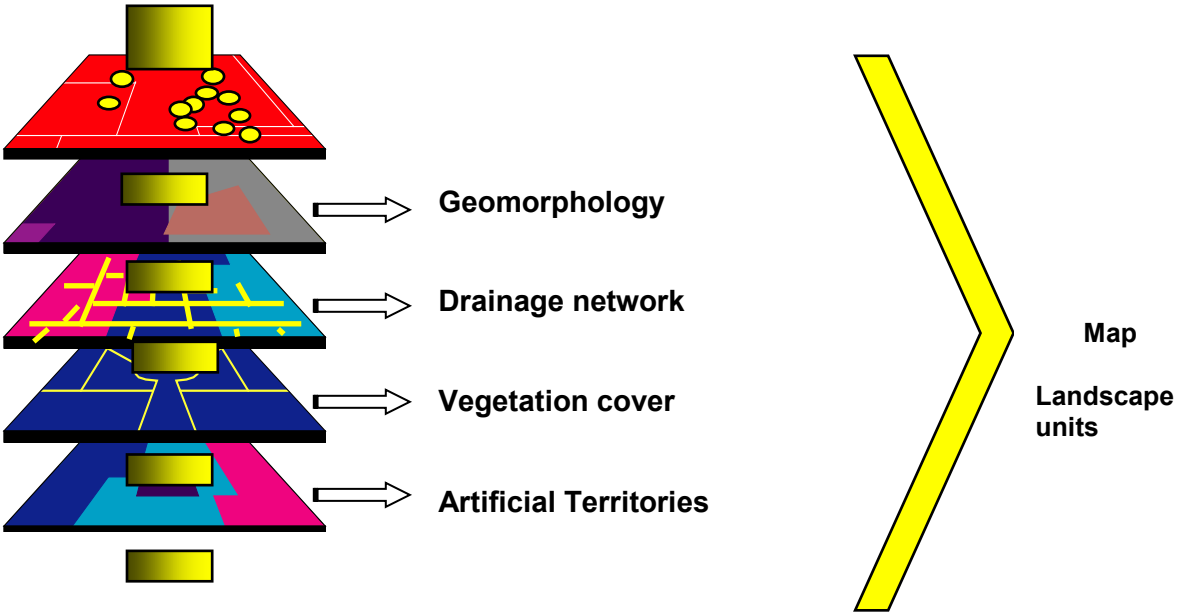

Figure No. 2.1 Model Landscape Units
Source: Aqua & Terra Consultores Asociados S.A.S, 2015 Modified from Peralta

Later, in order to obtain the boundaries of the landscape units, the different layers were crossed with the help of the Geographical Information System - GIS tool, which is presented on a map at a scale of 1: 10,000 or more detailed. Figure No. 2.1

graphically presents the process of obtaining the landscape units in the study area of the project from the abiotic, biotic and sociocultural factors.

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[1]20 PERALTA. Op cit.

To obtain the map of landscape units, the layers of the defined components were crossed, see Figure No. 2.2.

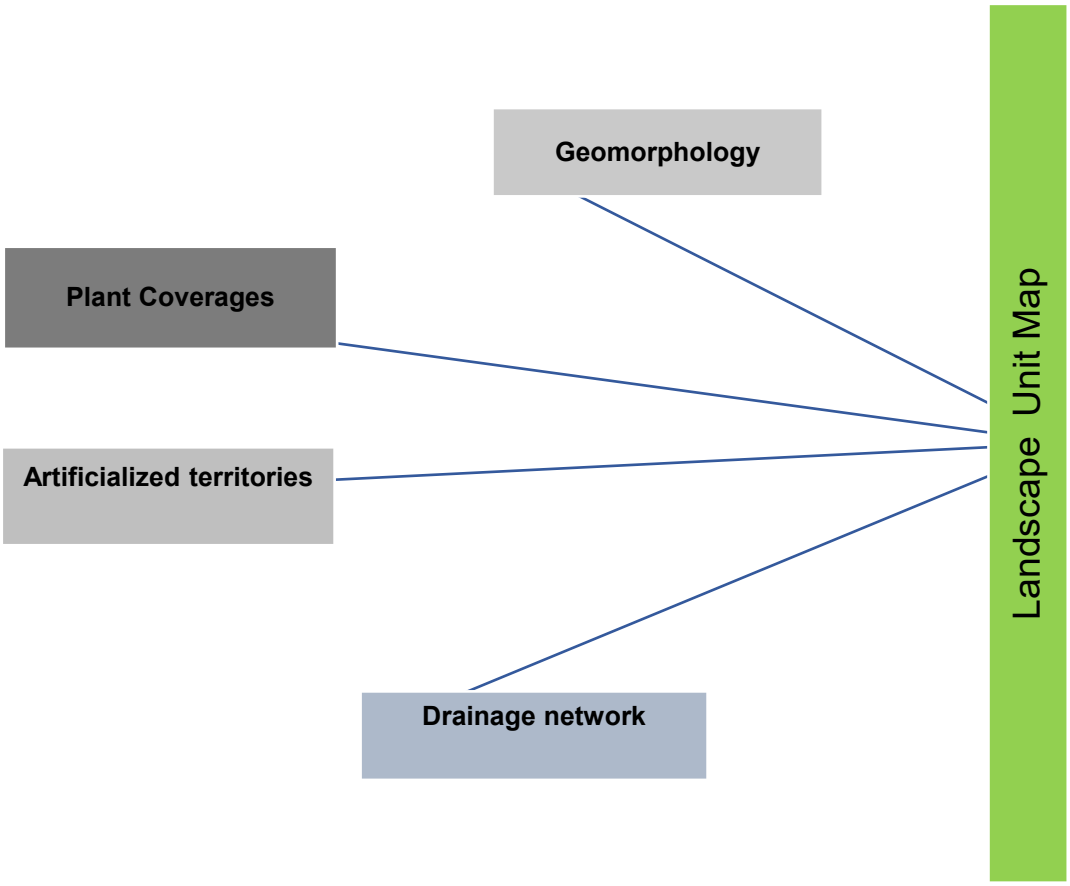

Figure No. 2.2 Flow diagram of the developed model
Source: Aqua & Terra Consultores Asociados S.A.S, 2015 Modified from Peralta

- Lanscape Visibility Analysis

For the analysis of the visibility of the landscape, observers were proposed in the scenic sites that allows to enjoy the landscape of the study area and the visual plane is determined according to the distance of the observer according to the provisions of Landscape Aesthetics A Handbook for Scenery Management and adjusted according to the characteristics of the project area.

The visual scale is classified in close, medium and distant plane from horizontal distance of the trails, waterways and water network, which are the transit routes of the observers. It should be mentioned that the project area is located in a lacustrine fluvial plain landscape with few differences in altitudes, therefore, it was not done with visibility by dimensions. Table No. 2.2 presents the scale of landscape visibility analysis proposed.

Table No. 2.2 Scale analysis of landscape visibility

Visual scale	Distance of the observer	Nomenclature
Far plane	Horizontal distance >1.000 meters	Pl
Medium plane	Horizontal distance ≥ 300 meters ≤ 1.000 meters	Pm
Close plane	Horizontal distance < 300 meters	Pc

Source: Aqua & Terra Consultores Asociados S.A.S, 2015 Modified by United States Department of Agriculture, 1995.

- Visual quality of the landscape

Regarding the assessment of the visual quality of the landscape, the methodology used is that indicated by Montoya et al with modification of the qualification criteria according to the study area. In the application of the visual quality model variables were used that were considered to define the visual quality of the landscape, among them the physiography, plant cover and land uses, water drainages or film of water and degree of humanization (roads and urban centers), as presented in Figure No. 2.3.

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21 UNITED STATES DEPARTMENT OF AGRICULTURE, 1995. Op cit.
22 MONTOYA, Raymundo., PADILLA, Jorge., STANFORD, Sergio. Assessment of the quality and visual fragility of the landscape in the Valley of Zapotitlán de las salinas, Puebla (Mexico), 2003. In: Bulletin of A.G.E. No. 35, p. 123 - 136.

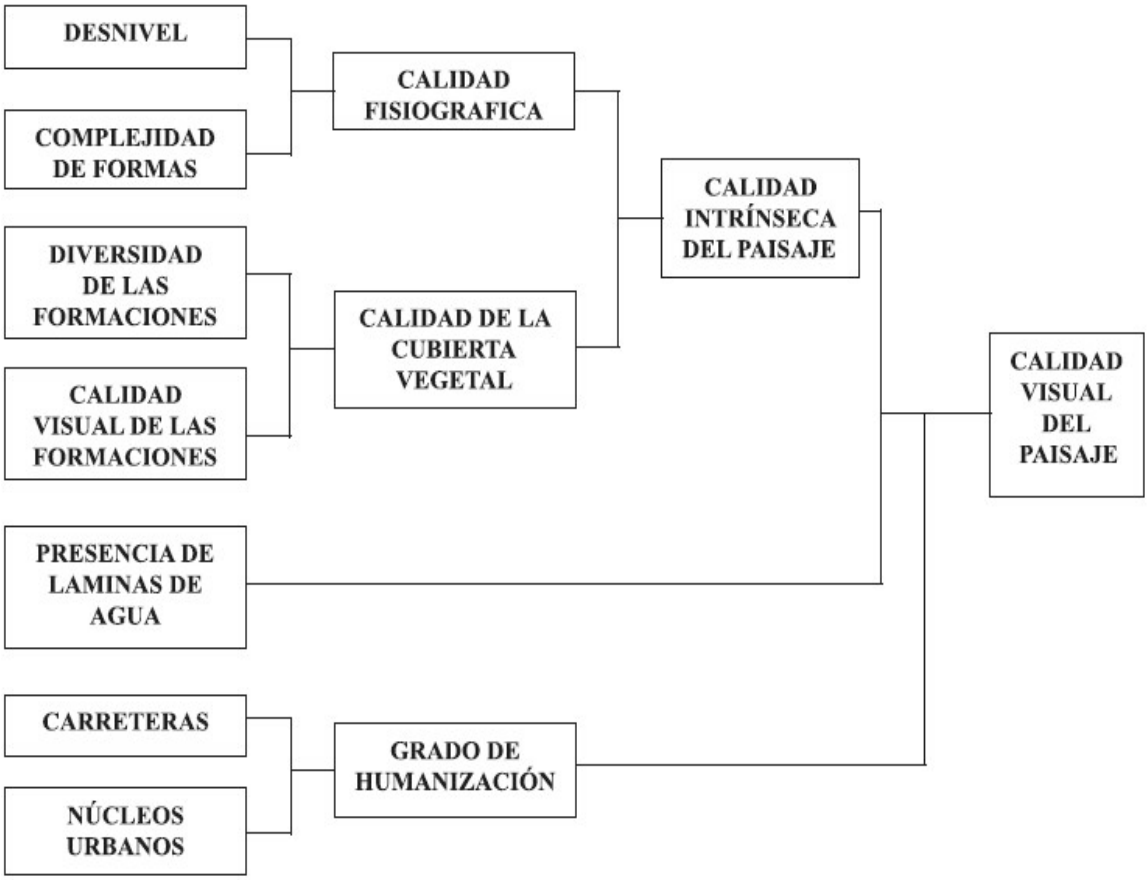

Figure No. 2.3 Model of Visual Quality of the Landscape
Source: Montoya et al, 2003[1]

Quality Physiography

23[1] MONTOYA et al, 2003. Op Cit.

It was assessed according to two aspects: slope and complexity of shapes or topography.

Valuation by altitude. Where, at a higher altitude, the visual quality of the landscape is greater. It is worth mentioning that the project area is relatively flat and therefore does not have representative altitudes, in this sense, the highest altitudes of the geoforms located on the outskirts of the river bank and coastline were considered (see Table No 2.3).

Table No. 2.3 Valuation by altitude

Environmental criteria	Visual quality	Rating value
Level 0_Cota 0 msnm	Low	1
Level I_Cota between >0 and <2 msnm	Medium	2
Level 2_Cotas >2 msnm	High	3

Source: Aqua & Terra Consultores Asociados S.A.S., 2015

Quality of the plant cover

The vegetation and the current land uses are a fundamental factor to evaluate the quality of the landscape because it is an extensive element throughout the territory. It was assessed as the best visual landscape quality, the coverage that is closer to the natural vegetation in a state or those uses that due to its traditional nature, are already integrated into the environment.

Diversity of vegetation cover formations. The highest quality of landscaping was assigned to the presence of areas with forest and of lower quality those areas with agricultural vegetation cover (see Table No. 2.4).

Table No. 2.4 Assessment for the diversity of vegetation cover formations

Environmental criteria	Visual quality	Rating value
Agricultural territories	Low	1
Areas with herbaceous and/or shrubby vegetation	Medium	2
Areas with presence of forest	High	3

Source: Aqua & Terra Consultores Asociados S.A.S., 2015

Diversity of formations of current land use. Greater quality of landscaping was assigned to the use of conservation and protection, of lower quality those areas with residential and industrial use (see Table No. 2.4).

Table No. 2.5 Assessment for the diversity of formations of current land use

Environmental criteria	Visual quality	Rating value
Residential and industrial	Low	1
Agriculture and livestock	Medium	2
Conservation and protection	High	3

Source: Aqua & Terra Consultores Asociados S.A.S., 2015

Presence of water

The presence of bodies of water in a landscape is constituted as an element of better visual quality in the landscape (see Table No. 2.6).

Table No. 2.6 Assessment for the presence of water

Environmental criteria	Visual quality	Rating value
Absence of bodies of water	Low	1
Presence of bodies of water	High	3

Source: Aqua & Terra Consultores Asociados S.A.S., 2015

Degree of humanization

The degree of humanization is associated with artificial structures, which suppose a decrease in the quality of the landscape. To measure the distribution of these variables in the territory, two criteria were used: presence of roads and presence of urban, industrial or population areas.

Presence of roads. The main road network (asphalted secondary or intermunicipal road) has been valued with lower visual landscape quality due to its greater constructive requirements, followed by an average rating for the rural roads without asphalt and higher quality the absence of roads (see Table No. 2.7).

Table No. 2.7 Assessment for the presence of roads

Environmental criteria	Visual quality	Rating value
Presence of asphalted roads	Low	1
Presence of roads without asphalt	Medium	2
Absence of roads	High	3

Source: Aqua & Terra Consultores Asociados S.A.S., 2015

Presence of urban nuclei or populations. The areas occupied by urban nuclei and of higher quality areas without population have been assessed with lower visual quality (see Table No. 2.8).

Table No. 2.8 Assessment for the presence of urban nuclei or populations

Environmental criteria	Visual quality	Rating value
Continous urban fabric and/or industrial zones	Low	1
Discontinous urban fabric	Medium	2
Areas without populations	High	3

Source: Aqua & Terra Consultores Asociados S.A.S., 2015

Result of the application of the landscape visual quality model

After obtaining the categorized criteria, the result of the application of the quality model allows each of the landscape units to be assessed according to their landscape quality or scenic integrity, these will be analyzed with the Geographical Information System - GIS tool, having considered the following rating scale established in five (5) classes (see Table No. 2.9). Additionally, an analysis of the visual quality of the landscape units in the study area is carried out:

- ✓ Class I represents Very Low quality. It indicates that the landscape visually has a very altered scenic condition or landscape quality, that is, when existing elements, both natural and cultural, do not show harmony with each other or with the environment.
- ✓ Class II represents low visual quality. It indicates that the landscape visually presents a moderate alteration of the form of the landscape.
- ✓ Class III represents moderate visual quality. Indicates that the landscape visually has a scenic condition or landscape quality slightly altered.
- ✓ Class IV represents high visual quality. It indicates that the landscape visually has a scenic condition or landscape quality that seems unaltered.
- ✓ *Class V* represents visual quality Very High. Indicates that the landscape visually has a scenic condition or unaltered landscape quality, that is, when there is harmony between the elements of the unit and the environment being pleasant to the contemplation of it.

Table No. 2.9 Scale for assessing environmental criteria for visual quality or scenic integrity of the landscape

Class	Rating (points)	Visual Quality	Scenic Integrity
Class I	6 - 8	Very low Visual quality	Very Low (very unsettled)
Class II	>8 - 10	Low Visual quality	Low (Moderately altered)
Class III	>10 - 13	Moderate Visual quality	Moderate (Mildly altered)
Class IV	>13 - 15	High Visual quality	High (It seems unchanged)
Class V	>15 - 18	Very High Visiual quality	Very High (unchanged)

Source: Aqua & Terra Consultores Asociados S.A.S., 2015

It is worth mentioning that for the total qualification of the visual quality that is generated in the crossing of the layers of the previously established variables, an adjustment was made in the sum of the criteria in order to balance the result when there are criteria that do not apply to all landscape units. That is, if all the criteria are applied (6 criteria) it is 100%, if only five (5) criteria are applied it is 83%, then the

sum is divided by the percentage (according to the number of criteria) to obtain the true value of visual quality and then classify it according to the ranges of Table No. 2.9.

- Sites of scenic interest or scenic attractions

The sites of scenic interest were identified with secondary information and field trips, in order to verify the information obtained and the current status of vegetation coverage, land use and geomorphology of the study area.

For the classification and assessment of the current status of sites with scenic appeal in the area of influence of the project, it was classified according to the methodology established in Landscape Aesthetics A Handbook for Scenery Management and in the classes proposed in the model of data from the ANLA geodatabase, as presented in Table No. 2.8.

Table No. 2.10 Classes of scenic attractions

Ítem	Classes of scenic appeal	Nomenclature
1	Deteriorated	Dt
2	Common o typical	Cm o Tp
3	Singular	Sg

Source: United States Department of Agriculture. Landscape Aesthetics A Handbook for Scenery Management, 1995.

- Perception of communities as referents of their physical environment in cultural terms.

The description of the perception of the landscape in cultural terms was made with secondary information and field trips, in order to verify the information obtained from the population.

24UNITED STATES DEPARTMENT OF AGRICULTURE. Landscape Aesthetics A Handbook for Scenery Management. Agriculture Handbook Number 701. 1995. 104 p.
25 NATIONAL AUTHORITY OF ENVIRONMENTAL LICENSES - ANLA. Update of the design and structure of the data model of the geodatabase for the presentation of the environmental diagnosis of alternatives - DAA, Environmental Impact Studies - EIA, Specific Environmental Management Plans - PMA, Environmental Compliance Reports - Ica and compensation and investment 1% . Bogotá D.C, 2012.

- Seafloor landscape

To identify the landscape units present in the seabed of the Gulf of Urabá in Bahía Colombia, it was necessary to resort to the study of "continental, coastal and marine ecosystems of Colombia" and the Atlas of the Gulf of Urabá, to define the existing

type of background in the sector of the mouth of the León River in Bahía Colombia, according to the marine geomorphology, the patterns of oceanographic circulation, bathymetries, marine water quality, climatology and the substratum of the seabed.

2.3.1.4 *Soils and land use*

To determine the classification of the soils for the 1: 10,000 scale of detail of this study, the methodology designed by the United States Department of Agriculture (USDA), adjusted and adopted by the Agustín Codazzi Geographic Institute (ACGI), was used. Among its main stages are the following:

Review and evaluation of existing secondary information: The stage consists of an analysis of the information developed, such as the General Survey of Soils and Land Zoning of the Department of Antioquia, the Land Management Plan of the municipality of Turbo and the study of land use capacity in Colombia. The information regarding: climate, geology, geomorphology and current coverage of the land was also analyzed and evaluated; information that served as support to determine the factors of greater incidence in the processes of formation and evolution of soils.

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26 INSTITUTE OF HYDROLOGY, METEOROLOGY AND ENVIRONMENTAL STUDIES - IDEAM, INSTITUTO GEOGRÁFICO AGUSTÍN CODAZZI - IGAC; INSTITUTE OF RESEARCH OF BIOLOGICAL RESOURCES ALEXANDER VON HUMBOLDT - IavH; INSTITUTE OF MARINE AND COASTAL INVESTIGATIONS JOSÉ BENITO VIVES DE ANDRÉIS - INVEMAR; INSTITUTO AMAZÓNICO DE INVESTIGACIONES CIENTÍFICAS SINCHI -I.SINCHI; INSTITUTE OF ENVIRONMENTAL RESEARCH OF THE PACIFIC JHON VON NEUMAN - IIAP. Continental, coastal and marine ecosystems of Colombia. Sheet 12 of 36. Scale 1: 500,000. [Online] <http://www.invemar.org.co/portal_old/noticias.jsp?id=3458&idcat=104> [Accessed 24, July, 2015]

27 INSTITUTE OF MARINE AND COASTAL INVESTIGATIONS JOSÉ BENITO DE ANDREÍS (INVEMAR) and GOVERNMENT OF ANTIOQUIA. 2007. Op Cit.

28 SOIL SURVEY STAFF, Keys to Soil Taxonomy, United States Department of Agriculture, USDA, Ninth Edition. Washington D.C., 2006

29 GEOGRAPHIC INSTITUTE AGUSTÍN CODAZZI -IGAC. General study of soils and land zoning of the department of Antioquia. National Printing of Colombia. Bogotá 2007. 1071 p

30 Ibid.

31 COLOMBIA. MUNICIPAL MAYOR OF TURBO. Agreement 022 of 2012. Whereby an ordinary revision to the Territorial Planning Plan of Turbo municipality is approved and new articles are modified, repealed and incorporated into Agreement 015 of July 25, 2000 and Agreement 09 of 2009 is repealed. Antioquia 2012, 155 p

Basic cartography and aerial photographs were also acquired for the study area.

Photointerpretation: The physiographic photointerpretation was carried out, with the following aerial photographs (see Table No. 2.11):

Table No. 2.11 Photographic resource for the study area

Flight	Photo	Date	Scale
R – 1148	308	22/03/1989	1:12.000
R – 1148	446	22/03/1989	1:12.000

Flight	Photo	Date	Scale
R – 973	293	09/08/1983	1:30.000

Source: Aqua & Terra Consultores Asociados S.A.S, 2015.

Similarly, an orthophoto of 2014 was used to interpret land cover and current land use; which were verified during the field stage.

To define and classify the soil units, hierarchizing them in the following order, climate, landscape, type of relief and landform. This interpretation is fundamental to infer the soil-landscape relationship, which goes beyond just geomorphology, but also the incidence of climate, geology and coverage. The final result of this stage is the construction of the soil legend for the area of influence of the project.

As for the cartography, the cartographic units of soils are presented, divided in the form of cartographic phases by slope, erosion and flood and / or ponding, other phases like surface stoniness, etc. can also occur.

The phase by slope can be presented in one of the seven classes established by the IGAC and represent the ranges and classes as can be seen in Table No. 2.12.

Table No. 2.12 Ranges and classes of slopes

Phase	Range	Class
a	0 - 3%	Slightly flat
b	3 - 7%	Slightly inclined or way
c	7 - 12%	Moderately tilted or wavy or slightly broken
d	12 - 25%	Strongly inclined or wavy or moderately broken
e	25 - 50%	Strongly broken or slightly steep or rugged
f	50 - 75%	Moderately steep or rugged
g	> 75%	Strongly steep or rugged

32GEOGRAPHIC INSTITUTE AGUSTÍN CODAZZI - IGAC, 2007. Op Cit.

Source: INSTITUTO GEOGRÁFICO AGUSTÍN CODAZZI - IGAC, 2007

Once the classification of the soil units and their limitations were identified, the grouping of the soils by agrological classes was made based on their capacity to produce cultivated plants (crops, pastures, forests), for long periods of time without deterioration of the resource is present; This classification is made according to the number of edaphic limitations that a soil may have. In addition, generalizations can be made based on the potential of the soils and the limitations regarding their use and management.

According to the agrological class, the classification of the potential use of the soil is carried out, so that as the agrological class increases, the number of crops that can

be produced decreases since the limiting factors are more drastic, at the same time as the conservation practices that must be carried out to protect the soil resource.

To determine conflicts over land uses, the interpretation of current use and potential use will be confronted to evaluate management and conservation practices according to the presence or not of limitations for use and their intensity levels; For this purpose, the decision matrix shown in Table No. 2.13 will be used, which was constructed based on the methodology established by IGAC and CORPOICA in 2002.

Table No. 2.13 Decision matrix used to classify conflicts over land use

Potential Use		Current Use									
		Agricultural	Livestock	Forest		Conservation			Residential		Industrial
Main type of use		Permanant semi-permanent and intensive crops	Intensive and semi-intensive grazing	Protection	Production	Protective Forest	Water resources	Recuperation	Settlement	Populated center	Industrial or commercial zones
Agrícultaral	Semi – permanent and semi-intensive permament crops	A	S1	S3	S3	S3					
Livestock	Grazing intensive and semi-intensive		A	A	S3	S3		A			
Conservation	Protective Forest	O3		A		A	A	A			
	Water resources			A		A	A				
Industrial	Industrial or commercial zones										ZU
Residential	Settlement								ZU		
	Populated center									ZU	

Source: IGAC, adapted by Aqua & Terra Consultores Asociados S.A.S., 2015

33Ibid.
34 GEOGRAPHIC INSTITUTE AGUSTÍN CODAZZI - IGAC and COLOMBIAN CORPORATION OF AGRICULTURAL RESEARCH - CORPOICA. Zoning of land use conflicts in the country. Chapter IV. Proper use and conflicts of land use in Colombia. IGAC, Bogotá D.C., 2002. 106 p.

In Table No. 2.13, the following categories are established for the classification of the land use conflict according to the decision matrix between potential use and current use:

Lands without conflict of use (A): Are called lands where the current dominant use corresponds to the vocation of main use or compatible use. Current use does not cause environmental deterioration.

Conflicts due to underutilization (S): Is the given rating where the current dominant use corresponds to a lower level compared to the vocation of main use or that of compatible uses, there are three degrees of intensity:

Slight underutilization (S1): Land whose current use is very close to the main one, therefore to compatible uses and are evaluated as less intense.

Moderate underutilization (S2): Land whose current use is below, in two levels of the recommended primary use class, according to the production capacity of the land.

Severe underutilization (S3): Land whose current use is far below, in three or more levels of the recommended primary use class.

Conflicts due to overuse (O) : Is the given rating where the current dominant use is more intense in comparison with the vocation of natural main use assigned to the land. They are subdivided into the following degrees of intensity:

Slight over-use (O1): Land whose current use is very close to the main use, but which has been evaluated with a level of intensity greater than the recommended level and, therefore, that of compatible uses.

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[1]35 Ibíd.

Moderate over-use (O2): Land in which the current use is above, in two levels, of the class of vocation of recommended main uses, according to the production capacity of the land.

Severe overuse (O3): Land in which the current use exceeds in three or more levels, the class of vocation of recommended main uses, presenting evidence of advanced degradation of resources, such as severe erosion processes, decreased productivity of the lands, salinization processes, among others.

Urbanized Zone (UZ): is the given rating where the current use are population centers, industrial and commercial zones, which correspond to the main use vocation assigned as industrial, commercial zones, settlements and population centers.

2.3.1.5 *Hidrology*

The analysis and review of the hydrological aspects was carried out with the existing information of the Environmental Impact Study that supports the environmental license granted by Resolution 0032 of 2012. Additionally, with secondary information, the required information was supplemented. However, it is important to bear in mind that the project will not require the direct intervention of the León River, the main stream in the area of influence.

2.3.1.6 *Water and sediment quality for inland and marine waters*

For the analysis of water quality and continental and marine sediments, secondary information was collected through historical results of the program stations of the Quality Monitoring Network of Marine and Coastal Waters of Colombia - REDCAM from 2001 to 2014 (located in Bahía Colombia and León River) and information from the Environmental Impact Study that supports the environmental license granted through Resolution 0032 of 2012. In

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36COLOMBIA. NATIONAL AUTHORITY OF ENVIRONMENTAL LICENSES - ANLA. Resolution 0032 (January 25, 2012). Op cit.
37INSTITUTE OF MARINE AND COASTAL RESEARCH "JOSE BENITO VIVES DE ANDRÉIS" - INVEMAR, INFORMATION SYSTEM OF THE MARINA ENVIRONMENTAL QUALITY SURVEILLANCE NETWORK OF COLOMBIA - REDCAM. [Online] <http://siam.invemar.org.co/siam/redcam/index.jsp> [Accessed 11, August, 2015]
38 PUERTO BAHÍA COLOMBIA DE URABA S.A. and ARAÚJO IBARRA & ASOCIADOS S.A. Environmental impact study for the construction and operation of a port terminal of solid bulk. Turbo. 2010. 428 p
39 COLOMBIA. NATIONAL AUTHORITY OF ENVIRONMENTAL LICENSES - ANLA. Resolution 0032 (January 25, 2012. Op cit.

order to corroborate this information, primary information was available where quality water and sediment samples were taken in continental and marine waters in the month of July between the 7th and the 8th of 2015 in the stations located in the areas of intervention of the project with a laboratory accredited to the IDEAM.

For this case, the SGS COLOMBIA SAS laboratory was contracted, which has the following accreditations and acknowledgments: IDEAM Accreditation Resolution 0899 of July 3, 2015 for the parameters: pH, Temperature, Dissolved Oxygen, Conductivity, Real Color, BOD5, COD , Greases and Oils, Detergents, Total Nitrogen, Calcium Hardness, Total Hardness, Dissolved Solids, Sedimentable Solids, Total Suspended Solids, Total Solids, Turbidity, Fecal Coliforms, Total

Coliforms, Polynuclear Aromatic Hydrocarbons, Phenols, Cadmium, Barium, Calcium, Nickel , Silver, Lead, Selenium, Copper, and Mercury.

For the remaining analyzes SGS COLOMBIA S.A.S subcontracted other accredited laboratories. Next, the relation parameter - subcontracted laboratory.

Table No. 2.14 Parameter relationship of subcontracted laboratory

PARAMETER	LABORATORY	ACCREDITED WITH
Total Zinc	Daphnia Ltda.	Resolution 0983 of the IDEAM
Total Arsenic	Chemilab.	Resolution 2016 of the IDEAM
Clorophyll	Coast zones	Resolution 0504 of the IDEAM

Source: SGS Colombia S.A.S., 2015

- ✓ *Sampling stations for water quality and continental and marine sediments*

Table No. 2.15 shows the Magna Sirgas flat coordinates from the Bogotá sampling stations defined for the analysis of water quality and continental and marine sediments in the study area of the Project and in Figure No. 2.4 and in Figure No. 2.5 shows the location of these stations.

Table No. 2.15 Location of sampling stations water quality and continental and marine sediments

ID	Station Name	FLAT COORDINATES MAGNA SIRGAS Origin BOGOTÁ	
		East	NORTH
A1	Station upstream of the León River	706.327,33	1.368.671,49
A2	Station downstream of the León River	705.956,74	1.369.095,03
A3	Viaduct Station	703.792,94	1.371.083,51
A4	Maneuvering Area Station 1	702.783,75	1.370.390,87
A5	Maneuvering Area Station 2	702.487,86	1.371.110,59
A6	Maneuvering Area Station 3	702.943,68	1.371.628,00
A7	Access Channel Station Phase I	702.099,85	1.371.870,99
A8	Control point station	696.387,84	1.372.825,31
A9	Landfill	697.792,41	1.375.464,03

Source: Prepared by Aqua & Terra Consultores Asociados S.A.S, 2015

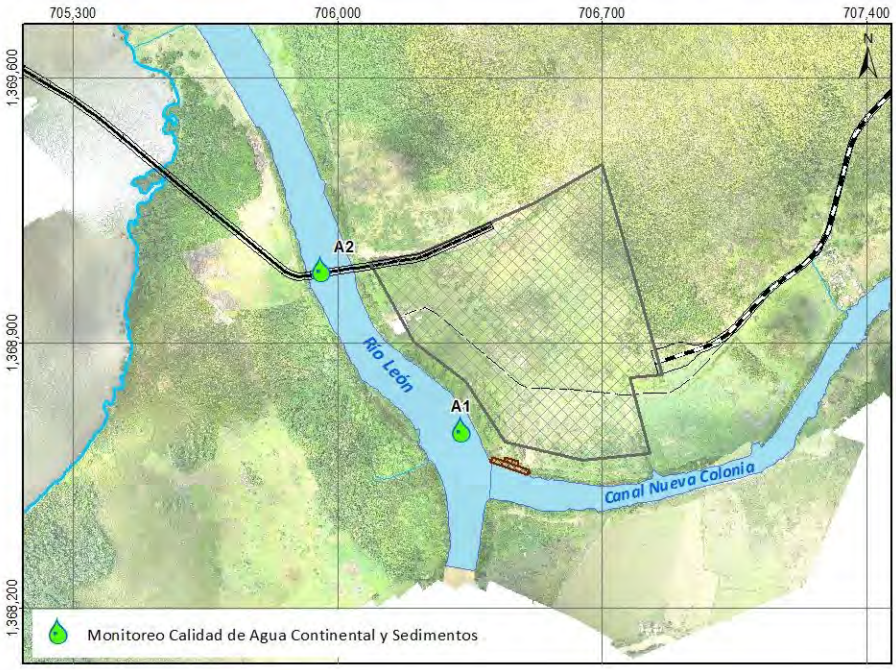


Figure No. 2.4 Location of sampling stations for water quality and continental sediments
Source: Prepared by Aqua & Terra Consultores Asociados S.A.S, 2015

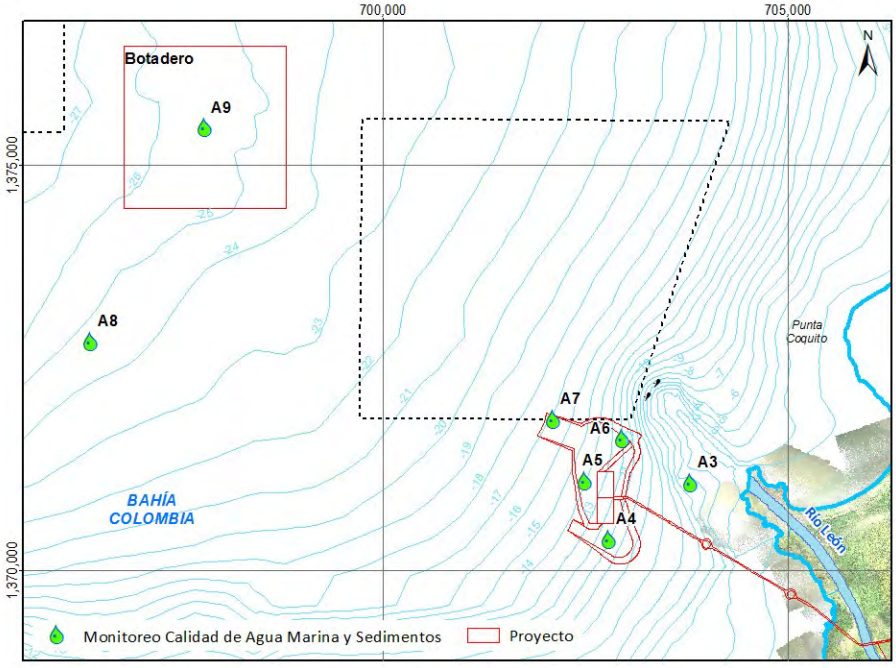


Figure No. 2.5 Location of sampling stations for water quality and marine sediments
Source: Prepared by Aqua & Terra Consultores Asociados S.A.S, 2015

- ✓ *Water quality and continental sediments*

In order to know the quality of the water and continental sediments on the León River, two (2) stations located in the area of influence of the project were defined.

Type of sampling continental waters

An integrated type sampling was carried out in the depth and in the cross section in two (2) stations distributed over the León River (downstream of the confluence of the Nueva Colonia Canal to the León River and downstream of the bridge that will be built over the León River). The stations were defined with the objective of verifying the influence that the construction and operation of the dock and the bridge on the water quality of the León River can have.

Parameters evaluated

In accordance with the terms of reference established by Resolution 0112 of 2015 for large-scale seaports, the parameters presented in Table No. 2.16 for the physicochemical and bacteriological characterization of continental water and in Table No. 2.17 were considered. the physical-chemical characterization of the sediments, which will be susceptible to intervention by the construction and operation of some project works on the León River.

The measurement of the physicochemical parameters were carried out under technical standards and methods officially accepted in the Standard Methods for the Examination of Water and Wastewater 22nd Edition 2012, in the officially accepted methodologies and under the criteria established by Decree 1076 of 2015 by the Ministry of Environment and Sustainable Development.

Table No. 2.16 List of physicochemical and bacteriological parameters of continental water

Characterization	Parameter	Unit	Preservation	Analysis method
Physical	Temperature	°C	–	S.M 4500 H-B Potentiometric NA-A
	Total suspended solids	mg/L	Refrigeration	SM 2540 D -Gravimeter -A
	Total disolved solids	mg/L	Refrigeration	SM 2540 C - Gravimeter -A
	Sedimentable solids	mL/L–h	Refrigeration	SM 2540 F - Gravimeter -A
	Electric conductivity	µS/cm	—	SM 2510 B Electrometric – NA-A
	Potential of Hydrogen – pH	Units of pH	—	S.M 4500 H-B Potentiometric NA-A
	Turbidity	UNT	Refrigeration in the dark	SM 2130 B Nephelometric – 1.14 NTU - A

Characterization	Parameter	Unit	Preservation	Analysis method
	Color Real	m^{-1}	Refrigeration	SM 2120 C Spectrophotometric 6.3 UPC -A
Chemistry	Dissolved Oxygen (DO)	mg/L	–	EPA 360.3 Electrodo de Luminescence –NA-A
	Chemical Oxygen Demand (COD)	mg/L O_2	Refrigeration + H_2SO_4 Up to pH<2	SM 5220 D Colorimetric closed reflow - A
	Biochemical Oxygen Demand at five (5) days (BOD5)	mg/L O_2.	Refrigeration	SM 5210 B / 4600 O G Modified -A
	Total Nitrogen Kjeldahl	mg/L NTK	Refrigeration	SM 4500- Norg and 4500 NH3 B,C – Destilation/volumetric -5.16 -A
	Total phosphorus	mg/L P	Refrigeration	S.M .4500-P B and E Colorimetric - A
	Fats and oils	mg/L	Refrigeration + H_2SO_4 Up to pH <2	NTC 3362 - Method C Infrared Partition -A
	Total Alkalinity	mg/L $CaCO_3$	Refrigeration	S.M 2320 –B- Volumetric -A
	Total Acidity	mg/L $CaCO_3$	Refrigeration	S.M 2310 –B- Volumetric -A
	Calcic Hardness	mg/L $CaCO_3$	Refrigeration	S.M 3500 Ca –B-Volumetric -A
	Total Hardness	mg/L $CaCO_3$	Refrigeration	S.M 2340 –C- Volumetric -A
	Total Phenols	mg/L	Refrigeration	S.M 5530 –B Modified and D Direct Photometric -A
	Arsenic	mg/L	Refrigeration + HNO_3 Up to pH <2	SM 3030K- EPA 200.8 ICP/MS - A
	Barium	mg/L	Refrigeration + HNO_3 Up to pH <2	SM 3030K- EPA 200.8 ICP/MS - A
	Cadmium	mg/L	Refrigeration + HNO_3 Up to pH <2	SM 3030K- EPA 200.8 ICP/MS - A
	Zinc	mg/L	Refrigeration + HNO_3 Up to pH <2	SM 3030K- EPA 200.8 ICP/MS - A
	Chrome	mg/L	Refrigeration + HNO_3 Up to pH <2	SM 3030K- EPA 200.8 ICP/MS - A
	Copper	mg/L	Refrigeration + HNO_3 Up to pH <2	SM 3030K- EPA 200.8 ICP/MS - A
	Mercury	mg/L	Refrigeration + HNO_3 Up to pH <2	SM 3030K- EPA 200.8 ICP/MS - A
	Nickel	mg/L	Refrigeration + HNO_3 Up to pH <2	SM 3030K- EPA 200.8 ICP/MS - A
	Silver	mg/L	Refrigeration + HNO_3 Up to pH <2	SM 3030K- EPA 200.8 ICP/MS - A
	Lead	mg/L	Refrigeration + HNO_3 Up to pH <2	SM 3030K- EPA 200.8 ICP/MS - A
	Selenium	mg/L	Refrigeration + HNO_3 Up to pH <2	SM 3030K- EPA 200.8 ICP/MS - A
Bacteriological	Total Coliforms	NMP/100 mL	Sterilization + Refrigeration	SM 9223 B Substrate defined
	Fecal Coliforms	NMP/100 mL	Sterilization + Refrigeration	SM 9223 B Substrate defined

Source: Resolution 0112 of January 28, 2015 and Laboratory SGS Colombia S.A.S, 2015
40 COLOMBIA. MINISTRY OF ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. Resolution 0112 (January, 28, 2015). Whereby the terms of reference for the preparation of the Environmental Impact Study - EIA, required for the processing of the environmental license of construction projects or expansion and operation of deep seaports are adopted and other determinations are made. Bogotá D.C, 2015.
41 COLOMBIA. MINISTRY OF ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. Decree 1076 (May, 26, 2015). By means of which the Single Regulatory Decree of the Environment and Sustainable Development Sector is issued. Section 3 Quality criteria for the destination of the resource. Bogotá D.C., 2015.
Table No. 2.17 Relationship of chemical parameters analyzed from continental sediments

Characterization	Parameter	Unit	Preservation	Analysis method
Chemistry	Chrome	mg/L	Refrigeration	SM 3030K-EPA 200.8 – ICP/MS -B
	Zinc	mg/L	Refrigeration	SM 3030K-EPA 200.8 – ICP/MS -B
	Copper	mg/L	Refrigeration	SM 3030K-EPA 200.8 – ICP/MS -B
	Nickel	mg/L	Refrigeration	SM 3030K-EPA 200.8 – ICP/MS -B
	Greases and oils from the bottom sediment layer	mg/L	Refrigeration	EPA 9071B-SM 5520-C Soxhlet extraction /infrared-ND-B
	Phenols from the bottom sediment layer	mg/L	Refrigeration	SM 5530-D Modified –Direct photometric –ND-B
	Total hydrocarbons of the bottom sediment layer	mg/L	Refrigeration	EPA 9071 B – SM 5520 –D and F - Soxhlet extraction /gravimetric ND-B

Source: Resolution 0112 of January 28, 2015 and Laboratory SGS Colombia S.A.S, 2015

Sampling and transport methodolgy

The sampling carried out was of a manual type by means of a vertical Van Dorn bottle, following the guidelines established in the internal procedure ENVI-OPE-P-02 of water sampling by the company SGS Colombia SA, which has an accreditation by the IDEAM under Resolution 2310 of September 8, 2014.

The continental sediments were taken in the first layer of the Leon River bottom by means of a dredger, which were collected in hermetic plastic bags.

Sampling and transportation of the samples was carried out in a way that guaranteed their physical, chemical and biological integrity during the period between the taking and the analysis of the same; applying internationally accepted preservation methods such as pH control, addition of chemical compounds and temperature control when refrigerating samples at 4oC, using ice for that purpose.

Analysis of laboratory results

Continental water quality

From the results generated by the laboratory for inland waters, the analysis of the parameters was made based on comparisons between the points and the Water Quality Index - ICA, the Langelier Index, the Alteration Index of the Potential of Water Quality - IACAL, index of contamination by mineralization - ICOMI, Index of contamination by organic matter - ICOMO and the index of contamination by suspended solids - ICOSUS, in order to simplify in a numerical expression the positive or negative characteristics of the water source and implement the respective environmental management measures in the water resource management plans of the project.

Likewise, the parameters analyzed for inland waters were compared with the reference values issued by Decree 1076 of 2015 Chapter 3 in Section 9 Quality criteria for the destination of the resource, for the preservation of wildlife and vegetation in surface waters nationally and internationally by reference values issued by National Recommended Water Quality Criteria EPA (salt water).

Below is a description of the calculation of each of the indexes, which are indicators of easy analysis to determine the contamination of surface water.

- Water Quality Index – WQI

The WQI water quality index was developed in the early 70's by the National Foundation for National Sanitation of the United States (NSF), as a result of the conciliation of criteria of 142 experts from that country. It allows to have a general idea of the problems that water can have and the approach that should be given to further studies; In addition, it serves as a basis for spatial and temporal comparison of quality in different bodies of water.

The WQI index determination requires the measurement of the variables: dissolved oxygen, fecal coliforms, pH, biochemical oxygen demand, nitrates, phosphates, temperature change, turbidity and total solids, and is calculated as shown in Equation No. 2.1. .

$$WQI = \sum_{i=1}^{9} W_i \times Q_i$$

Equation No. 2.1 Water quality index
Source : National Sanitation Foundation -NSF Water Quality Index

42Ibid.
43 UNITED STATES ENVIROMENTAL PROTECCTION AGENCY - EPA. National Recommended Water Quality Criteria. [Online] <http://water.epa.gov/scitech/swguidance/standards/criteria/current/upload/nrwqc-2009.pdf> [Accessed July 14, 2015]

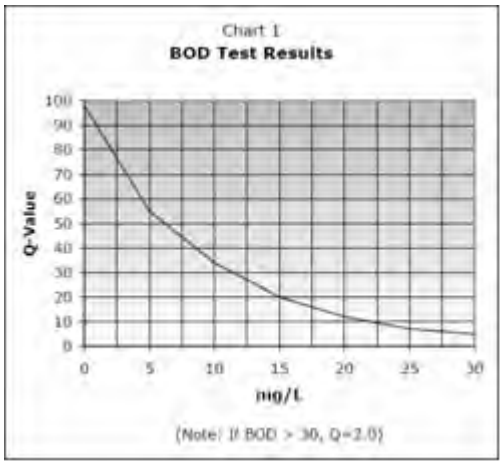
Where Wi denotes the importance factor of the variable i, with respect to the other variables involved in the index, and Qi corresponds to the scale factor of the same. The latter depends on the magnitude of the variable and is independent of the rest.

In Table No. 2.18 the weights of each variable are presented and Figure No. 2.6, schematizes the obtaining of Q for the each of these.

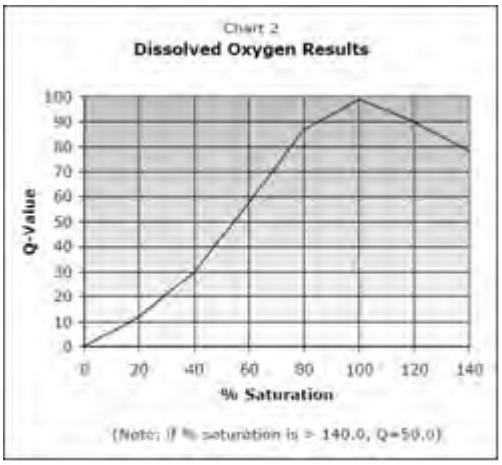
Table No. 2.18 Weighting factors NSF

Variable	Wi Factor
% Oxygen saturation	0,17
Fecal coliforms	0,16
pH	0,11
Biochemical Oxygen Demand	0,11
Nitrates	0,10
Phosphates	0,10
Temperature ΔT	0,10
Turbity	0,08
Total solids	0,07

Source: Water Research Center [2]



(a)



(b)

[2]44WATER RESEARCH CENTER. Monitoring the Quality of Surfacewaters. [Online] <http://www.water-research.net/watrqualindex/waterqualityindex.htm>. [Accessed 14, July, 2015]

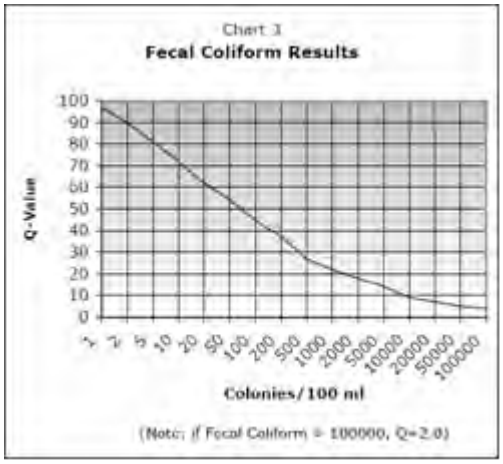


Chart 3
Fecal Coliform Results
Q-Value
Colonies/100 ml
(Note: if Fecal Coliform > 100000, Q=2.0)

(c)

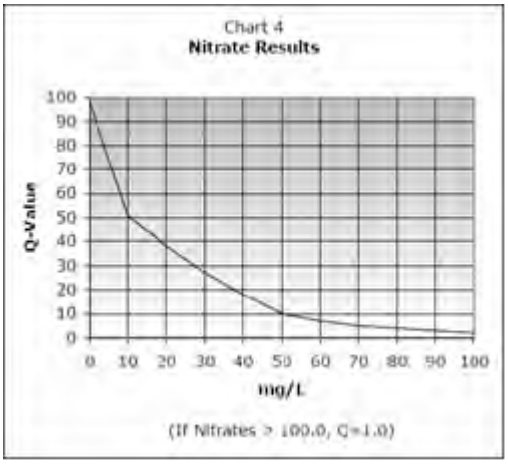


Chart 4
Nitrate Results
Q-Value
mg/L
(If Nitrates > 100.0, Q=1.0)

(d)

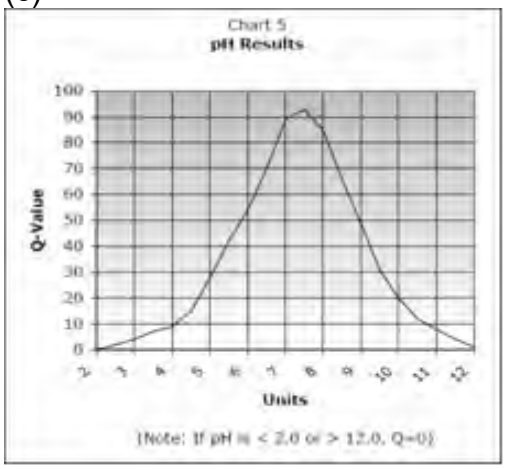


Chart 5
pH Results
Q-Value
Units

(e)

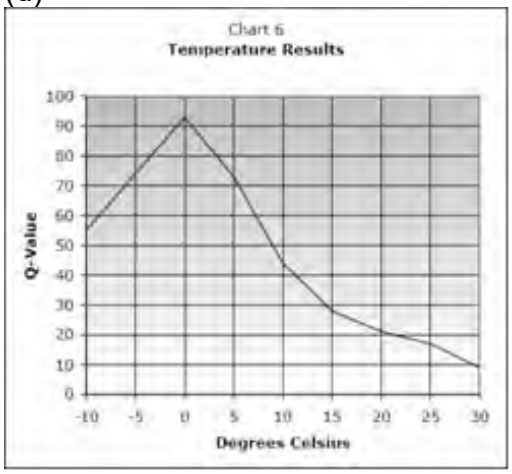


Chart 6
Temperature Results
Q-Value
Degrees Celsius

(f)

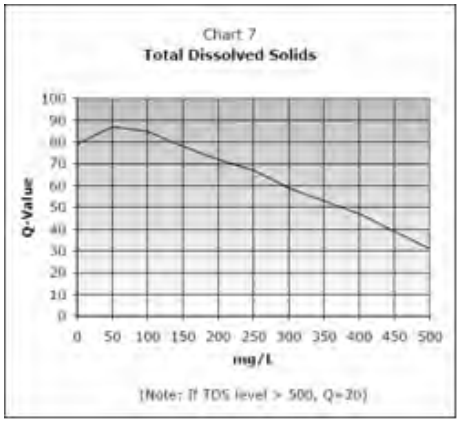


Chart 7
Total Dissolved Solids
Q-Value
mg/L
(Note: if TDS level > 500, Q=20)

(g)

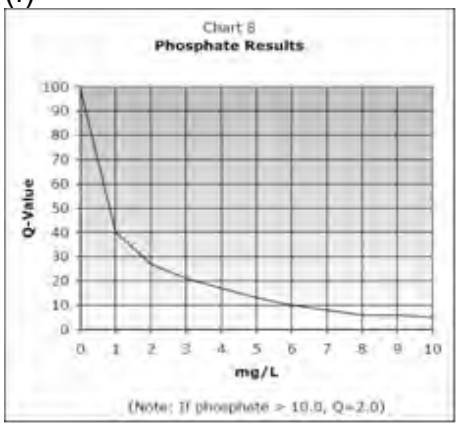
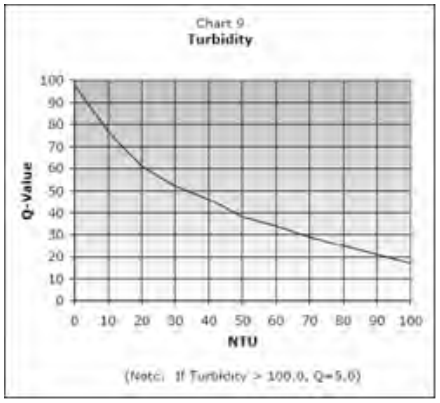


Chart 8
Phosphate Results
Q-Value
mg/L
(Note: if phosphate > 10.0, Q=2.0)

(h)



(i)

Figure No. 2.6 Q scale factors for the parameters involved in the WQI-NSF
Source: Water Research Center [3]

Once the WQI index is determined at a certain point, the source can be classified according to the ranges indicated in Table No. 2.19.

Table No. 2.19 Classification of water quality based on the NSF index

Value of the Index	Color	Classification
0 – 25		Very bad quality (MM)
25 – 50		Bad quality(M)
50 – 70		Average quality (R)
70 – 90		Good quality (B)
90 – 100		Excellent quality (E)

Source: Water Research Center[4]

To determine the percentage of dissolved oxygen saturation from the concentration of dissolved oxygen (DO), it was calculated according to what was proposed by Roldan, 1992. In Figure No. 2.7, it is presented in the nomogram to determine the percentage of oxygen saturation from the water temperature and the oxygen concentration measured.

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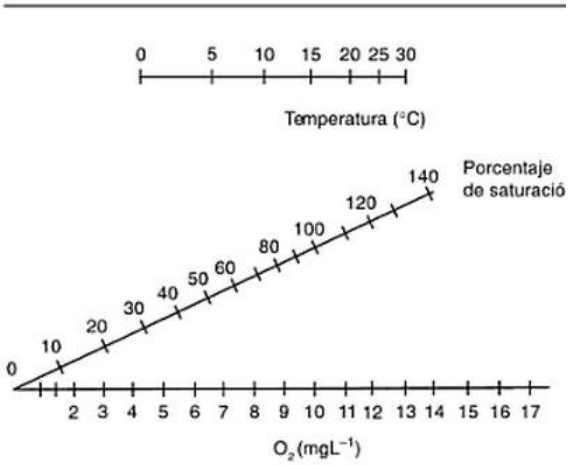
[1]45 Ibíd.
[1] 46Ibíd.
[1]47 ROLDAN P., Gabriel; RAMÍREZ R., John Jairo. Foundations of neotropical limnology. Editorial University of Antioquia, 1992



Source No. 2.7 Nomogram to determine the percentage of oxygen saturation
Source : Roldan, 1992

- Langelier Index - ISL

In accordance with the provisions of Resolution 00001618 of 2010, the Langier Index - ISL, also called the Stability Index or Cosmetological Index, is used as an approach method to determine the corrosive or incrustation condition of a body of water in a swimming pool. Normally it is a value associated to the characteristics of: pH, Total Alkalinity, Total Hardness and Temperature.

In order to know the chemical balance of water, the procedure is presented below:

Measure the characteristics of Temperature, pH, Total Hardness and Total Water Alkalinity, In Situ.

Compare the results of the analysis obtained from the previous number with the values indicated in Table No. 2.20 and use the corresponding coefficient found to bring it to Equation No. 2.2:

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48 COLOMBIA. MINISTRY OF SOCIAL PROTECTION. Resolution 00001618 (May, 7, 2010). Whereby Decree 2171 of 2009 is partially regulated. Bogotá D.C., 2010.

$$ISL = pH + CT + CD + CA - 12,1$$

Equation No. 2.2 Index of Saturation or Langelier – ISL
Source: Resolution No. 00001618 of May 7, 2010

Where: ISL = Index of Saturation, Langelier or Cosmetology

pH = PH value of the water

CT = Water temperature coefficient ° C

CD = Coefficient of total hardness

CA = Total alkalinity coefficient

12,1 = Correction constant applicable to swimming pools and similar structures

This Langelier index has allowable limits for the aforementioned resolution for pools or similar ponds, whose acceptable values must be between - 0.5 and + 0.5. This index was calculated because it is important to control the incrustation or corrosion in the water distribution networks and for the domestic interior installations of the project, however the water source is a river and will be used for human consumption and dumping and construction of projects on riverbed.

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[1]49 Ibíd.

Table No. 2.20 Saturation Index or Langelier

Temperatura (°C)	Coeficiente de Temperatura (CT)	Dureza Total (mg/L)	Coeficiente de Dureza (CD)	Alcalinidad Total (m/L)	Coeficiente de Alcalinidad (CA)
5	0,130	5	0,305	10	1,006
10	0,257	10	0,606	20	1,307
15	0,376	15	0,782	30	1,484
17	0,422	25	1,004	35	1,551
19	0,466	50	1,306	40	1,609
20	0,487	75	1,482	45	1,660
21	0,509	100	1,607	50	1,706
22	0,529	125	1,704	55	1,747
23	0,550	150	1,784	60	1,785
24	0,570	175	1,851	65	1,820
25	0,590	200	1,909	70	1,852
26	0,610	225	1,960	75	1,882
27	0,629	250	2,006	80	1,910
28	0,648	275	2,047	85	1,937
29	0,667	300	2,085	90	1,961
30	0,685	350	2,152	95	1,985
31	0,703	400	2,210	100	2,007
32	0,721	450	2,261	105	2,028
33	0,738	500	2,307	110	2,049
34	0,755	550	2,348	120	2,087
35	0,772	600	2,386	130	2,121
36	0,789	650	2,421	140	2,154
39	0,836	900	2,563	250	2,406
40	0,851	1000	2,608	300	2,485

Source: Resolution No. 00001618 of May 7, 2010

- ❖ Index of contamination by mineralization – ICOMI

The index of contamination by mineralization (ICOMI) includes variables such as conductivity, hardness and alkalinity. The ICOMI is the average value of the indices of each of the three (3) variables, which are defined in a range of 0 - 1; Indices close to zero (0) reflect very low contamination by

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[1]50 Ibíd.

mineralization, and indices close to one (1) otherwise, as presented in Table No. 2.15

Table No. 2.15 Physicochemical and bacteriological variables taken into account for the determination of mineralization contamination rates - ICOMI.

Índixes	Variable	Interpretation
ICOMI Index of contamination by mineralization	Conductivity	0 = Low contamination 1 = High contamination
	Hardness	
	Alkalinity	

Source: Ramírez et al., 1998[5].

To calculate the contamination index by mineralization, the formulas described below were applied (see Equation No. 2.3):

$$ICOMO = 1/3\ (\mathrm{I.Conductivity} + \mathrm{I.Hardness} + \mathrm{I.Alkalinity})$$

Equation No. 2.3 Index of contamination by mineralization
Source: RAMÍREZ et al, 1998

Where:

$I._{Conductivity,}$ is obtained from the following expressions.

Log_{10}. I.Conductivity = -3,26 + 1,34 Log_{10} Conductivity (µS/cm)

$I._{Conductivity}$: $10^{Log.I.Conductivity}$

Conductivities greater than 270 µS/cm, have a conductivity index =1

$I._{Hardness}$: Obtained from the following expression

Log_{10}. $I._{Hardness}$ = -9,09 + 4,40 Log_{10} hardness (mg/L)

$I._{Hardness}$: $10^{Log.I.Hardness}$

Hardness greater than 110 mg/L has $I._{Hardness}$= 1

Hardness less than 30 mg/L has $I._{Hardness}$=0

[5] RAMÍREZ, Alberto; VIÑA, Alberto. Colombian Limnology. Contributions to your knowledge and analysis statistics. Printed in Colombia, 1998.

$I._{Alkalinity}$: Obtained from the following expression

$I._{Alkalinity}$: -0,25 + 0,005Alkalinity (mg/L)

Alkalinities greater than 250 mg/L has $I._{Alkalinity}$:=1

Alkalinities less than 50 mg/L has $I._{Alkalinity}$:=0

- Index of contamination by organic matter – ICOMO

The index of contamination by organic matter (ICOMO) is conformed by the biochemical demand of oxygen, total coliforms and dissolved oxygen. By means of this index, it is possible to determine the degree of contamination of water bodies according to each variable considered (see Table No. 2.21).

Table No. 2.21 Physicochemical and bacteriological variables taken into account for the determination of water pollution indexes (ICO).

Índixes	Variable	Interpretation
ICOMO Index of contamination by organic matter	DBO_5	0 = Low contamination 1 = High contamination
	Total Coliforms	
	Dissolved Oxygen	

Source : RAMÍREZ et al., 1998[6].

To calculate the pollution index, the formulas described below were applied (see Equation No. 2.4):

$$ICOMO = 1/3\ (\text{IDBO} + \text{I Total coliforms} + \text{I Oxygen\%})$$

Equation No. 2.4 Index of contamination by organic matter

Source : RAMÍREZ et al, 1998

Where:

$I.DBO = -0,05 + 0,70\ Log_{10}\ DBO(mg/l)$

DBO> 30 mg/l = 1 has I.DBO = 1

DBO< 2 mg/l =0 has I.DBO = 0

$I._{\text{Total coliforms}} = -1,44 + 0,56\ Log_{10}.$ Col.Total (NMP/1400ml)

Total Coliforms > 20.000 (NMP/100ml) =1 has I.DBO = 1

Total Coliforms < 500 (NMP/100 ml) =0 has I.DBO = 0

[6]52 Ibíd.

I.Oxygen%= 1 - 0,01 Oxygen%

Oxygens (%) greater than 100% has I.DBO = 0

- ❖ Index of contamination by suspended solids – ICOSUS

The index of pollution by suspended solids (ICOSUS) is calculated with the variable of suspended solids, by means of this index it is possible to determine the degree of contamination of the bodies of water according to the considered variable (see Table No. 2.22 and Equation No. 2.5).

Table No. 2.22 Physicochemical variable for the determination of water contamination indexes (ICO)

Índixes	Variable	Interpretation
ICOSUS Index of contamination by suspended solids	Suspended solids	0 = Low contamination 1 = High contamination

Source: Ramírez et al., 1998[7].

$$\text{ICOSUS} = -0{,}02 + 0{,}0003\ \text{Suspended solids}\ (\text{mg/l})$$

Equation No. 2.4 Index of contamination by suspended solids

Source: RAMÍREZ et al, 1998

Suspended solids> at 340 mg / l have an ICOSUS = 1

Suspended solids <at 10 mg / l has an ICOSUS = 0

For the ICOMI, ICOMO and ICOSUS contamination indexes, the qualification ranges of water quality and its characteristics are established according to the degree of contamination (see Table No. 2.23).

Table No. 2.23 ICOS ranges and characteristics

ICO	Contamination	Characterization	Color Scale
0 – 0,2	None	Pure waters and perhaps with biogenetic contribution	
>0,2 – 0,4	Low	With slight anthropic incidence	
>0.4 – 0,6	Half	Remarkable anthropic activity	
>0,6 – 0,8	High	Significant incidence of contamination	
>0,8 – 1	Very High	Highly contaminated areas	

Source: RAMÍREZ et al., 1998[8]

[7]Ibíd.
[8]Ibíd.

Continental sediments

For continental sediments were taken as reference values those reported by the Canadian guide "Canadian Sediment Quality Guidelines for the protection of aquatic life", which synthesizes the relationship between the concentration

54 CANADIAN COUNCIL OF MINISTERS OF THE ENVIRONMENT - CCME. Canadian water quality guidelines for the protection of aquatic life: Guidance on the Site-Specific Application of Water Quality Guidelines in Canada: Deriving

of chemicals in sediments and any adverse biological effects that may occur. The limits established by this guide are:

- ISQG (*Interim Sediment Quality Guidelines*): Referred to the intermediate standard of sediment quality, which represents the concentration under which adverse biological effects are expected to occur rarely.
- PEL (*Probable effect levels*): Referred to the level of probable effect, which defines the level over which the frequent occurrence of adverse biological effects are expected, more than 50% of the adverse effects occur.

These values define three (3) ranges of chemical concentrations: the minimum effect range within which adverse effects rarely occur (less than 25% of adverse effects under the ISQG), the range of possible effects within which the adverse effects occur occasionally, and the range of likely effect within which adverse biological effects will occur frequently (more than 50% of adverse effects occur on the PEL).

Table 2.24 shows the reference values for the parameters that apply in the continental sediment sampling stations.

Table No. 2.24 Canadian regulations for continental sediments

Continental sediments		
Parameter	**ISQG**	**PEL**
Copper , mg Cu/kg	35,7	197
Chrome, mg Cr/kg	37,3	90
Zinc, mg Zn/kg	123	315

Numerical Water Quality Objectives. In: Canadian environmental quality guidelines, 1999. [Online] <http://ceqg-rcqe.ccme.ca/en/index.html> [Accessed September 11, 2015]

54 CHILE FOUNDATION. Project spill of broken hydrocarbons Blanca, Choja and Maní, proposed selection international reference values soils / sediments, Chile, 2013 [online] http: // www. snifa.sma.gob.cl/ [quoted on September 25, 2015]

Ibid.

55 CANADIAN COUNCIL OF MINISTERS OF THE ENVIRONMENT - CCME. Canadian water quality guidelines for the protection of aquatic life: Guidance on the Site-Specific Application of Water Quality Guidelines in Canada: Procedures for Deriving Numerical Water Quality Objectives. In: Canadian environmental quality guidelines, 1999. [Online] <http://ceqg-

rcqe.ccme.ca/en/index.html> [Accessed 11, September 2015] Procedures for Deriving Numerical Water Quality Objectives. In: Canadian environmental quality guidelines, 1999. [Online] <http://ceqg-rcqe.ccme.ca/en/index.html> [Accessed September 11, 2015]
56 CHILE FOUNDATION. Project spill of broken hydrocarbons Blanca, Choja and Maní, proposed selection international reference values soils / sediments, Chile, 2013 [online] http: // www. snifa.sma.gob.cl/ [quoted on September 25, 2015]
57 Ibid.
Source: Canadian Sediment Quality Guidelines for the protection of aquatic life "

- ✓ *Water quality and marine sediments*

In order to know the quality of the water and marine sediments in Bahía Colombia, seven (7) stations located in the area of influence of the project were defined.

Type of sampling marine waters

The samples taken from marine water quality were of the integrated type in the depth; the seven (7) stations were distributed in the area of influence of the project where the construction and operation of the maritime projects of the port terminal in Bahia Colombia are planned, of which, five (5) were distributed in the area of influence of the marine platform and the deepening dredging area for the maneuver activities and access channel, one (1) station in the proposed dump area for the final disposal of the dredged material and the last control station (1) between the dump and dredging area.

Parameters evaluated

In accordance with the terms of reference established by Resolution 0112 of 2015 for large-scale maritime ports, the parameters presented in Table No. 2.25 for the physicochemical and bacteriological characterization of seawater were considered and in Table No. 2.26 for the characterization physicochemistry of marine sediments, which will be susceptible to intervention for the construction and operation of the port terminal in Bahía Colombia.

The measurement of the physicochemical parameters was carried out under technical standards and methods officially accepted in the Standard Methods for the Examination of Water and Wastewater 22nd Edition 2012, in the officially accepted methodologies and under the criteria established by Decree 1076 of 2015 by the Ministry of Environment and Sustainable Development.

Table No. 2.25 List of the physicochemical and bacteriological parameters to be analyzed

Characterization	Parameter	Unit

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59 MINISTRY OF ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. Resolution 0112 (January, 28, 2015). Op cit.
60 COLOMBIA. MINISTRY OF ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. Decree 1076 (May, 26, 2015). By means of which the Single Regulatory Decree of the Environment and Sustainable Development Sector is issued. Section 3 Quality criteria for the destination of the resource. Bogotá D.C., 2015.

Characterization	Parameter	Unit
Physical	Temperature	°C
	Total suspended solids	mg/L
	Total dissolved solids	mg/L
	Sedimental solids	mL/L–h
	Electric conductivity	uS/cm
	Hydrogen potential – pH	Units of pH
	Turbidity	UNT
	Real Color	m^{-1}
Chemistry	Dissolved oxygen (OD)	mg/L
	Chemical Oxygen Demand (DQO)	mg/L O_2
	Biochemical Oxygen Demand at five (5) days (DBO5)	mg/L O_2
	Total Nitrogen Kjeldahl	mg/L NTK
	Total Phosphorus	mg/L P
	Fats and Oils	mg/L
	Total Alkalinity	mg/L $CaCO_3$
	Total Acidity	mg/L $CaCO_3$
	Calcic hardness	mg/L $CaCO_3$
	Total hardness	mg/L $CaCO_3$
	Totales Phenols	mg/L
	Arsenic	mg/L
	Barium	mg/L
	Cadmium	mg/L
	Zinc	mg/L
	Chrome	mg/L

Characterization	Parameter	Unit
	Copper	mg/L
	Mercury	mg/L
	Nickel	mg/L
	Silver	mg/L
	Lead	mg/L
	Selenium	mg/L
	Chlorophyll a	mg/L CHLa
	Chlorophyll b	mg/L CHLb
	Polycyclic aromatic hydrocarbon	mg/L HAP
	Methylene Blue Active Substances (SAAM)	mg/L
Bacteriological	Total coliforms	NMP/100 mL
	Fecal coliforms	NMP/100 mL

Source: Resolution 0112 of January 28, 2015

Table No. 2.26 List of physicochemical parameters to analyze

Characterization	Parameter	Unit
Physical	Temperature	°C
	Hydrogen Potential – pH	Units of pH
Chemistry	Fats and Oils	mg/L
	Arsenic	mg/L
	Barium	mg/L
	Cadmium	mg/L
	Zinc	mg/L
	Chrome	mg/L
	Copper	mg/L
	Mercury	mg/L
	Nickel	mg/L
	Silver	mg/L
	Lead	mg/L
	Selenium	mg/L
	Total Hydrocarbons	mg/L
	Phenols	mg/L
	Polycyclic Aromatic Hydrocarbons	mg/L HAP
	Total Organic Carbon	mg/L COT
	Volatile Acid Sulphide	mg/L S^{-2}
	Total Phosphorus	mg/L
	Total Nitrogen	mg/L

Source: Resolution 0112 of January 28, 2015

Sampling and transport methodology

The sampling carried out was of a manual type by means of a vertical Van Dorn bottle, following the guidelines established in the internal procedure ENVI-OPE-P-02 of water sampling by the company SGS Colombia SA, which has an accreditation by the IDEAM under Resolution 2310 of September 8, 2014.

The marine sediments were taken in the first layer of the bottom in Bahía Colombia, for the measurement of the parameters we will work with the fine fraction of the sediment (<200 µm, first m, in dry basis). The analysis of the information will contribute to the clear identification of the ecological status of the area of influence of the oceanographic component.

Sampling and transportation of the samples was carried out in a way that guaranteed their physical, chemical and biological integrity during the period between the taking and the analysis of the same; applying internationally accepted preservation methods such as pH control, addition of chemical compounds and temperature control when refrigerating samples at 4 oC, using ice for that purpose.

Analysis of laboratory results

To carry out the analysis of the information coming from the stations in Bahía Colombia, an interpretation was made of the concentrations obtained and a comparison was made with the criteria established in the Single Environmental Decree 1076 of 2015

Likewise, according to the results of the characterization the application of the Quality Index of the Marine and Coastal Waters (ICAM) was made, which is an indicator that facilitates the interpretation of the quality of the marine environment, the evaluation of the impact of the activities anthropogenic and the taking of prevention and recovery measures to assess the quality of marine waters, ie their ability to withstand marine life and biological processes.

The ICAM formulation uses holistically (Equation 2.6) the eight minimum variables dissolved oxygen, nitrates (NO3), total suspended solids (TSS), thermotolerant coliforms (CTE), pH, dissolved and dispersed hydrocarbons (HDD), demand oxygen biochemistry (BOD) and orthophosphates (PO4), as determinants of natural and anthropogenic processes in marine-coastal waters. Each variable is qualified by the measured concentration, according to its values of acceptance or rejection, which must comply with the pre-established standards and considered suitable to protect the habitat of the marine ecosystem.

$$ICAM = (\prod_{i=1}^{n} x_t^{wi})^{\sum_i^1 wi}$$

Equation No. 2.6 Marine and coastal water quality index (ICAM)

Source : INVEMAR[9]

Where,

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61 COLOMBIA. MINISTRY OF ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. Decree 1076 (May, 26, 2015). Op Cit.

62 INVEMAR Op. cit.

ICAM = it is the quality of the water according to the destination of the resource and the concentration of each one of the variables.

Xi = quality sub index of the variable i

Wi = weighting factor for each subscript i, according to its importance within the ICAM, which is weighted between zero and one (importance value).

The indicator represents the quality of the marine water resource, where the qualification is adjusted to the quality curves with values between 0 and 100 according to the descriptive scale for the preservation of vegetation and wildlife (ICAM) in marine-coastal waters (see Table No. 2.27).

Table No. 2.27 Scale of assessment of the quality index of marine waters - ICAM

Quality Scale	Color	Category	Description
Optimal	Blue	100 – 90	Excellent water quality
Adequate	Green	90 – 70	Water with good conditions for aquatic life
Acceptable	Yellow	70 – 50	Water that conserves good conditions but few restrictions of use
Inadequate	Orange	50 – 25	Water that presents many restrictions of use
Terrible	Red	25 - 0	Waters with many restrictions that do not allow proper use

Source: INVEMAR[10]

- ✓ *Quality of marine sediments in the depth*

In order to know the characteristics of the sediment of depth that will be extracted during the deepening dredging activities, the monitoring of three (3) points in the Gulf of Urabá, located on the seabed around the area corresponding to the maritime terminal area, was carried out. and the viaduct.

The samples were taken on March 25, 2015 during the exploration of the geotechnical characteristics of the area. Subsequently, they were sent to Bogotá to carry out the physicochemical analyzes in laboratories duly accredited before the IDEAM.

The first laboratory contracted was ANTEK S.A. where the following parameters were analyzed: Potential of Hydrogen, total phosphorus, copper, cadmium, barium, hexavalent chromium, selenium, total hydrocarbons (HCT) and Polycyclic Aromatic Hydrocarbons (PAHs). Additionally, the following parameters were contracted with the Analquim LTDA laboratory: arsenic, total organic carbon (TOC), chromium, phenols, fats and oils, mercury, nickel, total nitrogen, silver, lead,

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[1]63 INVEMAR. Op. cit.

temperature and zinc. Finally, the analysis of Volatile Acid Sulfide (VAS) was contracted with SGS SA, who in turn subcontracted the parameter with the Dr. Calderon Labs laboratory. The analysis of the parameters was made taking as reference the Standard Methods for the Examination of Water and Wastewater. 22d Edition 2012 of the EPA (United States)

Sampling points

The depth sediment samples analyzed were extracted from the drilling done for the exploration of the subsoils in the seabed in the area of influence of the project in Bahía Colombia in the Gulf of Urabá. Table No. 2.28 presents the Magna-Sirgas flat coordinates of the Bogotá origin of each of them. At each point four (4) samples were taken at different depths. The location of the points is presented in Figure No. 2.8.

Table No. 2.28 Plans coordinates of the perforations

Drilling	FLAT COORDINATES MAGNA SIRGAS Origin BOGOTA	
	EAST	NORTH
PF-8	703.242,56	1.370.757,58
PF-9	702.766,57	1.370.550,31
PF-10	702.771,47	1.371.303,17

Source: PIO S.A.S. (2015)

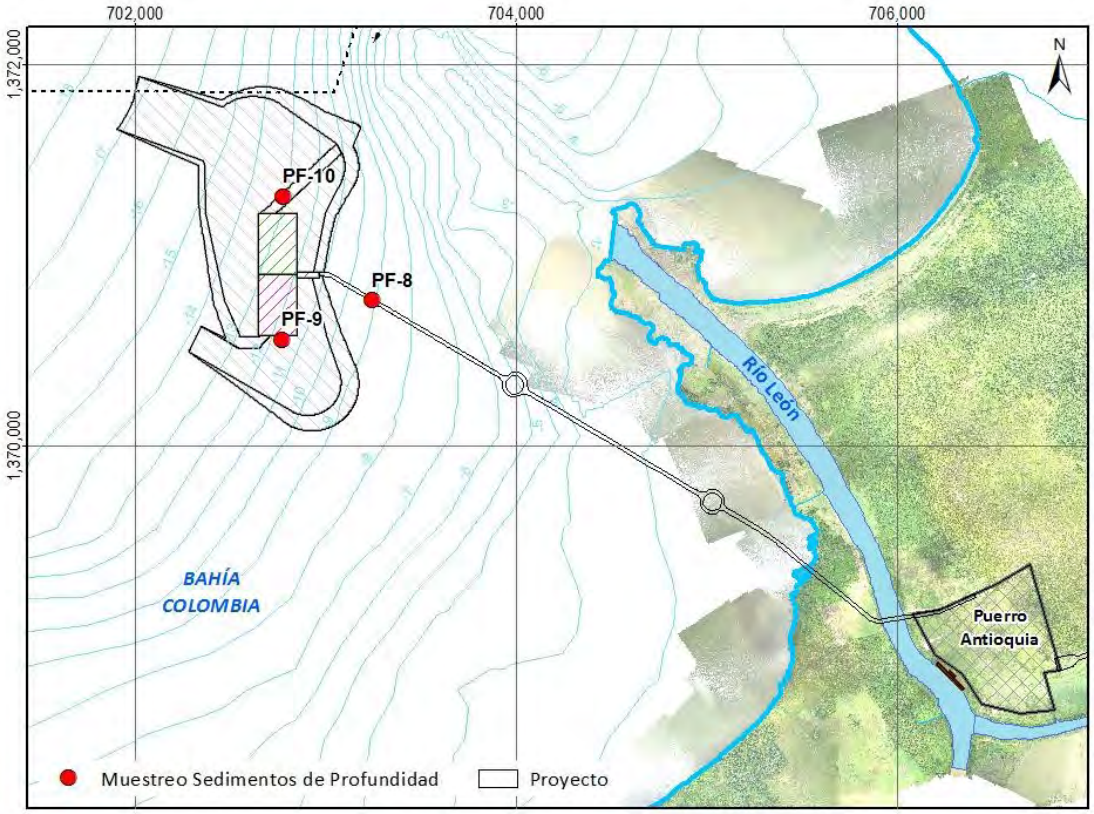

Figure No. 2.8 Location of perforations

Source: Aqua & Terra Consultores Asociados S.A.S. (2015)

Sampling and type of sample:

For the collection of sediment samples, Shelby tubes were used, which are thin-walled steel tubes used for drilling and extraction of relatively undisturbed soil samples. Within these same implements the samples were transported to the accredited laboratory to analyze the parameters. At each point, four (4) samples were taken at different depths, as shown in Table No. 2.29. Table No. 2.29 Depth of sampling The objective of the sampling was to know in depth the physico-chemical characteristics of the seabed in the area where the deepening dredging will be carried out in the area that will be used for maneuvers of the vessels and access channel, as such in this way, the information serves as an input to evaluate the environmental impacts associated

64 HERRERA HERBERT, J., & CASTILLA GÓMEZ, J. (2012). Use of survey techniques in geotechnical studies. Madrid Spain.

with that activity and the disposal of dredged material in the area designated for that purpose.

Table No. 2.29 Depth of sampling

Drilling	Depth range (m)			
Sample	**M1**	**M2**	**M4**	**M5**
PF-8	9-9,6	12-12,6	18-18,6	20,5-21,1
Sample	**M1**	**M2**	**M3**	**M4**
PF-9	12.0-12.6	15.0-15.6	18.0-18.6	21.0-21.6
PF-10	13.0-13.6	15.75-16.35	18.5-19.1	21.25-21.50

Source: PIO S.A.S. (2015)

Parameters evaluated

The measurement of the physicochemical parameters was made under technical standards and methods officially accepted in the Standard Methods for the Examination of Water and Wastewater 22nd Edition 2012, in the officially accepted methodologies and under the criteria established by Decree 1076 of 2015 issued by the Ministry of Environment and Sustainable Development (See Table No. 2.30)

Table No. 2.30 Parameters evaluated and reference methods and analytical techniques used for the determination

Parameter		Unit	Analytic technique	Reference method	Laboratory
Physical	Temperature	°C	Thermometor	SM 2550 B	ANALQUIM LTDA
	Hydrogen Potential - pH	Units of pH	Electrometric	SW846	ANTEK
Chemicals	Fats and oils	mg/kg	Soxhlet Extraction	EPA -9071 B	ANALQUIM LTDA
	Arsenic	mg/kg As	A.A. Hydride generator	SM 3114 C	ANALQUIM LTDA
	Barium	mg/kg	I.C.P	EPA 3050 B - SM 3120B	ANTEK
	Cadmium	mg/kg	E.A.A	EPA 3050 B - SM 3113B	ANTEK
	Zinc	mg/kg Zn	A.A Flame	SM 3111 B	ANALQUIM LTDA
	Chrome	mg/kg Cr	A.A Flame	SM 3111 B	ANALQUIM LTDA
	Hexavalent chromium	mg/kg	Colorimetric	SM 3500 Cr B	ANTEK
	Copper	mg/kg	E.A.A	EPA 3050 B - SM 3111B	ANTEK

Parameter		Unit	Analytic technique	Reference method	Laboratory
	Mercury	mg/kg Hg	A.A – Cold Steam	SM 3112 B	ANALQUIM LTDA
	Nickel	mg/kg Ni	A.A: Flame	SM 3111 B	ANALQUIM LTDA
	Silver	mg/kg Ag	A.A Flame	SM 3111 B	ANALQUIM LTDA
	Lead	mg/kg Pb	A.A Flame	SM 3111 B	ANALQUIM LTDA
	Selenium	mg/kg	E.A.A.E	EPA 3050 B - SM 3113B	ANTEK
	Total Hydrocarbons	%	Ultrasound /infrared extraction	NMX-AA-145-SCFI-2008 y SM 5520 CF	ANTEK
	Phenols	mg/kg	Direct (4-aminoantipyrine)	SM 5530 D	ANALQUIM LTDA
	HAP's	mg/kg	Gas chromatography - FID	EPA 3550B-EPA 8100	ANTEK
	Total organic carbon	mg/kg	Colorimetry	NTC 5403	ANALQUIM LTDA
	Volatile Acid Sulphide	mg/kg	-	LBC 371 Anderson and Wilson	Dr. Calderón Labs
	Total Phosphorus	mg/kg	Digestion - Colorimetry	SM 4500 - P B.4 SM 4500-PE	ANTEK
	Total Nitrogen	mg/kg	Titulometric H2SO4	NTC 5889	ANALQUIM LTDA

Source: Aqua & Terra Consultores Asociados S.A.S. (2015)

65 COLOMBIA. MINISTRY OF ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. Decree 1076 (May, 26, 2015). By means of which the Single Regulatory Decree of the Environment and Sustainable Development Sector is issued. Section 3 Quality criteria for the destination of the resource. Bogotá D.C., 2015.

Analysis of laboratory results

Based on the results presented by the laboratory, the values were compared with international references of marine sediment quality, within which are those reported in the CEDEX standard of Spain, specific for dredging material (see Table No. 2.31). Based on this comparison it will be possible to establish if the characteristics of the depth sediments in the area meet the requirements so that there is no direct inference with the aquatic biota in the area of influence of the project.

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66 MINISTRY OF PUBLIC WORKS TRANSPORTATION AND THE ENVIRONMENT. (1994). Recommendations for the management of dredged material in Spanish ports. Madrid Spain

Table No. 2.31 International references in marine sediment quality

Parameter		CEDEX (Spain)[4]	
		AL1	AL2
Physical	Temperature	-	-
	Hydrogen Potential - pH	-	-
Chemicals	Fats and oils	-	-
	Arsenic	80,00	200,00
	Barium	-	-
	Cadmium	1,00	5,00
	Zinc	500,00	3000,00
	Chrome	200,00	1000,00
	Hexavalent chromium	-	-
	Copper	100,00	400,00
	Mercury	0,60	3,00
	Nickel	100,00	400,00
	Silver	-	-
	Lead	120,00	600,00
	Selenium	-	-
	Total Hydrocarbons	-	-
	Phenols	-	-
	HAP's	-	-
	Total organic carbon	-	-
	Volatile Acid Sulphide	-	-
	Total Phosphorus	-	-
	Total Nitrogen	-	-

Source: Aqua & Terra Consultores Asociados S.A.S. (2015)

AL1 and AL2: Action levels 1 and 2. Values used to classify the level of contamination of the dredged material, using the following categories.

- Category I: when the value is less than AL1
- Category II: when the value obtained is between AL1 and AL2
- Category IIIa: when the value is between AL2 and eight (8) times the value of AL2
- Category IIIb: when the value is eight (8) times greater than AL2

In category I are those materials from dredging whose chemical and biochemical effects on the aquatic vegetation and wildlife are null or insignificant. Category II contains materials with moderate concentrations of pollutants, so they can be discharged into the sea in a controlled manner. Finally, to category III belong the materials with high concentrations of pollutants, these must receive some treatment or be isolated from the sea. Within category III we find two subgroups:

- Category IIIa corresponds to materials that require soft insulation management techniques such as underwater confinement and discharge into aquatic or terrestrial enclosures.
- The category IIIb are those materials that require hard treatment techniques such as pouring into enclosures with specific characteristics (impermeable walls, leachate control devices, among others) for the storage of these, the "on line" treatment before performing the shedding at sea and solidification or inertization for land disposal.

For the analysis of parameters that do not have reference values in Spanish regulations or that could not be analyzed by the technical constraints of the laboratory (Volatile Acid Sulfide, Total Organic Carbon, Barium, Cadmium, etc.), secondary information was consulted databases like Science Direct.

- ✓ *Historical secondary information on the quality of continental and marine water – REDCAM*

Additionally, to evaluate the quality of the continental and marine water, the information was taken from five (5) monitoring stations, one over the León River and the others over the mouth of the León River to Bahía Colombia and in Bahía Colombia through the quality network of marine water (REDCAM) of the Institute of Marine and Coastal Research José Benito Vives de András - INVEMAR, where the historical average of the seasons was extracted in the two seasons of the rainy season and dry season between the years of 2001 and 2014.

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[1]67 Ibid.
68 INSTITUTE OF MARINE AND COASTAL RESEARCH JOSÉ BENITO VIVES DE ANDARÉIS - INVEMAR. Monitoring network of marine and coastal waters of Colombia - REDCAM. [Online] <http://siam.invemar.org.co/siam/redcam/estadisticas/index.jsp> [quoted on July 6, 2015]

Table No. 2.32 and Figure No. 2.9 show the location of the stations located in the area of influence by the REDCAM Marine and Coastal Water Monitoring Network of Colombia, which provide information for the analysis of quality of the water.

Table No. 2.32 Location of REDCAM stations in the study area

Station	Description	Place	Geographical coordinates	
			Latitude	Longitude
C05003001	C05URBAC013	Mouth of The León River -DGI013	7° 56' 26.8" N	76° 45' 15.6" W
C05003002	C05URBAC015	(Front) km after León River - DGI015	7° 56' 53" N	76° 46' 7.1" W
C05003006	C05URGUR001	Gulf of Urabá-DG001	7° 58' 2.2" N	76° 48' 31.7" W
C05003007	C05URGUR002	Gulf of Urabá-DG002	7° 58' 2.1" N	76° 53' 58.3" W
C05003015	C05URBAC014	km above the León River-DGI014	7° 55' 13.6" N	76° 44' 35.3" W
C05003046	DGI030	Colombia Bay	7° 59' 44" N	76° 50' 57.3" W

Source: Aqua & Terra Consultores Asociados S.A.S, 2015 with information from REDCAM

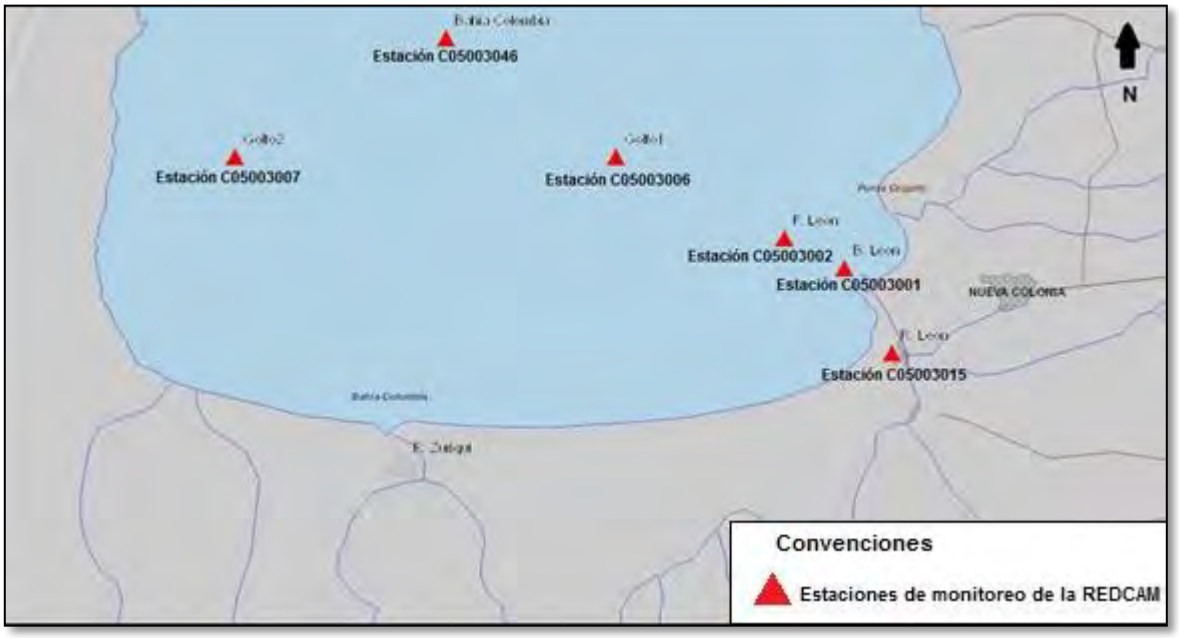

Figure No. 2.9 Location of the REDCAM stations- continental and marine water quality
Source: Prepared by Aqua & Terra Consultores Asociados S.A.S, 2015 with information from REDCAM

2.3.1.7 *Water uses*

To identify current uses and users of water, an inventory was made of information provided by the Corporation for the Sustainable Development of Urabá -

CORPOURABA of authorized concessions and discharges located 5 km from the area of abiotic influence of the project.

The National Water Study (ENA 2014) was used as reference information in which three levels of hydrographic units are defined: areas, zones and subzones. From the conception of them, the surface water supply and the development of the different water indicators for the Leon River subzone are described.

Of the indicators related by the National Water Study, the Water Use Index (IUA), Water Retention and Regulation Index (IRH) and the Water Shortage Vulnerability Index (IVH) were taken into account for this study.

It should be noted that for the Leon River basin there is no Management and Ordination Plan (POMCA) to date, therefore it was not possible to define the quality goals and objectives established by the environmental authority for said basin.

2.3.1.8 *Hydrogeology*

To determine the conformation of the different lithological units in depth for the area of influence, the geophysical records of the existing wells, information from previous geophysical surveys, and information from relatively recent exploration campaigns focused on the characterization of the subsoil for the port project that wants to advance in the area.

The activities that were carried out to reach the main objective are the following:

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69 INSTITUTE OF HYDROLOGY, METEOROLOGY AND ENVIRONMENTAL STUDIES - IDEAM, MINISTRY OF ENVIRONMENT HOUSING AND TERRITORIAL DEVELOPMENT -MAVDT. National Water Study. Bogotá, 2014. 493 p. ISBN: 978-958-8067-70-4.

- Review of secondary information focused on the determination of the hydrogeological characteristics of the area of influence, according to CORPOURABA, UNAL and PIO S.A.S.
- Plane realization with wells with records in the study area.
- The wells considered of interest were selected (due to their depth, location).

- Interpretation of the geophysical records of the wells of interest.
- Compilation and elaboration of lithostratigraphic columns based on the interpretation of the geophysical and geomechanical records available.
- Representative hydrogeological profiles were made between the stratigraphic columns.
- The hydrogeological model of the area of influence was defined.
- The applicable block diagram for the aquifer in the area was defined.

2.3.1.9 *Oceanography*

Below are the different activities developed for the oceanographic characterization:

✓ *Marine water quality*

The item of water and sediment quality for inland and marine waters, the location of the sampling stations and the physicochemical and bacteriological parameters made for the characterization of the marine water column and the marine sediments in Bahía Colombia, distributed in the area of intervention of the deepening dredging for the

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70 CORPORATION FOR THE SUSTAINABLE DEVELOPMENT OF URABÁ - CORPOURABÁ. Conceptual hydrogeological model of the aquifer of the Gulf of Urabá elaborated from the interpretation of geological and geophysical information. 2013

71 CORPOURABÁ. Evaluation of hydrogeological information derived from the drilling of deep wells and vertical electric soundings. 2011

72 CORPORATION FOR THE SUSTAINABLE DEVELOPMENT OF URABÁ - CORPOURABÁ, NATIONAL UNIVERSITY - UNAL. Hydrogeology of the aquifer of the Banana Hub of Urabá. 2010

73 PIO SAS, EDIFICA COLOMBIA Ltda. Basic and detail engineering, procurement and supply of materials, construction, assembly and commissioning of the works required for phase 1 of the Puerto Antioquia port terminal located at the mouth of the Lion River, in the Gulf of Urabá, department of Antioquia ". Geotechnical Study for Conceptual Engineering. 2015

maneuvers of the vessels, the access channel, the landfill for the final disposal of the dredged material and control point between the landfill and the dredging area.

✓ *Surf*

- Bathymetry

For this study two digital terrain models were made, one before the works, that is, the current situation, and another after the projected works, that is, the future situation. The current situation model takes into account the initial conditions of the

study area; for this, the Oceans and Coasts Map Atlas was used, supplied by the General Maritime Directorate and prepared by the Oceanographic and Hydrographic Research Center - CIOH, in addition to the detailed bathymetry of the dredging and proposed sectors for the landfill. They contain the study area that are 412 and 625, which is shown in Figure No. 2.10.

The second model or final condition takes into account the dredging of the maneuver basin, the access channel and the final level of the dump, after the dumping of material; For this, the inputs of the general bathymetry and initial detail were used and the final design of the dredging and the discharge that is intended to be carried out in the study area were superimposed (Figure No. 2.11 and Figure No. 2.12).

74 MARITIME DIRECTORATE GENERAL (DIMAR) and CENTER OF OCEANOGRAPHIC AND HYDROGRAPHIC INVESTIGATIONS (CIOH). Cartographic Atlas of the Oceans and Coasts of Colombia. 2nd edition. Publication 3007. Bogotá: 2005. 105 p.

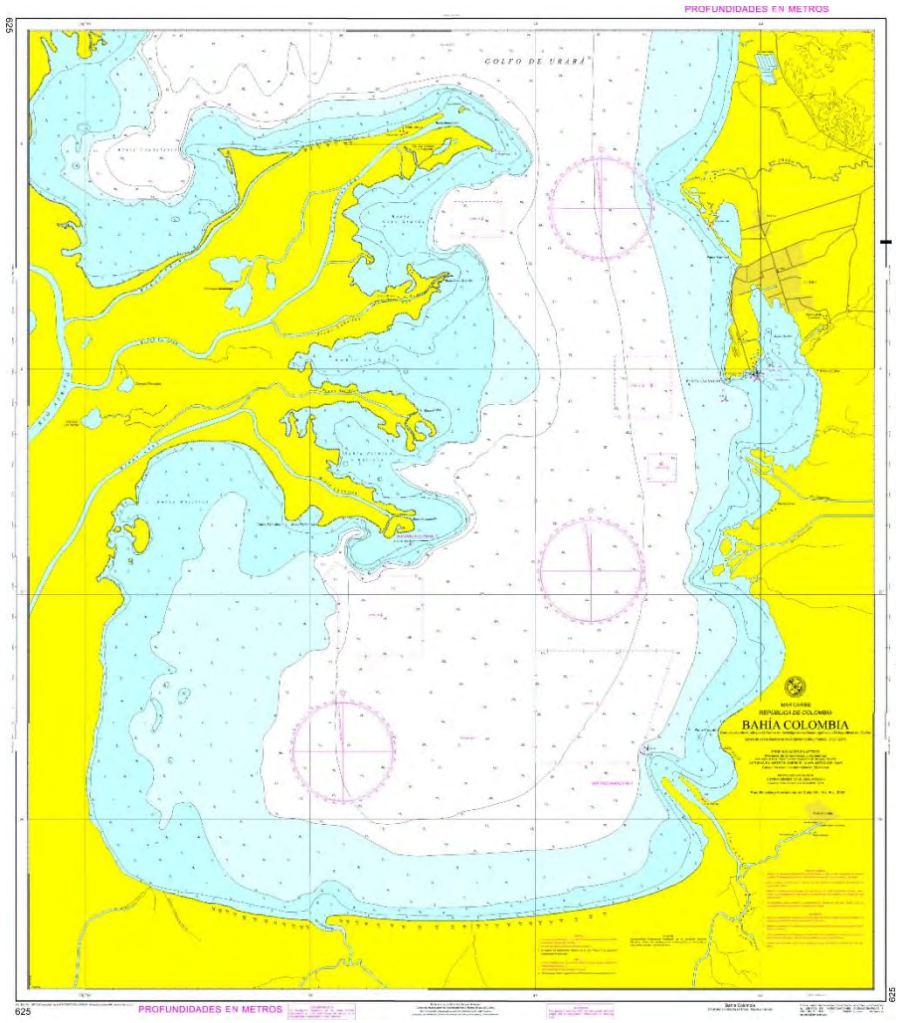

Figure No. 2.10 Nautical chart 625
Source: General Maritime Directorate.

75 MARITIME DIRECTORATE GENERAL (DIMAR) and CENTER OF OCEANOGRAPHIC AND HYDROGRAPHIC INVESTIGATIONS (CIOH). Cartographic Atlas of the Oceans and Coasts of Colombia. 2nd edition. Publication 3007. Bogotá: 2005. 105 p.

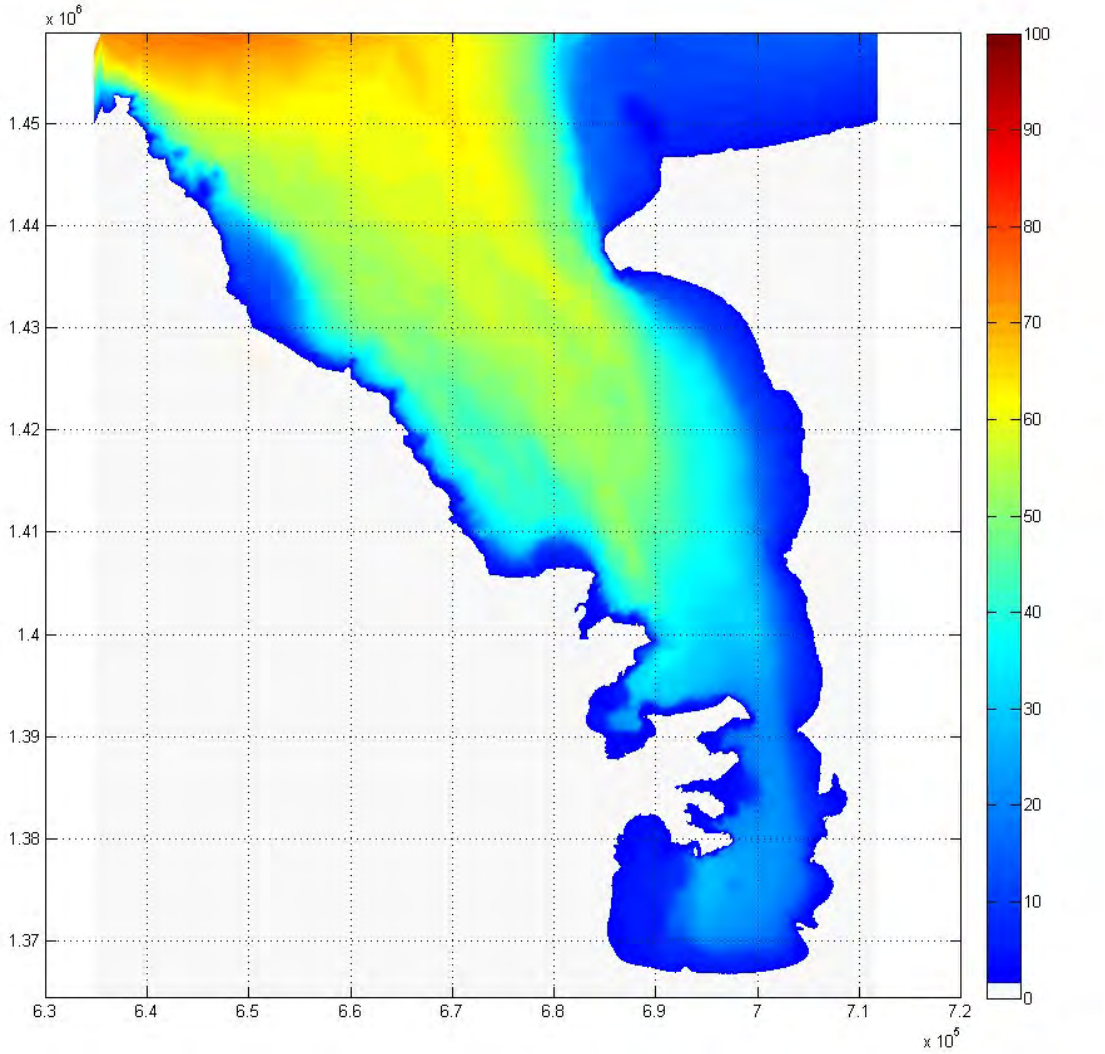

Figure No. 2.11 Interim General Initial Bathymetry
Source: Developed Aqua & Terra Consultores Asociados S.A.S, 2015.

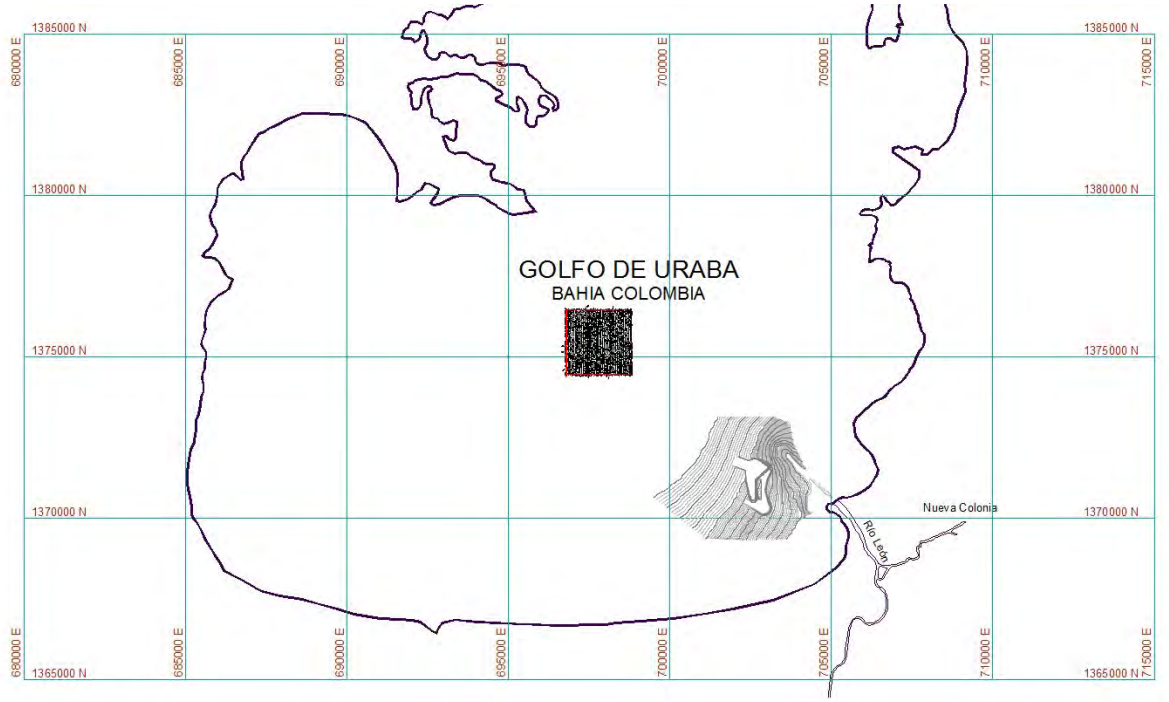

Figure No. 2.12 Bathymetry Detail of the design of the dredging of the dock and the Dump area.
Source: Aqua & Terra Consultores Asociados S.A.S, 2015.

The analysis of the data of instrumental waves which were obtained from the buoy of the DIMAR, located in Barranquilla in coordinates 11 ° 9'41.0 "N and 74 ° 44'00" W (928.364,26E; 1,726.165,0N) (Figure No. 2.13). It is important to highlight the relevance for the country of a project such as the one being developed by DIMAR, in conjunction with its research centers, the Oceanographic and Hydrographic Research Center (CIOH) and the Oceanographic and Hydrographic Research Center of the Pacific (CCCP); thanks to which we have instrumental information that allows us to have a better knowledge of the wave climate along the two Colombian coasts, for some years now. This work has required a lot of resources and time, but all this is reflected in the quality of the information that is currently available. This series of data, of temporal time resolution, has a record length from March 2006 and ending in April 2009. It should be noted that, although the information held by the DIMAR goes to 2014, Aqua & Terra Consultores Asociados SAS, You only have access to the data mentioned above. This series is not continuous because it presents several null

76 MARITIME DIRECTORATE GENERAL (DIMAR)

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records, which can be seen in the blanks of the series, so it is very difficult to extract a behavior from the series, because there is no continuous year of measurement, which does not allow to establish what the variation is like of wave height throughout the year. What we can see from the graph is that in the first months of the year the magnitude of the height of the wave has maximum values and that the months of August and September present minimum values.

Figure No. 2.13 Location of the Barranquilla Buoy.
Source: Google EarthTM (2013), modified by Aqua & Terra Consultores Asociados S.A.S, 2015

No. 2.14 Location of the NOAA buoys, with whose data the model was calibrated
Source: WaveWatchIIITM. Tomado de Caires et al (2002).

The available data of the model are spatially distributed over the Colombian Caribbean on a 0.25 ° x0.25 mesh (see Figure No. 2.15), the WW_Barranquilla point correspond to the WaveWatchIIITM series that was used to calibrate the model data with the data from the Barranquilla buoy, the series located at the WW_GOLFO point is the series used to obtain the mean regime at indefinite depths whose temporal resolution is one hour and recorded variables such as Hs, Tp and between 1999 and 2014.

Figure No. 2.15 Sites with wave information from the WaveWatchIIITM project. The point WW_Barranquilla correspond to the series of WaveWatchIIITM that was used to calibrate the data of the model with the data of the Barranquilla buoy and the point WW_GOLFO is the series used to obtain the average regime in indefinite depths.
Source: Aqua&Terra Consultores Asociados S.A.S, 2015

- ✓ *Calibration of the waves*

In order to calibrate the data of the WaveWatchIIITM model, data from the Barranquilla buoy were used. The calibration procedure of the series consisted of the following: 1) We searched for one of the virtual buoys obtained with the WaveWatchIII^{TM} model near the location of the buoys, in this case we worked with

the data from the virtual buoy located at 11 ° 15'00 "N 74 ° 45'00" W (926,566.04E 1,735,971.54N), 2) Once we have the data of the model and the data of the buoy, we search all the data corresponding to the same date in the two series, 3) With the data pairs, a linear regression is performed between the model data and the buoy data, both with the same non-exceedance probability level, in order to obtain the calibration parameters of the series of wave for the significant wave height and 4) The calibration parameters are applied to the WaveWatchIIITM series in the Gulf of Urabá.

- ✓ *Winds turbo station*

Because in the Gulf of Urabá the background swell can be affected when it enters this, and its magnitude can be drastically reduced by effects of refraction and diffraction, it was considered to model to part the effect that has the wind or local swell to the interior from the Gulf of Urabá. The wind or local swell in geographies such as the Gulf of Urabá and Bahía Colombia, may have more relevance in the background swell. Everything will depend on the configuration of the gulf and the length of development (or FETCH).

To feed a model that converts the wind into swell, the data recorded by the Turbo station, property of the International Station Meteorological Climate Summary (ISMCS), which was located in the Punta Las Vacas sector in the Municipality of Turbo, Antioquia, were used, and has records between January 1949 and May 1984. The available information of this station is not the time series of magnitude and direction of the wind but the statistics of probability of occurrence of the wind throughout the period of registration by intervals of magnitude for the 16 main directions.

- ✓ *Propagation of the swell*

The wave propagation was carried out to obtain a characterization of the swell (significant height and direction), along the study area and in greater detail in the vicinity of the proposed dump, so as to establish the effect of this on the littoral dynamics of the study area (see Figure No. 2.16).

The cases of propagation allow to obtain a qualitative and quantitative image of the propagation process from indefinite depths to the study area, allowing to detect areas of wave concentration or dispersion, to know the angle of incidence of the waves and its height (magnitude) once it has gone through the different processes that the waves suffer when approaching the coast. This work is divided into four types of propagation, the first and the second, consist of determining the average swell regime, based on the background and local swell information, in the study zone

without works, with this we establish the conditions existing in the study area and the second is with the same cases of propagation, but with the bathymetry modified by the project. This will serve to know the impacts that the dump has on the littoral dynamic of the study area.

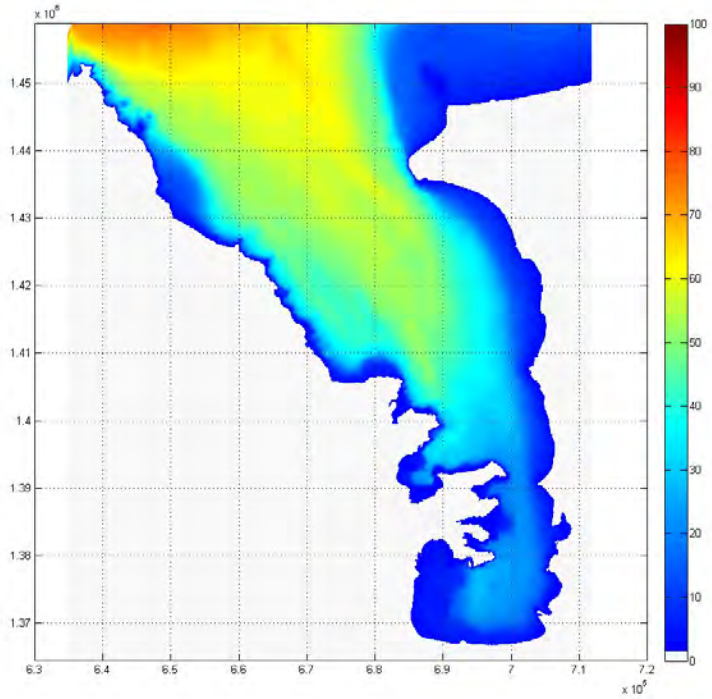


Figure No. 2.16 Study area (taken from the union of the nautical charts).
Source: Aqua&Terra Consultores Asociados S.A.S, 2015

This study was carried out with the help of the SWAN model and the Coastal Modeling System of Colombia (SMC-COL), adjusted to the bathymetries of the Colombian coasts by the Oceanographic and Coastal Research Group of the University of Cantabria (GIOC), with the assistance from the General Maritime Directorate (DIMAR). The SMC-COL integrates a series of numerical models, which allow to give a practical support to the correct application of the methodology of work for Coastal Engineering.

- ✓ *Currents for breakage*

As it is known, wave breaking generates additional currents that are manifested through the radiation tensor, which must be estimated to evaluate the effects that the project would have on the coast surrounding it. To know its behavior, it is necessary to use a model that determines the wave's radiation tensor from the results of height and wave incidence obtained in the propagation, calculating the

field of currents and levels due to said radiation tensors. To achieve this, the SWAN model was coupled to the flow module of the DELFT 3D model.

✓ *Description of the DELFT 3D model*

Delft3D is an integrated modeling system of flow and transport oriented to the aquatic environment that solves the Navier-Stokes equations for shallow waters with the hypothesis of hydrostatic pressures and the Boussinesq approach. The mathematical formulations included in the model allow to consider the following physical phenomena.

- Effects of the rotation of the Earth (Coriolis force).
- Baroclinic effects.
- Mass of induced turbulence and moment flows (turbulent closure models).
- Transportation of salinity, temperature and other conservative substances.
- Tidal forcings in open contours.
- Spatial and temporal variations of the tangential tension of the wind on the surface of the water body.
- Spatial variations of the tangential tension in the background.
- Spatial and temporal variations of atmospheric pressure on the surface.
- Temporary variation of sources and sinks (i.e. discharges in rivers).
- Flooding and drying of low tides.
- Heat flows.
- Effect of the waves.

✓ *Propagation case and meshes*

To characterize the field of currents in the study area, the wave case was selected, which is exceeded twelve hours per year, for the predominant direction in deep waters and thus estimate the behavior of currents in the study sector. Next (Table No. 2.33 and Figure No. 2.17) the propagation meshes used to estimate wave currents are shown.

Table No. 2.33 Mesh data used in the flow module of the DELFT 3D model.

Name	Origin X, Origin Y	Angle	Cell size (m)	[Nodes]
M1	696000,1366700	0	25 x 25	Variable

Source: Aqua & Terra Consultores Asociados S.A.S., 2015.

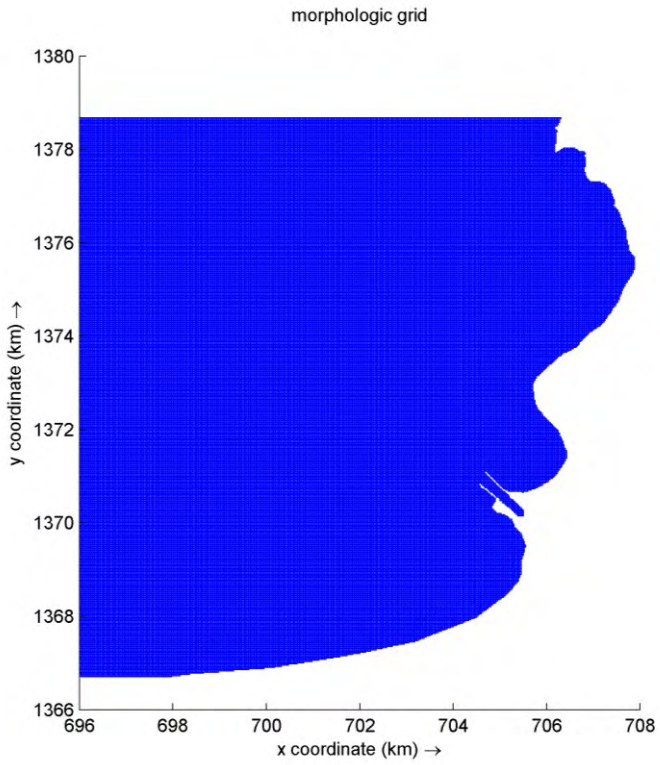


Figure No. 2.17 Meshes for the propagation of currents. F1, mesh on bathymetry with the current condition for swell extremal.
Source: Aqua & Terra Consultores Asociados S.A.S., 2015.

✓ *Tides*

The astronomical tide is defined as the set of regular movements of sea level rise and fall with periods close to 12 or 24 hours that are produced by the gravitational effects of the earth-moon-sun system. From the practical point of view, it is necessary to know the behavior of tidal waves, especially to predict the amplitude of the same at a certain time and place. That is why a way to approach the study of their behavior is to consider the astronomical tide as the sum of a finite number of

waves, whose amplitude and data are known because they have been associated with some planetary movement.

According to the previous hypothesis, several researchers have worked on the development of periodic components of the driving force as forcing generated from the tide. Darwin and Doodson managed to carry out this decomposition by performing an astronomical analysis considering the movements of the earth, moon and sun, from which they determined the frequency and relative importance of each of the components.

The decomposition is basically done assuming that the generating forces produced by the moon and the sun in their variable trajectories are generated by a finite number of fictitious planets. Each of these planets revolves around the earth with a circular orbit located in the plane of the equator at a constant angular velocity, and they are selected in such a way that, one or a combination of several of them, reproduce the frequency of a certain disturbance astronomical

- ✓ *Calculation methodology*

The description and prediction of the tide in a given location could be done through what is called harmonic tidal analysis, which consists of decomposing the records of sea level in a finite number of waves whose period and phase have been perfectly established, given which coincide with the periods of some of the relative astronomical movements between Earth, Moon and sun, as has been described above. In general terms, the method of harmonic analysis consists of measuring the sea level during a certain period and obtaining, from said record, the amplitudes and phases of the component waves. These parameters are called harmonic components, due to the implicit assumption that the responses of seas and oceans to tidal forces do not change over time. In this case, the method that is going to be presented is the one elaborated by Dronkers (1964) and based on the least squares.

The astronomical tide approaches, then to the sum of those constituent waves in the following way:

$$S_{MA}(t) = a_0 + \sum_{i=1}^{n} a_i + \cos(\overline{w}_i t + \varphi_i)$$

Where:

- a_0 is the amplitude of the average reference level
- a_i is the amplitude of the wave i

- ωi is the frequency of the component wave i
- φi is the phase shift of the component wave i
- t is the moment when the tide is calculated
- n is the number of components considered

Next, the harmonic components were obtained to forecast the tide events in a period between January 1, 1990 and January 1, 2000. The harmonic components were obtained from the TPXO model, which is one of the most accurate global tide models, which provides four semidiurnal harmonic components (M2, S2, N2, K2), four diurnal components (K1, O1, P1, Q1), two of long period (Mf and Mm) and three of short period (M4, Mn4, Ms4) in a mesh with global coverage of 1440 x 721 points with 0.25º of spatial resolution. In this study we have used the most recent database, TPXO7.2. Figure No. 2.18 shows the location of the TPXO point closest to the study area.

Table No. 2.34 Tidal harmonic components, obtained from TPXO

Component	Frequency	Period (hr)	Amplitude (m)	Phase (°)
m2	28.984101	12.42	0.0693	151.22
s2	30	12	0.0168	12.35
n2	28.43973	12.66	0.0255	120.74
k2	30.082137	11.97	0.0052	0.04
k1	15.041069	23.94	0.0937	239.45
o1	13.943036	25.8	0.0576	240.29
p1	14.958931	24.07	0.029	244.4
q1	13.398661	26.87	0.0082	236.03
mf	1.098033	328	0.0168	356.53
mm	0.544375	661	0.0081	353.33
m4	57.96821	6.2103	0.0019	151.72
ms4	58.984104	6.1033	0.005	340.28
mn4	57.423	6.2393	0.0018	193.14

Source: Aqua&Terra Consultores Asociados S.A.S, 2014

Figure No. 2.18 Location of the point where the harmonic components of the TPXO were obtained.
Source: Aqua&Terra Consultores Asociados S.A.S, 2014.

With the components obtained from the TPXO and the equation that relates the amplitude and the phase of these, the astronomical tide series was constructed for the point in the outskirts of the gulf.

2.3.1.10 *Geotechnics*

The geotechnical studies for the study area were carried out by EDIFICA. The methodology used during the development of these studies is described below.

For the conceptual design stage, 10 holes were made between 70 m and 100 m depth (seven (7) in water and three (3) in the ground) and four (4) piezcones CPTu (two (2) in water and two (2) on land). The location of the exploration points is presented in Table No. 2.35 and Figure 2.19.

Table No. 2.35 Location of perforations and piezocone tests

KIND	PROBE	FLAT COORDINATES MAGNA SIRGAS Origin BOGOTÁ	
		EAST	NORTH
Drilling	PF-1	706,662.69	1,368,775.85
	PF-2	706,510.00	1,369,064.68
	PF-3	706,332.47	1,368,921.89
	PF-4	705,925.06	1,369,079.51
	PF-5	705,364.76	1,369,492.76
	PF-6	704,771.00	1,369,850.88
	PF-7	703,990.25	1,370,309.87
	PF-8	703,242.56	1,370,757.58
	PF-9	702,766.57	1,370,550.31
	PF-10	702,771.47	1,371,303.17
Piezocone test	CPT-F-1	706,520.54	1,368,987.12
	CPT-F-2	704,419.08	1,370,052.44
	CPT-F-3	702,780.13	1,370,937.74
	CPT-F-4	706,355.40	1,369,054.60

Source: EDIFICA, 2015

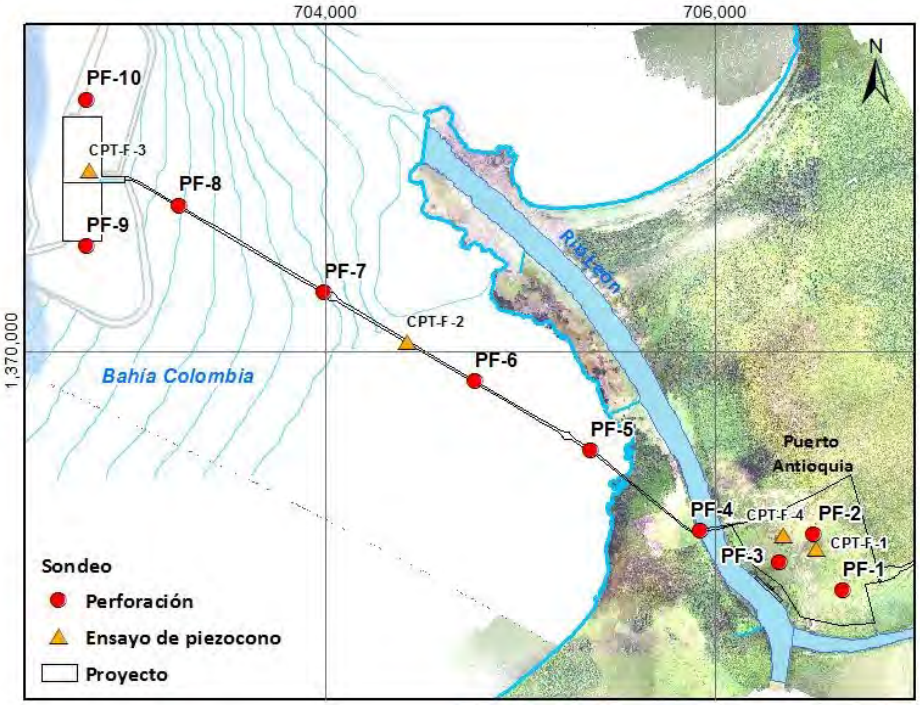


Figure No. 2.19 Location of geotechnical exploration points
Source: Aqua & Terra Consultores Asociados S.A.S, 2015 with information from EDIFICA

Additionally, several types of laboratory tests were carried out, including geotechnical classification tests, resistance, compressibility, dynamic tests, electrical resistivity, and even groundwater characterization.

The subsoil investigation stage also included the installation of Casagrande open tube piezometers. These were installed in drilling PF-1, PF-2 and PF-3 located on land and in drilling PF-5 located in water.

There was a weather station for offshore work to keep a daily record of temperature, relative humidity, rain and wind speed.

- ❖ Perforations

The exploration of the subsoil was made by drilling using the following equipment (see Photograph No. 2.1):

Hydraulic drilling rig ST-51 for ground drilling

Hydraulic drilling rig TP-50D for water drilling

UNIBAN barge for TP-50D equipment operation in water.

Photograph No. 2.1 Equipment for the exploration of the subsoil in water
Source: EDIFICA, 2015

In the perforations, different types of tests were performed, and samples taken (altered and unchanged). The tests consisted of SPT Standard Penetration Test (ASTM D1586), MC Modified California Penetration Test (ASTM D3550), Field Vane (VS) Test (ASTM D2573), Laboratory Vane (VL) Test and Strength Test the penetration measured with the pocket penetrometer (Rp). The samples correspond to those obtained from the SPT and MC tests, to samples with Shelby thin-walled tubes pressed under pressure, samples with advance of the sampler to rotation with drill in the form of saw and samples in metal tube for the muds of the bottom of the sea.

The SPT and MC penetration tests were performed by applying blows to the sampler with a standard energy. The equipment they used has an automatic hammer, which offers the advantage of greater uniformity in the transmitted energy. The SPT test measures the penetration resistance by counting the number of strokes necessary for the sampler to penetrate a distance of one foot into the ground and allows altered samples to be obtained in granular soils and in fine soils. This type of sample is 3.5 cm in diameter and serves to identify the type of soil that is drilled and perform natural humidity and classification tests in the laboratory. Given their high degree of alteration, these samples do not allow resistance or compressibility tests.

The MC test also measures the resistance in a similar way to the SPT, but since the sampler has a larger diameter, a conversion must be made to pass the number of strokes from MC to equivalent SPT (the number of strokes of the MC is multiplied by 0, 55 to obtain the equivalent SPT). The number of strokes per foot indicated in the drilling records is the count made in the field, without any type of correction.

Photograph No. 2.2 Equipment for underground exploration of the ground
Source: EDIFICA, 2015

The samples obtained with the MC test are 6.35 cm in diameter. This test is widely used in practical engineering, especially on the west coast of the United States. With the CM samples are obtained "relatively undisturbed", both in granular soils and in fine soils of firm to hard consistency, which allow to make compressibility and cut resistance tests. Samples come out of the sampler encapsulated in a plastic tube or in bronze rings that protect them during handling and transport.

Shelby tube samplers are used in soft to medium soils and come out of the sampler encapsulated in a plastic tube that avoids its alteration during handling and transport.

Samplers with a serrated drill allow to take undisturbed samples in soils of hard consistency. During sampling, water is not used to prevent sample alteration.

- ❖ Piezocono CPTu assays

The CPTu test was performed in accordance with ASTM D5778. Said test consists of pushing an electronic penetrometer with a conical tip into the soil at a speed of 2 cm / s. The penetrometer used in this project has a cross-sectional area of 10 cm2 and a capacity of 10 tons. The penetrometer is instrumented with a series of sensors that allow to measure when penetrating in the ground the resistance by the tip, the resistance by friction, the pressure of the water in the pores of the ground, the

inclination, the temperature and counts on an accelerometer that allows measure the speed of propagation of normal and shear odes.

Piezocone measurements are recorded in the field with a computer and then the data obtained is applied by software (CPeT-IT) to a series of correlations that allows inferring various soil parameters such as compressibility and deformation, resistance, permeability, etc. The CPTu data is used to determine the capacity of piles and surface foundations.

- ❖ Laboratory tests

The laboratory tests in this project correspond to the following:

1) Basic and classification tests: Natural humidity, unit weight, Atterberg limits (or limits of consistency), specific gravity, granulometry by sieving and hydrometer, washing by sieve No. 200, carbonate content, content of organic matter, content of salts, pH and corrosion.

2) Compressibility tests: consolidation, triaxial compression CU.

3) Strength tests: unconfined compression, triaxial compression UU (unconsolidated, not drained), triaxial CU (consolidated, not drained), direct cut.

4) Seismic characterization tests: resonant column, bender element in confined and unconfined samples.

5) Physical-chemical characterization tests of artesian water: In accordance with instructions received from the supervision, a sample of the artesian water was taken in the PF-2 drilling and subjected to characterization tests.

6) Tests of electrical resistivity in the soil determined in the laboratory and of electrical resistivity in the water measured in the sea and in the León River.

- ❖ Geotechnical zoning

The geotechnical zoning was carried out according to the results of standard penetration tests, penetration tests with Dutch cone, field vane cutting tests, unconfined compressions, direct cutting and triaxial tests on recovered samples, based on characteristics resistant of the subsoil material following the following premises presented in Table No. 2.36. The geotechnical zoning was represented on a 1: 10,000 work scale.

Table No. 2.36 Geotechnical classification of subsoil material according to resistance to penetration (mainly granular soils) and undrained shear resistance (mainly cohesive soils)

Nomenclatura	Clasificación Geotécnica del Material (Consistencia/Densidad Relativa)	Resistencia a la Penetración Estandar (Nspt)	Resistencia al Corte no Drenado (Su) (Kg/cm2)	Código de Colores
1	**(Muy Blando/Muy Suelto)** - Depósito fluviomarino principalmente lodolitas, con material arcillo limoso, e intercalaciones de arena. Humedad y plasticidad alta.	Nspt < 2 golpes	Su < 0,25	
2	**(Blando/Muy Suelto)** - Depósito fluviomarino arcillo limoso, con intercalaciones de arena. Humedad y plasticidad alta.	2 < Nspt < 4 golpes	0,25 < Su < 0,50	
2	**(Poco compacto/Suelto)** - Arcilla Limosa de alta plasticidad, humedad media a baja.	4 < Nspt < 8 golpes	0,50 < Su < 1,00	
3	**(Compacto/Densidad Media) -** Arcilla limo arenosa, plasticidad media, humedad media a baja.	8 < Nspt < 15 golpes	1,00 < Su < 2,00	
4	**(Muy Compacto/Densidad Media) -** Arena limosa, con intercalaciones de arcillas, humedad media.	15 < Nspt < 30 golpes	2,00 < Su < 4,00	
6	**Duro/Denso a muy denso -** Arenas con matriz arcillosa, humedad media.	Nspt > 30 golpes	Su > 4.00 Kg/cm2	

Source: Aqua & Terra Consultores Asociados S.A.S., 2015

2.3.1.11 *Atmosphere*

The atmospheric component was carried out in three subcomponents: climate, air quality and environmental noise.

- ✓ *Weather*

The climate in the area of influence of the project was carried out with secondary information from the Environmental Impact Study that supports the environmental license granted through Resolution 0032 of 2012 and other information consulted in

the Atlas of the Gulf of Urabá and the Institute of Hydrology, Meteorology and Environmental Studies - IDEAM.

✓ *Air quality*

The air quality in the area of influence of the project was characterized with secondary information from the Environmental Impact Study that supports the environmental license granted through Resolution 0032 of 2012. It should be mentioned that air quality monitoring of the criteria pollutants was not carried out, since the conditions under which the characterization of the aforementioned environmental study was carried out did not show significant variations in terms of infrastructure, industries, traffic flow and source. of emission that could cause variations in the contamination to the environment, therefore, it was considered that it was not representative to perform again air quality monitoring for the modification of environmental license.

- Location of monitoring points:

The records taken from the air quality monitoring stations carried out by the company Air Clean Systems S.A. (ACS S.A.), were located as follows, see Table No. 2.37 and Figure No. 2.20:

Table No. 2.37 Location of air quality monitoring stations

Seasons	ID	NAME	FLAT COORDINATE MAGNA SIRGAS Origin BOGOTÁ	
			EAST	NORTH
1 (PST) y 4 (PM_{10})	A 1-4	North Sector	706516.54	1369224.56
2 (PST) y 5 (PM_{10})	A 2-5	Sur Sector	706430.13	1368659.23
3 (PST) y 6 (PM_{10})	A 3-6	Center	706490.39	1368972.54

Source: Aqua & Terra consultores Asociaos S.A.S., 2015 with data from ARAÚJO IBARRA, 2009.

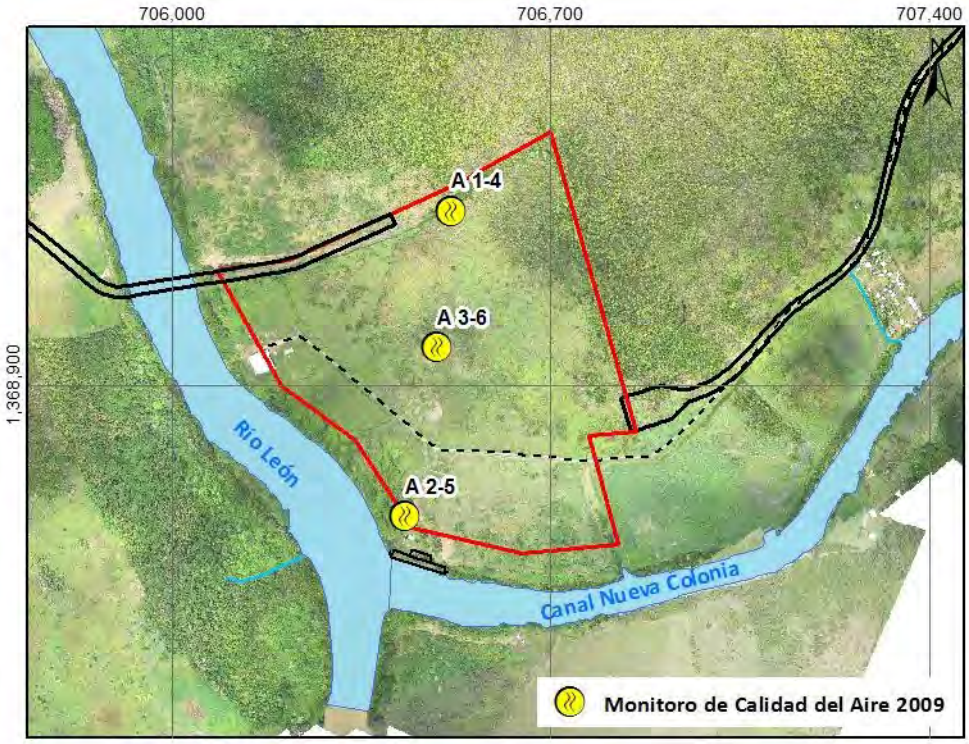


Figure No. 2.20 Location of air quality monitoring stations
Source: Aqua & Terra consultores Asociaos S.A.S., 2015 2015 with data from ARAÚJO IBARRA.

It is important to explain that the monitoring stations were located in accordance with the technical criteria established in the IDEAM air quality protocol to ensure representativeness and homogeneity during sampling and thus ensure that the results obtained are related to the conditions of the place evaluated in particular, the following criteria were taken into account:

- The distance between the station and the nearest obstacle must be twice the height of the obstacle.
- The sampling equipment can be located from ground level.
- There should not be close (less than 20 m) fixed point sources of emission.
- The distance to the trees must be greater than 10 m.
- Have a 270º radius free of flow restrictions around the sampler.

The climatic conditions of the site at the time of sampling were also considered, in order to locate the three (3) stations in line, according to the prevailing wind direction

when starting the field work. In this case, the predominant direction of the winds was south, according to what was expected for this time of year.

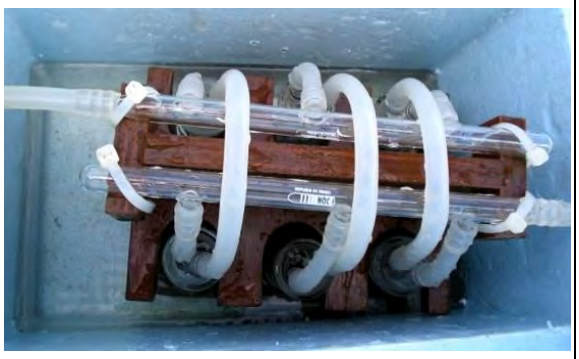
- Parameters and methods of sampling and analysis:

The levels of total suspended particles, respirable particles, nitrogen oxides, sulfur oxides and carbon monoxide expressed as PST, PM10, NO2, SO2 and CO were determined.

The monitoring was carried out according to the standardized sampling and analysis techniques of the EPA (United States Environmental Protection Agency), 40 CFR part 50 Appendices A (SO2), B (PST), F (NO2) and J (PM10) methods, established by the IDEAM in the Operation Manual of Air Quality Surveillance Systems.

This is how three (3) stations HI-VOL type were used to evaluate total suspended particles (PST), three (3) stations type HI-VOL to assess the respirable particles (PM10), three (3) gas trains to evaluate ambient air concentrations of sulfur oxides (SO2) and nitrogen oxides (NO2) and non-dispersive infrared equipment for the direct measurement of carbon monoxide (CO). For the calibration of the particle monitoring equipment (TSP and PM10), a variable flow calibrator was also used as presented in Photograph No. 2.3 (see Annex 5.1.4 Air quality and noise, calibration data and calibration certificates).

As stated in the attached certificates (see Annex 5.1.4 Air quality and noise), companies Air Clean System S.A. and Quimicontrol Ltda (responsible for the analysis of samples in the laboratory), are accredited by the IDEAM according to ISO 17025.

HI-VOL equipment for TSP and HI-VOL equipment with header for PM10, both with continuous measurement of effective monitoring time and measuring device and flow control.	Variable flow calibrator for HI-VOL equipment, either for PST or with PM_{10} header.
	
Sampling train for gas measurement (NO2, SO2) by absorption in special solutions (gas rack).	The assembly of one of the air quality stations located on the property is appreciated.

Photograph No. 2.3 Equipment used in air quality sampling
Source: ACS. Op. Cit.

- Methods of Analysis

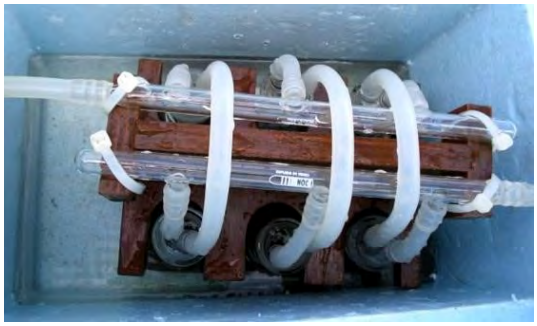
Table No. 2.38 presents the methods of analysis that were used for the analysis of the criteria pollutants.

Table No. 2.38 Summary of sampling and analytical methods used for air quality monitoring

Parameter	Sampling	Analysis method	Reference
Suspended particles (PST)	Hi-Vol PST stations TISCH brand (serial: 7422, 7423 and 7424).	Gravimetric.	US EPA 40 CFR Part 50 Appendix B.
Suspended particles (PM10)	Hi-Vol stations PM-10 brand TISCH (serial: 7414, 7414 and 7416).	Gravimetric.	US EPA 40 CFR Part 50 Appendix J.
Sulfur dioxide (SO2)	Absorption train Andersen.	Colorimetric (pararosaniline).	US EPA 40 CFR Part 50 Appendix A.
Nitrogen dioxide (NO2)	Absorption train Andersen.	Colorimetric (NEDA).	US EPA 40 CFR Part 50 Appendix F.
Carbon monoxide (CO)	Infrared absorption equipment for CO analysis.	Absorption in infrared.	Carbon monoxide analyzer CO12Module.

Source: Ibid., Modified by Araújo Ibarra.

Equipment for measuring flow and time in high volume equipment for determination of PST	Calibration of high volume equipment with hole pattern with PST header

Equipment of measurement of flow and time in the high-volume equipment with header for determination of PM10	Calibration of high volume equipment with PM10 header with hole pattern
	
Gas train, vacuum pump and bubblers for determination of NO2 and SO2	Gas train and bubblers (top view)

Photograph No. 2.4 Equipment used for air quality analysis
Source: ACS. Op. Cit.

- Permissible limits:

Resolution 601 of 2006, modified since then by Resolution 610 of 2010, of the Ministry of Housing, Environment and Territorial Development establishes the

permissible limits for concentrations of pollutants in the air (see Table No. 2.39), established at reference conditions 25° C and 101.325 kPa:

Table No. 2.39 Maximum permissible levels for criteria pollutants in immission air

Pollutant	Maximum allowable limit in µg / m³ (at 25 ° C and 101,325 kPa)	Averaging time
PST	100	Anual
	300	24 hours
PM_{10}	50	Annual
	100	24 hours
SO_2	80	Annual
	250	24 hours
	750	3 hours
NO_2	100	Annual
	150	24 hours
	200	1 hour
CO	10.000	8 hours
	40.000	1 hour

Source: Resolución 610 de 2010 del MAVDT[11].

- Air quality modeling during the operation of the viaduct

The information of the Air Quality Modeling Study of Puerto Bahía Colombia de Urabá presented in the ordinary line was compiled by means of the file ANLA 2015008528-1-000 of February 20, 2015 for the operation of the viaduct of the Project, as an activity licensed in the Resolution No. 0032 of January 2012. File LAM 5060.

Model

To determine where the pollutants are going, and the type of concentration reached, a dispersion model was used to locate the points of maximum concentration. It is at these points where the air quality stations should theoretically be located to record the maximum concentrations of the area, as well as determine the receivers that could be affected.

The software model AERMOD view, version 8.8.9, was developed, which is developed by the government of the United States, together with the Environmental Protection Agency (EPA) and the American Meteorological Society.

[11] Ibíd.

Description of the Aermod View Software

AERMOD View is an interface, in a Windows® environment, developed by Lakes Environmental (www.weblakes.com). It includes the three original modules of the model: AERMET to pre-process the meteorological information, AERMAP to process the land information and AERMOD the dispersion model.

This Gaussian model in stationary state, allows modeling the dispersion of particulate matter, gases, vapors and odors at a distance up to 50 km from the emission sources such as chimneys, line sources, area and volume sources as well as lighters or elevated burners.

The interface is completely graphical, intuitive and very user-friendly for experienced or non-experienced users, who are guided step by step in the use of the model and who have interactive help on each screen of the software.

The results of the modeling are shown in the form of graphs of colored contours of iso-concentration which can be superimposed on abstract maps or Google Earth® images.

AERMOD is a Gaussian pen model in steady state that simulates the dispersion of pollutants in the air and their deposition; performs its calculations considering the characteristics of the land and the presence of buildings near the source of emission, which can affect the dispersion of the boom; uses weather data from the upper atmospheric layer. It is a regulatory model of the United States EPA and is considered the latest generation model.

- ✓ *Environmental noise*

In order to complement the current status of the Project in terms of environmental noise in the area of influence of the section of access road to the terminal on land subject to modification, samplings of sound pressure levels were carried out in accordance with the protocols of measurement and evaluation of noise established in Resolution 627 of 2006 and the recommendation made in the ordinary course will be accepted through the file ANLA 2015008528-1-000 of February 20, 2015, where three (3) stations are proposed and additionally, one (1) additional control point is proposed at the end of the Nueva Colonia corregimiento.

- ❖ Sampling stations

To determine the baseline on the access road to the terminal on the ground, environmental noise sampling was proposed in four (4) stations, which will be

distributed at the ends and north of the Nueva Colonia district and at the end of the section, as shown in Table No. 2.40 and in Figure No. 2.21.

Table No. 2.40 Location of environmental noise sampling stations

ID	Station name	Flat coordinates -MAGNA SIRGAS Origin BOGOTÁ	
		EAST	NORTH
R1	East of Nueva Colonia	709.518,96	1.369.996,53
R2	West of Nueva Colonia	708.833,52	1.369.842,90
R3	North of Nueva Colonia	708.553,10	1.370.542,73
R4	Access to the Onshore Terminal	706.969,86	1.368.841,19

Source: Aqua & Terra Consultores Asociados S.A.S, 2015

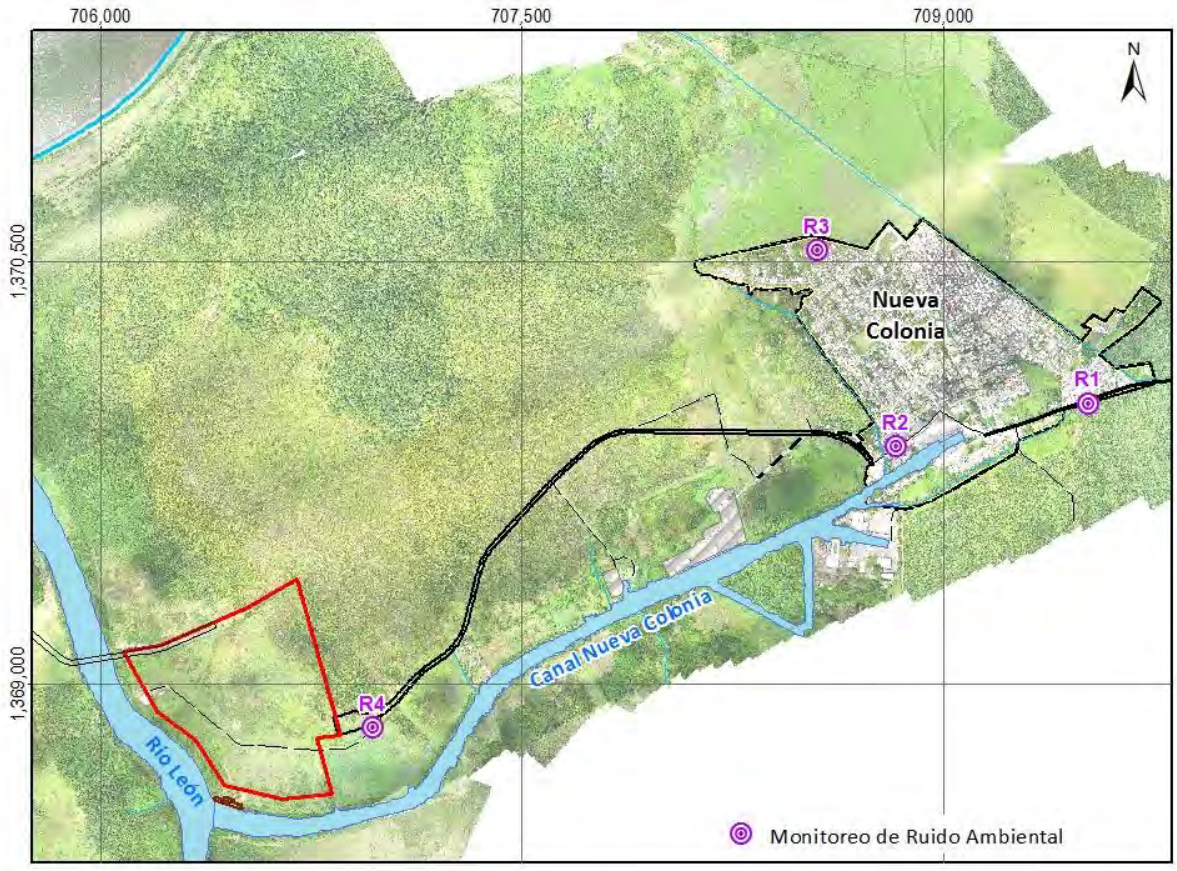


Figure No. 2.21 Location of environmental noise sampling stations
Source: Aqua & Terra Consultores Asociados S.A.S, 2015

- Sampling parameters

In accordance with the provisions of Resolution 627 of 2006, measurements of the environmental noise level were made in accordance with the procedures stipulated in the aforementioned resolution for the days:

1) Business Day: Day and night
2) Non-skilful: Day and night

In each station the main parameters for noise will be measured as they are:

1) Sound pressure level continuous weighted equivalent A, LAeq, T and slow weighted (S).
2) Residual Noise, measured as a continuous weighted equivalent sound pressure level A, LAeq, T, Residual
3) L90 percentile level

Based on the results, compliance with the current Colombian environmental regulations will be verified (Resolution 627 of 2006) in Article 17 in which it establishes the maximum permissible standards of environmental noise emission levels, expressed in weighted decibels A (dBA) for different sectors, according to the current use of urban and rural land in the study area.

- ❖ Calculation of environmental noise

The environmental noise was calculated by the expression presented in Equation No. 2.7:

$$L_{Aeq} = 10.\log\left((1/5).(10^{L_N/10}+10^{L_O/10}+10^{L_S/10}+10^{L_E/10}+10^{L_V/10})\right)$$

Equation No. 2.7 Equivalent level resulting from the measurement
Source: Resolución 627 de 2006

Where:

LAeq = Equivalent level resulting from the measurement.

LN = Equivalent level measured at the microphone position facing north

LO = Equivalent level measured at the position of the microphone facing west

LS = Equivalent level measured at the microphone position facing south

LE = Equivalent level measured at the microphone position facing east

LV = Equivalent level measured at the microphone position oriented vertically

- Considerations for the execution of measurements

The measurements of ambient noise levels should be made in dry weather, for this reason, measurements should not be developed in:

Conditions of rain, drizzle, thunder or hail fall.

Wind speed greater than 3 m / s.

Wet floors

The monitoring will be postponed until the optimal conditions for its development are presented.

- Adjustment of sound pressure levels

The equivalent continuous sound pressure levels weighted A, LAeq, T, LAeq, T, Residual and L90 percentile level, are corrected for impulsivity, tonality, weather conditions, schedules, types of sources and receivers, to obtain corrected levels of continuous sound pressure Weighted equivalent A, LRAeq, T, LRAeq, T, Residual and L90 percentile level, respectively. Equation No. 2.8 will serve as a basis for making such corrections:

$$L_{RA(X)T} = L_{A(X)T} + (K_I, K_T, K_R, K_S)$$

Equation No. 2.8 Corrections of the equivalent level resulting from the measurement
Source: Resolución 627 de 2006

Where:

KI = is a pulse adjustment (dB (A))

KT = is a setting for tone and information content (dB (A))

KR = is an adjustment for the time of day (dB (A))

KS = is an adjustment (positive or negative) for certain sources and situations, for example low frequencies (dB (A))

(X) = corresponds to any of the parameters of measurement referred to in article 4 resolution 627 of 2006 MVADT

The A-weighted equivalent sound pressure level A, LAeq, T, is only corrected by a single K factor, the highest value in dB (A).

- Sampling equipment

The equipment used for the measurement of noise emission were automatic integrating sound level meters Marca CASELLA, the measurements were made applying a filter of frequency weighting dB (A) and a filter of temporary weighting S (Slow, response, slow), with removable microphone and wind screen. Additionally, to verify the wind speed, which should not exceed 3 m / s, a weather station was used.

To verify the correct operation of the sound level meter, an acoustic calibrator with type 1 precision was used for sound level meters with an output frequency of 1000 Hz and 114 dB.

In Figure No. 2.22 and in Table No. 2.41, the equipment used is presented

Figure No. 2.22 Used Sonometer and Verification Pistonphone Brand CASELLA
Source: SGS Colombia S.A., 2015

Table No. 2.41 Reference Sound level meter

Instrument	Serial number
CASELLA sound level meter	CEL 63X
CASELLA Pistophone	AC 300003971

Source: SGS Colombia, July 2015

- Modeling prediction of sound pressure levels during the operation of the viaduct

The information of the Moderation Study of Puerto Bahía Colombia de Urabá Viaduct Noise Emission Modeling submitted in the ordinary line was compiled by means of the file ANLA 2015008528-1-000 of February 20, 2015 for the operation of the Project viaduct, as an activity licensed in Resolution No. 0032 of January 2012. File LAM 5060.

Calculation of noise emission -viaduct

For the noise modeling, the road traffic noise calculation procedure (CRTN - ISBN 0 11 550847 3) of the Department of Transport of the United Kingdom was implemented.

The objective of the CoRTN is to provide a basic platform for the calculation of traffic noise levels for non-complex situations. The model is limited when, for example, a separate calculation is necessary to take into account complex arrangements of reflective surfaces, since the model only implements a simple reflexive correction.

The method uses a series of graphs and equations to apply corrections to a base noise emission level, for different situations. The CoRTN model has been accepted by many regulatory authorities in Australia, as the basic model to be used for the prediction of traffic noise and for the design of acoustic barriers, with corrections generally applied for "Australian conditions" accepted by the industry.

CoRTN implements a calculation method, segment by segment, for each entry road segment. The calculation of the propagation is carried out by applying the following corrections at the level of noise emission:

* Distance correction
* Ground attenuation
* Angle correction
*Projection
* Correction by Reflection.

Modeling Parameters

The CoRTN calculation predicts noise levels based on the Leq, 1hr statistical noise descriptor for operational roads. The input data to the model were the following:

Period of time: 1h Leq

Total Vehicle Flow: 50 vehicles / hour

Speed: 40 km / hr

Heavy vehicles: 100%

Gradient: 1%

Road surface: Raincoat

Low Traffic Volume

The calculation algorithm of the CoRTN implements a correction for roads with low traffic volume (ie, below 200 vehicles / hour) to account for the effect that intermittent traffic has on the statistical descriptor Leq, 1hr. This correction factor does not apply to calculations of energy-based LAeq descriptors (AECOM, 2011). The application of this correction factor is taken into account for the study in question.

Noise modeling with modified source height

The CoRTN calculation algorithm assumes a traffic noise emission height of 0.5 m above the road surface for all classes of vehicles. This assumption may overestimate the effect of noise barriers, especially on heavy vehicle routes, since noise sources from heavy vehicles (ie. engine and exhaust) have a noise emission located at a significantly higher height.

Interpolation of Kriging.

According to Cano (2009)[12] the Kriging interpolation (in reference to its creator) is a geostatistical method, which is based on the regionalized and autocorrelated variables in the space.

This autocorrelation is determined from the elaboration of semivariograms, with which it is possible to define the best fitting model, to proceed to the interpolation and in which the maximum distance or "range" where the autocorrelation ends is defined.

For practical purposes, it is impossible to get data values at each desired point, due to the inaccuracy originated in practice. Thus, interpolation is important and fundamental in the graphic representation and in the analysis and understanding of the data.

Kriging is an interpolation method that predicts unknown values of the data observed in the known locations, therefore the need arises in this study to resort to this interpolation method, which delivers results consistent with the dynamics of the variable to be interpolated, respecting, as far as possible, the actual information

[2]CANO J. A. Methodology for the analysis of noise dispersion in airports, case study: Olaya Herrera Airport in the city of Medellín. Master thesis in environment and development. National university of Colombia. Medellín, 2009. 111 p.

provided; it is for this reason that this method of interpolation is considered as the best of the linear unbiased estimators existing at present.

This method takes into account both the spacing of the points in which information is available, and its distribution in the domain to be interpolated. In addition, it considers the spatial variability of the data, which it does by means of the semivariogram (which will be explained later), which is constructed from the covariance between each pair of points located at different distances; to this one a theoretical variogram that represents most faithfully the variability of the data is adjusted.

Each theoretical model is associated with a set of parameters such as the nugget effect, the plateau and the range that are determined from the characteristics of the data and that are subsequently used by Kriging during the interpolation. The semivariogram establishes an effective distance of influence from which it is assumed that there is no correlation between the data[13].

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[3]GALLEGO, L. and TORO, E. Noise analysis in the center of Medellín through the application of statistical tools. Industrial Engineering Degree Thesis. National university of Colombia. Medellín, 2006. 98 p
[14] CANO J. A, 2009. Op Cit.

- Modeling prediction of sound pressure levels in the access road

This model was made with the purpose of predicting the acoustic impact of the operation activities of vehicle sections between the Nueva Colonia corregimiento and the Construction and Operation project of a Port Terminal of Solid Bulk of Gran Calado in Colombia Bay, through software of acoustic prediction CadnaA V4.5, which adopts different international standards to perform the calculation of sound pressure levels at a given receiver point. The method recommended by the ordinary route was adopted through the file ANLA 2015008528-1-000 of February 20, 2015 is the French NMPB Routes 96: "Nouvelle Méthode de Prévision du Bruit des Routes" (New Method of Noise Prediction in Roads) and additionally, the results obtained were compared with Resolution 627 of 2006[15].

Scenarios for modeling

Scenario I: Operation of existing roads, "Corregimiento Nueva Colonia - Puerto Bahía de Urabá".

Scenario II: Operation of projected roads, from the corregimiento of Nueva Colonia to the Puerto Bahía de Urabá project in Colombia.

[5]COLOMBIA. MINISTRY OF ENVIRONMENT, HOUSING AND SUSTAINABLE DEVELOPMENT. Resolution 627 (April, 07, 2006). By which the national norm of emission of noise and environmental noise is established. . Bogotá D.C., 2006.

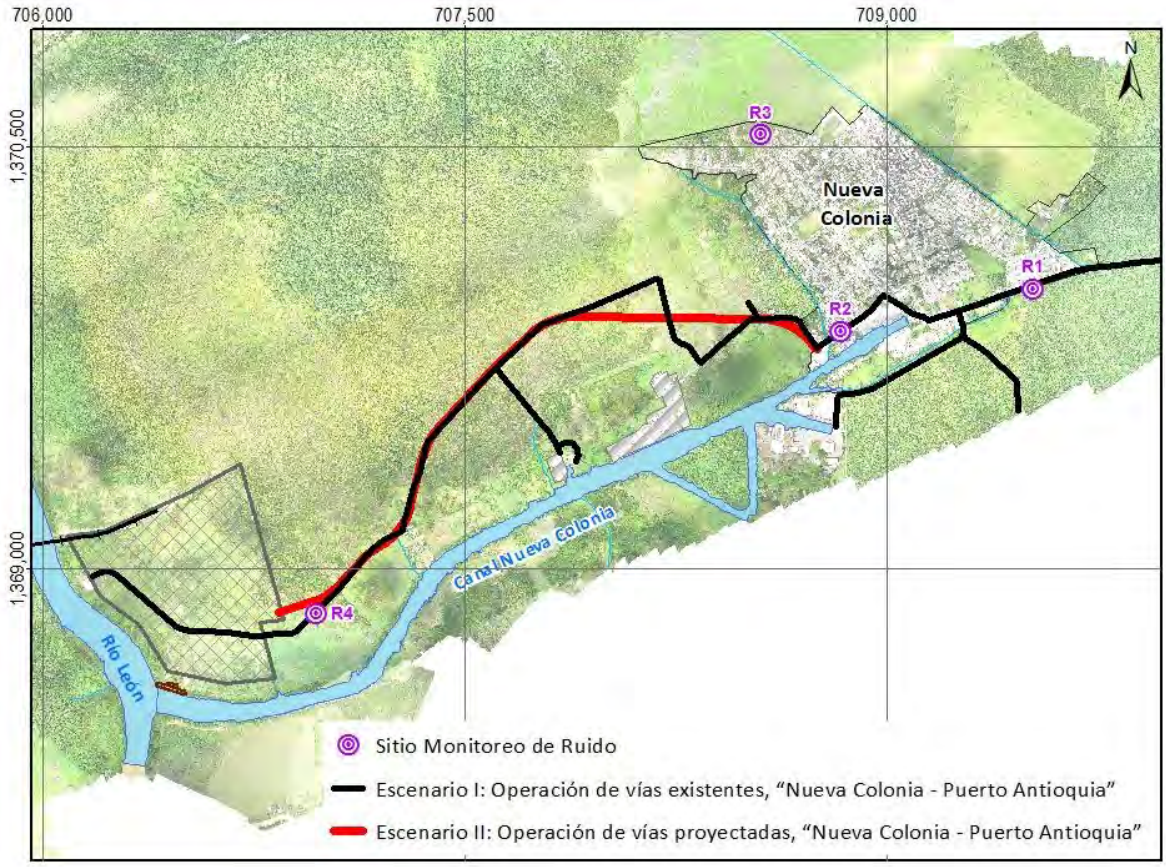


Figure No. 2.23 Scenarios
Source: Aqua & Terra Consultores Asociados S.A.S, 2015

Information sources

The traffic flow information was taken from the traffic study of the "Rio Grande-Nueva Colonia" road. For scenario I, which corresponds to the existing roads, the year 2015 was considered and for scenario II, the projected routes are the year 2025, due to the fact that the project for this year is expected to be fully operational.

Calculation of sound propagation

The routes that were modeled were considered sources of noise and were configured under the parameter "roads" within the CadnaA model, where data such as vehicle gauging, gauging schedules, speed limits, road type and percentage were specified. of light and heavy vehicles, among others.

Based on the information provided, a simulation of the vehicular flow was performed for each of the scenarios through all the specified roads, considering whether they were existing roads (Scenario I) or projected routes (Scenario II).

According to the French standard used for this modeling (NMPB Routes 96), the emission parameter is the weighted sound power level-A per octave band LAW, i of a sub-source in the form of a point Si in dB (A) and it is calculated by means of the following equation:

$$L_{Aw,i} = 10\lg\left(10^{(E_{VL}+10\lg Q_{VL})/10} + 10^{(E_{PL}+10\lg Q_{PL})/10}\right) + 20\,dB + 10\lg l_i + R(i)$$

Equation No. 2.9 Sound power level according to NMPB-Router 96
Source: CadnaA V4.5

Where:

E_{VL}: Sound power level of light vehicles, in dB (A).

Q_{VL}: Traffic number of light vehicles (maximum mass m <3500kg), in vehicles / h

E_{PL}: Sound power level of heavy vehicles, in dB (A).

Q_{PL}: Traffic number of light vehicles (maximum mass m> 3500kg), in vehicles / h

l_i: Length of the sub-source Yes, in m

$R_{(i)}$: Octave values of the reference spectrum for road noise, in dB (A)

I: Consecutive octave number

Location and creation of emission sources

For this process, the traffic report[16] data corresponding to each scenario was used, which provided information about the vehicle capacity as a percentage of heavy and light vehicles. With this information, each route to simulate as a source of vehicular noise was configured within CadnaA and the data were entered in terms of vehicles per day, vehicles per hour in day and night hours, percentage of heavy vehicles and

[16] PIO SAS y GRUPO VIAL. Ingeniería básica y de detalle, compras y suministro de materiales, construcción, montaje y puesta en operación de las obras requeridas para la fase 1 del Terminal Portuario Puerto Antioquia ubicado en la desembocadura del Río León, en el Golfo de Urabá - Estudio de Tránsito, Departamento de Antioquia. Cali, 2015. 203 p

speed limits. Automatically CadnaA calculates the sound power levels (PWL) corresponding to each specific section.

Likewise, four (4) receivers were created in the same coordinates of the environmental noise monitoring points (see Figure No. 2.21), to compare the results in such points.

Software configuration

The software was configured within the reference times CadnaA and the schedules established by Resolution 627 of 2006[17], to evaluate the periods of operation during daytime (07:01 - 21:00) and at night (21:01 - 07:00).

Figura No. 2.9 CadnaA reference periods
Source: Software CadnaA

Within the properties of the calculation grid, a separation between 10 m receivers was assigned to have a wide sampling of data throughout the calculation area.

In the CadnaA Software, the wind rose was set with the statistics of the winds of 2014 and the temperature, relative humidity and level curves data were entered to simulate the contours of the real terrain.

We proceeded to verify the topographic properties of the shapes of contour lines by modeling in 3D through CadnaA and located the homes surrounding the project area to which they were assigned a certain height, to simulate the effects of sound screening that was created because of the facades of the same. Finally, a satellite image of the area was imported as a tool to recognize the surroundings and sensitive areas of the project.

To enter the data corresponding to the sources of vehicular noise, the "Route" window within the CadnaA Software was selected and the specifications of each section were configured. Next in Figure No. 2.25 an example of this window corresponding to the first section that enters Nueva Colonia, coming from National Route 62 at the junction with the Rio Grande district, is shown.

[17] MINISTRY OF ENVIRONMENT, HOUSING AND SUSTAINABLE DEVELOPMENT. Resolution 627 (April, 07, 2006). Op Cit.

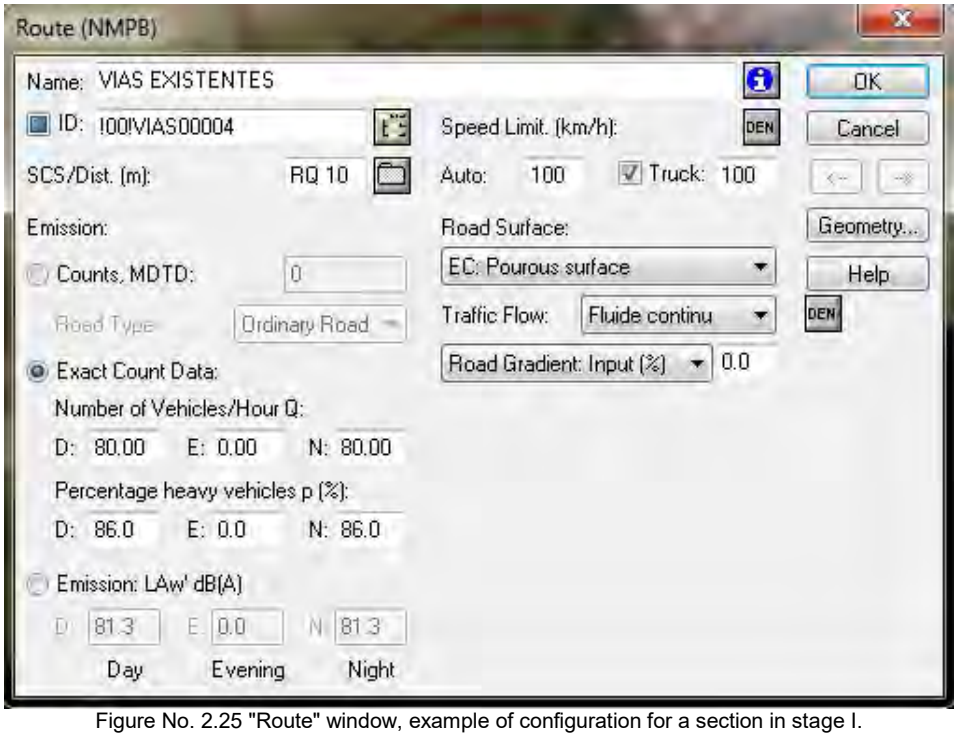


Figure No. 2.25 "Route" window, example of configuration for a section in stage I.
Source: Software CadnaA

Once this process was completed for all the sections of the different scenarios, the classification of them was consolidated, and the level of sound power (Law) corresponding to each sub-source of noise represented by its corresponding channel was calculated.

Analysis of obtained results

The results obtained by the CadnaA acoustic prediction model were reflected in noise maps representing the A-weighted equivalent continuous sound pressure level (Leq (A)) within a previously configured grid, with receiver points separated by 10m from each other. These sound pressure levels are represented by colors that divide the same in ranges of 5 and 1 dB (A) depending on the format in which they are exposed.

A comparison was made between the sound pressure levels calculated by CadnaA in the cadastral blocks of the corregimiento of Nueva Colonia and the permissible limit value of Resolution 627 of 2006 for the two scenarios (E1 and E2), see Table No. 2.42.

Table No. 2.42 Comparison of sound level in daytime and night time

Name cadastral apple	ID	Sound level calculated by the CadnaA Software				Resolution 627/2006		Difference between Level measured by Software CadnaA and Res 627/2006				Coordinates (m)		Height (m)
		E1		E2		Limit Level (dBA)		E1		E2				
		Leq level (dBA)		Leq level (dBA)				Excess Level (dB)		Excess Level (dB)				
		Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	East	North	H

Source: SGS Colombia S.A, 2015

From the results obtained in Table No. 2.42, the cells were classified with three colors according to the level of excess, which is the difference between the sound level calculated by CadnaA and the limit level of the standard (Resolution 627 of 2006), see Table No. 2.43.

Table No. 2.43 Color classification of the levels of excess sound pressure

	It indicates a negative difference of more than 10 dBA, that means there is no risk whatsoever for the dwelling in question.
	Indicates that households that register a difference between -10 and -0.1 dBA. They are receiving points that do not exceed the limit levels but may require attention.
	It indicates the houses that present excess of the limit levels established by the norm.

Source: SGS Colombia S.A, 2015

The values were taken 10 dB below the norm because in every mathematical process there is a range of uncertainty, which in the present case is due to the accuracy of the input data in general. Consequently, the manufacturer recommends a range of 10 dB below the regulations to apply to be able to affirm that there is no and no contamination effect.

With the results obtained, (i) it is possible to evaluate the acoustic impact of the two scenarios on the corregimiento of Nueva Colonia, (ii) compare the sound pressure levels with the maximum permissible standards by the current regulations and (iii) estimate the contribution to the global sound energy to the area of interest once the project is in full operation.

2.3.2 Biotic environment

For the characterization of the biotic environment, the stipulations of the terms of reference for the preparation of the environmental impact study - EIA in construction projects or expansion and operation of deep sea ports (MM-INA-05)[18], as well as the

[18] COLOMBIA. MINISTRY OF ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. Resolution no. 0112 (January 28, 2015). Whereby the terms of reference for the preparation of the Environmental Impact Study - EIA, required for the processing of the environmental license of the construction or expansion and operation projects of large seaports, are adopted and other determinations are made. Bogotá D.C., 2015. 103 p.

methodology for the presentation of environmental studies [19] and the specific documentation for each of its components.

It is noteworthy that, for the different components of the biotic environment, the type of sampling carried out was systematic sampling, which consists of locating the samples or sampling units in a regular pattern in each of the vegetation cover and / or identified habitats[20]. The methods used for this characterization are shown below.

2.3.2.1 *Ecosystems*

To identify the large biome, biome and terrestrial, coastal and marine ecosystems present in the area of influence, the guidelines of the map of continental, coastal and marine ecosystems of Colombia prepared by the IDEAM et al.[21]. With the ecosystems present in the area, the land cover of these ecosystems was described using the guidelines of the CORINE Land Cover methodology adapted for Colombia. [22]. Additionally, the identification of the life zones to which the area of influence of the project belongs was made following the system of classification of life zones of Holdridge. [23].

To generate a map of ecosystems present in the area of influence at a scale of 1: 10,000, layers were superimposed on the following components: climate, land cover and geomorphological, following what was proposed in the methodology for the preparation of the Ecosystem map at scale 1: 100,000[24].

2.3.2.2 *Terrestrial ecosystems*

[19] COLOMBIA. MINISTRY OF ENVIRONMENT, HOUSING AND TERRITORIAL DEVELOPMENT. General methodology for the presentation of environmental studies. Ministry of Environment, Housing and Territorial Development - MAVDT-. Republic of Colombia. Bogotá, 2010. 72p.
[20] MOSTACEDO, Bonifacio and FREDERICKSEN, Todd. Manual of basic methods of sampling and analysis in plant ecology. Sustainable Forest Management Project - BOLFOR. 2000. 87 p
[21] IDEAM, IGAC, IAvH, Invemar, I. Sinchi and IIAP. Continental, coastal and marine ecosystems of Colombia. Institute of Hydrology, Meteorology and Environmental Studies, Agustín Codazzi Geographic Institute, Alexander von Humboldt Institute of Biological Resources Research, Pacific Environmental Research Institute Jhon von Neumann, José Benito Vives de Andres Institute of Marine and Coastal Research and the Amazon Research Institute Scientific Sinchi. Bogotá, D.C. 2007. p. 276 + 37 cartographic sheets.
[22] IDEAM National Legend of Coverage of the Earth. CORINE Land Cover methodology adapted for Colombia. Scale 1: 100,000. Bogotá: IDEAM, 2010. 72 p. ISBN: 978-958-806729-2.
[23] HOLDRIDGE, Leslie. Ecology based on life zones. San José, Costa Rica: IICA.1978. 216 p.
[24] INSTITUTE OF HYDROLOGY, METEOROLOGY AND ENVIRONMENTAL STUDIES OF COLOMBIA - IDEAM. Methodology for the elaboration of the Ecosystem Map scale 1: 100,000. IDEAM Bogotá 2011. 42 p.

Below are the methods used to perform the floristic and faunal characterization of the terrestrial ecosystems present in the area of influence according to the stipulations of the terms of references M-M-INA-05.

- Flora

Floristic composition and structural analysis

For floristic characterization was determined from a probability of 95% and sampling error no greater than 15%[25], which is equivalent to 2 plots per unit of sampled coverage. To carry out this sampling, the methodology proposed by Pinelo was adapted [26], Two parcels of 0.25 ha (50 m long x 50 m wide) were installed per unit of forest cover as shown in Figure No. 2.26 (Map MOD_LA_PTO_ANT_38_Flora). Each plot was delimited with PVC pipes and was georeferenced.

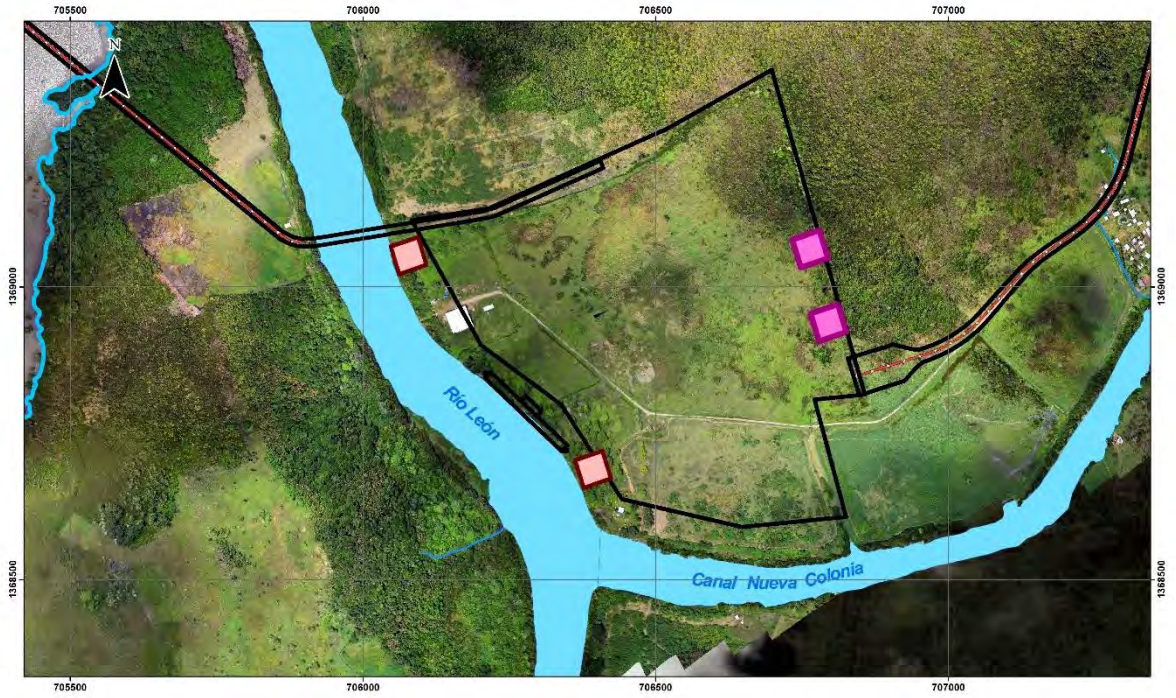


Figure No. 2.26 Location of the sampling plots in the forest cover
Source: Aqua & Terra Consultores Asociados S.A.S, 2015.

[25] COLOMBIA. MINISTRY OF ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. Resolution no. 0112 (January 28, 2015). Op. Cit., P. fifty.
[26] PINELO, Gustavo Israel. Integrated forest inventory manual for management units. WWF Central America. 200449 p.

The floristic characterization of the vegetal coverings identified in the field was carried out by means of the analysis of the index of value of importance, the quotient of the mixture (CM), the diametric and altimetric distribution (sociological composition), the ecological indexes, analysis of natural regeneration and analysis of fragmentation.

Finally, Resolution 0192 of 2014 was consulted[27], red book of Colombian plants, timber spices [28], the list of threatened species of IUCN[29] and CITES Appendices I, II and III [30]. Next, each of the items named for the analysis is shown in detail.

- Importance value index (IVI)

In order to perform the structural analysis of the forest, the importance value index (IVI), formulated by Curtis & Mc Intosh, was calculated. [31], which is possibly the best known, this is calculated for each species from the sum of relative abundance, relative frequency and relative dominance.

This analysis allows to evaluate the behavior of individual trees and species on the forest surface through the occurrence of the species and their ecological importance within the ecosystem.

This index allows determining the most relevant species within the structure of a forest, through the parameters of abundance, frequency and dominance. The relevant species determined by this index are those that best adapt to the environmental conditions of the forest cover under study. Equation No. 2.10 expresses the way in which this index is found.

$$IVI = Ar + Fr + Dr$$

Equation No. 2.10 Equation to find the importance value index (IVI)

Where:

IVI: Importance Value Index

[27] COLOMBIA. MINISTRY OF ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. Resolution 0192 (10, February 2014). Op. Cit., P. 28-32.
[28] CÁRDENAS, Dairon and SALINAS, Nelson. Red book of plants of Colombia. Volume 4. Threatened timber species: First part. Red books series of threatened species of Colombia. Amazon Scientific Research Institute SINCHI - Ministry of Environment, Housing and Territorial Development. 2007. 232 p. ISBN: 978-958-8317-19-9
[29] INTERNATIONAL UNION FOR THE CONSERVATION OF NATURE - IUCN. The IUCN Red List of Threatened Species. Op. Cit.
[30] CONVENTION ON INTERNATIONAL TRADE IN THREATENED SPECIES OF WILDLIFE AND WILDLIFE - CITES. List of CITES species. Op. Cit.
[31] LAMPRECHT, H. 1990. Forestry in the Tropics. GTZ German Federal Republic. Pp. 64 - 92.

Ar: relative abundance: Percentage of each species in relation to the total number of individuals of all the species found in the sample. Equation No. 2.11 shows how relative abundance is calculated.

$$Ar = \left(\frac{Aabs}{\sum AabsTotal}\right) * 100\%$$

Equation No. 2.11 Equation to find relative abundance (Ar)

Fr: relative frequency: It is the absolute frequency of a species in relation to the sum of absolute frequencies of all the species present in the sample. Equation No. 2.12 shows the way in which the relative frequency is found.

$$Fr = \left(\frac{Fabs}{\sum FabsTotal}\right) * 100\%$$

Equation No. 2.12 Equation to find the relative frequency (Fr)

Dr: relative dominance. It is the percentage of the absolute dominance of a species with respect to the sum of the absolute dominances of all the species present in the sample. Equation No. 2.13 shows how relative dominance is calculated:

$$Dr = \left(\frac{Dabs}{\sum DabsTotal}\right) * 100\%$$

Equation No. 2.13 Equation for finding relative dominance (Dr)

- Mixture ratio (CM)

The mixing ratio expresses the relationship between the number of species and the number of total individuals. This quotient provides an idea of the mixing intensity as well as an approximation of forest heterogeneity (Equation No. 2.14).

$$CM = N/S$$

Equation No. 2.14 Equation to find the mixture ratio (CM)

Where:

S = Total number of species in the sample

N = Total number of individuals in the sample

- Diameter and altimetric distribution

To perform the analysis by diametric distribution within the area of influence, sampled trees were grouped within diametric classes. Which were determined from the difference between the larger diameter minus the smaller diameter and divided into the number of intervals. When determining the number of trees by diametric class, the absolute, accumulated and relative frequency was obtained. To visualize the presence of strata in the forest, Ogawa[32], proposed the construction of the glasses scatter diagram [33], which corresponds to a Cartesian graph, where the trees are represented by coordinates generated by the values of the total height for the ordinate axis and the reiteration heights on the abscissa axis. For example, the coordinate (25.5, 19.5) corresponds to an individual whose total height is 25.5 m and his height of repetition 19.5 m.

Once the diagram is constructed, several trends can be presented, if one observes clusters or more or less isolated sets of points, these indicate the virtual vacuum of the glasses at the intermediate levels. The number of strata is equivalent to the number of clusters. Likewise, the diagram allows the visualization of the emergent trees, which appear as isolated points in the upper - right part of the graph, without constituting a proper stratum.

- Ecological indices

The diversity of species is an attribute of the communities measured by the heterogeneity and uniformity of these. Diversity is composed of two elements: the first is the variation of species and the second is the relative abundance of these. The main indices reported in the literature were evaluated: species richness and diversity, dominance and equity.

Margalef's wealth index

The Margalef index relates the number of species according to the total number of individuals and is expressed by Equation No. 2.15:

[32] Ogawa, H., K. Yoda, K. Ogino & T. Kira. Comparative ecological studies on three main types of forest vegetation in Thailand II Plant biomass. Nature an Life Southeast Asia 1965. 4: 49-80
[33] MELO CRUZ, O. A. AND R. VARGAS RIOS. Ecological and silvicultural evaluation of forest ecosystems. University of Tolima, CRQ, Corpocaldas and Cortolima, Ibague. 2002. 207 p.

$$D_{Mg} = (S-1)/lnN$$

Equation No. 2.15 Equation to find the Margalef index

Where:

S: number of species

N: total number of individuals

Menhinick Index

The Menhinick Diversity Index is based on the relationship between the number of species and the total number of individuals observed, which increases with increasing sample size; it is calculated with Equation No. 2.16.

$$\text{Dmn} = \frac{S}{\sqrt{N}}$$

Equation No. 2.16 Equation to calculate the Menhinick index

Where,

S: number of species

N: number of individuals

Shannon-Wiener diversity index

This index indicates how uniform the species are represented (in abundance) taking into account all the species sampled and is expressed with Equation No. 2.17:

$$H' = \sum_{i=1}^{s} p_i ln\, p_i$$

Equation No. 2.17 Equation to calculate the Shannon-Weiner index

Where:

S: number of species

p_i: proportion of individuals found in the ith species. In a sample the true value of pi is unknown, but it can be estimated as shown in Equation No. 2.18:

$$p_i = {}^{p_i}/_{N}$$

Equation No. 2.18 Equation to find the proportion of individuals

The value of this index varies between 1 and 5, although exceptions may occur in some ecosystems that may exceed the maximum value.

Simpson's dominance index

This index refers to the probability that two individuals of an infinitely large community, taken at random, belong to the same species. For finite communities the index is expressed by the expression (Equation No. 2.19):

$$D = \sum \frac{n_i\,(n_i - 1)}{N(N-1)}$$

Equation No. 2.19 Equation to calculate Simpson's dominance index

Where,

n_i: number of individuals of the ith species

N: total of individuals.

As D increases, diversity decreases. Therefore, the index is usually expressed as 1-D, which ensures that the value of the index increases with the increase in diversity.

Berger Parker Index

The Berger Parker index in a measure of dominance that expresses the proportional abundance of the most abundant species, this index is independent of the species but is strongly influenced by the size of the sample; it is calculated with Equation No. 2.20.

$$d = Nmax / N$$

Equation No. 2.20 Equation to calculate the Berger Parker index

Where,

Nmax = The highest abundance of the evaluated species N = Number of total individuals

For the interpretation of the Simpson and Berger Parker indices, the numerical values are expressed in reciprocal form (1 / D and 1 / d), in this way they are directly proportional to the diversity.

- Natural regeneration

For the analysis of natural regeneration, quadrant and sub-quadrant plots were established for the sampling of pole stages and saplings. The dimensions, characteristics and variables measured are shown below:

- Pole stages: The counting of pole stages is done in quadrants of 100 m2 (10 m x 10 m). Where the variables of circumference to the height of the chest (CAP) and total height are taken for all those arboreal species that presented between 1.5 and 3 cm of CAP. As in the plots, the quadrant was georeferenced and the individuals marked. For the analysis of the pole stages, the IVI (Equation No. 2.10) and the CM (Equation No. 2.14) for plant cover were established.

- Saplings: The count of saplings is done in a subdivider of 25 m2 (5 m x 5 m) where the abundance of the arboreal species that had a height lower than 1.30 cm was registered and the subquadrant was georeferenced. Its abundance and frequency were analyzed within the identified plant cover....

- Temporal dynamics and analysis of forest cover fragmentation

The typical fragmentation processes occur when the natural coverage is modified and replaced by new elements due to productive, industrial or infrastructure activities, whose nature determines the degree of impact on the natural dynamics of the ecosystem.

To carry out the analysis of fragmentation of natural coverage, the digitalization and visual interpretation of forest cover and semi-natural areas using the classification levels according to the CORINE Land Cover methodology adapted for Colombia, was carried out in the office prior to field sampling. Detail scale 1: 10,000, from an orthophoto of the year 2014.

During the field stage, the verification and capture of control points for each interpreted coverage was performed. This information was processed in the office to establish the landscape context index for each fragment of the natural ecosystem.

Once the current state of the forest cover for the year 2015 was elaborated, a multitemporal analysis was made from aerial photographs as shown in Table No. 2.44, with this interpretation the annual loss of the forests present in the area of influence of the project was estimated.

Table No. 2.44 Photographic resource for the study area

Flight	Photo	Date	Scale
R – 1148	308	22/03/1989	1:12.000
R – 1148	446	22/03/1989	1:12.000
R – 973	293	09/08/1983	1:30.000

Source: Aqua & Terra Consultores Asociados S.A.S, 2015.

Once the forest fragments were identified for the years 2015, 1989 and 1983, the shape of each fragment was described through three indices: a) the Patton Diversity Index, (Di), b) the Form Factor (Ff), and c) the Fractal Dimension (D). The first two are based on Euclidean geometry ("smooth" lines, squares, circles, spheres, cubes), the third in fractal geometry ("serrated" lines, irregular shapes)[34] .

Table No. 2.45 shows the information used for the analysis of landscape metrics within the area of influence of the project. This analysis was carried out for each one of the forest coverings of the area of influence of the project.

Table No. 2.45 Metrics used in the forest cover fragmentation analysis for the area of influence of the project

[34] SUGIHARA G. & MAY R. Applications of fractal in ecology. Trends in Ecology and Evolution. Vol 5, 1990.79 p.

METRICS OF CLASS		
Metrics	**Description**	**Formula**
Total area of the nucleus AC	*Indicates the state of conservation of landscape patches, since it expresses the internal area that is not affected by the edge effect, which allows to identify in a general way the potentially viable area for the maintenance of the fauna of a landscape. The magnitude of the edge of the patch has been standardized an edge length of 100 meters, although it can vary according to specific conditions and landscape analyzed. The result of this metric is given in meters and is analyzed keeping in mind that the more This is the result of zero (0), the area of patch affected by edge effect is smaller, so there is less fragmentation. Similarly, when the result of the metric is zero (0), the central area of the patch is on the buffer, the patch being more vulnerable to external effects and therefore to fragmentation.*	CA = Σaij Where: aij: Central area of the patch
Number of patches NP	*Determine the number of patches of the same type or coverage (abundance), allowing an approximation to the representativeness of each type of patch or coverage of the landscape studied.*	NP = ni Where: ni: number of patches of the same type or coverage
Patch Density P.S.	*This metric calculates the total number of patches of the same type, over the total area of the landscape (in square meters) and is multiplied by 10,000 to be expressed in hectares, resulting in several patches of the same type per 100 hectares. When the density approaches zero (0), there is no representativeness of the type of patches in the total area analyzed, and the higher the greater, there are more patches of the same type on the analyzed area.*	PD = N / A (10000) (100) Where: N: Total number of patches of the same type in the landscape analyzed A: Total landscape of landscape area analyzed in square meters
average patch size MPS	*This metric calculates the average size of the patches of the same type, the total areas are summed and divided by the number of patches.*	MPS = (aij + bij + cij .... xij) / N Where: aij, bij, cij ... xij: total areas of each patch of the same type n: Total number of patches of the same type in the landscape analyzed

Source: Ogawa[35]

Patton's Diversity Index

[35] Ogawa, H., K. *et al. Op. cit.*

The Patton Diversity index expresses the shape of the fragments and is calculated using Equation No. 2.21.

$$Di = \frac{P}{2\sqrt{A\pi}}$$

Equation No. 2.21 Equation to calculate Patton's Diversity index

Where,

Di: Patton diversity index of each fragment

P: perimeter in (m)

A: area in (m^2)

Di varies between 1 and 2, when Di is 1, the shape of the fragment resembles a circle, as it increases, the form becomes more complex. For each period analyzed, the Di was grouped into five (5) ranges according to the methodology established by Henao (1988)[36], who. classifies them in: round (Di <1.25), round oval (1.25> Di <1.5), oblong oval (1.5> Di <1.7), rectangular oblong (1.7> Di < 2) and amorphous (Di> 2).

The average Di for each year (± standard error) was obtained as the average value of all Di per period.

Fractal dimension

The fractal dimension (D), is a quantitative measure of landscape complexity, is considered the most ad hoc descriptor to quantify the fragmentation of different landscapes [37].

The fractal dimension, D, for the total set of fragments in each year, was obtained following the calculation method proposed by Lovejoy (1982)[38]. The fractal dimension is usually applied to large landscapes by using the area-perimeter relationship and is calculated with Equation No. 2.22.

$$D = \frac{2logP}{logA}$$

[36] HENAO S. Introduction to watershed management. University of Santo Tomas. Deschooling Teaching Center. Usta editions. Bogota Colombia. 395 p. National Institute of Statistics INE. 1997. VI National Agricultural Census, preliminary results 1997. INE. 443 p.
[37] TURNER M.G. Landscape ecology: the effect of pattern on process. Annu. King. Ecol. Syst. Year 1989. P.171-197.
[38] LOVEJOY TE. Area-perimeter relation for rain and cloud coffers. Science Vol 216. Year 1982. P. 185 -187

Equation No. 2.22 Equation to calculate the Fractal Dimension

Where,

D: Fractal Dimension

P: perimeter in (m)

A: area in (m^2)

The fractal dimension expresses the degree of complexity of the fragments, thus, in both formulas, D oscillates between 1 (simple Euclidean forms) and 2 (complex, amorphous and elongated forms)[39]

Form factor

The Form Factor (FF) relates the perimeter of a circle of the same area as the fragment vs. the perimeter of the fragment, using Equation No. 2.23:

$$Ff = Pc / P$$

Equation No. 2.23 Equation to calculate the form factor

Where,

Ff: Form Factor

Pc: is the perimeter of a circle of the same area as the fragment

P: is the perimeter of the fragment in (m)

The form factor varies between 0 (far away forms of circularity) and 1 (circular shapes)[40]. The average value per year was obtained as the average value of all Ff per period.

On the other hand, the tree species identified during the field phase were analyzed according to their main use in the area, such as timber, medicinal and food uses, among others. For this, secondary information was used, especially in forest species of timber interest, taking as reference research studies and productive projects, among others.

[39] KRUMMEL J.R.; R.H GARDNER; G. SUGIHARA; R.V O'NEILL & P.R. COLEMAN. Landscape patterns in a disturbed environment. Oikos. Año 1987. 321 - 324. P.
[40] Íbid

- Wildlife

The methodology used in the sampling of each of the terrestrial faunal components is mentioned below, to establish the abundance, richness, ecological indexes and threat status, among other aspects, of the species found per unit of coverage present in the area. The information collected in the field for each faunal group was recorded in field templates, which are found in Annex 5.2.3 of the biotic characterization.

Herpetofauna

For the characterization of the herpetofauna in the area of influence of the project, direct observation sampling techniques were used, following the methodologies and procedures described by Manzanilla and Péfaur[41] and Angulo and editors[42] (VES Method - Visual Encounter Survey). An initial tour of the area was carried out in order to verify the vegetation cover and carry out a systematic sampling in habitats. After verification, 12 polygons were installed in aquatic and semi-aquatic habitats for sampling, which was carried out during the day and night (Figure No. 2.27, Table No. 2.46, Map MOD_LA_PTO_ANT_35_Fauna). These polygons were sampled in four (4) days with a sampling effort of 8 hours / day. Additionally, dry trunks and stones were collected to record reptiles in the area, especially snakes.

[41] MANZANILLA, Jesús & PÉFAUR, Jaime E. Considerations on methods and field techniques for the study of amphibians and reptiles. In: Journal of Latin American Ecology. August, 2000. vol. 7. no 1-2 art. 3, p. 17 - 30.
[32]ANGULO, Ariadne., RUEDA-ALMONACID, José Vicente., RODRÍGUEZ-MAHECHA, José Vicente & LA MARCA, Enrique (eds). Inventory and monitoring techniques for amphibians in the Tropical Andean region. Bogotá, D.C. - Colombia .: Panamericana formas y impresos S.A, 2006. 150 p. (Manual series of Field No. 2). ISBN 978-958-97690-5-8.

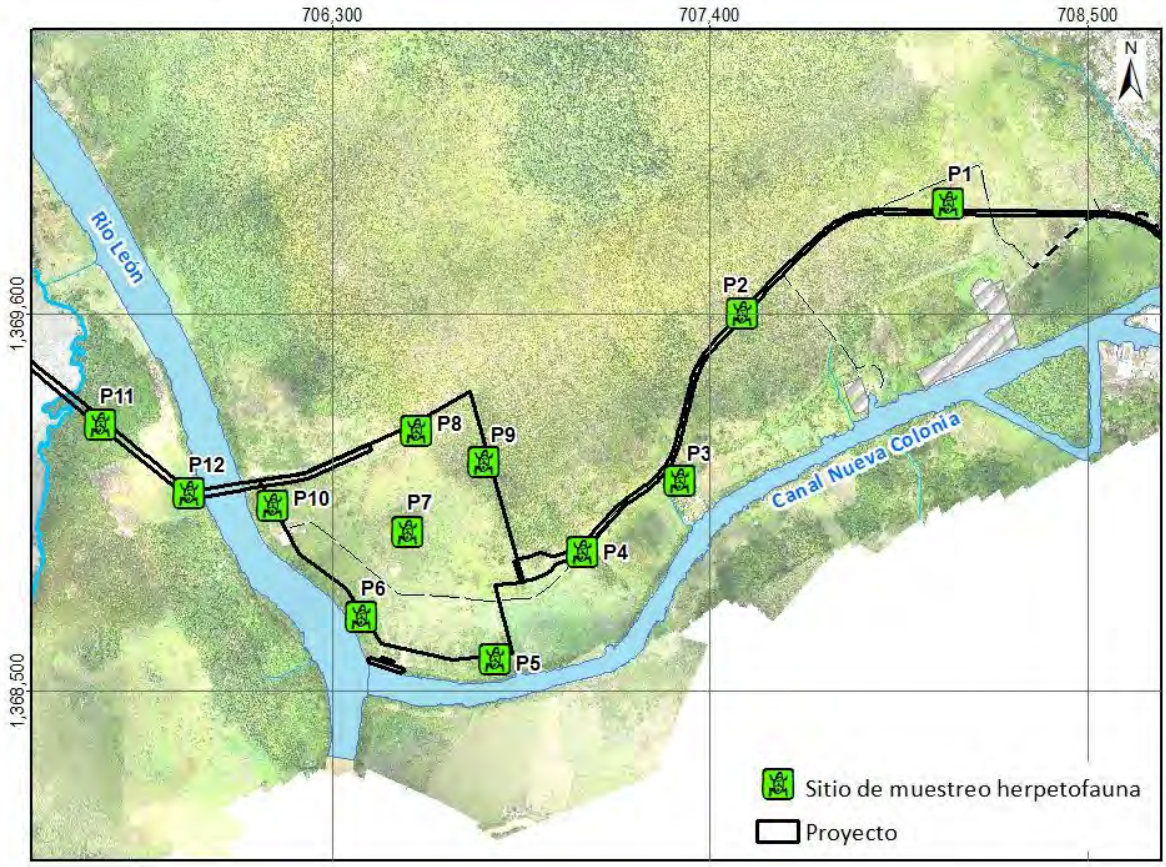


Figure No. 2.27 Location of polygons for the sampling of the herpetofauna in the area of influence
Source: Aqua & Terra Consultores Asociados S.A.S., 2015

Table No. 2.46 Geographic location of the polygons for the sampling of the herpetofauna in the area of influence

Place	Flat coordinates magna sirgas origin Bogotá		Area (m^2)
	East	North	
P1	708.093,25	1.369.919,54	8.571
P2	707.492,96	1.369.598,30	11.205
P3	707.309,69	1.369.110,63	23.932
P4	707.026,68	1.368.903,97	10.737
P5	706.773,52	1.368.588,61	11.840
P6	706.384,91	1.368.714,50	14.406
P7	706.516,91	1.368.963,03	12.615
P8	706.544,48	1.369.257,85	6.345
P9	706.738,40	1.369.164,21	9.114
P10	706.124,41	1.369.036,91	17.354
P11	705.621,36	1.369.274,65	11.462
P12	705.880,89	1.369.073,65	5.681

Source: Aqua & Terra Consultores Asociados S.A.S., 2015

The identification of species was done in situ or with photographs taken in the field and with the help of the Palacio et al.[43], Renjifo y Lundberg[44], Castro[45], Páez *et al*.[46] it reached the minimum possible taxonomic level. The species collected for the taking of photographs facilitating their identification were released in the environment where they were collected. For the processing of the information and because the amphibians have experienced in recent years constant reassignments in their classification, their taxonomy was verified following the classification[47].

The analyzes of the community of herpes present in the area were made per unit of coverage sampled. For each coverage the richness and abundance of species was calculated and with this information a map was constructed at a scale of 1: 10,000, showing the distribution of the species on the vegetation cover and the current use of their soil. Likewise, Margalef's ecological wealth indexes (Equation No. 2.15), Shannon-Weiner diversity (Equation No. 2.17), Simpson's dominance (Equation No. 2.19), and Pielou's equitability were found. This last index shows the distribution of the abundance of the species within the community and its values fluctuate between 0 and 1, where those close to zero indicate that the species are not equally abundant and if the values are close to one, it expresses that the species They are equally abundant. Equation No. 2.24 expresses the way in which this index is calculated.

$$J = \frac{H'}{H'\max}$$

Equation No. 2.24 Equation to calculate Pielou's equitability index

Where,

$H'\max = \ln S$

S = number of species

[43] PALACIO BAENA, Jaime Alberto., MUÑOZ ESCOBAR, Eliana María., GALLO DELGADO, Sandra Milena., RIVERA CORREA, Mauricio. Amphibians and reptiles of the Aburrá Valley. Medellín.: Editorial Zuluaga Ltda, 2006. 92 p. ISBN 958-33-9901-9.
[44] RENJIFO, Juan Manuel and LUNDBERG, Mikael. Field guide Amphibians and reptiles of Urrá. Medellín Colombia.: Editorial Colina, 1999. 51 p. ISBN 958-33-1200-2.
[45] CASTRO-HERRERA, Fernando. Taxonomy of major groups of amphibians and Colombian reptiles (written in preparation and revision). Cali Colombia.: Editorial Universidad del Valle, 2008. 88p.
[46] PÁEZ Vivian, BOCK BC, ESTRADA JJ, ORTEGA AM, DAZA JM and GUTIÉRREZ Paul David. Field Guide of Some Species of Amphibians and Reptiles of Antioquia. Medellín.: Editorial University of Antioquia, 2002.136 p.
[47] FROST, Darrel R. Amphibian Species of the World: An Online Reference Version 6.0. American Museum of Natural History. Electronic Database. New York, USA. 2014. (Date of access 2015-30-07). Accessible at http://research.amnh.org/herpetology/amphibia/index.html.

In addition, the potential routes of herpetofauna displacement within the area of influence of the project were identified and mapped at a scale of 1: 10,000. Finally, it was asked if the registered species were endemic or almost endemic in the country[48] and their threat status was verified by consulting Resolution 0192 of 2014[49], the red book of amphibians[50] and reptiles[51] of Colombia, the list of threatened species of IUCN and the Appendices I, II and III of CITES[52]. In turn, for these species with existing secondary information their ecological characteristics were described, including their potential breeding, reproduction and feeding areas.

Birds

For the characterization of the avifauna the methodology proposed by Villareal et al.*[53]*, which consists of the visual detection of the fauna through the realization of random routes, for which no specimens were collected. For this, 16 transects were made throughout the area of influence, thus covering the vegetation coverage present (Figure No. 2.28, Table No. 2.47, Map MOD_LA_PTO_ANT_35_Fauna). The samplings were carried out for two (2) days in the morning and afternoon hours to register the birds in their busiest hours, for a sampling effort of 8 hours / day. Additionally, a video camera with tripod was installed at 16 fixed points where there was more bird activity (Figure No. 2.29, Table No. 2.48, Map MOD_LA_PTO_ANT_35_Fauna).

[48] THE REPTILE DATABASE. . [en línea] http://reptile-database.reptarium.cz/ [citado el 30 de julio de 2015]
[49] COLOMBIA. MINISTRY OF ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. Resolution 0192 (10, February 2014). Op. Cit., P. 27-28, 34-35.
[50] RUEDA-ALMONACID, José Vicente., LYNCH, John., AMÉZQUITA, Adolfo. Red book of the amphibians of Colombia. Bogotá.: Colombian International Conservation, National University, Institute of Natural Sciences, Ministry of the Environment. 2004. 384 p. (Series of red books of threatened species of Colombia).
[51] CASTAÑO-MORA, Olga Victoria. Red book of reptiles of Colombia. Bogotá.: Colombia Humboldt Institute, National University of Colombia, 2002. 160 p. (Series of red books of threatened species of Colombia). ISBN 9587011872.
[52] CONVENTION ON INTERNATIONAL TRADE IN THREATENED SPECIES OF WILDLIFE AND WILDLIFE - CITES. List of CITES species. [online] http://checklist.cites.org/#/es [quoted on July 30, 2015].
[53] VILLARREAL et al. Op. cit., 91 – 105.

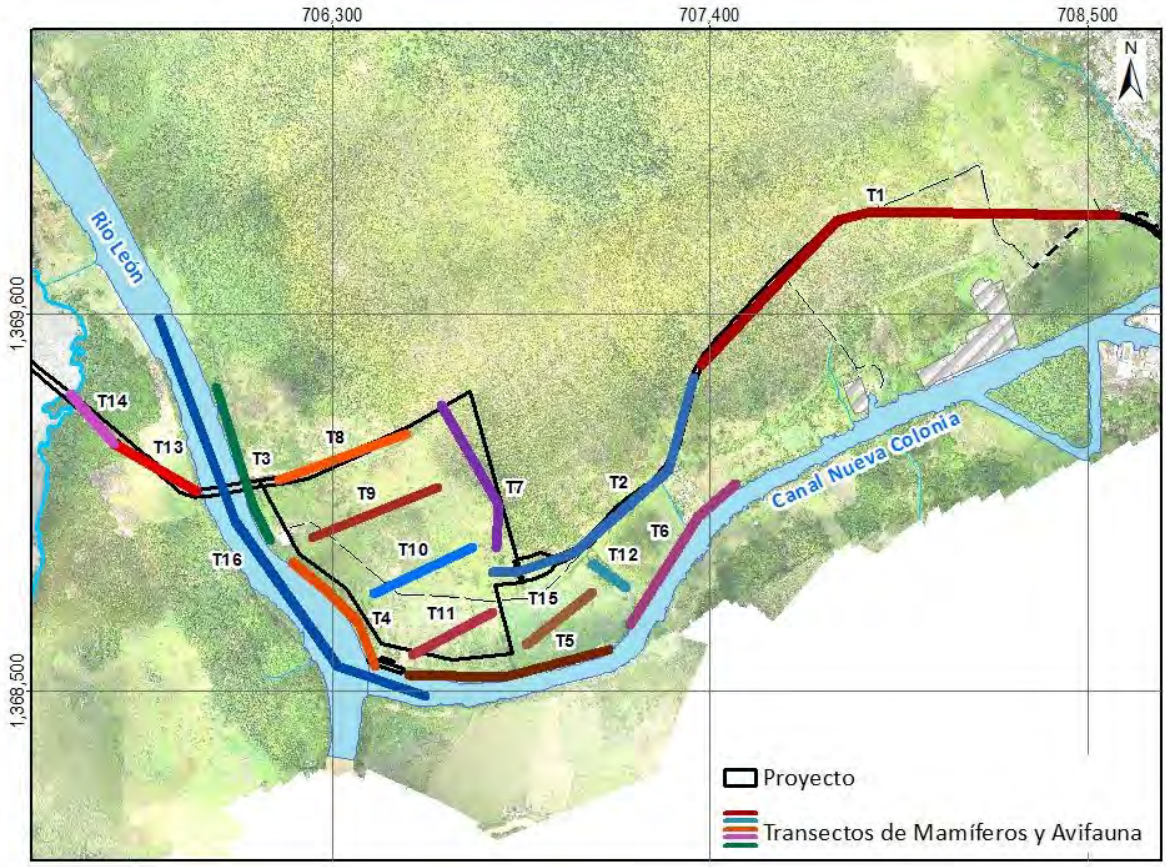


Figure No. 2.28 Location of transects for the sampling of birds and mammals in the area of influence
Source: Aqua & Terra Consultores Asociados S.A.S., 2015

Table No. 2.47 Geographic location of the transects for the sampling of birds and mammals in the area of influence

Transect	Flat coordinates magna sirgas origin Bogotá				Length (m)	Azimut
	East initial	Initial North	East final	North final		
T1	708.580,90	1.369.883,93	707.372,88	1.369.448,91	1.398,54	250
T2	707.350,21	1.369.412,42	706.766,40	1.368.846,77	888,39	226
T3	705.960,91	1.369.383,09	706.118,60	1.368.940,28	471,13	160
T4	706.182,78	1.368.875,08	706.421,62	1.368.571,16	397,21	142
T5	706.521,31	1.368.546,96	707.103,18	1.368.617,85	591,97	83
T6	707.166,30	1.368.692,06	707.476,26	1.369.102,42	519,15	37
T7	706.615,74	1.369.332,42	706.776,66	1.368.919,49	458,55	159
T8	706.514,28	1.369.249,29	706.144,52	1.369.115,52	393,21	250
T9	706.603,75	1.369.091,64	706.240,89	1.368.947,35	390,50	248
T10	706.707,04	1.368.916,44	706.420,80	1.368.782,14	316,18	245
T11	706.764,99	1.368.727,57	706.531,02	1.368.603,41	264,88	243
T12	707.054,75	1.368.868,84	707.155,25	1.368.801,87	120,77	124
T13	705.904,17	1.369.082,16	705.671,86	1.369.216,30	268,26	301

Transect	Flat coordinates magna sirgas origin Bogotá				Length (m)	Azimut
	East initial	Initial North	East final	North final		
T14	705.661,44	1.369.219,86	705.537,08	1.369.363,78	190,21	320
T15	707.057,72	1.368.788,53	706.861,83	1.368.632,70	250,31	232
T16	706.568,54	1.368.484,48	705.792,53	1.369.582,05	1.414,85	325

Source: Aqua & Terra Consultores Asociados S.A.S., 2015

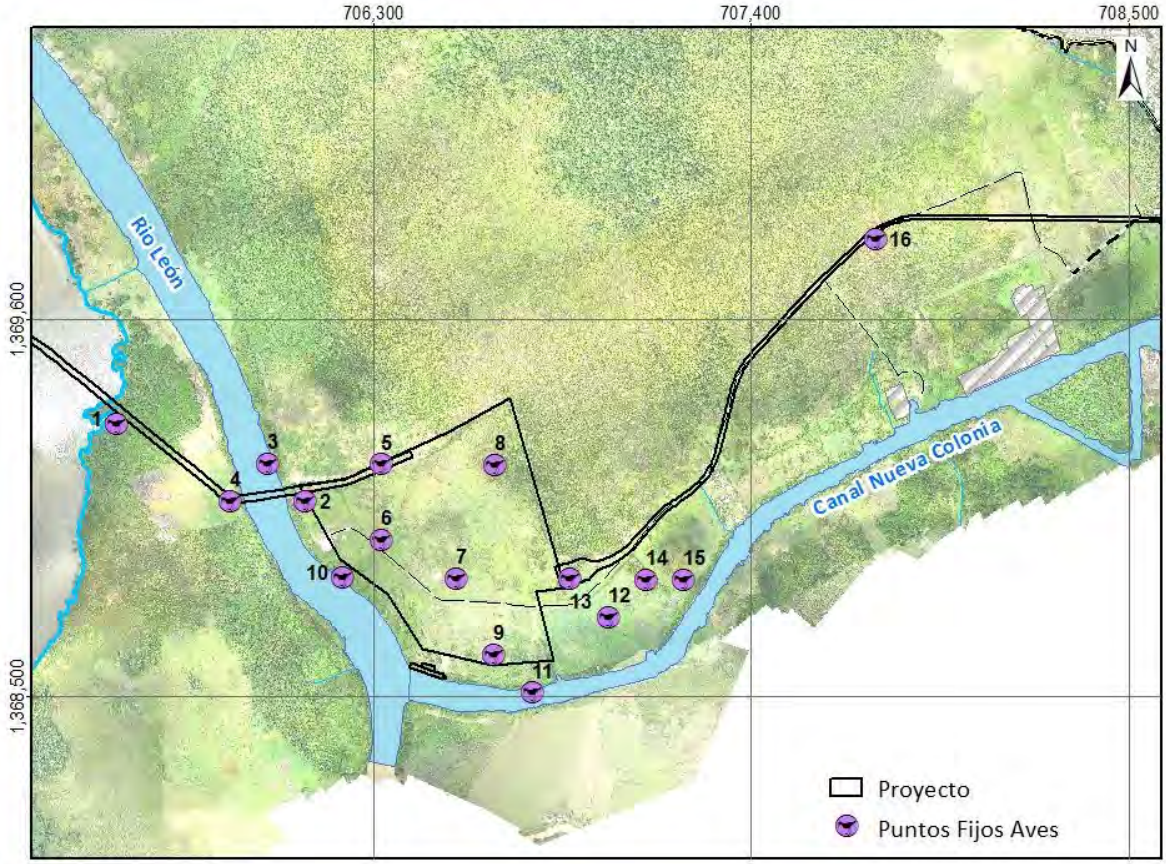


Figure No. 2.29 Location of fixed points for bird detection in the area of influence
Source: Aqua & Terra Consultores Asociados S.A.S., 2015

Table No. 2.48 Geographic location of the fixed points for the detection of birds in the area of influence

Birds fixed point	Flat coordinates magna sirgas origin Bogotá	
	East	North
1	705.551,13	1.369.292,27
2	706.101,60	1.369.067,30
3	705.991,93	1.369.178,72
4	705.880,84	1.369.068,72
5	706.323,07	1.369.176,60
6	706.321,65	1.368.955,18
7	706.541,69	1.368.843,05
8	706.654,20	1.369.174,48

Birds fixed point	Flat coordinates magna sirgas origin Bogotá	
	East	North
9	706.650,66	1.368.620,92
10	706.210,56	1.368.845,17
11	706.760,33	1.368.509,50
12	706.982,50	1.368.729,51
13	706.872,83	1.368.840,93
14	707.093,59	1.368.839,52
15	707.203,97	1.368.838,81
16	707.762,22	1.369.831,68

Source: Aqua & Terra Consultores Asociados S.A.S., 2015

The identification of species was done in situ or with photographs taken in the field reaching the minimum possible taxonomic level. For the processing and verification of the taxonomy of this group, the one established in AviBase was followed[54]. The analyzes of the bird community present in the area were made per unit of sampled coverage.

For each coverage the richness and abundance of species was calculated and with this information a map was constructed at a scale of 1: 10,000, showing the distribution of the species on the vegetation cover and the current use of their soil. Likewise, Margalef's ecological wealth indices (Equation No. 2.15), Shannon-Weiner diversity (Equation No. 2.17), Simpson's dominance (Equation No. 2.19), and Pielou's equitability (Equation No. 2.24) were found). Additionally, possible routes of displacement of the herpetofauna within the area of influence of the project were identified and mapped at a scale of 1: 10,000.

On the other hand, the trophic guilds to which the registered species belong as well as the main use given to them were established[55]. It was also established which of the registered species are migratory species [56] and which are classified as endemic[57] [58]. Almost endemic and of interest in the country. Finally, the threatened status of the species reported was verified by consulting Resolution 0192 of 2014[59], the red bird book of Colombia[60] of Colombia, the list of threatened species of IUCN

[54] AVIBASE. The world bird database. [en línea] http://avibase.bsc-eoc.org/avibase.jsp [citado el 30 de julio de 2015]
[55] BirdLife International. Species factsheets. [en línea]. http://www.birdlife.org [citado el 30 de julio de 2015]
[56] COLOMBIA. Ministry of Environment and Sustainable Development. Guide to migratory species of biodiversity in Colombia - Birds. Volume 1. WWF Colombia. Bogotá, Eds: NARANJO, Luis German, AMAYA, Juan David, EUSSE GONZÁLEZ, Diana and CIFUENTES SARMIENTO, Yanira. 2012. 708 p. ISBN 978-958-8353-43-2
[57] SALAMAN, Paul, DONEGAN, Thomas and CARO, David. List of Birds of Colombia. In: Colombian Conservation. May, 2009. no. 8, p. 3-79
[58] CHAPARRO-HERRERA, Sergio, ECHEVERRY-GALVIS, María Ángela, CÓRDOBA-CÓRDOBA, Sergio and SUA-BECERRA, Adriana. Updated list of endemic and near-endemic birds of Colombia. In: Colombian Biota. 2013. vol. 14. No. 2. 235-272
[59] COLOMBIA. . MINISTERIO DE AMBIENTE Y DESARROLLO SOSTENIBLE. Resolución 0192 (10, febrero, 2014). Op. cit., p. 28-32.
[60] RENJIFO, Luis Miguel, FRANCO-MAYA, Ana María, AMAYA-ESPINEL, Juan David, KATTAN, Gustavo and LÓPEZ-LANÚS, Bernabé. Red book of birds of Colombia. Research Institute of Biological Resources Alexander von Humboldt. Ministry of Environment. Seri of red books of threatened species of Colombia. Bogotá 2002. p. 554. ISBN: 958-8151-08-2

and Appendices I, II and III of CITES. In turn, for these species with existing secondary information, their ecological characteristics were described, including their potential breeding, reproduction, feeding and nesting.

3. Mammals

To carry out the characterization of small, medium and large mammals and the fliers in the area of influence, direct observation and indirect detection methods were used[61]. The direct observation methods consisted in traversing 16 transects for the registration of mammals, in which searches for traces such as feces, marks on trees and burrows, among others, were carried out. These transects were the same as those used to register birds (Figure No. 2.28, Table No. 2.47, Map MOD_LA_PTO_ANT_35_Fauna). Samples were taken for two (2) days for a sampling effort of 8 hours / day. As indirect detection methods, 16 footprint traps and 16 trap chambers were implemented for the identification of medium and large mammals (Photograph No. 2.5, Figure No. 2.30, Table No. 2.49, Map MOD_LA_PTO_ANT_35_Fauna). The sampling effort for the traps footprint was 8 traps / day for a total of 16 traps / 2 days and for the traps cameras was 2 cameras / day for a total of 16 cameras installed / 8 days. For footprint traps, the plant material was removed from the soil, the ground was prepared with a hoe and then flattened.

Photograph No. 2.5 Footprint traps (left) and trap cameras (right) installed for indirect sampling of mammals
Source: Aqua & Terra Consultores Asociados S.A.S., 2015

[61] SÁNCHEZ, Francisco, SÁNCHEZ-PALOMINO, Pedro and CADENA, Alberto. Inventory of mammals in a forest in the central Andes of Colombia. In: Caldasia. 2004. vol. 26. no 1 p. 291-309.

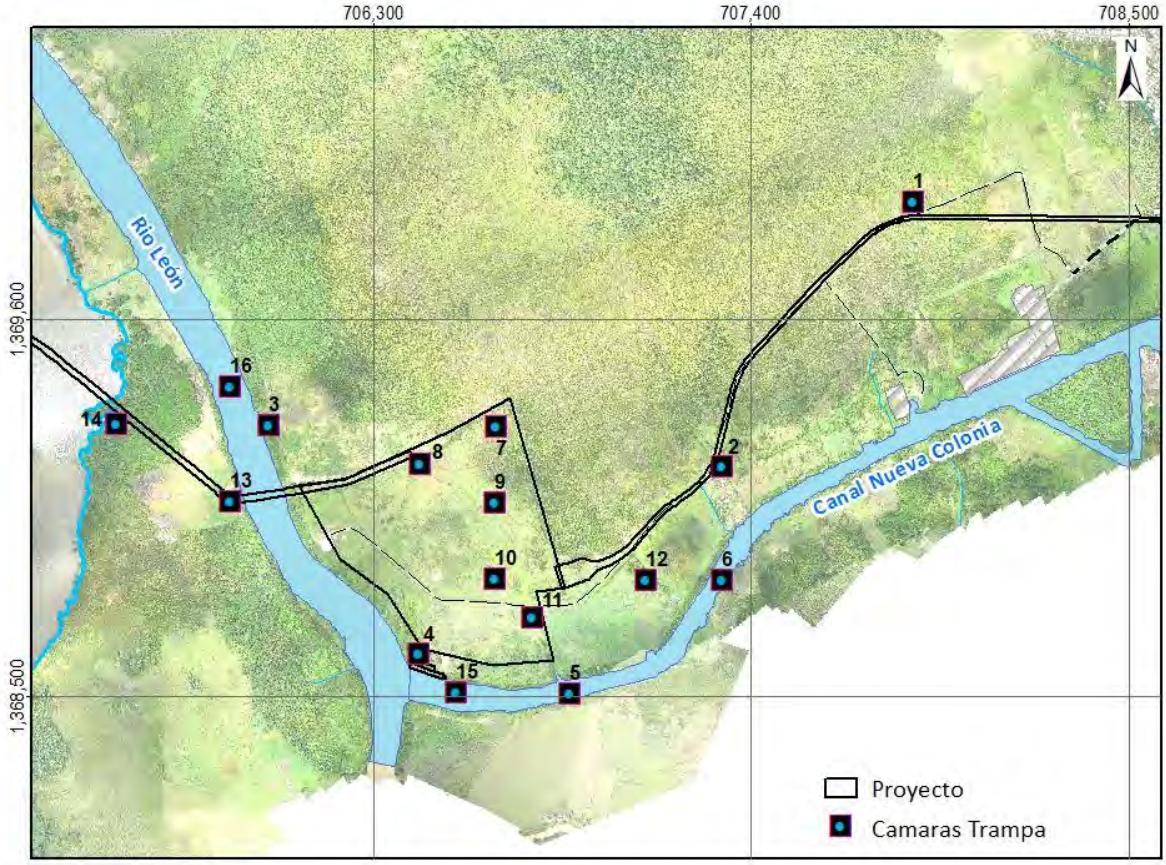


Figure No. 2.30 Location of installed trap cameras for the detection of mammals in the area of influence
Source: Aqua & Terra Consultores Asociados S.A.S., 2015

Table No. 2.49 Geographic location of the installed trap cameras for the detection of mammals in the area of influence

Camera	Plane coordinates magna sirgas origin Bogotá	
	East	North
1	707.873,30	1.369.941,68
2	707.316,47	1.369.170,24
3	705.992,64	1.369.289,43
4	706.429,90	1.368.622,34
5	706.870,71	1.368.508,80
6	707.314,35	1.368.838,11
7	706.654,91	1.369.285,19
8	706.433,44	1.369.175,89
9	706.653,49	1.369.063,77
10	706.652,07	1.368.842,34
11	706.761,74	1.368.730,93
12	707.093,59	1.368.839,52
13	705.880,84	1.369.068,72
14	705.551,13	1.369.292,27
15	706.539,57	1.368.510,92

Camera	Plane coordinates magna sirgas origin Bogotá	
	East	North
16	705.882,97	1.369.400,85

Source: Aqua & Terra Consultores Asociados S.A.S., 2015

For the capture of small non-flying mammals (PMNV), 60 Sherman-type traps were used, 30 of them were located in six (6) strategic points (Table No. 2.50, Map MOD_LA_PTO_ANT_35_Fauna) in gallery and dense forests during all the days of the Sampling and the other 30 were distributed in the other vegetation coverings (arracachal, pastures and grasslands) two nights for each cover, in order to intensify the sampling in the forest habitats where there is a greater probability of finding and / or capturing individuals of PMNV , for a total of 2,160 trap hours in the coverages evaluated. The traps were located on the ground, with an approximate separation of 10-15 m between each one, trying to cover the different strata of the sampling site.

Because small mammals are elusive to the presence of foreign elements in their environment, it is necessary to leave the traps, at least, for two nights in each coverage. These were located in strategic sites and microhabitats such as fallen trunks, base of trees, tree branches, foliage of branches, cavities formed by roots, near caves, on edges of stones, edges of bodies of water and in paths. For this sampling the methodology of different authors was followed[62] [63] [64] [65]. These traps are useful to capture small terrestrial and arboreal mammals, such as cricetids and small marsupials (mice, marmosas, marsupials, among others)[66].

All the traps were checked daily in the morning hours to check the catches and change baits. For the Sherman traps, a mixture of peanuts, oats and vanilla essence was used as bait.

The specimen captured in the traps was manually extracted using leather gloves and deposited in a cloth bag. Later in a field notebook, the date, time, scientific name, number of individuals, morphometric characteristics, sex, weight, location, the habitat where it was collected, and other interesting characteristics were recorded.

[62] SMITH, G.C., D.W. KAUFMAN, R.M. JONES, J.B. GENTRY, AND M.H. SMITH. 1971. The relative effectiveness of two types of snap traps. Acta Theriologia, 16 : 284 - 288.
[63] KALKO,E.K.V. AND C.O. HANDLEY, JR. 1992. Comparative studies of small mammal populations with transects of snap traps and pitfall arrays in southwest Virginia. Virginia Journal of Science 44 : 3 - 18 pp.
[64] WILSON D. E., F.R. COLE, J.D. NICHOLS, R. RUDRAN Y M.S. FOSTER. 1996. Measuring and monitoring biological diversity. Standard Methods for Mammals. Smithsonian Institution Press, Washington and London, 1-409 pp.
[65] ARANDA-SÁNCHEZ, J. M. 1981. Traces of wild mammals of Mexico. National Research Institute on biotic resources, Xalapa, Veracruz, Mexico.
[66] MINISTRY OF ENVIRONMENT, HOUSING AND TERRITORIAL DEVELOPMENT. 2010. General methodology for the presentation of environmental studies. Bogotá, D.C .: Colombia. Ministry of Environment, Housing and Territorial Development, 72 p.

The specimen was taken photographs and subsequently released in the same capture site.

Table No. 2.50 Geographic location of the sampling points where the Sherman traps were installed

Point	Flat coordinates magna sirgas origin Bogotá	
	East	North
M1	705.664,23	1.369.239,26
M2	705.652,11	1.369.260,87
M3	706.079,78	1.369.012,09
M4	706.809,80	1.368.573,77
M5	706.375,30	1.368.714,95
M6	705.630,65	1.369.261,01

Source: SAG S.A., 2015

For the flying mammals (bats - order Chiroptera), fog nets were used. Two (2) mist nets of 12 m long by 2.40 m high and 32 mm mesh eye were installed, for a total of 24 meters / network per selected coverage. These were located in the different vegetation units detected in the area of influence of the project and in strategic sites of each coverage. The networks were activated from 18:00 hours until 20:00 hours per day of sampling for a total of 504 hours / network per evaluated coverage. The captured individuals were placed in cloth bags for identification, taking measurements, weight, sex, photographic record and subsequent release.

The identification of species with direct and indirect methods was done in situ or with photographs taken in the field, reaching the minimum possible taxonomic level, in the case of bat species, bat lists from Colombia[67] [68] and taxonomic identification keys were used[69] [70].

The analyzes of the mammalian community present in the area were made per unit of sampled coverage. For each coverage the richness and abundance of species was calculated and with this information a map was constructed at a scale of 1: 10,000, showing the distribution of the species on the vegetation cover and the current use of their soil. Likewise, Margalef's ecological wealth indices (Equation No. 2.15), Shannon-Weiner diversity (Equation No. 2.17), Simpson's dominance (Equation No. 2.19) and Pielou's equitability (Equation No. 2.24) were found. Additionally, mammals' movement routes were identified within the area of influence

[67] FERRER PÉREZ, A, M. BELTRÁN, A. P DÍAZ-PULIDO, F. TRUJILLO, H. MANTILLA-MELUK, O. HERRERA, A. F ALFONSO, ESTEBAN PAYÁN. 2010. List of mammals in the Orinoco river basin. Biota Colombiana, 10: 179 - 207.
[68] ESTRADA-VILLEGAS, S & B. H., RAMÍREZ. 2013. Bats of Casanare, Colombia. Chiroptera Neotropical 19 (3) Special Volume: 1-13. SAO Bulletin, 15 (2): 105-111.
[69] AGUIRRE L.F; VARGAS A. AND SOLARI S. 2009. Field code for the identification of the bats of Bolivia. Center for Studies in Theoretical and Applied Biology, Cochabamba, Bolivia.
[70] MUÑOZ, J. 2001. The bats of Colombia. Systematics, distribution, description, natural history and ecology Universidad de Antioquia, Medellín. Colombia. Pp 390.

of the project. In addition, the potential routes of herpetofauna displacement within the area of influence of the project were identified and mapped at a scale of 1: 10,000.

Finally, it was asked if the registered species were endemic or almost endemic in the country [71] and their threat status was verified by consulting Resolution 0192 of 2014 [72], red book of mammals [73] of Colombia, the list of threatened species of IUCN [74] and Appendices I, II and III of CITES. In turn, for these species with existing secondary information, their ecological characteristics were described, including their potential breeding, reproduction, feeding and nesting areas.

2.3.2.3 *Continental and marine-coastal aquatic ecosystems*

The following are the methods that were used to carry out the floristic and faunal characterization of the continental and marine-coastal aquatic ecosystems present in the area of influence according to the stipulations of the terms of reference M-M-INA-05. The sampling stations for flora and fauna (hydrobiological) correspond to the coordinates of the water and sediment quality stations (Figure No. 2.31, Table No. 2.51, Map MOD_LA_PTO_ANT_35_Fauna) and their sampling was done during the transition or summer season.

[71] SOLARI, Sergio, MUÑOZ-SABA, Yaneth, RODRÍGUEZ-MAHECHA, José V., DEFLER, Thomas R., RAMÍREZ-CHAVES, Héctor E. and TRUJILLO, Fernando. Wealth, endemism and conservation of mammals in Colombia. In: Neotropical Mastozoology. 2013. vol. 20. no 20. p. 301-365

[72] COLOMBIA. MINISTRY OF ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. Resolution 0192 (10, February 2014). Op. Cit., P. 27-28, 34-35.

[73] RODRÍGUEZ-MAHECHA, José Vicente, ALBERICO, Michael, TRUJILLO, Fernando and JORGENSON, Jeff. Red book of mammals of Colombia. Research Institute of Biological Resources Alexander von Humboldt. Ministry of Environment. Seri of red books of threatened species of Colombia. Bogotá 2006. p. 430. ISBN: 978-958-97690-7-2

[74] INTERNATIONAL UNION FOR THE CONSERVATION OF NATURE - IUCN. The IUCN Red List of Threatened Species. Op. Cit.

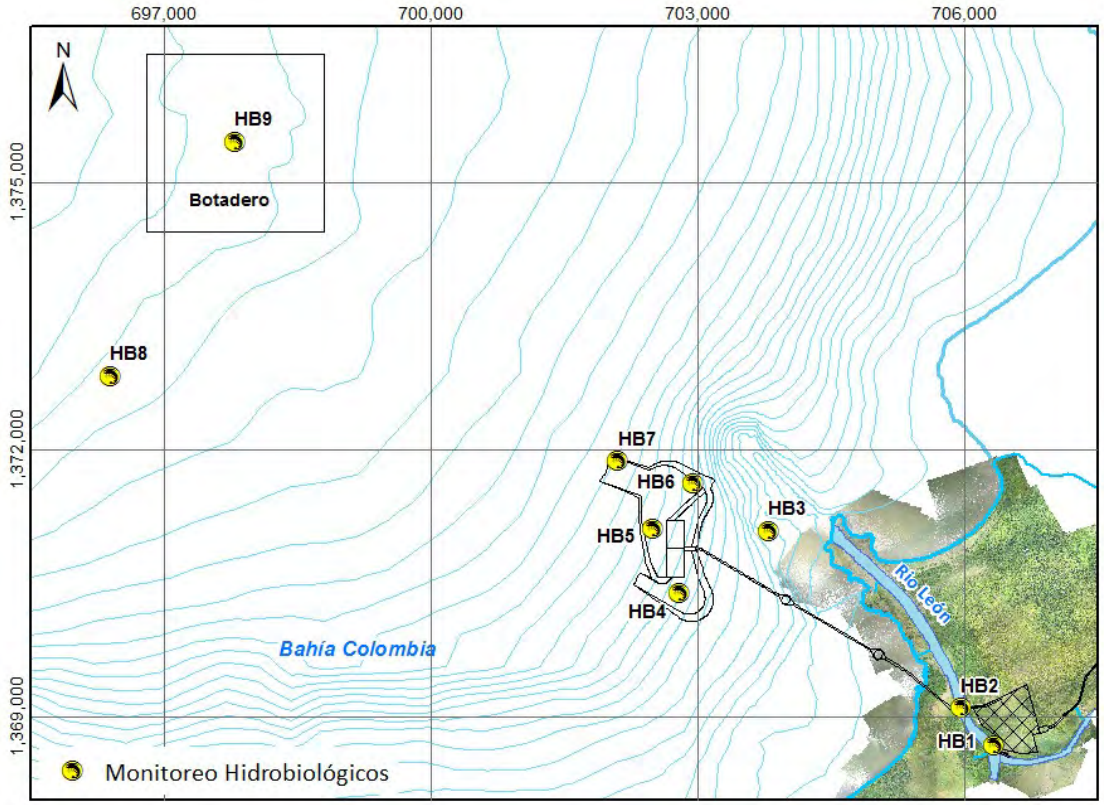


Figure No. 2.31 Fluvial and marine hydrobiological sampling points
Source: Aqua & Terra Consultores Asociados S.A.S., 2015

Table No. 2.51 Geographic location of flora and fauna sampling stations in the continental aquatic ecosystem

ECOSYSTEMS	ID	FLAT COORDINATES MAGNA SIRGAS Origin BOGOTÁ	
		East	North
Continental aquatic	HB1	706,327.33	1,368,671.49
	HB2	705,956.74	1,369,095.03
Marine-coastal	HB3	703,792.94	1,371,083.51
	HB4	702,783.75	1,370,390.87
	HB5	702,487.86	1,371,110.59
	HB6	702,943.68	1,371,628.00
	HB7	702,099.85	1,371,870.99
	HB8	696,387.84	1,372,825.31
	HB9	697,792.41	1,375,464.03

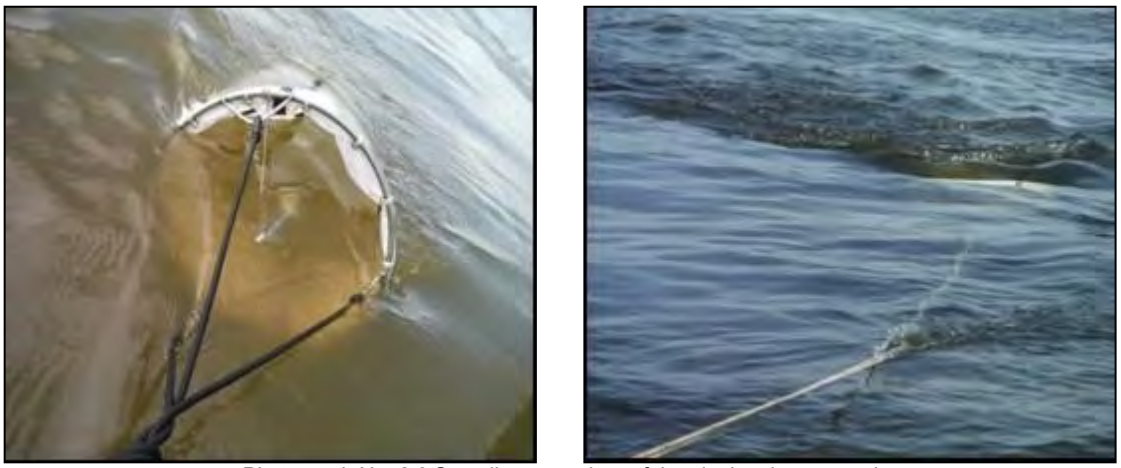
Source: Aqua & Terra Consultores Asociados S.A.S., 2015

- Flora

The characterization of phytoplankton and periphyton was carried out following the methodology proposed by the certified laboratory that conducted the sampling (SGS Colombia S.A.), which is in accordance with the guidelines established by IDEAM and INVEMAR. The methodology used is shown below. For the two stations located in the lotic ecosystem of the León River, only periphyton was considered.

1. Phytoplankton

The phytoplankton was collected with a conical network of 50 cm of mouth diameter and 80 µm of mesh opening, equipped with a previously calibrated mechanical flow meter. The trawls were horizontal and superficial (Photograph No. 2.6). Before carrying out each drag, the initial reading of the flow meter and the start time (Ti) were recorded. The trawls lasted 2 minutes at a constant speed and were performed in circles. At the end of the drag the time (Tf) and the final reading of the flow meter were recorded. Once the sample was deposited in the collection bottle, it was then packed in 250 ml bottles and then fixed with Transeau solution (distilled water, alcohol, formaldehyde), 1: 1: 1.



Photograph No. 2.6 Sampling procedure of the planktonic community

Source SGS Environmental Services, 2015

To perform the processing of the samples collected, each was homogenized by bubbling using a Pasteur pipette following the methodology proposed by Semina. This methodology allowed a better management of the data for the application of the analysis technique of an aliquot. For this analysis a transferpette micropipette of 10-100 µL was used, establishing a volume of 50 µL for each aliquot. Once the sample

was placed under the compound optical microscope, a zigzag sweep was performed in the 40x magnification to cover the largest possible area of the aliquot, analyzing 10 aliquots, where the accumulated wealth curve stabilized. For the identification

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1 SEMINA H.J. Treatment of an aliquot simple. In: Manual Phytoplankton. SOURNIA A. (ed.) Muséum National d'Histoire Naturelle. Paris. United Nations Educational, Scientific and Cultural Organization - UNESCO. 1978. 335 p. ISBN: 92-3-101572-9

of the samples, specialized literature was used and the taxonomic database Integrated Taxonomic Information System (ITIS) and Algaebase were considered for the taxonomic classification of each species.

The analyzes of the phytoplankton community were made according to the species and density richness (ind / L) of individuals per sampling station. To find the density of individuals, the Badillo equation was used to determine the filtered volume (Equation No. 2.25):

$$Vf = (3{,}14 * Dr^2 / 4)(Nr * Cr)$$

Equation No. 2.25 Equation to determine the filtered volume

Where:

Vf: Volume of water filtered by the network (m3)

Dr: Diameter of the mouth of the network, m

Nr: Number of revolutions in the flow meter (The number of revolutions in the flow meter is obtained by subtracting the initial reading from the final reading).

Rc: Rotor constant (0,3 m).

Once this value was obtained for each of the stations sampled, the density was calculated for each taxon following the Paggi and Paggi methodology (Equation No. 2.26):

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2 RAMÍREZ, J. Freshwater phytoplankton: ecological, taxonomic and health aspects, Medellín. Editorial University of Antioquia. 2000. 207 p.
3 STREBLE, HEINZ and KRAUTER, DIETER. Atlas of freshwater microorganisms. Editions Omega S.A .. Barcelona. 1987. 372 p. ISBN: 84-282-0800-X

4 WHITFORD, L. A. and SHUMACHER, A. A manual of the fresh-water algae in North Carolina. North Carolina Agricultural Experiment Station. Technical Bullletin. 1969. no. 188. 313 p
5 VIDAL-VELASQUEZ Luis Alfonso. Manual of Phytoplankton found in the Ciénaga Grande de Santa Marta and adjacent bodies of water. University of Bogotá Foundation Jorge Tadeo Lozano. Bogota Colombia. 2010. 348 p.
6 AMERICAN PUBLIC HEALTH ASSOCIATION, AMERICAN WATER WORKS ASSOCIATION AND WATER ENVIRONMENTAL FEDERATION (APHA-AWWA-WEF). Standard methods for the examination of water and wastewater. Washington D.C. Edition 22th. 2012
7 INTEGRATED TAXONOMIC INFORMATION SYSTEM - ITIS. [online] http://www.itis.gov/ [quoted on August 11, 2015]
8 GUIRY, M.D & GUIRY, G.M. 2015. AlgaeBase. World-wide electronic publication, Natonal University of Ireland, Galway. [online] http://www.algaebase.org/ [quoted on August 11, 2015]
9 BADILLO, M., GALINDO M., GALLARDO A., LIZAMA, G., PALOMINO, G., ARENA, M., and CHIAPPA, J. Handbook of aquatic ecology practices. National Autonomous University of Mexico. 2010. 98 p.
10 PAGGI, S.J. and J.C. PAGGI Determination of zooplankton abundance and biomass. In: Continental water ecosystems. Methodology for its study. Lopretto, E.C and G. Tell (eds) Ediciones Sur, La Plata, Argentina. 1995.

$$Ind/ml = (\#\ Ind/V1)*(V2/V3)$$

Equation No. 2.26 Calculation of density for different organisms for the planktonic community

Where:

Ind: number of individuals identified by taxon

V1: observed volume (# of aliquots * Aliquot volume)

V2: volume of the sample

V3: filtered volume

Note: According to Equation No. 2.26, the volumetric units were transformed to liter, making a conversion dividing by 1,000 each volume.

In addition, ecological Margalef diversity indices (Equation No. 2.15), Shannon-Weiner (Equation No. 2.17), Simpson dominance (Equation No. 2.19) and Pielou equitability (Equation No. 2.24) were calculated. To assess how similar the phytoplanktonic communities were in terms of composition, density and sampling stations, a quantitative analysis was performed using the Bray - Curtis similarity index, calculated from the density matrix.

After this triangular matrix a grouping analysis was performed using the method of grouping by unweighted averages and a graphic result was obtained (CLUSTER) that allowed to see the degree of similarity of the communities. Finally, it was correlated by means of Pearson's parametric (α: 0.05) and nonparametric Spearman's test (α: 0.05), the density obtained for phytoplankton with the following physicochemical parameters: Temperature, dissolved oxygen, pH, biochemical demand for oxygens, chemical demand for oxygen, total nitrogen and turbidity.

2. Perifiton

For this community and according to its origin, we proceeded to the selection of several substrates such as rocks, leaves and trunks. From these substrates a scraping was done with a toothbrush of the biofilm that was adhered to them, the scraping area was 45 cm2 Photograph No. 2.7). Subsequently, the sample was stored in 60 mL amber containers, where it was stained with lugol and fixed with Transeau solution (distilled water, alcohol, formaldehyde) ratio 1: 1: 1.

Photograph No. 2.7 Peripheral community sampling procedure

Source: SGS Environmental Services, 2015

The samples were homogenized by means of bubbling, using a Pasteur pipette following the Standard Methods for the Examination of Water and Wastewater, which allowed the best data management for the application of the analysis techniques of an aliquot.

For this analysis a transferpette micropipette of 10-100 µL was used, establishing a volume of 50 µL for each aliquot. Once the sample was located under the compound optical microscope, a zigzag sweep was performed in the 40x magnification to cover the largest possible area of the aliquot, analyzing 10 aliquots until the accumulated wealth curve stabilized.

For the identification of the samples, specialized literature was used and the taxonomic database Integrated Taxonomic Information System (ITIS) was taken into account for the taxonomic classification of each species.

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11 AMERICAN PUBLIC HEALTH ASSOCIATION, AMERICAN WATER WORKS ASSOCIATION AND WATER ENVIRONMENTAL FEDERATION (APHA-AWWA-WEF). Op. Cit

12 RAMÍREZ, J. Op cit.
13 STREBLE, HEINZ and KRAUTER, DIETER. Op. Cit
14 WHITFORD, L. A. and SHUMACHER, A. Op. Cit
15 AMERICAN PUBLIC HEALTH ASSOCIATION, AMERICAN WATER WORKS ASSOCIATION AND WATER ENVIRONMENTAL FEDERATION (APHA-AWWA-WEF). Op. Cit
16 INTEGRATED TAXONOMIC INFORMATION SYSTEM - ITIS. [online] http://www.itis.gov/ [quoted on August 11, 2015]

Periphytic community analyzes were carried out according to species richness and density (ind / cm2) of individuals per sampling station.

In addition, ecological Margalef diversity indices (Equation No. 2.15), Shannon-Weiner (Equation No. 2.17), Simpson dominance (Equation No. 2.19) and Pielou equitability (Equation No. 2.24) were calculated.

To assess how similar periphyton communities were in terms of composition, density and sampling stations, a quantitative analysis was performed using the Bray - Curtis similarity index, calculated from the density matrix. After this triangular matrix, a grouping analysis was performed using the method of grouping by unweighted averages and a graphic result was obtained (CLUSTER) that allowed to see the degree of similarity of the communities. In the continental aquatic ecosystem, no correlation was made with the physicochemical parameters, because the sampling was done in two points, which are not representative for this type of analysis.

3. Mangrove

To carry out the characterization of the mangrove present in the area of influence of the project, the high dense mangrove coverings and the secondary high vegetation corresponding to the natural regeneration of the mangrove were grouped. There the 100% forest inventory was made in a 30 meter strip on each side where the project viaduct will be built and which was considered as a direct intervention area, as shown in Figure No. 2.32 (Map MOD_LA_PTO_ANT_38_Flora). There, the census was conducted of all those individuals with CAP greater than or equal to 31.4 cm.

Figure No. 2.32 forest inventory in the mangrove area, area of direct impact of the project

Source: Aqua & Terra Consultores Asociados S.A.S., 2015

The floristic characterization of these coverings was determined from a probability of 95% and sampling error no greater than 15%, which is equivalent to 1 plots per unit of sampled coverage. To carry out this sampling, the methodology proposed by Pinelo was adapted, two parcels of 0.25 ha (50 m long x 50 m wide) were installed, one in the high dense mangrove cover and another in the secondary vegetation of the mangrove, as It is shown in Figure No. 2.33.

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17 COLOMBIA. MINISTRY OF ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. Resolution no. 0112 (January 28, 2015). Op. Cit., P. fifty.

18 PINELO, Gustavo Israel. Integrated forest inventory manual for management units. WWF Central America. 2004. 49 p.

Figure No. 2.10 Location of the sampling plots in the mangrove cover
Source: Aqua & Terra Consultores Asociados S.A.S, 2015.

The variables that were taken during the forest inventory were: Identification of the species, circumference at chest height (considering the exceptions presented in Figure No. 2.34), angle of inclination at chest height, angle of inclination to the first branch and angle of inclination to the apex of the tree, crown width, stem quality and the location coordinates of each tree; all individuals with CAP greater than or equal to 31.4 cm were measured.

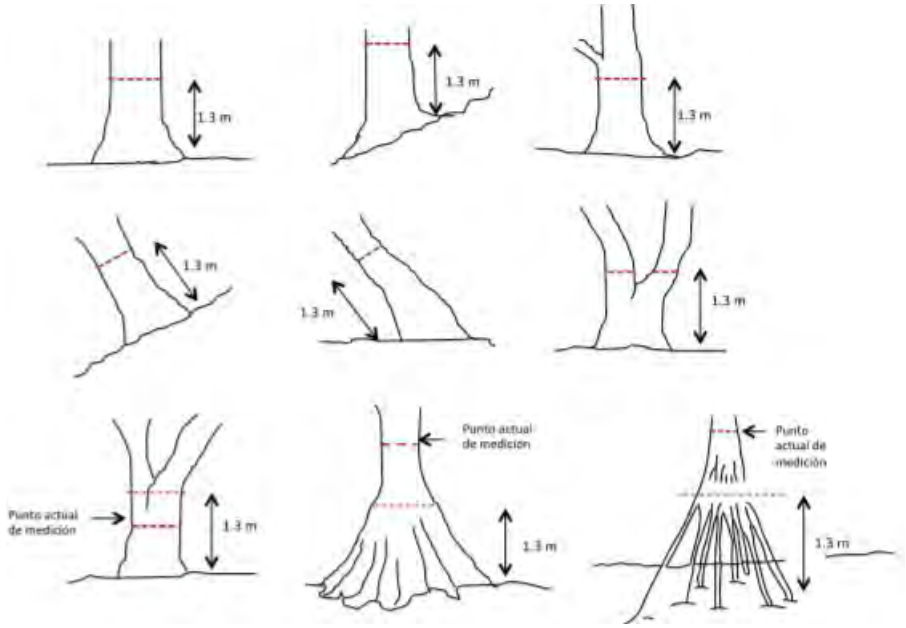

Figure No. 2.34 Recommendations for the measurement of the circumference to the height of the chest (CAP), according to the characteristics of the terrain and of each tree
Source: Melo and Vargas (2003)

All individuals were marked with red oil paint approximately 1.50 m high, numerically and the numbers were consecutive, as shown in Photograph No. 2.8.

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19 MELO CRUZ, O. A. AND R. VARGAS RIOS. 2002. Ecological and silvicultural evaluation of forest ecosystems. University of Tolima, CRQ, Corpocaldas and Cortolima, Ibague. 207 p.

Photograph No. 2.8 Marking of the inventoried trees in the mangrove area
Source: Aqua & Terra Consultores Asociados S.A.S., 2015

The floristic characterization of the mangrove was carried out by means of the analysis of the importance value index (Equation No. 2.10, Equation No. 2.11, Equation No. 2.12 and Equation No. 2.13), the quotient of the mixture (CM, Equation No. 2.14) , the diametric and altimetric distribution (sociological composition and ecological indexes of Margalef's wealth (Equation No. 2.15), Menhinick's (Equation No. 2.16), Shannon-Weiner diversity (Equation No. 2.17), Simpson's dominance (Equation No. 2.19) and Berger Parker (Equation No. 2.20).

Additionally, the natural regeneration analysis of the mangrove was carried out. All of the above following the scheme carried out for the analysis of the vegetation cover identified in the terrestrial ecosystem.

Finally, Resolution 0192 of 2014, red book of Colombian plants, timber species, the list of endangered species of IUCN

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20 COLOMBIA. MINISTRY OF ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. Resolution 0192 (10, February 2014). Op. Cit., P. 28-32.
21 CÁRDENAS, Dairon and SALINAS, Nelson. Red book of plants of Colombia. Volume 4. Threatened timber species: First part. Red books series of threatened species of Colombia. Amazon Institute of

and Appendices I, II and III of CITES were consulted. Next, each of the items named for the analysis is shown in detail.

- Wildlife

The characterization of the wildlife present in the continental aquatic ecosystems (macroinvertebrates and fish) and marine coastal ecosystems (zooplankton, benthos and fish) of the area of influence, was carried out following the methodology proposed by the certified laboratory that carried out the sampling (SGS Colombia SA) , which is in accordance with the guidelines established by IDEAM and INVEMAR, and the information found in the environmental impact study that supports the environmental license granted through Resolution 0032 for the construction of Puerto Antioquia.

The methodology used is shown below.

1. Zooplankton

The zooplankton was collected with a conical network of 50 cm of mouth diameter and 80 µm of mesh opening, equipped with a previously calibrated mechanical flow meter. The trawls were horizontal and superficial (Photograph No. 2.6). Before carrying out each drag, the initial reading of the flow meter and the start time (Ti) were recorded. The trawls lasted 2 minutes at a constant speed and were performed in circles. At the end of the drag time (Tf) and the final reading of the flow meter were recorded. Once the sample was deposited in the collection bottle, it was later packed in 250 ml bottles and proceeded to fix them with Transeau solution (distilled water, alcohol, formaldehyde), 1: 1: 1 ratio.

The samples were homogenized with a Pasteur pipette before being analyzed by means of bubbling. The analysis of the samples was carried out following the methodology proposed by Paggi and Paggi, which focuses on the use of an SR plate (Sedgwick-Rafter) and a graduated pipette of 1 mL (volume used by aliquot). The sample was placed under the compound optical microscope

Scientific Research SINCHI - Ministry of Environment, Housing and Territorial Development. 2007. 232 p. ISBN: 978-958-8317-19-9
22 INTERNATIONAL UNION FOR THE CONSERVATION OF NATURE - IUCN. The IUCN Red List of Threatened Species. Op. Cit.
23 CONVENTION ON INTERNATIONAL TRADE IN THREATENED SPECIES OF WILDLIFE AND WILDLIFE - CITES. List of CITES species. Op. Cit.
24 COLOMBIA. NATIONAL AUTHORITY OF ENVIRONMENTAL LICENSES - ANLA. Resolution 0032 (January 25, 2012).

By means of which an environmental license is granted. Bogotá, D.C. 135 p.
25 Paggi and Paggi. Op cit.

and analyzed by performing a zigzag sweep under the 10x magnification. 10 aliquots were analyzed until the accumulated species richness curve stabilized. The identification of the organisms was done with specialized literature and the taxonomic database Integrated Taxonomic Information System (ITIS) was used for the taxonomic classification.

The analyzes of the zooplankton community were made according to the species and density richness (ind / L) of individuals per sampling station. To find the density of individuals, the Badillo equation was used to determine the filtered volume (Equation No. 2.25). Once this value was obtained for each of the stations sampled, the density was calculated for each taxon following the Paggi and Paggi methodology (Equation No. 2.26).

In addition, ecological Margalef diversity indices (Equation No. 2.15), Shannon-Weiner (Equation No. 2.17), Simpson dominance (Equation No. 2.19) and Pielou equitability (Equation No. 2.24) were calculated.

To assess how similar the zooplanktonic communities were in terms of composition, density and sampling stations, a quantitative analysis was performed using the Bray - Curtis similarity index, calculated from the density matrix. After this triangular matrix a grouping analysis was performed using the method of grouping by unweighted averages and a graphic result was obtained (CLUSTER) that allowed to see the degree of similarity of the communities. Finally, it was correlated by Pearson's parametric (α: 0.05) and non-parametric Spearman's test (α: 0.05), the density obtained for zooplankton with the following physicochemical parameters: Temperature, dissolved oxygen, pH, biochemical demand for oxygens, chemical demand for oxygen, total nitrogen and turbidity.

2. Benthic macroinvertebrates and benthos

The community of benthic macroinvertebrates in the continental aquatic ecosystem and benthos in the coastal marine ecosystem was sampled with a Petersen dredger

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26 STREBLE, HEINZ and KRAUTER, DIETER. Op. Cit
27 GUTIÉRREZ M.E; SUAREZ. ME; GUTIÉRREZ A.M; SILVA. B.M; GRANADOS. R.J and GARFIAS. E.T. Cladocera and Copepoda. National Autonomous University of Mexico. School of Higher Studies Iztacala. 2008. 951 p.
28 INTEGRATED TAXONOMIC INFORMATION SYSTEM - ITIS. [online] http://www.itis.gov/ [quoted on August 11, 2015]
29 Badillo, et al. Op. Cit
30 Paggi and Paggi. Op cit.

with an area of 0.1 m2. The dredge is sent to the bottom and with the help of levers the closing mechanism is activated removing the substrate causing the organisms to be trapped in it (Photograph No. 2.9). Once the sample was collected, it was deposited in ziploc bags of 35 x 25cm and it was fixed with Transeau solution (distilled water, alcohol, formaldehyde), ratio 1: 1: 1.

Photograph No. 2.9 Sampling procedure of the benthic macroinvertebrate community

Source: SGS Environmental Services, 2015

To analyze this community each sample was worked independently, subjecting it to a water wash on 250 µm and 710 µm sieves whose objective is to separate the organisms from the other impurities (plant material and sediments).

The organisms were stained with Rose Bengal solution for 1 hour to facilitate separation, which was performed in petri dishes with the use of tweezers and the stereoscope. Once the organisms were separated, they were identified under the stereoscope using specialized literature, using for the continental aquatic organisms Liévano and Ospina and Roldán and for the marine organisms Díaz and Puyana and

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31 LIÉVANO, A AND OSPINA, R. Illustrated guide of the aquatic macroinvertebrates of the Bahamón River. First edition. El Bosque University and Alexander von Humbolt Institute. Bogotá 2007. 130 p.

32 ROLDAN, G. Guide for the study of aquatic macroinvertebrates. University of Antioquia. Faculty of Exact and Natural Sciences - Research Center, CIEN. Bogota Colombia. 1988. 217 p.

33 ROLDÁN, G. Bioindication of water quality in Colombia. Proposal for the use of the BMWP / Col method. Editorial University of Antioquia. Science and Technology Collection. Medellin 2003

34 DÍAZ, Juan Manuel and PUYANA, Mónica. Molluscs of the Colombian Caribbean: an illustrated catalog. 2009. 291 p. ISBN: 9589571204

Rouse and Pleijel. The taxonomic database Integrated Taxonomic Information System (ITIS) was considered for the taxonomic classification.

Analyzes of the community of benthic macroinvertebrates were carried out according to species richness and density (ind / m2) of individuals per sampling station. In addition, ecological Margalef diversity indices (Equation No. 2.15), Shannon-Weiner (Equation No. 2.17), Simpson dominance (Equation No. 2.19) and Pielou equitability (Equation No. 2.24) were calculated.

To evaluate how similar were benthic macroinvertebrate communities and benthos in terms of composition, density and sampling stations, a quantitative analysis was performed using the Bray - Curtis similarity index, calculated from the density matrix.

After this triangular matrix a grouping analysis was performed using the method of grouping by unweighted averages and a graphic result was obtained (CLUSTER) that allowed to see the degree of similarity of the communities. Finally, and only for the samples of the benthos collected in the area of marine influence was correlated by means of Pearson parametric statistical test (α: 0.05), the density of benthos with the following parameters analyzed in the sediment samples: carbon organic, fats and oils and total hydrocarbons.

3. Ichthyofauna

The characterization of the ichthyofauna of continental aquatic ecosystems was carried out using a 3-inch mesh eyelet over a period of 20 minutes where a total of 17 hauls were reached (Photograph No. 2.10). The characterization of the ichthyofauna of marine-coastal ecosystems was carried out using 4 trammels, which were located during a period of 4 hours. Once this time had passed, the networks were collected, and the species and the number of organisms were counted. The tasks for fish characterization were carried out by local fishermen. Once collected, the organisms spread over a clean surface and were photographed in situ, at different angles for later identification in the laboratory.

35[1] ROUSE, G., and PLEIJEL, F. POLYCHAETES. Published in the United States by the University of Oxford. 2001.354 p.
36[1] INTEGRATED TAXONOMIC INFORMATION SYSTEM – ITIS. [en línea] http://www.itis.gov/ [citado el 11 de agosto de 2015]

Photograph No. 2.10 Sampling procedure for the fish community

Source: SGS Environmental Services, 2015

The analyzes of the fish community were made according to the species richness and abundance of individuals per sampling station. In addition, ecological Margalef diversity indices (Equation No. 2.15), Shannon-Weiner (Equation No. 2.17), Simpson dominance (Equation No. 2.19) and Pielou equitability (Equation No. 2.24) were calculated.

To assess how similar the fish communities were in terms of composition, density and sampling stations, a quantitative analysis was performed using the Bray - Curtis similarity index, calculated from the density matrix. After this triangular matrix a grouping analysis was performed using the method of grouping by unweighted averages and a graphic result was obtained (CLUSTER) that allowed to see the degree of similarity of the communities. Finally, it was correlated by means of Pearson's parametric (α: 0.05) and non-parametric Spearman's test (α: 0.05), the abundance obtained for the ichthyofauna present in the area of marine influence with the following physicochemical parameters: Temperature, dissolved oxygen, pH, biochemical oxygen demand, chemical oxygen demand, total nitrogen and turbidity.

2.3.2.4 *Strategic, sensitive ecosystems and / or protected areas*

To identify the strategic ecosystems, sensitive and / or protected areas that are in the area of influence, the information available in the Technical Report was consulted: Ecoregional planning for in situ conservation of marine and coastal biodiversity in the Caribbean and the Colombian continental Pacific, in Decree 1120 of 2013, which regulates the Coastal Environmental Units -UAC- and the Territorial Ordinance Plan of the Municipality of Turbo.

Likewise, the TREMARCTOS Colombia early warning information system, the decision support support system of the subsystem of marine protected areas SSD_SAMP of INVEMAR, the geographical information portal of the Alexander von Humboldt Biological Resources Research Institute and the Environmental information system of Colombia of the National Authority of Environmental Licenses - ANLA. Additionally, the available documentation on the area was consulted at the Corporation for the Development of Urabá - CORPOURABÁ and public and private academic sources.

2.3.3 Socioeconomic environment

The work methodology to address the socioeconomic environment started from the recognition of the institutions and communities that interact in the territory where the study is developed, to those who attend the right to a healthy environment and to actively participate in the development of their community. In legal terms referring to the study, it was based on the requirements established in Decree

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37[1] INSTITUTE OF MARINE AND COASTAL INVESTIGATIONS JOSÉ BENITO VIVES DE ANDREIS - INVEMAR. Technical report: Ecoregional planning for the in situ conservation of marine and coastal biodiversity in the Caribbean and the Colombian continental Pacific. Series of General Documents No. 41. Santa Marta. 2009. 106 p + Annexes. ISBN 978-958-8448-23-7

38[1] COLOMBIA. MINISTRY OF THE ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. Decree 1120 (May 31, 2013). By which the Coastal Environmental Units -UAC- and the joint commissions are regulated, the rules of procedure and criteria are established to regulate the restriction of certain activities in seagrasses, and other provisions are dictated. Bogotá, D.C., 2013. 10 p.

39[1] REPUBLIC OF COLOMBIA. MUNICIPALITY OF TURBO. Agreement No. 015 (July 25, 2000). By means of which the plan of territorial ordering of the municipality of Turbo is adopted. Turbo. 151 p.

40[1] RODRÍGUEZ-MAHECHA, JV, ARJONA-HINCAPIÉ, F., MUTO, T., URBINA-CARDONA, JN, BEJARANO-MORA, P., RUIZ-AGUDELO, C., DÍAZ GRANADOS, MC, PALACIOS, E., MORENO, MI, GÓMEZ, A. and. GEOTHINKING LTDA. Ara Colombia. Geographic Information System for the Analysis of State Institutional Management (Otus Colombia Module) and the Affectation to Sensitive Biodiversity and Cultural Heritage (Tremarctos-Colombia Module). Version 2.0 (28; 01; 2013) Conservation International-Colombia & Ministry of Environment and Sustainable Development. Online information system available at http://www.tremarctoscolombia.org/ [quoted on July 29, 2015].

41[1] INSTITUTE OF MARINE AND COASTAL INVESTIGATIONS JOSÉ BENITO VIVES DE ANDREIS - INVEMAR. Decision support system for the Subsystem of Marine Protected Areas SSD_SAMP. In: INVEMAR [online]. http://gis.invemar.org.co/ssdsamp/

42[1] INSTITUTE OF RESEARCH OF BIOLOGICAL RESOURCES ALEXANDER VON HUMBOLDT. Information System on Biodiversity of Colombia (SiB-Colombia) GeoSiB. Bogotá D.C. Online information system available at: http: //hermes.humboldt.org.co/visoruniversal2010/bin/Visor.html#

43[1] NATIONAL AUTHORITY OF ENVIRONMENTAL LICENSES - ANLA. Environmental Information System of Colombia - SIAC. Available at: http://sig.anla.gov.co:8083/

2041 of 2014, the General Methodology for the Presentation of Environmental Studies and the Terms of Reference for construction projects or expansion and operation of deep sea ports - MM-INA-05- adopted by Resolution 0112 of January 2015.

In this regard, and in accordance with the characteristics of the territory, work techniques were established in which the collection of primary information was combined with the inputs contained in the secondary information from the institutions and other studies carried out in the area. These resulted in the recognition of the socioeconomic and cultural conditions of the study area before the execution of the project, which are contrasted with the activities of the same to identify the possible impacts that would occur in the environment and thus establish the management measures adequate to the conditions found.

Below is a description of each of the moments that will be advanced in the development of the modification of the environmental license granted to the Puerto Bahía Colombia Society of Urabá SA through Resolution 0032 of January 2012 for the socioeconomic component, in such aspects as the population and economic dynamics, the coverage and quality of the existing public and social services, the forms of organization and the cultural aspects of the population located in the area of influence of the project.

2.3.3.1 *Documentary review*

This technique was used for the characterization of the area of influence of the project, for which quantitative and qualitative information is reviewed especially of the larger territorial unit, which for the present study corresponds to the municipality of Turbo, consulting updated secondary information of government institutions and other institutions of recognized suitability, as well as the information recorded in recent regional and local studies.

To do this, they studied among other sources:

- From the national order:
    - National Administrative Department of Statistics -DANE-,

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44 COLOMBIA, MINISTRY OF ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. Decree 2041 (October 15, 2014). By which regulates the title VIII of the law 99 of 1993 on environmental licenses.

- Geographical Institute Agustín Codazzi
- General Maritime Directorate - DIMAR –
- Presidential agency for social action
- Observatory for Human Rights of the Vice Presidency of the Republic

- Colombian Institute for Rural Development -INCODER-
- Institute of Marine and Coastal Research -INVEMAR-
- National Authority of Environmental Licenses -ANLA-
- National Authority for Aquaculture and Fisheries -AUNAP-

The main documents consulted included the National Development Plan, national statistics through the DANE (2005 Census), information reported by environmental authorities, documents and reports issued by the vice president of the republic among others.

- From the departmental order:
  - Government of Antioquia
  - Ministry of Social Development
  - Planning secretary
  - Health Secretary

Documents were consulted such as the Departmental Development Plan, departmental statistics (Antioquia Statistical Yearbook), Regional Environmental Management Plan, LOTA Land Management Guidelines, among others.

- Of the municipal order
  - Turbo City Hall and its different secretaries
  - University of Antioquia Urabá headquarters
  - UNIBAN Foundation
  - CORPOURABÁ

Likewise, valuable sources were consulted for a comprehensive understanding of the territory, communities and community organization. Among the documents, are the Territorial Ordinance Plan and the Municipal Development Plan 2012-2015, the environmental impact study prepared in 2009 for the licensing of Puerto Antioquia, and other texts published by State entities, universities and social organizations with presence in the territory studied.

2.3.3.2 *Primary information survey*

To obtain primary information, within the framework of the procedure for modification of the environmental license, a methodology anchored in qualitative research principles was used, with the adoption of some quantitative research tools that allow the recognition of the different communities and their environment.

To carry out this methodological design, an information verification of the minor territorial units previously identified was carried out, based on the information reported in the Environmental Impact Study - EIA carried out by the company of Araújo Ibarra & Asociados SA in 2009.

It was carried out in the same way, social cartography with the community in which a diagnosis of the territory could be made.

The verification of information referring to the smallest territorial units was done through the gathering of information in the field, using as a main tool the elaboration of an applied socio-economic card with the participation and accompaniment of the leaders of the area previously identified, the realization of semi-structured interviews to the residents and officials of public entities, as well as field visits, observation of the economic social and cultural dynamics of the communities identified.

In the same way, a fish information survey form was designed based on the AUNAP guidelines, to characterize and identify the intensity of this activity in the area.

Report making

Once the primary and secondary information was collected in the field, we proceeded to digitize the data, in such a way that they could advance statistical processes to quantitatively and qualitatively describe the characteristics of the social, economic and cultural environment.

The different methodologies used allowed the collection of primary and secondary information for the theoretical construction of the socioeconomic environment in the present study, as well as the approach and contact with the different actors involved in its development.

Finally, the processing of these data allowed identifying and describing the potential impacts that the project would cause to each of the identified groups and establishing the management measures to address them.

- Participation guidelines

The process of information and participation was developed at different times, namely: first contacts were made with municipal administrations, local authorities,

communities, living forces, economic and social associations in the area of influence, then three formal meetings were held in the development of the participation component.

The first activity start meeting explains the technical characteristics, scope and activities of the project and study to be developed, as well as the information related to the area of influence, demand, use and utilization of natural resources.

The second meeting was held during the preparation of the environmental impact study in which the project was socialized and its implications, as well as information on each of the components of the study.

For this, a multidimensional workshop was held in which the community could participate in the identification of the impacts and management measures that may be included in the environmental management plan.

Once the study for the modification of the environmental license is completed, a third meeting will be held, where the results of the same will be socialized.

For the development of the previous meetings, the following was considered:

- Plan the necessary logistics for the activities
- Offer ideal spaces for socialization and participation
- Make calls through correspondence and email
- Development of a specific methodology for each one of the meetings that will be held attending the moment of the elaboration of the study and the characteristics of the previously identified communities
- Document the development of the present meetings through (minutes raised in situ, support expressed concerns, attendance lists, photographic and film record).

The participants were given a copy of the minutes and supports of each meeting.

Bearing in mind that the presence in the area of influence of the project is recorded by the Canal community, which is in the process of relocation and resettlement, initial contacts were made through the UNIBAN Foundation and other entities with a presence in the area. accompany the process.

- Demographic dimension

An initial review was made of the information contained in the environmental impact study carried out in 2009 by the company Araújo Ibarra Asociados S.A.

A general reference of the general demographic conditions of the identified major territorial unit was presented, which for the specific case corresponds to the municipality of Turbo (population dynamics, demographic trends, index of unsatisfied basic needs NBI), for this the statistical yearbook was consulted of Antioquia.

For the smaller territorial units, the information reported in the municipal SISBEN office was consulted additionally and field visits were made. For the community of Vereda El Canal, the socioeconomic record was applied to verify the demographic information of the population subject to resettlement.

- Spatial dimension

The main tool to analyze this component was the secondary information. The information provided by the Territorial Planning Plan -POT-, the Municipal Development Plan -PDM- and the Identification and Classification System of Potential Beneficiaries for Social Programs -SISBEN- was reviewed. In these documents, the education, health and road plans were consulted, as well as other public and social services.

Likewise, some semi-structured interviews were conducted with the officials of the Municipal Planning Secretary and residents of the area under study.

For the smaller territorial units, the information reported in the municipal SISBEN office was consulted additionally and field visits were made.

For the community of Vereda El Canal, a socioeconomic record was applied to verify the demographic information of the population subject to resettlement according to the criteria established by the terms of reference and Resolution 077 of 2012 methodology information on the population to be resettled by the Agency National Infrastructure -ANI-.

All the above allowed to analyze the coverage and quality of public and social services, as well as the potential and weaknesses of these services within the area of influence of the project.

- Economic dimension

In order to comply with the terms of reference regarding the preparation of a general panorama of the regional economic dynamics, secondary sources of information were analyzed, such as the DANE, the POT, the PDM and AUNAP, among others; this information was processed in such a way as to serve as the main input to account for the distribution of the following aspects for the larger territorial units of aspects such as: ownership structure, productive and technological processes, characterization of the labor market and the different poles of development, trade and associated services.

For the smaller territorial units, the information reported in the SISBEN and the primary information raised in the field were analyzed through the socioeconomic tab for the El Canal community.

Additionally, for the fishing communities in the area, a fishery census was conducted, which was developed by compiling information related to the artisanal fishing dynamics identified in the area. For this, primary information of the different entities such as AUNAP, INCODER and UMATA was previously gathered, as well as the different associations that may be identified. Additional direct observation was made in the area, monitoring the existence of fishermen in the intervention area. The field format for data collection is in Annex 5.3.2.1

The artisanal fishing dynamics in the area was carried out in the stages described below:

In the first stage, through a file previously designed for the collection of fishing information, a day of fishing effort was carried out in which the following aspects were identified (Annex 5.3.2.2).

- Number of active fishermen and dependence on fishing
- Capture method and fishing gear (information on slaughter costs)
- Number and type of boat
- Navigation routes
- Species captured by type of fishing gear
- Average sizes
- Landing sites

- Seasonality of the catch
- Sale prices by species
- Alternative fishing activities developed
- Organizations or cooperatives to which fisherman belong
- Geographical identification of fishing grounds and fishing areas

Simultaneously, direct monitoring was carried out in the area of influence of the project, for 15 days, of which a monitoring was carried out in ten (10) days in a distance of three (3) kilometers, and five (5) days in the dump area located approximately (6) kilometers offshore from the mouth of the León River, towards Bahía Colombia.

Within this area the following data was considered:

- Diligence of the format.
- Georeferencing of the place (Fishing place and / or meeting with the fisherman).
- Photographic record (Species, type of vessel).

For the georeferencing, GPS model GPSMAP 76csx was used, and the respective photographic record was included.

It should be noted that this activity was carried out by a specialized professional who at times had the support of the AUNAP officials and the auditing of the project.

This activity was carried out more frequently in the morning and evening hours.

The fifteen (15) business days of monitoring were performed interspersed in a total time of four (4) weeks.

These schedules were subject to modifications according to the departure times of the fishermen, which are affected by weather conditions (winds, tide, rain, among others)

In the second stage, the analysis of the collected data was carried out, allowing obtaining information from the reported fishing units, generating quantitative and qualitative information of the fishing activities developed in the area.

Development trends

The trends of development in the area of influence, were analyzed from secondary sources contained in the Land Management Plan, the Municipal and Departmental Development Plan, and some other reports consulting through the web pages of the mayor's office and some companies that have a presence in the area. All this in order to analyze the possible influence of the Project on the development dynamics of the area.

- Information on population to resettle

The El Canal community, located 2 km away from the Nueva Colonia municipality, requires resettlement to avoid possible effects due to permanent traffic on the alternate road to the terminal on land. With the objective of updating the number of existing properties and establishing the socioeconomic status of the community, the census will be updated to the families settled there. The above according to guidelines contemplated in Resolution 077 of 2012, information methodology of population to resettle, which is described below:

Inventory of housing: The instrument to be applied is according to the information required in FR001 format, defined by the National Infrastructure Agency, according to the following requirements (See Annex 5.3.2.3).

- Characteristics of social Units
- Demographic and economic analysis
- Identification of social and cultural organizations
- Validation of information with the municipal administration.

Population census: According to the inventory of the houses made in the Environmental Impact Study of 2009 by the company Araujo Ibarra Asociados SA, home visits will be carried out to update the information with the application of a socio-economic card according to the information required. the FR002 format, (Annex 5.3.2.4) defined by the National Infrastructure Agency, for the characterization of the resident social unit and in case of evidencing a Productive Social Unit, the information required in the FR003 format will be filled out (Annex 5.3.2.5)

The above will be supported with a photographic record of each existing family group and of the productive units if they are evidenced. They will be presented in FR004

format (See Annex 5.3.2.6) defined by the National Infrastructure Agency according to the required characteristics such as:

- ✓ Two (2) photos of the facade the building
- ✓ Two (2) photos of the Interior
- ✓ Two (2) photos Productive Units (if any)
- ✓ One (1) photo of the family group

After the information has been collected, a proper analysis will be carried out and a social diagnosis of the status of the community of the Canal de la Corregimiento of Nueva Colonia will be made.

- Cultura dimension

Different sources of secondary information were consulted, with the purpose of highlighting the different cultural groups existing in the area of influence of the project. In the same way, the Ministry of the Interior was consulted to verify the presence of ethnic groups in the area.

- Archaeological dimension

The maritime cultural landscape, as an instrument of analysis, integrates the different components of a territory that shares two media (terrestrial and maritime). This allows us to understand the spatial distribution of the archaeological record and the attributes and interventions of the environment in its multiple dimensions. In this sense, the first phase of the research is the identification of the human and non-human components through an archaeological, documental, environmental and oceanographic approach to the coastal and underwater area of Bahía Colombia, as a port access channel.

For the development of this activity, as a first step for an adequate identification, evaluation and protection of potential submerged cultural resources, a review of the archaeological and historical background available for the geographic area where the project will be located was carried out. This cabinet investigation consists in the compilation and systematization of scientific literature and specialized bibliographic

information about the diverse material evidences that make up the archaeological record. We consulted the documentary sources and cartography corresponding to the sixteenth and nineteenth century housed in the General Archive of the Nation (AGN), Archivo General de Indias PARES system (AGI), National Library and Luis Angel Arango Library (BLAA).

This collection includes the following main categories:

- Prehistoric terrestrial and submerged sites
- Land settlements and flooded
- Remains of submerged prehispanic boats
- Wrecks or remains of wrecked historical vessels
- Marine and terrestrial war scenarios
- Decontextualized archaeological artifacts

In this way the backrounds that are presented include the Prehispanic, Colonial periods. Republican and Industrial and concentrated mainly on those who give descriptions of the territory, specifically on the area of influence. From there, possible sites and structures can be identified.

Field work

Maritime prospecting

An archaeological survey was carried out, through a geophysical survey, for a better archaeological coverage of seabed, a method of prospecting by remote sensing was applied, by means of the application of a Side Sweep Sonar (SBL) and a Magnetometer.

The result of this survey reflects a series of acoustic images with anomalies (SBL) and magnetic anomalies (Magnetometer) that are visually inspected by archaeological diving.

For the Prospecting, transects or tracking lines were designed 30 m apart for areas with depths less than <10 meters and 50 meters distance for areas with depths greater than> 10 meters.

Land Prospecting

The terrestrial survey consists of a systematic sampling in the area of rectification of the road that has a length of 850 meters with a corridor of 30 m on the projected axis of the road. Wells of 40 x 40 cm and 50 cm of depth are made, every 25 meters to verify or rule out the presence of possible archaeological remains in the study area. This process is documented by photography and drawing in case of a finding. Each well is identified with geographic coordinates which will be detailed in a plan.

Equipment to be used

Imagenex Side Scan Sonar, SportScan model (Photograph No. 2.11 a), with frequencies of 330 kHz / 800 kHz. With this equipment, the entire area under study is swept between the depths of 10 - 20 meters using a frequency of 330 kHz in the coverage range of 100 m total (50 m for each sonar band). In this way, 100% of the area to be surveyed is covered.

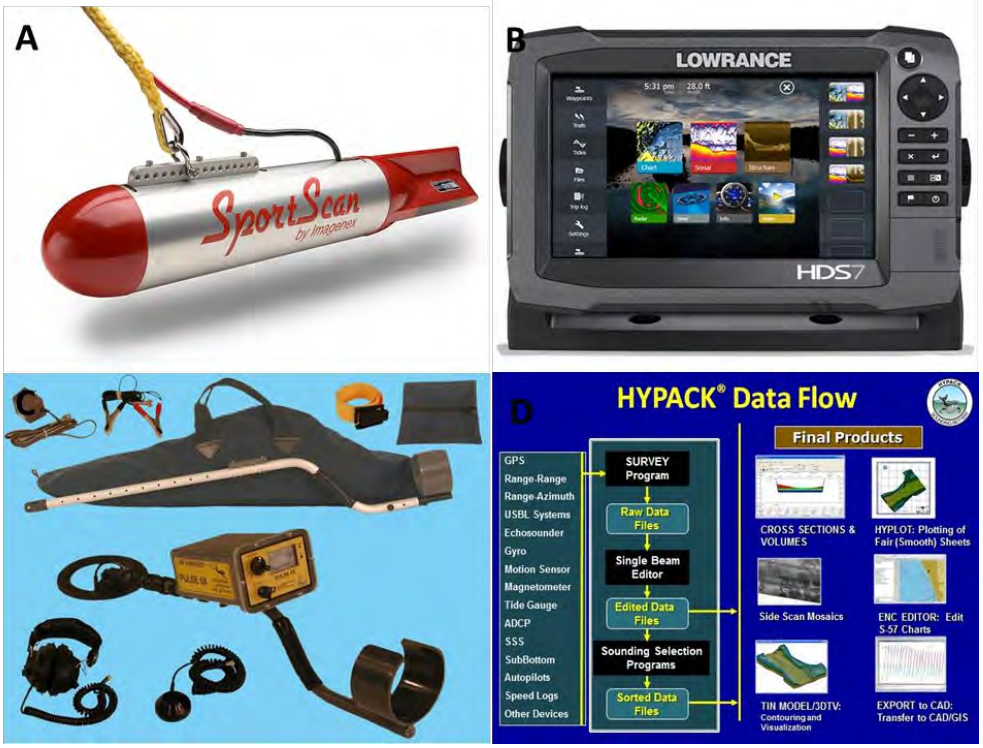
Manual metal detector, model JW Fishers, Pulse 8x (Photograph No. 2.11 c), operates by transmitting a continuous flow of high-energy magnetic pulses (hundreds per second) of the coil. After each impulse the detector is transmitted then listens for the return signal. When the transmitted pulse strikes a metallic object, an electro-magnetic field is induced in the object. This causes eddy currents to flow in the metal, which in turn generates a second electro-magnetic field visualized by the meter and is heard in the headphones.

Echosounder with function Side scan image, model Lowrance HDS 7 Gen 3 Structure Scan (Photograph No. 2.11 b). With this equipment, the entire area under study will be bounded between the depths of 2 - 10 meters, the coverage range will be 30 meters for each band. This equipment has the latest CHIRP and StructureScan® HD probe technology at the same time to get the best possible view of structures, both below and on the sides of the vessel. It has multiple selection of frequencies that will be modified to obtain the best possible image; Frequencies 455/800 kHz (StructureScan® HD), 40-60kHz, 85-145kHz, 130-210kHz (CHIRP), 50 kHz / 83kHz / 200kHz.

Hypack survey navigation software (Photograph No. 2.11 d), which follows in real time the route taken by the vessel on each of the predefined lines in the grid included

as a layer on the map base used in the area. This monitoring carried out by the pilot allows to maintain or correct immediately the course of the vessel during the reconnaissance of each line.

The postprocess in Hypack allows to analyze and project the sonographies obtained with the SSS in a mosaic, which consists of the projection of the seabed of the total area of the prospective project.



Photograph No. 2.11 Remote sensing equipment to be used in the marine archaeological survey. A. Side Scan Sonar Imagenex, SportScan model (imagenex) B. Echo sounder with side scan image, Lowrance model HDS 7 Gen 3 Structure Scan (Lowrance) C. Manual metal detector, model JW Fishers, Pulse 8x (JW Fishers), D. Navigation software Hypack survey (Hypack)

Archaeological diving

Subsequently, and in order to verify or discard the nature of the geophysical anomalies identified during the survey, processed and interpreted archaeologically, the archaeological diving phase is performed. By means of a standardized procedure of verification of the anomalies or individualized objectives, which consists in the fixation of its central position by means of a dead one with descent point and a buoy

based on GPS. The archaeological diving operations consist of visual inspections of the anomalies made by teams of 2 archaeologists - divers equipped with autonomous diving equipment.

Once a target has been set, the dive partner descends and proceeds to relocate it using a circular search technique with progressive radios, until a maximum of 20 m radius is reached around the established point. Any anomaly is recorded and documented by photography, video or drawing on record cards (Figure No. 2.35).

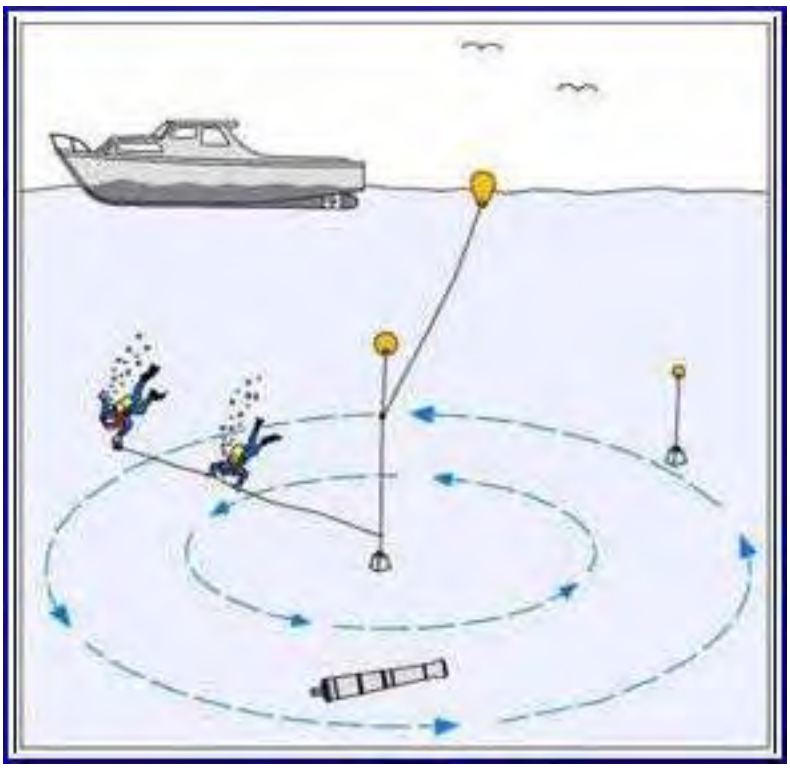


Figure No. 2.35 Circular diving technique

Source: Bowens 2009

At the same time, corridors are carried out in areas with archaeological potential in order to prospect visually together with the manual metal detector. These corridors are designed with nylon ropes and anchorages at their ends which are positioned with GPS. The divers must be separated by 2 to 5 meters according to the visibility and conditions of the sea.

The study as a whole is developed considering the dispositions and standards established both in the International Charter for the Protection and Management of the Underwater Cultural Heritage (Sofia Charter, 1996) issued by the International

Council on Monuments and Sites, as the later Convention for the Protection of the Underwater Cultural Heritage adopted by UNESCO (Paris, 2001).

- Ecosystem services

The analysis of ecosystem services was carried out based on the Millennium Ecosystem Assessment (MEA), which defined these services as the benefits that human populations obtain, directly or indirectly, from the processes and functions of ecosystems (UNEP -WCMC, 2011).

Based on the definitions of the MEA for the present study, the ecosystem services of the supply, regulation and cultural categories were evaluated. (See Figure No. 2.36).
Additionally, a semi-structured interview was conducted with 6 representatives of the base groups of the Territorial Unit of Nueva Colonia and 4 members of the environmental team that are part of the company Aqua & Terra Consultores Asociados (See Annex 5.3.2.7).

Figure No. 2.36 Ecosystem services
Source: Aqua & Terra Consultores Asociados S.A.S.2015

- **Provisioning**

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45 UNEP-WCMC. 2011. Developing ecosystem service indicators: experiences and lessons learned from sub-global assessments and other initiatives. Secretariat of the convention on biological diversity, Montreal, Canada. Technical series no. 58, 118 pp

Provisioning services are the products that people obtain from ecosystems, such as food, clean water, fuel, wood, fiber, genetic resources, natural medicines and others.

- **Regulation**

They are associated with the benefits derived from the regulation of ecosystem processes. This includes air quality, climate and water regulation (floods), erosion control, risk mitigation, biological control, waste treatment; they are all the ecological processes that have regulatory capacity.

- **Cultural**

These are the non-material benefits obtained through recreational, aesthetic, cognitive development, reflection and spiritual experiences (MA, 2005). These services are strongly linked to human values and behavior, so the assessment of this service is highly subjective.

We have for example: Cultural diversity, spiritual and religious values, social relations, sense of belonging and degree of synergy existing in the community.

Based on these criteria and to determine the importance or dependence of the community on the ecosystem that provides services, semi-structured interviews were conducted with the main social actors of the smaller territorial units of the present project. To this end, the representatives of the grassroots groups of the communities of Nueva Colonia and the El Canal settlement were asked to respond to a semi-structured interview and complement the exercise with the qualification in the high, medium and low ranks.

Questions were raised about the knowledge they had about ecosystem services and what they identified in the community and the degree of dependence that the community has in relation to the identified ecosystem services. They were asked to graphically perform the services identified and that

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46 IDEAM, 2011. Contributions from the IDEAM for the definition and application of the National Ecological Structure. Institute of Hydrology, Meteorology and Environmental Studies -IDEAM-. Bogotá D.C., Colombia. 43 p.

will qualify in the good, regular and moderate categories. In addition, they were asked to evaluate the scope of their community's religious and cultural issues. Finally, they were asked for suggestions for enrichment in environmental education.

In the same way, questions were asked to the environmental team in charge of carrying out the characterization, so that they responded from the knowledge of the communities of Nueva Colonia and the Canal obtained in the field work.

Based on this information, an analysis was made of the importance of ecosystem services, both the impacts and the dependence of the communities and the project on them.

2.3.4 Environmental zoning

Environmental zoning is a methodological planning tool that allows spatial differentiation of the study area and define the sensitivity / environmental importance of the area in its condition without project.

In accordance with the above, the environmental zoning methodology used for this environmental license modification was based on other exercises carried out for the hydrocarbon area, adapted to the need of the project, following are the steps to follow:

Based on the environmental characterization of the area of influence (AI), homogeneous zones were identified, which were formed from the integration of different criteria of the abiotic, biotic and socioeconomic media. It is understood as criteria, those attributes that characterize the environment, which can be expressed in qualitative, quantitative and cartographic form, describing the general situation of the area of influence.

The criteria were constructed considering the analysis of the qualities of the environment that express their susceptibility to natural and anthropic phenomena.

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47 DELGADO RIVERA. Felix Abraham. Environmental zoning of areas of petroleum interest, methodological guide. Bogotá 2013. 27 p.

48 REPSOL. Megaoil Consortium Environmental zoning In: Environmental impact study for the marine exploratory drilling area Siluro. Bogota, 2013. p. 1-37

Grouping, qualification and georeferencing of criteria by means, from which the initial thematic maps are generated. Overlay of thematic maps of each medium, using Geographic Information Systems (GIS), where the crossing and weighting of the different degrees of environmental sensitivity identified in each of the criteria is carried out.

Development of intermediate zoning maps in each of the factors (abiotic, biotic, socioeconomic) analyzed.

Obtaining the final environmental zoning in the project area, by means of the weighted superposition of the intermediate maps.

"It is important to clarify that the weightings or qualifications of each of the parameters considered are based on the knowledge, expertise and criteria of each of the specialists involved in the preparation of the environmental studies, in such a way that each component will be measured under the same criteria and scale of values held by each professional, thus guaranteeing the use of the same employer for each component. It is important to mention that the parameters and weights considered within the methodology can be modified at the discretion of each professional or specialist as long as said change is duly justified, it is kept within the given proportion for each component (physical, biotic, socioeconomic and cultural) and that is also accepted by the study coordinator, who will monitor the coherence, relevance and balance of the components ".

2.3.4.1 *General guidelines for the selection of criteria and assessment*

For the selection and evaluation of the criteria by means, the following units, among others, will be considered (Table No. 2.52):

- Areas of special ecological importance: "such as natural protected areas, reserves of civil society, integrated management districts, sensitive ecosystems, hydrographic rounds, biological corridors, presence of endemic, endangered (endangered, critically endangered and vulnerable) areas in accordance with Resolution number 0192 of 2014 or that regulation that modifies, replaces or repeals, areas of

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49[1] Delgado 2013. Op. cit.

- importance for breeding, reproduction, feeding and nesting, and passage zones for migratory species ".

- Areas of environmental recovery: "such as eroded areas, land use conflict or contaminated areas".

- Áreas de riesgo: “tales como áreas susceptibles a deslizamientos e inundaciones”.

- Areas of economic production: "such as livestock, agricultural, mining, fishing, tourism, recreational, port, among others."

- Areas of social importance: "such as human settlements, physical and social infrastructure, and historical importance and culture".

Also, areas or elements with dominant or special sensitivity will be handled. These areas correspond to areas that, due to their environmental characteristics, are considered strategic areas of preservation, conservation or socio-environmental importance, therefore they must be reflected directly in the synthesis map. Following the suggestion of Delgado (2013), three (3) types of areas or elements will be considered, namely:

- Areas of legal restriction: Considered all those areas that, based on specific administrative acts or national and international legislation, restrict or exclude in a clear way, the use of areas in the development of projects. They will shoot the qualification at **very high sensitivity**, thus determining their **exclusion**, considered under the reasonable criterion of activity and the environment on which it is executed.

- Areas of environmental importance: They include areas that have limitations or environmental values that classify them as strategic, critical, vulnerable, unique or simply important, but that are not necessarily exclusive for the implementation of projects, works or activities, as long as it is defined and implement a set of measures that control and handle the possible

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50[1] COLOMBIA. MINISTERIO DE AMBIENTE Y DESARROLLO SOSTENIBLE. Resolución no. 0112 (28, enero, 2015). Op. cit.
51[1] Ibid
52[1] Ibid
[1]53 Ibid
54[1] Ibid

55[1] Delgado 2013. Op. cit.

- impacts adequately. It will define **high and moderate** sensitivity, generating **areas of management with high, medium and low restriction** for its intervention.

- Infrastructure of social importance: Elements, works and projects that are totally incompatible with the project or that, due to their function or usefulness, are important for the community or for the country, are considered. They correspond **to high and moderate sensitivities**, generating **management areas with high and medium restrictions** for their intervention**.**

The above will be reflected in the environmental sensitivity synthesis maps when they predominate over the qualification by means.

Table No. 2.52 Evaluation attributes in the definition of the criteria for environmental zoning of the area of influence of the port terminal

ABIOTIC		BIOTECH	SOCIOECONOMIC	ELEMENTS WITH DOMINANT OR SPECIAL SENSITIVITY		
GEOSPHERIC	WATER	ECOSYSTEMS	AREAS OF SOCIOECONOMIC AND CUTURAL IMPORTANCE	AREAS OF LEGAL RESTRICTION	AREAS OF ENVIRONMENTAL IMPORTANCE	INFRASTRUCTURE OF SOCIAL IMPORTANCE
Geotechnical stability	Hydric density	Vegetable and land cover	Economic activity	Natural National Park – NNP	Protective-producing forest areas Law 2nd 1959	Schools, churches, coliseums, health center, etc
Susceptibility to erosion	Physicochemical quality of water	Areas of special ecological importance	Quality of life	Marine Protected Areas – MPA	Areas of the regional system of protected natural areas – SIRAP ▪Protective forest reserves ▪Regional Natural Parks ▪Integrated management districts ▪Soil conservation districts ▪Recreation areas	Submarine cables, transfer lines, etc
Pending	Water offer	Conservation objects	Community organization and areas of participation	Wildlife and Flora Sanctuaries – WFS	Civil society reserves	Fish ponds, water tanks, etc
Sedimentary facies	Water demand	Zoning of the Darien Coastal Environmental unit	Distribution of the land	Biosphere Reserves – MAB	Priority conservation sites – SPC	Channels and / or irrigation districts
Geological structures	Hydrographic rounds	Pelagic community	Archaeological and cultural potential		Currents and bodies of surface water (30 m)	Signal buoys
Seismicity			Fishing grounds (Industrial – Craft)			
Hydrogeology			Boat routes			
Land uses and conflicts						

Source: Aqua & Terra Consultores Asociados S.A.S., 2015

Then, the parameters were defined under which the criteria were evaluated and a scale of values of sensitivity and / or importance was established in five (5) main categories:

Very high environmental sensitivity

High environmental sensitivity

Moderate environmental sensitivity

Low environmental sensitivity

Very low environmental sensitivity

2.3.4.2 *Definition of the environmental sensitivity of the Area*

Once the groupings and qualifications of each one of the analyzed means by each professional are obtained, the superposition of these will be realized to establish the different categories of sensitivity and that it serves like input to establish the categories of use and restriction in the zoning of handling environmental. The environmental sensitivity will be defined by the following mathematical expression:

$$Sa = \sum (Ab, B, Sc)$$

Equation No. 2.5 Mathematical expression for the definition of environmental sensitivity

Source: Delgado (2013), Adapted by Aqua & Terra Consultores Asociados S.A.S., 2015

Where:

Sa= Environmental sensitivity

Ab= Abiotic media, like this:

$$Ab = \sum (Cri1, Cri2, Cri3, Cri \ldots)$$

Equation No. 2.6 Mathematical expression for the assessment of sensitivity of the abiotic environment

Source: Delgado (2013), Adapted by Aqua & Terra Consultores Asociados S.A.S., 2015

Note: Sum of all the criteria selected for the abiotic environment

B= Biotic Factor

$$B = \sum (Cri1, Cri2, Cri3, Cri \dots)$$

Equation No. 2.7 Mathematical expression for the assessment of sensitivity of the biotic environment

Source: Delgado (2013), Adapted by Aqua & Terra Consultores Asociados S.A.S., 2015

Note: Sum of all the selected criteria for the biotic environment

Sc= Socioeconomic and cultural environment

$$SC = \sum (Cri1, Cri2, Cri3, Cri \dots)$$

Equation No. 2.8 Mathematical expression for the sensitivity assessment of the socioeconomic environment.

Source: Delgado (2013), Adapted by Aqua & Terra Consultores Asociados S.A.S., 2015

Note: Sum of all the criteria selected for the socioeconomic environment

The maximum score by means will be: abiotic factor 33, biotic factor 33 and socioeconomic environment 34.

2.3.4.3 *Valuation ranges*

Considering Equation No. 2.27, the sum of the variables of each of the means: abiotic (Ab), biotic (B) and socioeconomic (Sc) will be framed within the ranges of 6 to 100 points, which They will define the basic sensitivity of the areas included within the study area in the categories that are established from very low to very high sensitivity (Figure No. 2.37).

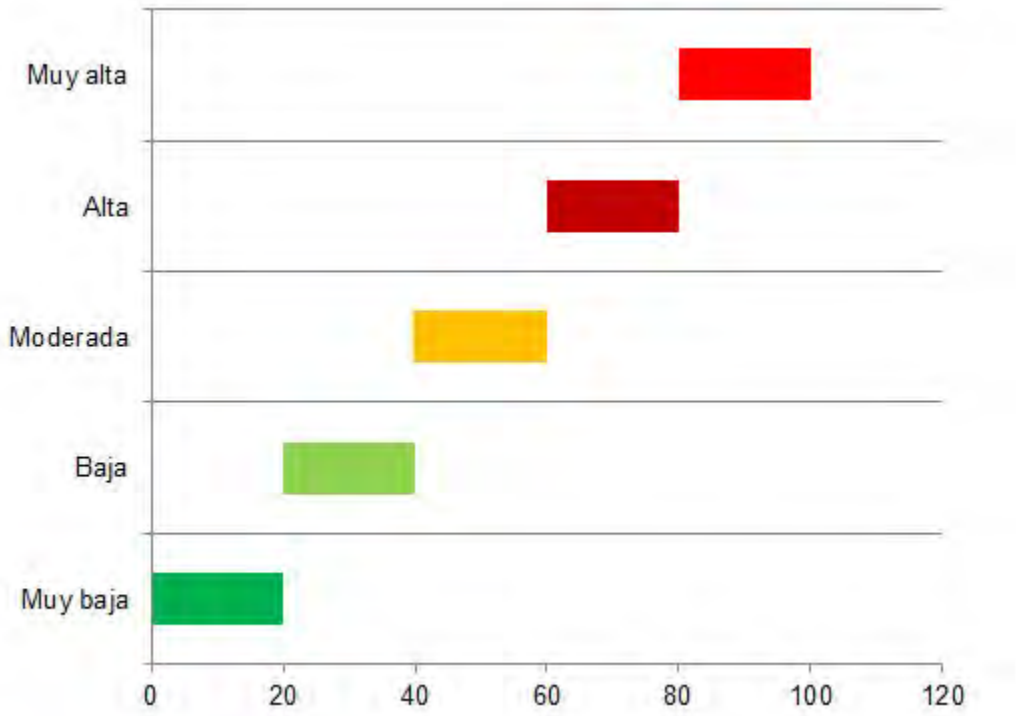

Figure No. 2.37 Environmental sensitivity ranges

Source: Delgado (2013), Adapted by Aqua & Terra Consultores Asociados S.A.S., 2015

For the different analyzes of the results, the environmental zoning proposed in the guidelines and integrated management strategies of the coastal environmental unit of the Darién and the Territorial Planning Plan of the municipality of Turbo in 2012 was taken into account, as applicable for its respective articulation.

Finally, the intermediate maps of each of the media were integrated and superimposed using the GIS tool, to obtain the final environmental zoning.

2.3.5 Demand, use, exploitation and / or affectation of natural resources

Based on the information on the designs for the construction and operation of a large-port solid bulk port terminal in Bahía Colombia, and the characterization of the area of influence, the natural resources that the project will demand will be used, exploited or affected during the different stages of construction and operation, where the resources that require or not permits, concessions and authorizations were included.

The required information is presented in the National Unique Forms, which are attached as annexes in the chapter on demand for natural resources.

2.3.5.1 *Water resource, discharges, forest use and sources of material*

An identification was made of the natural resources that the construction and operation of the infrastructure associated with the project will require, as well as the quantities of material, flows and volumes required to cover the demand of the project during the useful life of the project.

2.3.5.2 *Forest exploitation*

To carry out the forestry inventory of the present study in order to establish the use, a 30-meter strip on each side of the road that will lead from Nueva Colonia to Puerto Bahía Colombia in Urabá was taken as the direct area of the project. where the terminal will be built on land, as shown in Figure No. 2.38.

There, the forest inventory was made of 100% of the species corresponding to the category of small trees (Circumference at chest height equal to or greater than 31.4 cm) according to Decree 1791 of 1996, as a regime for forest exploitation.

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56 COLOMBIA. MINISTRY OF ENVIRONMENT. Decree 1791 (04, October 1996). By means of which the regime of forest exploitation is established. Bogotá: Ministry of the Environment, 1996. p. 24

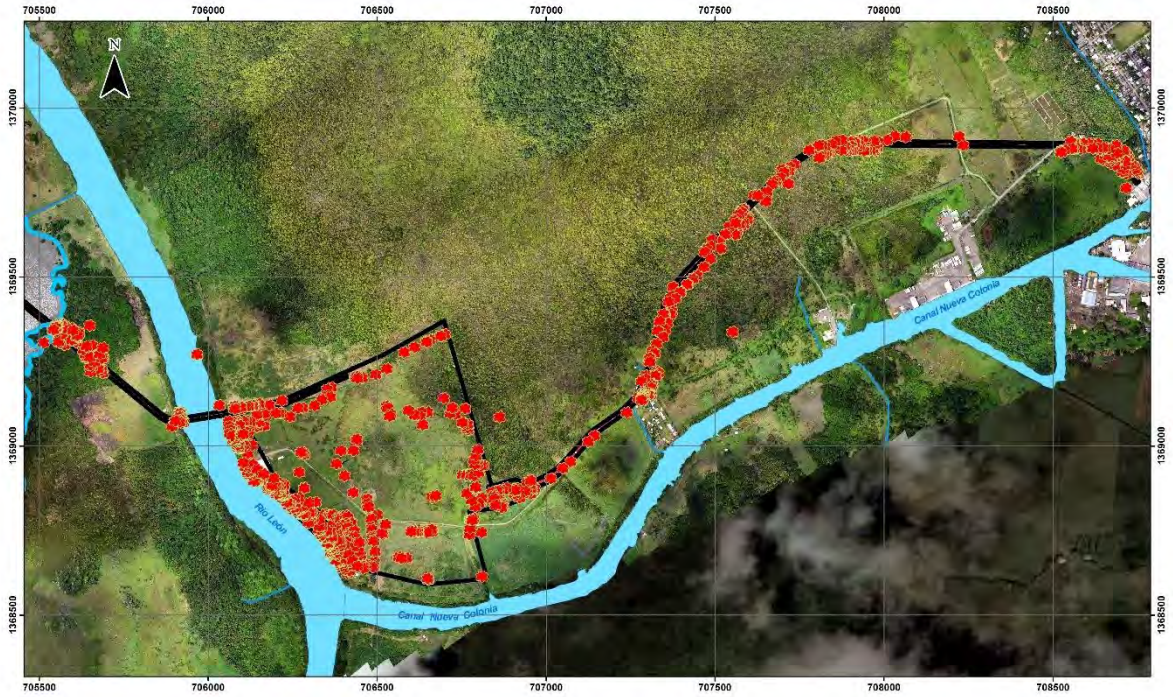

Figure No. 2.38 Forest inventory points in the area of direct impact of the project

Source: Aqua & Terra Consultores Asociados S.A.S., 2015

The variables measured in the field were: identification of the species, circumference to the height of the breast (CAP), angle of inclination at chest height, angle of inclination to the first branch and angle of inclination at the apex of the tree, crown width, stem quality and the location coordinates of each tree; all individuals with CAP greater than or equal to 31.4 cm were measured. All individuals were marked with red oil paint approximately 1.50 m high, numerically and the numbers were consecutive, as shown in Photograph No. 2.12.

Photograph No. 2.12 Marking of individuals inventoried in the field
Source: Aqua & Terra Consultores Asociados S.A.S., 2015

The circumference at chest height (CAP) was measured at a height of 1.30 m above ground level, in units of centimeters, using a tape measure. When measuring each tree, it was checked that no vines, parasites or other plants that alter the accuracy of the measure were considered, as shown in Photograph No. 2.13.

Photograph No. 2.13 Measurement of the CAP during the forest inventory

Source: Aqua & Terra Consultores Asociados S.A.S., 2015

With the value taken from CAP, the diameter at chest height was calculated using Equation No. 2.31.

$$DAP = CAP/ \pi$$

Equation No. 2.31 Calculation to find the diameter at breast atura (DAP)

The total height of the tree was calculated from the angles of inclination taken in the field with the help of a clinometer (Photograph No. 2.14), these were taken at chest height (α1) and at the apex of each tree (α3). Then with Equation No. 2.32. Which was taken from the manual of basic methods of sampling the total height calculation.

$$Ht = d + \tan(\alpha 1 - \alpha 3) + 1{,}3$$

Equation No. 2.32 Equation to find the total height of trees where:

Ht = total height

d = distance in meters between the clinometer and the tree

α1 = angle from the stump (50 cm)

α3 = angle at the apex of the tree

The commercial height of the tree represents the part of the shaft that can be used commercially. This was measured with the help of a clinometer (Photograph No. 2.14) from the stump (about 50 cm above the ground), to where the cup starts or to where there is some limitation such as deformation, damage, or diameter less than 25 cm; then, using Equation No. 2.33, the commercial height was calculated.

$$Hc = d + \tan(\alpha 1 - \alpha 2) + 1{,}3$$

Equation No. 2.33 Equation to find the commercial height of trees where:

Hc = commercial height

d = distance in meters between the clinometer and the tree

α1 = angle at chest height (1,3 m)

α2 = angle to the shaft or commercial height

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57 Mostacedo and Fredericksen. Op. Cit., P. 29
58 Ibid.

Photograph No. 2.14 Measurement of heights during the field phase

Source: Aqua & Terra Consultores Asociados S.A.S., 2015

To quantify the amount of wood per individual the commercial volume of each tree must be calculated, for which the equations that are exposed in the manual of basic sampling methods were used. Equation No. 2.34 was used to calculate the basal area of each tree in units of square meters (m2); to determine the commercial volume in cubic meters (m3) for each of them, Equation No. 2.35 was used.

$$g = \frac{\pi}{4} * DAP^2$$

Equation No. 2.34 Equation to calculate the basal area

Where,

g = basal area of a tree (m^2)

DAP = diameter at chest height (m)

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59 Mostacedo and Fredericksen. Op. Cit., P. 39-42

$$V = g + Hc$$

Equation No. 2.35 Equation to calculate the commercial volume Where:

V = volumen of the tree in m^3

g = basal area of the tree (m^2)

Hc = comercial height of the tree (m)

To obtain the diameter classes, eleven (11) intervals with a minimum record of 9 cm and a maximum record of 120 cm were determined to obtain a class mark of 10 cm. Table 2.53 shows the diameter classes by class interval for each category.

Table No. 2.53 Diametric classes by class interval for the variable normal diameter, for trees in the area of direct impact of the project

Diameter class	Class interval	Class mark
1	9 - 19 cm	14
2	19,1 - 29 cm	24
3	29,1 - 39 cm	34
4	39,1 - 49 cm	44
5	49,1 - 59 cm	54
6	59,1 - 69 cm	64
7	69,1 - 79 cm	74
8	79,1 - 89 cm	84
9	89,1 - 99 cm	94
10	99,1 - 109 cm	104
11	109,1 - 120 cm	114

Source: Aqua & Terra Consultores Asociados S.A.S., 2015

2.3.5.3 *Solid waste*

Table 2.54 shows the assignment of the level of complexity of the system (NCS) based on the RAS 2000 standard. With this level of complexity and the typical values

of the per-capita production of solid waste presented in Table No. 2.55, the production of solid waste for the construction and operation of the project can be calculated.

Table No. 2.54 Typical Values of the Per-capita Production Estimate - PPC for Colombian municipalities according to the NCS

Level of compexity	Minimum value	Maximum value	Average value
Low	0,30	0,75	0,45
Medium	0,30	0,95	0,45
Medium Hig	0,30	1,00	0,53
High	0,44	1,10	0,79

Source: Standard RAS 2000. Title F.
* NCS: Level of Complexity of the System

For the specific case of the project, a PPC of 0.75 kg / inhab-day will be used.

According to the waste generated, the following proportion will be assigned (see Table No. 2.55).

Table No. 2.55 Proportion of non-hazardous waste

Classification	Proportion (%)
Biodegradable	60
Recyclabe	20
Ordinary and inert	20

Source: Aqua & Terra Consultores Asociados S.A.S, 2015.

To calculate the waste production of the project, the following expression is used (see Equation No. 2.36):

$$waste\left(\frac{Kg}{day}\right) = (PPC * P * Ds)$$

Equation No. 2.9 Production of solid waste

Source: RAS 2000, Title F[75]

Where:

60 Ibid.
61 Ministry of Economic Development. Technical Regulation of the Drinking Water and Basic Sanitation Sector RAS- 2000. Title F. Urban cleaning systems. Bogotá D.C, November 2000.
62 Ibid.

Waste: Production of solid waste (kg/día)

P: Population

PPC: Solid waste production per person day.

Ds: 1 day of generation

2.3.6 Identification and Assessment of environmental impacts

Initially, the environmental impacts of the activities that have the greatest impact on the area of influence were identified and evaluated (scenario without project - Ex Ante).

Subsequently, based on the activities defined in the project description and based on the impacts previously identified in the environmental impact study and in accordance with the analyzes carried out in the characterization of the project, the impacts were identified, and their impact was analyzed (Ex. - Post)

The environmental impact assessment was based on the assignment of values to each criterion, analyzing the scenario with the project and determining the current conditions and the environmental problems existing in the area of influence, as a result of the main works and activities carried out during the construction and operation of the port terminal.

The process of assessing environmental impacts was carried out jointly (discussion tables) with the interdisciplinary group of specialist professionals who participated in the modification of the environmental license.

In addition to analyzing each effect generated on the different environmental factors (abiotic, biotic and socioeconomic), the results obtained were synthesized with the objective of defining the alternatives of prevention, mitigation, compensation and correction; all this, with the purpose of minimizing the environmental impacts generated.

Below are the different actions developed to evaluate the impacts identified during the construction and operation of the Port Terminal.

2.3.6.1 *Identification of impactful actions*

It consists of the identification of anthropic impacting actions, which during the development of the project are considered Pressure Indicators, because they exert influence on the environment by varying or altering the degree of quality of the environmental components.

These actions can generate changes such as: modifications to land use, emission of pollutants, deterioration of the landscape, modification of the social, economic and cultural environment, consumption of natural resources, risks, among others.

2.3.6.2 *Identification of environmental components susceptible to receiving changes or impacts*

It consists in the identification of the components and elements (environmental factors) of the abiotic, biotic and socioeconomic environment that can be altered or modified positively or negatively by the different activities of the project.

For the definition of the most susceptible environmental factors, it was necessary to consider the following criteria: representative, relevant, excluding, easy to identify and quantifiable.

2.3.6.3 *Qualification and quantification of impacts*

Once the identification of impacting actions and identification of the environmental components susceptible to receiving changes were made, nature (NA), intensity (IN), extension (EX), moment (MO), persistence (PE), criteria were evaluated and evaluated. reversibility (RV), synergy (SI), accumulation (AC), effect (EF) recoverability (MC) and periodicity (P) to define the range of environmental importance of each impact, as proposed by the Conesa Fernández Vítora Methodology (2010).

This methodology includes a rating system for each criterion that ranges from 1 to 12, according to the qualitative characteristics determined for each of the impacts to be evaluated, as shown in Table No. 2.56.

Table No. 2.56 Assessment criteria

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63 CONESA FDEZ.-VÍTORA. methodological guide for environmental impact assessment. 4 ed. Madrid. Ediciones Mundi-Prensa, 2010. 864 p.

CRITERIA		DEFINITION	QUALITATIVE ASSESSMENT	
NA	**NATURE**	Beneficial or harmful nature of the impact, as to whether the action improves or degrades the environment now or in the future.	Beneficial or positive	+
			Harmful or Negative	-
IN	**INTENSITY**	Defines the degree of degradation offered by the action on the resource	Low	1
			Half	2
			High	4
			Very High	8
			Total	12
EX	**EXTENTION**	The theoretical influence area of the impact in relation to the environment in which the effect is manifested. Punctual refers to when the effect is localized. If, on the contrary, the effect does not support a precise location within the project environment, having generalized influence throughout, the impact will be total. Considering the intermediate conditions, according to their gradation, as partial and extensive impact.	Punctual	1
			Partial	2
			Extensive	4
			Total	8
			Review	(+4)
MO	**MOMENT**	Time that elapses from the beginning of the action until the beginning of the impact it produces. When the time elapsed is zero, the moment is immediate, if it is less than one year it is short term. If the period goes from 1 to 5 years medium term, while if the effect takes longer than 5 years its long term.	Long term	1
			Medium term	2
			Immediate	4
			Critical	(+4)
PE	**PERSISTENCE**	Time in which the impact is expected to remain from its appearance. Shooting less than 1-year, it is temporary if it is between 1 and 10 years and permanent if it is greater than 10 years.	Leaks	1
			Temporary	2
			Permanent	4
RV	**REVERSIBILITY**	Possibility of the affected factor to return to its previous conditions to the affectation by natural means, once it has stopped acting on the environment. If it is short term it will be in a period of less than 1-year, medium term is between 1 and 10 years and permanent or irreversible if it is more than 10 years.	Short term	1
			Medium term	2
			Irreversible	4
SI	**SYNERGY**	There is synergy if two effects are manifested together, and this is greater than its isolated manifestations. If there is a weakening between the effects, the synergy is negative, reducing the importance (I)	Without synergism (simple)	1
			Synergistic	2
			Very Synergistic	4
AC	**ACCUMULATION**	An impact is cumulative if the continued presence of the action grows over time.	Simple	1
			Cumulative	4
EF	**EFFECT**		Indirect Secondary	1

CRITERIA		DEFINITION	QUALITATIVE ASSESSMENT	
		Derived from the Cause / Effect relationship. An Effect is direct when the action itself generates the effect, while it is indirect if it is generated from another impact.	Direct	4
PR	**PERIODICITY**	Regularity of manifestation of the impact. It can be presented continuously, periodically or irregularly, which must be evaluated in terms of probability of occurrence, and discontinuous ones.	Irregular or aperiodic and discontinuous	1
			Periodic	2
			Continuous	4
MC	**RECUPERABILITY**	Possibility of recovery of the affected factor through environmental management (introduction of corrective measures). It can be recoverable if it is achieved immediately or in the medium term, if it is partially the effect is mitigable, while it is unrecoverable if the alteration is impossible to repair both natural and natural action.	Recoverable immediately	1
			Recoverable in the middle term	2
			Mitigable	4
			Irrecoverable	8
I	**IMPORTANCE**	Qualitative measure of the impact from the degree of incidence of the alteration produced and its effects.	**Irrelevant**	**0-25**
			Moderate	**25-50**
			Severe	**50-75**
			Critical	**75-100**

Source: CONESA, (2010)

Considering the values given for each criterion and the following formula, the importance rating will be obtained for each impact, where the lowest possible value is 13 and the highest value is 100.

$$I = (3IN + 2EX + MO + PE + RV + SI + AC + EF + PR + MC)$$

Equation No. 2.10 Equation to calculate importance

Equation No. 2.37 shows the scale of assessment and qualification of the importance of negative (-) or harmful character and of a positive (+) or beneficial character.

This scale considered as **significant impacts** those whose absolute value of importance is greater 25 evaluated as critical, severe and moderate impacts, that is, they require the implementation of specific management measures and / or strategies to minimize the importance of the impact during dredging of deepening of the access channel. While **non-significant impacts** are those whose absolute value of importance is less than 25 evaluated as irrelevant or compatible with the environment, since these present a greater assimilation of the environment after the cessation of activities and do not require corrective measures or measures implemented for moderate impacts they can absorb these impacts.

It is important to highlight that if positive (+) or beneficial impacts are identified, the Recoverability criterion will not be assessed according to the established ranges, since by obeying the beneficial type, the environment has no effects on which to revert or recover. Therefore, these will have a value equal to zero (0) within the valuation.

Table No. 2.57 Qualification ranges and assessment of environmental importance

Rating scale	Importance of negative character	Rating scale	Importance of positive character
0 a -25	Irrelevant		
-26 a -50	Moderate	0 a +39	Not important
-51 a – 75	Severe	+40 a +70	Important
-76 a -100	Critical	+71 a +100	Very important

Source: Conesa, (2010) modified by Aqua & Terra Consultores.

2.3.6.4 *Analysis of impacts and their effects*

The analysis of the impacts and their effects was carried out for the impacts identified in the scenario with the project, in accordance with the absolute importance rating, to identify the most relevant impacts, the most aggressive activity with the environment and the environmental factor affected

For the most relevant impacts, the analysis of the accumulation and synergy of the impacts of the project with the impacts that could occur in the area and of the impacts of the project on its own.

The guidelines used to analyze the impacts defined as cumulative and synergistic for the preparation of the study are described below.

- Cumulative impacts

To carry out the evaluation of cumulative impacts it is necessary to conceptualize the term in order to avoid ambiguities that can lead to errors. Therefore, it is defined as a cumulative impact to the changes caused in the environment by some activity that in combination with others, brings therefore secondary effects to the area of influence of the project (see Figure No. 2.39).

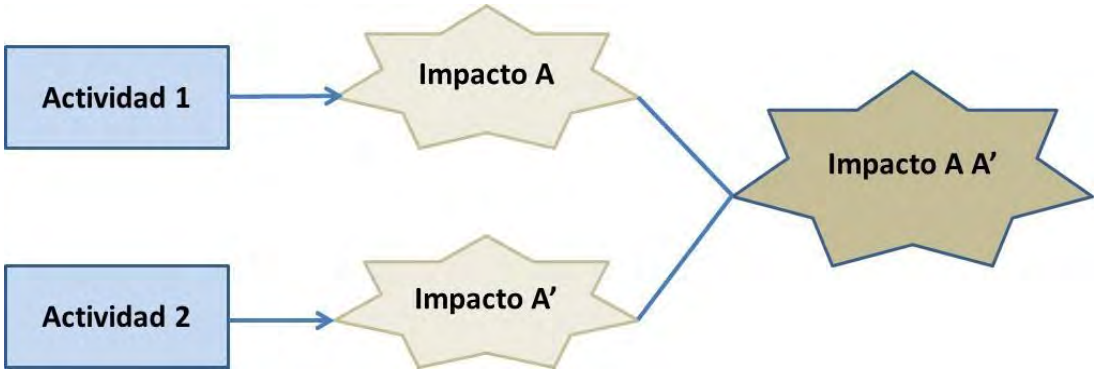


Figure No. 2.39 Cumulative impact

Source: Prepared by Aqua & Terra Consultores.

- Synergistic impacts

Synergistic impacts are those that occur because of several actions, and whose final incidence is greater than the sum of the partial impacts (see Figure 2.40).

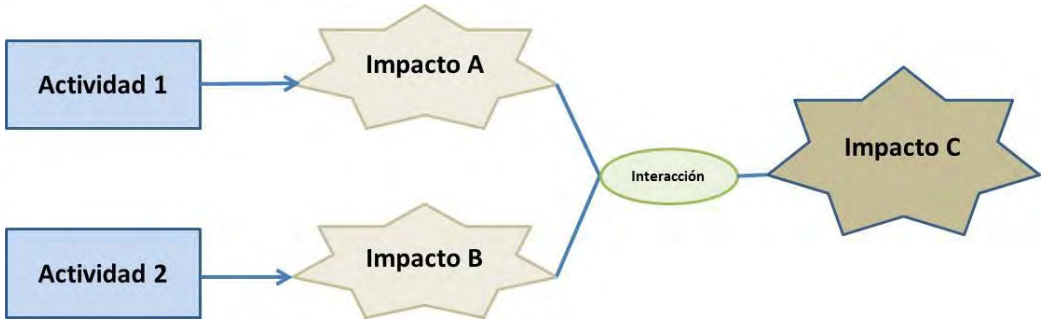


Figure No. 2.40 Synergistic Impact

Source: Prepared by Aqua & Terra Consultores.

The analysis of the synergistic impacts was made considering that there is no synergy when:

- The impacts develop at different times or do not occur simultaneously.
- The activity that causes the different impacts is the same, but the effects are on different environmental components, because these are not comparable to each other.
- There is no synergy between a negative impact and a positive one.
- There is no synergy between two positive impacts.

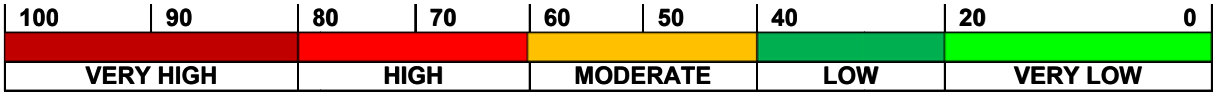
2.3.7 Environmental management zoning

Following the guidelines established by Delgado. The zoning of environmental management is obtained from the crossing of environmental zoning and the evaluation of project activities. Under this scheme, the zoning must consider the degrees of sensitivity of each system against the degree of affectation that will be the object of the project. The result of the interaction allows establishing exclusion areas, areas susceptible to intervention and areas of intervention with restrictions (major or minor) and is specified in the existing type of restriction. The characteristics of the mentioned areas are defined below:

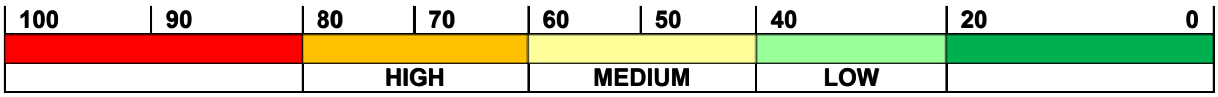
AREAS OF EXCLUSION

It considers all those areas that by their nature, state or magnitude have a **VERY HIGH** environmental degree of susceptibility (greater than 90 points). In the definition of this category should be considered the type of activity that is required to develop, social environment and the ecosystem itself, to be as objective as possible in the qualification determined by environmental sectorization (***The zoning of*** Environmental Management is the result of the interrelation between the Environmental Zoning (environmental offer of the area) and the environmental evaluation of the activities to be developed in the project area. Under these conditions, this zoning must consider the degree of sensitivity of each of the ecosystems compared to the degree of intervention or impact that will be the object of the project. Because of this interaction, areas of exclusion, areas susceptible to intervention and areas of intervention with restrictions must be established, specifying in said zoning the type of existing restriction. It is very important that each specialist apply their sectorization under reasonable criteria that respond to the characteristics or impacts generated by the activities of the project, so that it does not punish or exclude areas that under proper management and control can be used without deterioration. from the same. The characteristics of the mentioned areas are defined below:

Environmental sensitivity



Environmental Management Zoning



EXCLUSION	INTERVENTION WITH RESTRICTIONS	INTERVENTION WITHOUT RESTRICTIONTS

dark red color).

64 DELGADO RIVERA. Felix Abraham. Environmental zoning of areas of petroleum interest, methodological guide. Bogotá 2013. 27 p.

AREAS OF INTERVENTION WITH RESTRICTIONS.

HIGH. Given their nature and environmental sensitivity they need to limit their intervention as much as possible and maximize preventive controls and measures to avoid possible effects. Sectorization includes areas with sensitivities with ratings between 70 and 90 points (***The zoning of*** Environmental Management is the result of the interrelation between the Environmental Zoning (environmental offer of the area) and the environmental evaluation of the activities to be developed in the project area. Under these conditions, this zoning must consider the degree of sensitivity of each of the ecosystems compared to the degree of intervention or impact that will be the object of the project. Because of this interaction, areas of exclusion, areas susceptible to intervention and areas of intervention with restrictions must be established, specifying in said zoning the type of existing restriction. It is very important that each specialist apply their sectorization under reasonable criteria that respond to the characteristics or impacts generated by the activities of the project, so that it does not punish or exclude areas that under proper management and control can be used without deterioration. from the same. The characteristics of the mentioned areas are defined below:

Environmental sensitivity

100	90	80	70	60	50	40	20	0
VERY HIGH		HIGH		MODERATE		LOW	VERY LOW	

Environmental Management Zoning

100	90	80	70	60	50	40	20	0
		HIGH		MEDIUM		LOW	INTERVENTION WITHOUT RESTRICTIONTS	
EXCLUSION		INTERVENTION WITH RESTRICTIONS						

, ocher color).

HALF. Considered all those sites that due to their nature, status or magnitude require that the activities are developed in a careful way, maximizing the controls

and preventive measures to avoid possible affectations. For the purposes of this classification, those areas whose environmental sensitivity is rated between 50 and 70 points will be considered. (***The zoning of*** Environmental Management is the result of the interrelation between the Environmental Zoning (environmental offer of the area) and the environmental evaluation of the activities to be developed in the project area. Under these conditions, this zoning must consider the degree of sensitivity of each of the ecosystems compared to the degree of intervention or impact that will be the object of the project. Because of this interaction, areas of exclusion, areas susceptible to intervention and areas of intervention with restrictions must be established, specifying in said zoning the type of existing restriction. It is very important that each specialist apply their sectorization under reasonable criteria that respond to the characteristics or impacts generated by the activities of the project, so that it does not punish or exclude areas that under proper management and control can be used without deterioration. from the same. The characteristics of the mentioned areas are defined below:

Environmental sensitivity

100	90	80	70	60	50	40	20	0
VERY HIGH		HIGH		MODERATE		LOW	VERY LOW	

Environmental Management Zoning

100	90	80	70	60	50	40	20	0
		HIGH		MEDIUM		LOW	INTERVENTION WITHOUT RESTRICTIONTS	
EXCLUSION		INTERVENTION WITH RESTRICTIONS						

, light yellow color).

LOW. These sites have a Low Environmental sensitivity, in which it is considered that environmental management must have low restrictions, given the sensitivity that it manifests. (***The zoning of*** Environmental Management is the result of the interrelation between the Environmental Zoning (environmental offer of the area) and the environmental evaluation of the activities to be developed in the project area. Under these conditions, this zoning must consider the degree of sensitivity of each of the ecosystems compared to the degree of intervention or impact that will be the object of the project. Because of this interaction, areas of exclusion, areas susceptible to intervention and areas of intervention with restrictions must be established, specifying in said zoning the type of existing restriction. It is very important that each specialist apply their sectorization under reasonable criteria that respond to the characteristics or impacts generated by the activities of the project,

so that it does not punish or exclude areas that under proper management and control can be used without deterioration. from the same. The characteristics of the mentioned areas are defined below:

Environmental sensitivity

100	90	80	70	60	50	40	20	0
VERY HIGH		HIGH		MODERATE		LOW	VERY LOW	

Environmental Management Zoning

100	90	80	70	60	50	40	20	0
		HIGH		MEDIUM		LOW	INTERVENTION WITHOUT RESTRICTIONTS	
EXCLUSION		INTERVENTION WITH RESTRICTIONS						

, light green color).

AREAS OF INTERVENTION WITHOUT RESTRICTIONS.

Defined as all those that present a total rating of environmental sensitivity, lower than 20 points and are within the categories of **VERY LOW** environmental sensitivity (***The zoning of*** Environmental Management is the result of the interrelation between the Environmental Zoning (environmental offer of the area) and the environmental evaluation of the activities to be developed in the project area. Under these conditions, this zoning must consider the degree of sensitivity of each of the ecosystems compared to the degree of intervention or impact that will be the object of the project. Because of this interaction, areas of exclusion, areas susceptible to intervention and areas of intervention with restrictions must be established, specifying in said zoning the type of existing restriction. It is very important that each specialist apply their sectorization under reasonable criteria that respond to the characteristics or impacts generated by the activities of the project, so that it does not punish or exclude areas that under proper management and control can be used without deterioration. from the same. The characteristics of the mentioned areas are defined below:

Environmental sensitivity

100	90	80	70	60	50	40	20	0
VERY HIGH		HIGH		MODERATE		LOW	VERY LOW	

Environmental Management Zoning

100	90	80	70	60	50	40	20	0
		HIGH		MEDIUM		LOW	INTERVENTION WITHOUT RESTRICTIONTS	
EXCLUSION		INTERVENTION WITH RESTRICTIONS						

, Green color).

The zoning of Environmental Management is the result of the interrelation between the Environmental Zoning (environmental offer of the area) and the environmental evaluation of the activities to be developed in the project area. Under these conditions, this zoning must consider the degree of sensitivity of each of the ecosystems compared to the degree of intervention or impact that will be the object of the project. Because of this interaction, areas of exclusion, areas susceptible to intervention and areas of intervention with restrictions must be established, specifying in said zoning the type of existing restriction. It is very important that each specialist apply their sectorization under reasonable criteria that respond to the characteristics or impacts generated by the activities of the project, so that it does not punish or exclude areas that under proper management and control can be used without deterioration. from the same. The characteristics of the mentioned areas are defined below:

Environmental sensitivity

100	90	80	70	60	50	40	20	0
VERY HIGH		HIGH		MODERATE		LOW	VERY LOW	

Environmental Management Zoning

100	90	80	70	60	50	40	20	0
		HIGH		MEDIUM		LOW	INTERVENTION WITHOUT RESTRICTIONTS	
EXCLUSION		INTERVENTION WITH RESTRICTIONS						

Figure No. 2.41 Zoning valuation range of environmental management

Source: Delgado, 2013

2.3.8 Environmental economic evaluation

For the economic evaluation of impacts, in this study the market price methods were used, with emphasis on the costs associated with productivity, and the transfer of benefits. The application of the first was based on the existence of a real market for fishing, for which it was possible to obtain directly the price of commercialization of

different species of economic importance. With regards to the methodology of transfer of benefits, its use is appropriate for situations in which it is very expensive to perform the assessment or there is little time available to carry out an original assessment study.

In this case, the configuration in fragments of the affected ecosystems and the high degree of intervention of the same, derived to the activities that are carried out in the area, configure a high complexity in the analysis and assignment of loads to different goods or services. with economic value, such as fishing productivity.

This situation requires studies with a high degree of complexity and time, which is why we resorted to this method of assessment considering parameters such as the similarity in the characteristics of the sites or ecosystems to be compared and the availability of studies, among others.

2.3.8.1 *Market prices method*

The market price method estimates the economic values of the products or services of the ecosystems that are bought and sold in commercial markets, being used to quantify changes in value in the quantity or quality of a good service. It uses standard economic techniques for measuring the economic benefits of the products marketed according to the number of people who buy, at different prices, and the quantity offered at different prices.

The standard method for measuring the use value of the resources traded in the market is the estimation of the consumer surplus and the surplus of the producer using the market price and quantity data. The total net economic benefit, that is, the economic surplus, is the sum of the surplus of the consumer and the surplus of the producer.

According to the methodologies based on market prices are: (a) changes in productivity (using normal economic prices or corrected when there are distortions in the markets of the goods and / or services impacted), (b) costs of illness (quantifies the costs that an individual must incur to treat the disease), and (c) human capital costs (relates to the loss of productivity of human beings caused by premature death). In this case, the estimates will be made through an analysis of the fishing productivity, considering the volumes of fishing and their price in the market.

2.3.8.2 *Method of transfer of benefits prices*

The method of transfer of benefits is used to estimate the economic values of ecosystem services by transferring the information available from studies already conducted in another place or context. Therefore, the basic objective of the transfer of benefits is to estimate the benefits of a context, adapting an estimate of benefits from some other context.

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65 Freeman Iii, M.A. (1993). The Measurement Of Environmental And Resource Values. Theory And Methods. Resources for The Future, Washington, D.C.

This methodology is used when the analysis with primary information is very expensive or there is little time to do it. This method has greater reliability when the original site and the study site are very similar in terms of factors such as the quality, location and characteristics of the population; when the environmental change is very similar for the two sites and when the initial assessment study was carried out carefully and used rigorous techniques.

To apply the methodology, according to Ecosystem Valuation, the first step is to identify the existing studies that can be used for the transfer; secondly, existing data must be evaluated to determine if they are appropriate to use in the transfer; third, to evaluate the quality of the studies that will be used for the transfer of benefits; fourth, adjust existing values to better reflect the values of the site in question, using all available and relevant information; and finally, estimate the value of the total benefit; multiplying the values transferred by the number of people affected.

2.3.9 Plans and Programs

2.3.9.1 *Environmental Management Plan (EMP)*

For the elaboration of the environmental management plan, we started with the management measures approved in the environmental license, the measures were adjusted and complemented as required, according to the new project activities.

The measures proposed in the WFP propose a set of actions or necessary measures to prevent, mitigate, correct and compensate the identified potential impacts generated on the abiotic, biotic and socioeconomic media.

These plans present an encoding and structuring that will make it possible to control and update them. In addition, they contain the following objective items, goals, stage, impacts to be controlled, types of measure, actions to be developed, place of

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66 Colombia, Ministry of environment, housing and territorial development, Methodologies for the economic valuation of goods, environmental services and natural resources, December 2003

application, beneficiary population, personnel required, monitoring and monitoring indicators, responsible for execution, schedule and budget.

2.3.9.2 *Tracking and Monitoring Plan (TMP)*

Once the environmental management plans have been formulated, it is necessary to ensure the implementation and compliance with them. To this end, the tracking and monitoring strategies of the project were designed, in order to determine the behavior, efficiency and effectiveness of the environmental management plans in terms of the impact of the abiotic, biotic and socioeconomic media.

2.3.9.3 *Risk Management Plan*

The Risk Management plan is a set of measures aimed at the prevention, care and recovery of adverse events (accidents, defective operations, and external phenomena) that, due to their characteristics, can generate effects on abiotic, biotic and socioeconomic factors. The objective of this plan is to provide prompt and timely attention to the parties affected by the event, the design of programs that designate the functions and the efficient use of resources, plans where emergency procedures are established and an information system that allow a communication with the personnel that make up the brigades, the external support entities and the affected community.

The preparation of the Risk Management Plan was based on the plan approved in the environmental license. In addition, the risks of the new project activities were identified, which may be caused by the natural conditions present in the area or by factors anthropic products of the different stages of the project. For this, it is necessary to determine the threats that could arise during the development of the project, and the vulnerability that will depend on the level or degree of exposure to a threat.

After identifying and prioritizing threats and vulnerability, both are related to obtain the level of risk to which the project is exposed, which can be classified as high, medium and low.

Being clear about the type and levels of risk to which the project is exposed, the following plans were drawn up:

Strategic plan: where the structure and organization for emergency care was defined, the functions, responsibilities, material, institutional and human resources needed.

Operational plan corresponds to the tool to be used in case of an emergency. It contemplates the activation levels of the plan, the notification procedures, who intervene, operative procedures and strategies for the termination of operations.

Informative Plan defines the requirements of the Contingency Plan in terms of data and information systems that allow to identify and classify the available resources, as well as the basic and logistical information that allows strategic and operational plans to be efficient, achieving their articulation.

2.3.9.4 *Plan of abandonment and final restoration*

For direct areas and project structures that should be dismantled after their useful life has been completed, an abandonment plan was prepared based on the plan presented in the environmental impact study approved by Resolution 0032 of 2015 and updated for new projects.

2.3.9.5 *1% Investment plan*

According to the demand of the water resource and the costs of the project, the investment plan of 1% was updated and adjusted, in accordance with the provisions of Decree 1900 of 2006 and complying with the requirements of the environmental license.

2.3.9.6 *Compensation Plan for loss of biodiversity*

According to what was defined in the baseline and in the forest development plan, the compensation plan for loss of diversity was drawn up, in accordance with the guidelines established in the "Manual for the allocation of compensation for loss of biodiversity". through Resolution 1517 of 2012.

2.3.10 GIS component

The methodology for the development of the GIS component was carried out following the following technical specifications in terms of the collection, storage, structuring and administration of geographic information

- All the thematic cartography information generated for the abiotic, biotic and socioeconomic component was stored in the ANLA corporate geodatabase regulated with Resolution 1415 of 2012 (By which the Geographical Storage Model (Geodatabase) adopted by the Resolution 1503 of 2010).

- All the basic cartography information generated for the study area was stored according to the current IGAC data model.

- The metadata was prepared in Excel format according to NTC 4611 (Minimum Metadata) and following template version 3 available on the ANLA website. For the basic cartography, a metadata is done in a general way and for the thematic cartography a metadata is provided for each feature class.

- The coordinate system in which all the basic and thematic information is presented is MAGNA SIRGAS origin Bogotá.

- For both basic and thematic cartography, the quality of the information is validated in terms of: accuracy of position and scale, logical and domain consistency, connectivity, topology, coherence of attributes, classification, completeness and totality.

2.3.10.1 *Basic Cartography*

The basic cartography (roads, coastline, drainages, curves level, toponymy, bathymetry, anchoring areas, etc.) was generated from the structuring of the photogrammetric restitution information made by Edifica Colombia in October 2014, updated and complemented with the orthophoto resolution of 15cm / pixel generated on the same date from the aerial photographs taken by means of drones UAV (unmanned aerial vehicle) operated by remote control. We used a Turbo Ace X830 Quad drone and a DJI Phanton 2 drone, with

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67 EDIFICA COLOMBIA LTDA. Topographic survey by photogrammetric restitution. Scale 1: 400. Bogotá, 2014.
68 EDIFICA COLOMBIA LTDA. Orthophotomapa. Resolution of 15cm / pixel. Bogotá, 2014.

Nikon D5300 24-megapixel cameras with GPS and a 14-megapixel DJI camera with GPS.

The administrative political division, toponymy, nomenclature and equipment were structured in the cartography of the Land Management Plan of 2012 (POT). The maritime information was digitized and structured of the nautical chart COL-625 acquired in the CIOH-DIMAR, the bathymetry extracted from the nautical chart of Bahía Colombia was adjusted in the sectors of the dredging area and the dump with the precision bathymetry carried out by Batiestudios SAS in 2014 for the dredging area and in 2015 for the dump.

2.3.10.2 *Thematic cartography*

The thematic cartography was obtained from the structuring of the secondary information and incorporation of the primary information for the biotic, abiotic and social components.

The geology information was elaborated based on the information of lithological units defined in the POT 2000 and 2012, adjusted by means of the interpretation of the orthophoto of the year 2014 and the verification in the field visit. The geomorphological units, morphodynamic processes, threats and the analysis of coastal line evolution were carried out with the photointerpretation and digitalization of the coast lines, units and drainages on the aerial photographs of the years 1983 and 1989 (Table No. 2.58) and images of Google Earth. Based on the threats, the vulnerability and risk zones for the study area were determined.

Table No. 2.58 Aerophotographs years 1983 and 1989

Flight	Photograph	Date	Scale
R-1148	308	22/03/1989	12,000
	446		
R-973	293	09/08/1983	30,000

Source: Aqua & Terra Consultores Asociados S.A.S, 2015

69 MUNICIPAL MAYOR OF TURBO. Review and Adjustment of the Land Management Plan. Basic cartography scale 1: 50,000. Turbo, 2012.
70 GENERAL DIRECTORATE MARÍTIMA-ARMADA DE COLOMBIA (DIMAR). Nautical Chart COL 625 4th edition. Scale 1: 35,000. DIMAR, 2013.
71 BATIESTUDIOS SAS. Results obtained in the precision bathymetric survey in the "Puerto Bahía de Urabá S.A." project area and anchoring area, located in the municipality of Turbo - Antioquia. Cartagena, 2014.
72 BATIESTUDIOS SAS. Results obtained in the precision bathymetric survey in the dump area of the "Puerto Antioquia" project, located in Bahía Colombia - Golfo de Urabá. Cartagena, 2015.

73 MUNICIPAL MAYOR OF TURBO. Territorial arrangement planning. Turbo, 2012
74 MUNICIPAL MAYOR OF TURBO (2012). Op. Cit.
75 EDIFICA COLOMBIA LTDA. Orthophotomapa (2014). Op. Cit.

For the generation of the digital terrain model, the bathymetry of the nautical chart, the precision bathymetries in the dump areas and the dredging area and the level curves resulting from the photogrammetric restitution were used.

The potential use of the soil was delimited and defined based on the cartographic units of soils at 1: 100,000 scale of the General Survey of Soils of Antioquia, the current use was determined according to the vegetation cover at scale 1: 10,000 identified in the area and the conflict of land use is the result of the intersection of the layers of potential use and current use and their subsequent classification into adequate, overused or underutilized.

To determine the coverage of the land, the delimitation of units was made on the orthophoto 2014 at work scale 1: 5000 and corroborated with the field visit, making the classification of coverage according to the Corine Land Cover methodology.

Terrestrial ecosystems were developed according to the 2011 IDEAM methodology, by superimposing the maps of climatic zoning, geomorphology and coverage, the name and nomenclature of the ecosystems resulting from the union of the name of the coverage and the name of the biome to which they belong the marine ecosystems were taken from the study of ecosystems of IDEAM 2007.

For the delimitation of the landscape units, the layers of land cover and geomorphological units were superimposed. Landscape quality and / or scenic integrity were evaluated for each landscape unit. The visual scale was determined with buffers at different distances from the places where

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76 DIMAR (2013). Op. Cit.
77 BATIESTUDIOS SAS. (2015). Op. Cit.
78 EDIFICA COLOMBIA LTDA (2014). Op. Cit.
79 GEOGRAPHIC INSTITUTE AGUSTÍN CODAZZI (IGAC). General study of soils and land zoning of the department of Antioquia. Bogotá, 2007.
80INSTITUTE OF HYDROLOGY, METEOROLOGY AND ENVIRONMENTAL STUDIES (IDEAM). National Legend of Coverage of the Earth. CORINE Land Cover methodology adapted for Colombia. Scale 1: 100,000. Bogotá: IDEAM, 2010. 72 p. ISBN: 978-958-806729-2
81 INSTITUTE OF HYDROLOGY, METEOROLOGY AND ENVIRONMENTAL STUDIES (IDEAM). Methodology for the elaboration of the Ecosystem Map scale 1: 100,000. Bogotá: IDEAM, 2011.
82 IDEAM, IGAC, IAvH, Invemar, I. Sinchi, and IIAP. Continental, coastal and marine ecosystems of Colombia. Institute of Hydrology, Meteorology and Environmental Studies, Agustín Codazzi Geographical Institute, Alexander Von Humboldt Research Institute of biological resources, Institute of Environmental Research of the Pacific, Institute of Marine and Coastal Research Josè Benito Vives De Andreis, and Amazonian Institute of Scientific Research Sinchi , Bogotá, D. 276 p. + 37 cartographic sheets. Bogotá, 2007.

the observers traveled (highways and roads, Canal Nueva Colonia and the León River) and classified according to the geodatabase domains.

For the environmental zoning the biotic, physical and social units were classified according to the criteria defined for each component, obtaining intermediate maps for each medium and then the overlap was made to obtain the final environmental zoning.

The protection floors were delimited with the information of the shapefiles available for download in the geographic information system of the SIAC, the Regional Natural Park shapefile scale 1: 500,000 whose original source is the National Natural Parks System (SPNN) and Wetlands 2012 scale 1: 100,000 whose source is the Ministry of Housing and Sustainable Development (MADS).

The geographic viewers and WMS map services (web map service) of the Invemar were consulted for the different components: Geovisor Caribbean Ecoregional Planning, Geovisor Coastal Erosion and Geovisor ANH Biodiversity. Also, the geographical viewer of the ANLA: Geographic information system of the SIAC. The IGAC viewer: Agrological Information Management System and the Tremarctos tool (TCo) 3.0.

The primary information associated with samples of water quality, sediments, monitoring of environmental noise, flora and fauna sampling, were incorporated into the geodatabase, maintaining the structure defined by the ANLA reporting the parameters and species found.

The following diagram summarizes the general methodology for each of the elements that make up the GIS component

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83NATIONAL AGENCY OF ENVIRONMENTAL LICENSES (ANLA). Geographic System SIAC (Environmental Information System of Colombia). Available at http://sig.anla.gov.co:8083/. Consulted in July 2015.
84 INSTITUTE OF MARINE AND COASTAL INVESTIGATIONS JOSÉ BENITO VIVES DE ANDREIS (INVEMAR). Geovisor Caribbean Ecoregional Planning. Available at http://gis.invemar.org.co/PERCaribe/. Consulted in July 2015.
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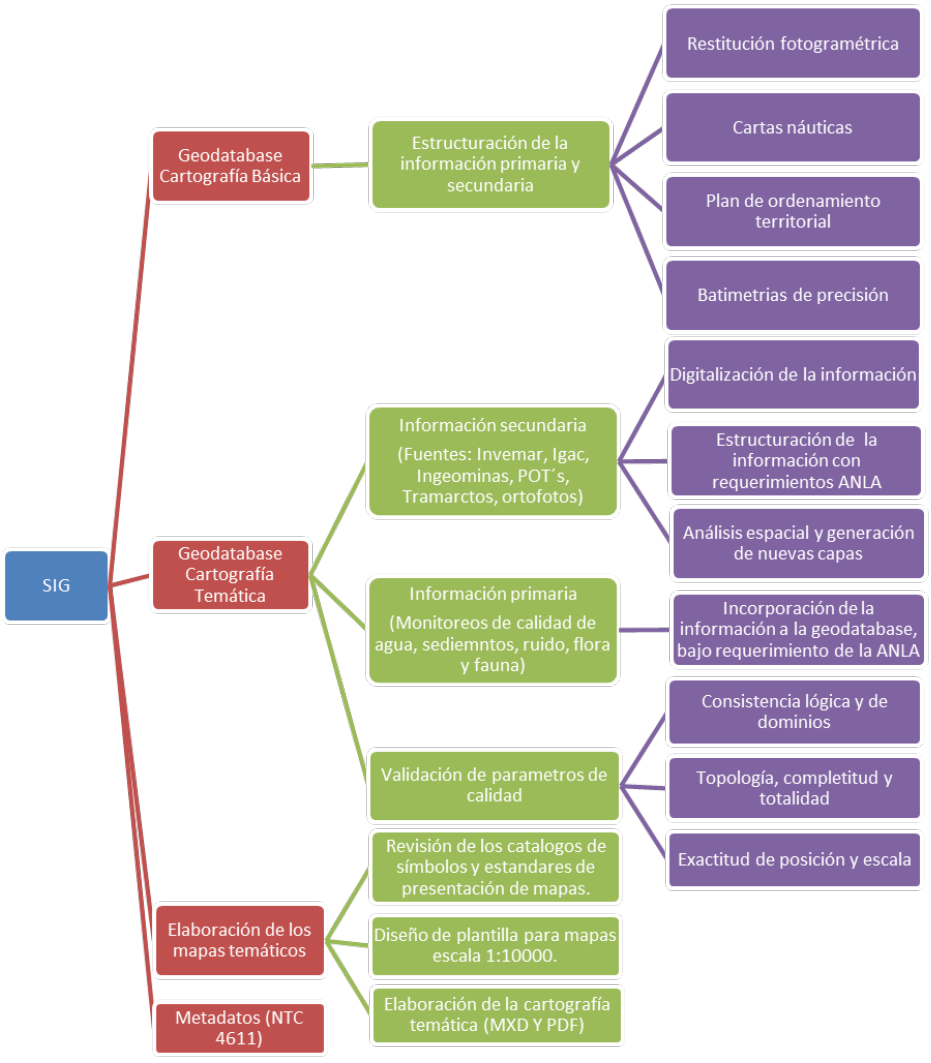

Figure No. 2.42. Methodology for the implementation of the GIS

Source: Prepared by Aqua & Terra Consultores Asociados, 2015

2.3.11 Professionals involved in the preparation of the study

Table No. 2.59 shows the professionals involved in the preparation of this environmental impact study, together with their responsibility within it.

Table No. 2.59 Professionals involved in the preparation of this environmental impact study

Name	Profession	Responsibility in the project
Maria Andrea Patiño	Environmental Engineer Specialist in Project Managing	Direction of Study
Esteban Rendón G	Environmental Engineer Specialist in marine tropical ecology	Environmental coordinator
Carlos Arturo Rey	Civil Engineer MSc Water Engineering	Project description, Oceanography
July Bibiana Salazar	Sanitary Engineer	Abiotic coordination
Julio Cesar Mesa	Civil Engineer MSc. Hydraulic resources	Oceanography
Luisa Fernanda Alzate	Environmental Engineer	Environmental baseline, demand for resources, Risk Management Plan, Management and Monitoring Plans and Monitoring, environmental evaluation
David Gallo	Engineering Intern	Abiotic baseline, Risk Management, Management and Monitoring Plans and Monitoring, environmental evaluation
Juan Guillermo Salazar	Geologist	Abiotic baseline
Marlon Agamez	Geotechnist	Abiotic baseline
Janeth Viviana Pérez Arteaga	BSc. Biologist	Biotic coordination
Juliana Jaramillo González	BSc. Biologist MSc in Sciences - Biology	Environmental baseline, marine ecosystems, hydrobiological, terrestrial fauna, Management and Monitoring Plans and Monitoring, environmental assessment
Diana Mileydi Guzmán Celemín	Forestry Engineer	Environmental baseline, terrestrial ecosystems, flora, demand for resources, Management and Monitoring Plans and Monitoring, environmental assessment
Isabel Cristina Panesso Murillo	A lawyer Specialist in environmental law	Social coordination
Dinorat Murillo	Social worker	Socioeconomic baseline, impact assessment, Management Plans and Monitoring and Monitoring
Andrea Fontecha	Cadastral and Geodesta Engineer. GIS specialist	GIS component