HYDROELECTRIC PROJECT – EL MOLINO – SAN MATÍAS RIVER

ENVIRONMENTAL DIAGNOSIS OF ALTERNATIVES

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GENERAL CONTENT

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1 GENERAL FACTS

By issuing Laws 142 and 143 of 1994, the government initiated a process of linking private investment in the provision of public services and in the construction of infrastructure. This policy has been supported and continued by subsequent governments. With respect to electricity, changes in regulation have favored income for minor plants motivating investors to construct more of these assets. These modifications to the system changed the look of small hydroelectric plants, which also have a lower environmental impact.

HMV Ingenieros Ltda identified this opportunity in an early stage and started promoting this type of assets to private investors, while identifying suitable sites for the development of small plants. As a result of this effort, HMV Ingenieros Ltda built the small plant La Cascada 2.3 MW in San Roque, Antioquia. This small hydro power plant has been operating since July 2007 and is one of the first plants in the country to achieve the Clean Development Mechanism, allowing it to sell CERs (Certified Emission Reductions).

Also, two additional small hydro power plants of 9.7 MW each are soon to start operations in the town of Santa Rosa (December 2009 and March 2010), as HMV Ingenieros Ltda has begun the construction of a 20.5 MW plant in the town of Salgar that should start operating in the first half of 2012. HMV Ingenieros Ltda has started preparing documentation to certify them as CDM projects, given that this is a key element to assure profitability.

The pipeline of potential hydropower projects identified by HMV Ingenieros Ltda includes San Matías – El Molino, projects that would take advantage of the waters of the river San Matías. HMV Ingenieros Ltda intends to register these plants as CDM projects. The projects are located in the East region of Antioquia, about 95 km away from the city of Medellin, in the jurisdiction of the municipalities of Cocorna and Granada.

This paper assess the Environmental Diagnosis of Alternatives for the project El Molino – San Matías, and consists of 9 chapters: Overview, Background, Methodology, Project Description, Characterization of the Influence Area, Identification of Environmental Impacts, Strategies Management, Monitoring and Comparison of Strategies.

2 BACKGROUND

Since 2006, HMV ENGINEERS LTD. Began studying the possibility of developing some type of hydropower project in the basins of the rivers San Matías, Tafetanes, Cocorná and Calderas.

By communication HMV 39692 of February 9, 2007, HMV Ingenieros Ltda requested study permits to Corporación Autónoma Regional Rionegro Nare –CORNARE to determine the feasibility of forecasting works to take advantage of the hydraulic force of the waters of the basin river of San Matias and Tafetanes by building hydropower plants.

By Resolution No. 112-4112 of August 23, 2007, Corporación Autónoma Regional Rionegro Nare –CORNARE granted permission to study natural resources to forecast works to take advantage of the hydraulic force of the waters of the basin of the San Matías and Tafetanes rivers, in the jurisdiction of municipalities like Cocorná, El Santuario and Granada.

As a result of this activity, HMV identified that it was feasible to make use of the waters of the basin river of San Matias to generate electricity, between 1,280 m elevation and Cocorná confluence with the river by following two strategies (alternatives). The first alternative consists of developing two hydroelectric projects in cascade called El Molino I and El Molino II. The second alternative consists of developing a single integrated project called El Molino.

Since there were two alternatives, CORNARE, in response to the request presented by HMV through Auto 112-0739 of July 4, 2008 states that the hydropower development of the San Matías River, between 1,280 m elevation and Cocorná confluence with the river, requires the submission of Environmental Diagnosis of Alternatives - DAA- and sets the terms of reference for this purpose.

Taking into account the terms of reference, HMV prepared the following 2-alternative DAA: Alternative 1 consists of developing two hydroelectric projects in cascade to take advantage of the benefits provided by the market regulation to minor plants, by building El Molino I and El Molino II with 21 MW of installed capacity each. Alternative 2, a project called El Molino with 34 MW of installed capacity. This project varied with respect to the request for terms, due to more advanced designs of the works and optimization in terms of installed capacity. HMV suggested to follow alternative 1 and to prepare the Environmental Impact Study based on this strategy. This documents assess the objective reasons why HMV reached this conclusion.

If CORNARE shares our suggestion, we suggest the corporation to issue the reference terms for HMV to start preparing the Environmental Impact Study for the hydropower projects El Molino I and El Molino II in order to go forward with the legal procedures.

3 METHODOLOGY

3.1 COLLECTION AND REVIEW OF INFORMATION

HMV collected and reviewed the secondary data available taking into account studies and data that was published in different dates. Within the secondary sources of information that were analyzed, HMV highlights the following sources:

Veredal Atlas of Antioquia, 2007

2005 Census by DANE.

SISBEN database for the municipality of Cocorná.

Land Management Schemes in the municipalities of Granada and Cocorná.

Hydrologic and hydraulic information published by IDEAM.

General study of soils and zoning of the department of Antioquia, 2007.

Aerial photographs of the Basin of San Matías River, scale 1:20.500 2008.

3.2 SITE VISITS

Between May and July 2009, HMV performed site visits and complemented information regarding the following topics:

Mulches or vegetation layers

Fauna

Economic activities of the population of the area of influence

Based on these two activities, HMV characterized the baseline.

3.3 IDENTIFICATION AND EVALUATION OF IMPACTS

Based on the experience of the consultant, and on existing environmental studies for hydropower projects, HMV identified the potential impacts derived from the construction of the project using a methodology proposed by CONESA[1].

3.4 DEVELOPMENT OF MANAGEMENT STRATEGIES

Based on the results of the collection of information, which allowed a zoning analysis of the area of influence, and the identification and assessment of impacts, HMV formulated strategies to prevent, mitigate, control or compensate for potential impacts derived from the project. In addition to these strategies, HMV established monitoring strategies.

[1] Conesa Fernandez, Vicente. Guía Metodológica para la evaluación del Impacto ambiental. Madrid, 1995

4 PROJECT DESCRIPTION

4.1 LOCATION

The project is located in eastern Antioquia, about 95 km from the city of Medellin, in the jurisdiction of the municipalities of Cocorná and Granada, in the villages of El Molino, Campo Alegre, Los Mangos and La Inmaculada; and in the rural zone of Quebradona Abajo, las Faldas y La Arenosa de Granada.

4.2 TECHNICAL DESCRIPTION OF THE ALTERNATIVES

HMV analyzed two alternatives, the first one consisting of two projects in cascade, and the second one consisting of one single integrated project.

Both Alternatives consider subscribing the project as a CDM project.

4.2.1 Alternative 1

This Alternative consists of two projects in cascade called El Molino I and El Molino II, each with an installed capacity of 21 MW and an effective capacity of 19.9 MW. It is important to highlight that these projects have to operate independently. Although El Molino II will make use of the waters that have been turbinated by El Molino I, the projects will be constructed and operated separately. However, the two projects will be built independently and will be commercially separated, as they will be connected to different commercial boundaries.

The projects have a design flow of 11 m^3 /s and a net head of 223 m each. Designs predict a 3.50 km tunnel for El Molino I and 3.44 km for El Molino II.

4.2.1.1 Hydropower project El Molino I

Hydropower project El Molino I consists of a concrete weir at a low altitude, lateral intake, a retention grit for coarse sediments, a box culvert, a conduction tunnel with a beacon, a house valve, a pressure pipe, a power house in the surface, and a discharge channel to deliver water back to San Matías river.

The waters will be derived from the construction of a concrete dam of approximately 4.0 m high and 45.0 m long on the river, which count towards the left side with a bottom discharge formed by a radial damper of 5.0 m by 5.0 m for the periodical sediments discharge, accumulate in the small storage. The damper may be operated manually and mechanically.

For the intake, there will be a lateral socket on the right side of the weir, formed by rectangular openings sized to derive the flow to the conduction system.

The water collected will be carried to a sand trap, which is located on the right bank of the San Matías River, through a concrete channel of about 30.4 m long and 4.0 m wide by 3.0 m high.

After the sand trap, waters will be driven into a high pressure culvert box, section 2.5 mx 2.5 m and 45.8 m in length, which is tied with a tunnel of 3.1 m diameter with hydraulic concrete coating in its first 25 m. The tunnel is 2,623 m in length, modified horseshoe section of 1.55 m radius of excavation and a slope of 1.1 %, which connects with a pipe, first steel and then - GRP Glass Reinforced Polyester.

The power house of the project, located at an altitude of 1035.50 meters, will be conventional surface type, located on the right bank of the San Matías river, where two generating units will be providing a total installed capacity of 21 MW.

Turbinated waters will be channeled to a storage tank, which will ensure the steady flow of water to El Molino II. In case of maintenance of project El Molino II, water will be discharged into a storage tank and the surplus will be evacuated by a chute (1.5 m wide and 15.0 m in length). Water will be conducted to a high pressure box culvert to finally be delivered to the San Matías River at elevation 968 m.

The electrical substation will be built in the vicinity of the power house and will be connected to the system through the construction of a 3 miles 44 kV to Cocorná substation. Given that it is a new substation, the property and construction will be undertaken by whoever Mining and Energy Planning Unit - UPME decided to appoint.

4.2.1.2 Hydropower project El Molino II

Hydroelectric project El Molino II makes use of the turbinated waters from hydroelectric project El Molino I, which are taken to a storage tank, and conducted by a box culvert to a conduction tunnel, then taken to a house valve, then to a high pressure lining, then to the powerhouse and finally to a discharge channel that delivers the waters back to San Matías river.

El Molino II captures the waters from the discharge of El Molino I, taking it through a storage tank of about 6.20 m tall, 7.50 m wide and 32.0 m.

The water will be driven by a 89.3 m length high pressure box culvert of 2.5 m wide by 2.5 m high, which connects with the conduction tunnel of 3.1 m in diameter, which initially has a hydraulic concrete lining a at its first 25 m. The tunnel is 2,245 m in length, “modified horseshoe section” of 1.55 m radius and has a slope of 1.0 % to the valve house.

The powerhouse, located at an elevation of 787.50 meters will be situated at the surface level, which will house two generating units, each made up of a horizontal axis Francis turbine, for a total installed capacity of 21 MW.

The turbinated waters will return to San Matías river at an elevation of 780 meters, using two square-type collector box culvert of 1.9 m, one per unit, which will be connected to a square-type box culvert of 2.3 m, operating free flow for about 336 m in length, which delivers the water to the river via a free flow channel with concrete blocks in between.

The routes to be used for this alternative (projects Molino I and Molino II) are:

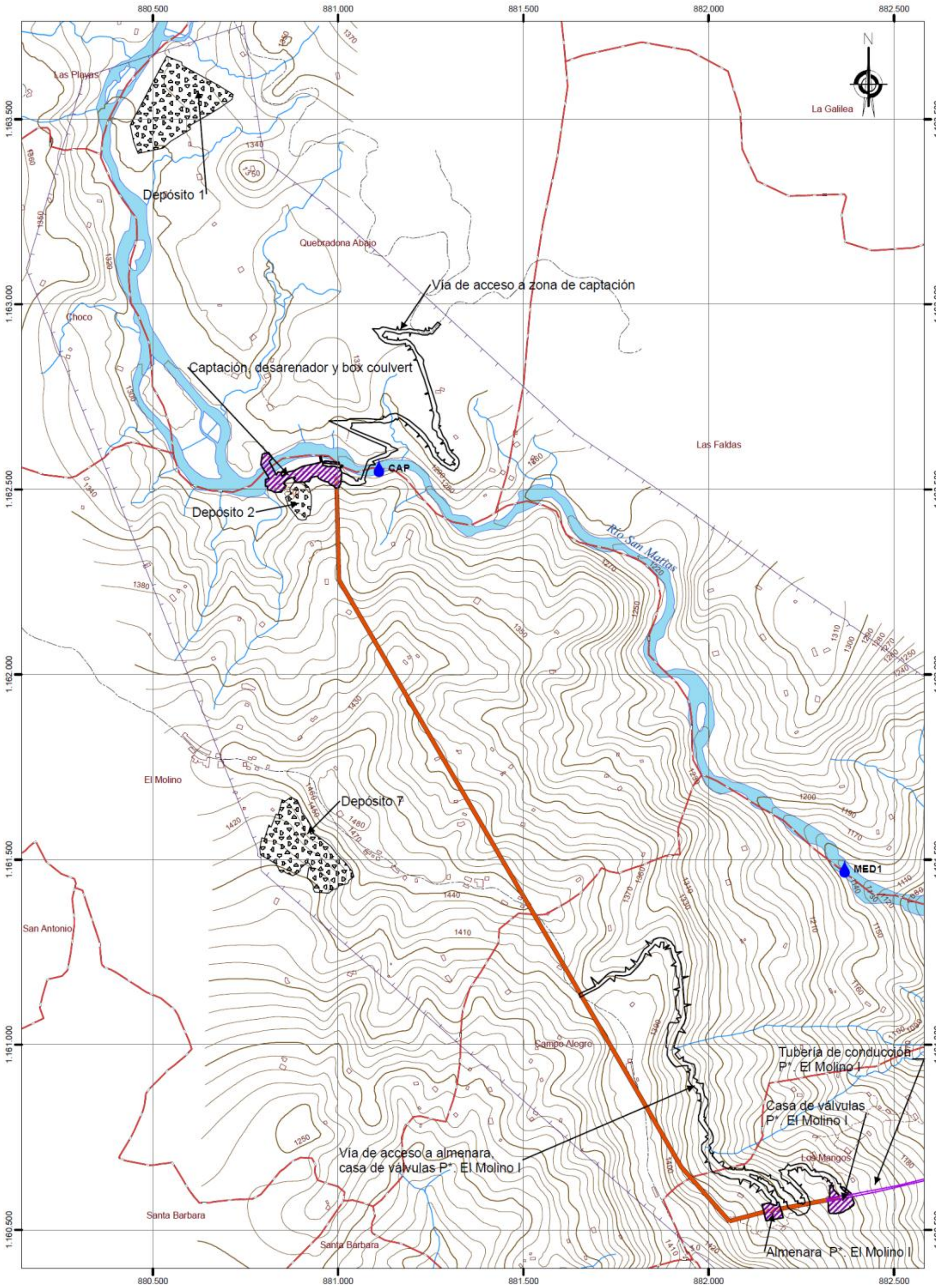
An existing unpaved road that goes from the municipal center of the municipality of Cocorná to rural community Quebradona Abajo of the municipality of Granada. At about 9.3 km there is a way that conducts to the intake site, which has a length of 1.27 km and an average slope of 4.8%.

To access the beacon, the house of valves and the exit site of the conduction tunnel of El Molino I, the project will take advantage of about 3.4 km of the existing road that goes from El Chocó to El Molino, where a new 1,83 km long path is derived with an average slope of 9.0 %.

To access the powerhouse areas of El Molino II, the project will take advantage of the projected ways of hydroelectric project El Popal, from site La Mañosa of Autopista Medellin – Bogotá, 90 km away from Medellin, to the powerhouse of this last project, over a length of 3.3 km, which is in the same site of El Molino II powerhouse.

To access to the tunnel exit and the beacon of El Molino II, the project will take advantage of the projected routes to the beacon of hydropower project El Popal. After that, the project forecasts a 1.03 km road with a 6.5% average gradient, which will go from the beacon of El Molino II to the beacon of El Popal. From the beacon of El Molino II to the tunnel exit, the project forecasts a 0.30 km long road with an average gradient of 4.7 %.

To reach the powerhouse of El Molino I, the project will take advantage of the route projected from the powerhouse of El Popal to its beacon. At kilometer 1.07 of this route a new 1.95 km road is forecasted with an average gradient of 8% to reach the powerhouse El Molino I.



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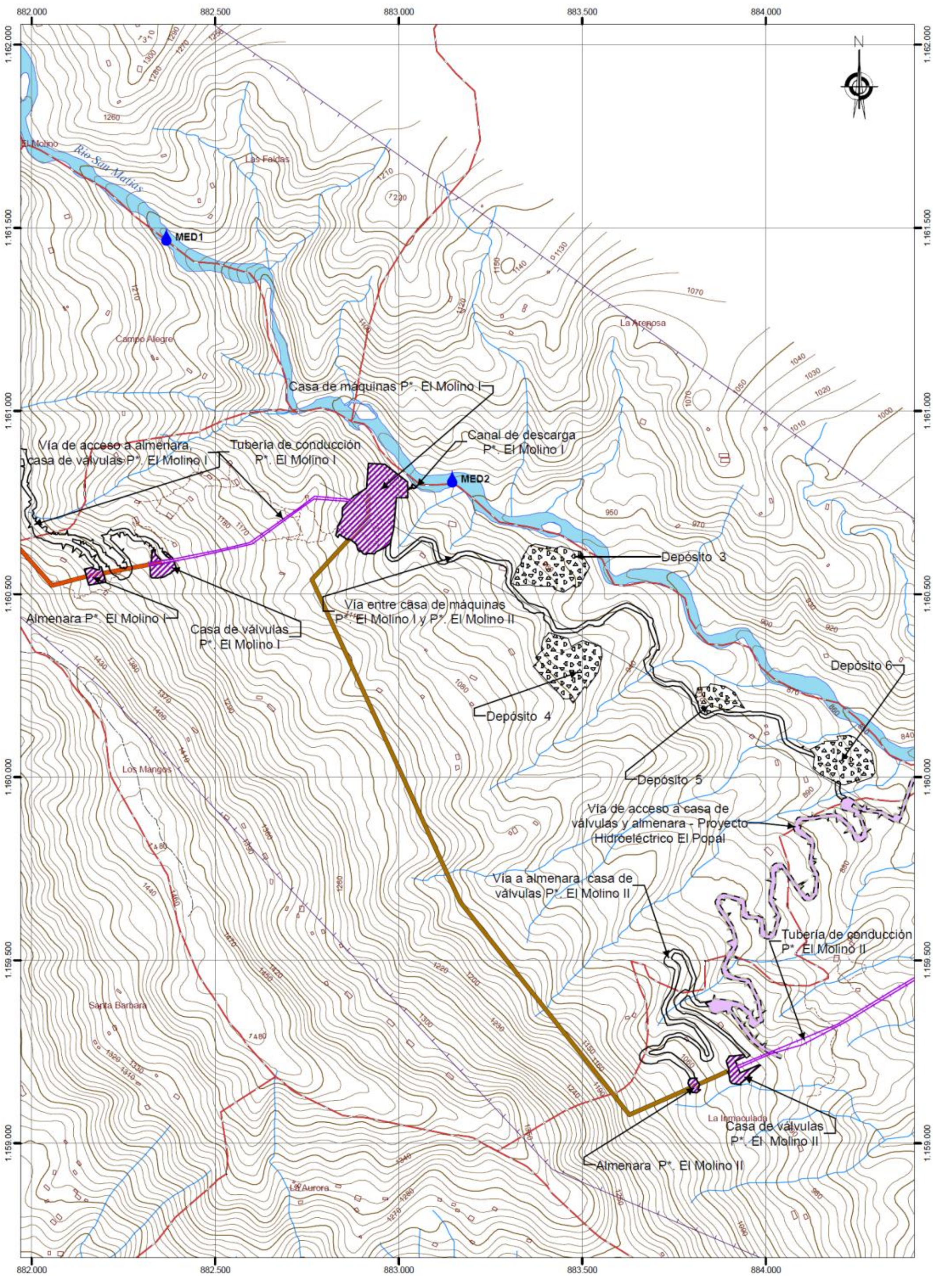
La Galilea
Depósito 1
Quebradona Abajo
Vía de acceso a zona de captación
Choco
Captación, desarenador y box coulvert
CAP
Las Faldas
Depósito 2
Río San Matías
El Molino
Depósito 7
MED1
San Antonio
Campo Alegre
Tubería de conducción P*. El Molino I
Casa de válvulas P*. El Molino I
Los Mangos
Vía de acceso a almenara, casa de válvulas P*. El Molino I
Santa Barbara
Santa Bárbara
Almenara P*. El Molino I

Figure 1 Alternative 1. Intake, sand trap, box coulvert, tunnel, valves house, beacon, conduction piping, deposits and Access roads El Molino I.



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El Molino
Río San Matías
Las Faldas
MED1
MED2
Campo Alegre
La Arenosa
Casa de máquinas P*. El Molino I
Canal de descarga P*. El Molino I
Vía de acceso a almenara, casa de válvulas P*. El Molino I
Tubería de conducción P*. El Molino I
Depósito 3
Vía entre casa de máquinas P*. El Molino I y P*. El Molino II
Almenara P*. El Molino I
Casa de válvulas P*. El Molino I
Depósito 6
Depósito 4
Depósito 5
Los Mangos
Vía de acceso a casa de válvulas y almenara - Proyecto Hidroeléctrico El Popal
Vía a almenara, casa de válvulas P*. El Molino II
Tubería de conducción P*. El Molino II
Santa Barbara
La Inmaculada
Casa de válvulas P*. El Molino II
Almenara P*. El Molino II
La Aurora

Figure 2 Alternative 1. Tunnel, powerhouse, discharge channel of El Molino I; tunnel, beacon, valves house and conduction piping El Molino II, Access roads and deposits.

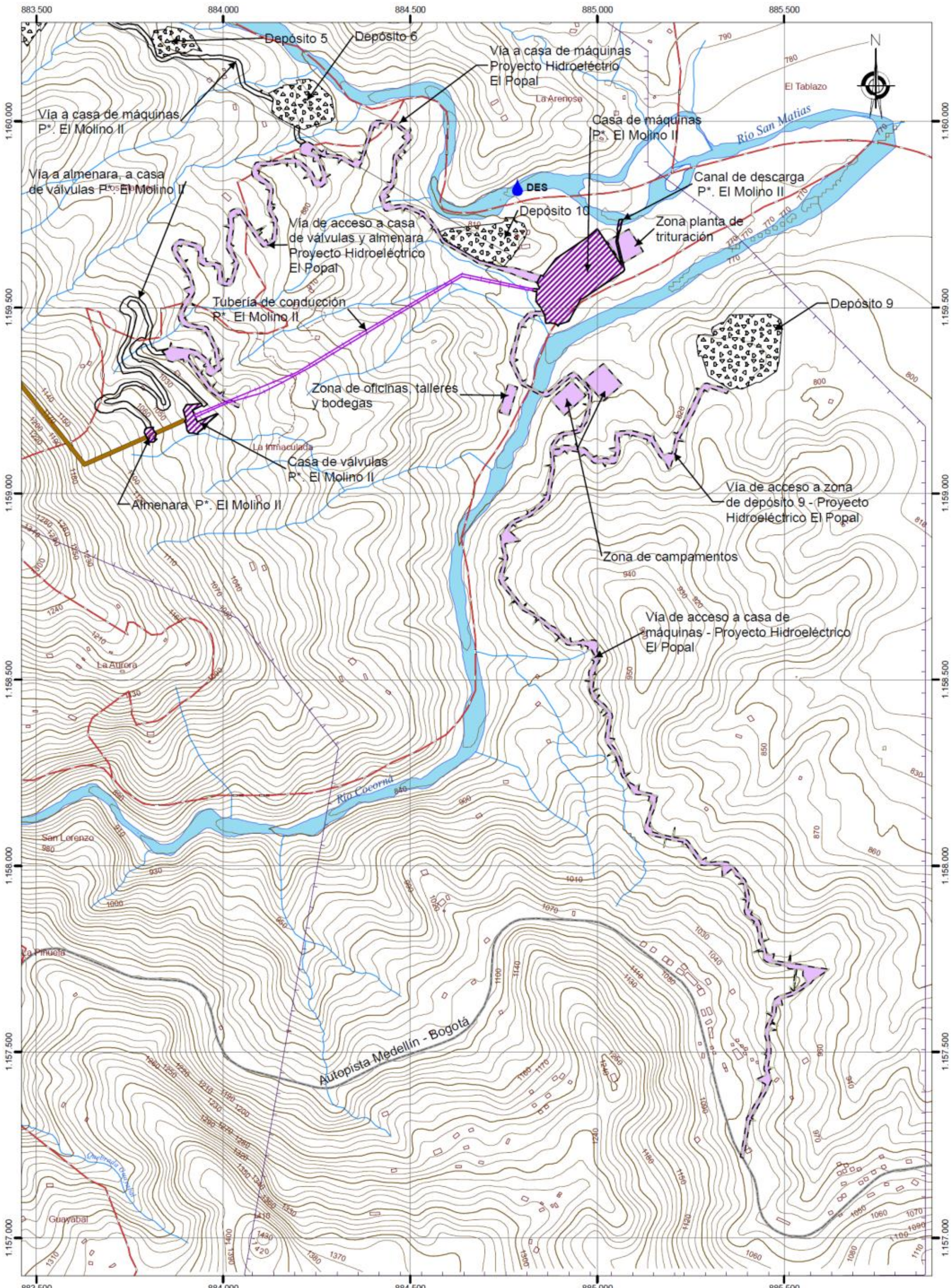

Figure 3 Alternative 1. Beacon, valves house, conduction piping, powerhouse, crushing plant, camp zone, discharge channel El Molino II, access roads and deposits.

4.2.2 Alternative 2

This alternative consists of a unique project called El Molino with an installed capacity of 34 MW. The project has a design flow of 9 m³ / s and a net head of 454 m. Conduction works are about 6.17 km in terms total length.

Diversion works will take place at an altitude of 1,282 meters and will consist of a concrete weir of about 4.0 m high and 45 m long on the river basin. The project have a left side discharge formed by a 5.0 m by 5.0 m radial gate to discharge the sediments accumulated in a small storage. The gate would be operated both manually and mechanically.

The spillway section of the dam would allow the passage of a current of 1246 m³/s corresponding to the 100-year return period, without overstepping the side walls at the abutments.

The project forecasts a lateral type intake on the left side of the weir, formed by rectangular openings sized to derive the flow to the conduction system.

Collected waters will be carried to a sand trap, which is located on the right bank of the San Matías River, thorough an open concrete channel of about 30.4 m long, 4.0 m wide by 3.0 m.

After the sand trap, conduction continues with a high pressure box culvert 2.5 m wide by 2.5 m high and 44.8 m in length, which is tied with the tunnel, which initially has a hydraulic concrete coating, whose internal section is 2.5 m in diameter and a 25 m length. The tunnel is 4,587 m in length, “modified horseshoe section” of 1.55 m radius and a slope of 3.9%.

In order to accelerate the construction of the tunnel, the project will have a construction window; the cross section will be as long as the conduction tunnel with a slope of 1%, coming to the abscissa 2 +622 the tunnel, with a length of 374 m.

The tunnel will be connected to a steel pipe whose diameter varies between 1.45 m and 1.40 m.

The powerhouse of the project, located at an elevation 787.50 meters, in the area of confluence of the rivers San Matías and Cocorná, on the left bank of the Cocorná river and the right bank of the San Matías river, will be conventional situated at the surface level, and will house two generating units, each made up of a Pelton turbine, for a total installed capacity of 34 MW.

Turbinated waters will be delivered to San Matias River by two square-type collector box culverts of 1.9 m, with free-flow operation, which are connected to a square-type box culvert of 2.3 m and 420 m in length.

The routes to be used for this alternative are the following:

An existing unpaved road that goes from the municipal center of the municipality of Cocorná to the rural community Quebradona Abajo of the municipality of Granada. About 9.3 km away from this site there is a 1.27 km road with an average gradient of 4.8% that goes to the intake.

To access the construction window, the project will take advantage of a 3.4 km existing road that runs from El Chocó to El Molino. From this existing road a new 2.44 km long road is derived with an average gradient of 9.2 %.

To access the powerhouse areas of El Molino II, the project will take advantage of the projected ways of hydroelectric project El Popal, from site La Mañosa of Autopista Medellin – Bogotá, 90 km away from Medellin, to the powerhouse of this last project, over a length of 3.3 km, which is in the same site of El Molino II powerhouse.

To reach the exit site of the conduction tunnel of El Molino, the project will take advantage of the roads that will run all the way the beacon of El Popal. A new 3.85 km road and average gradient 8.5% will be built running from the beacon of El Popal to the beacon of El Molino.

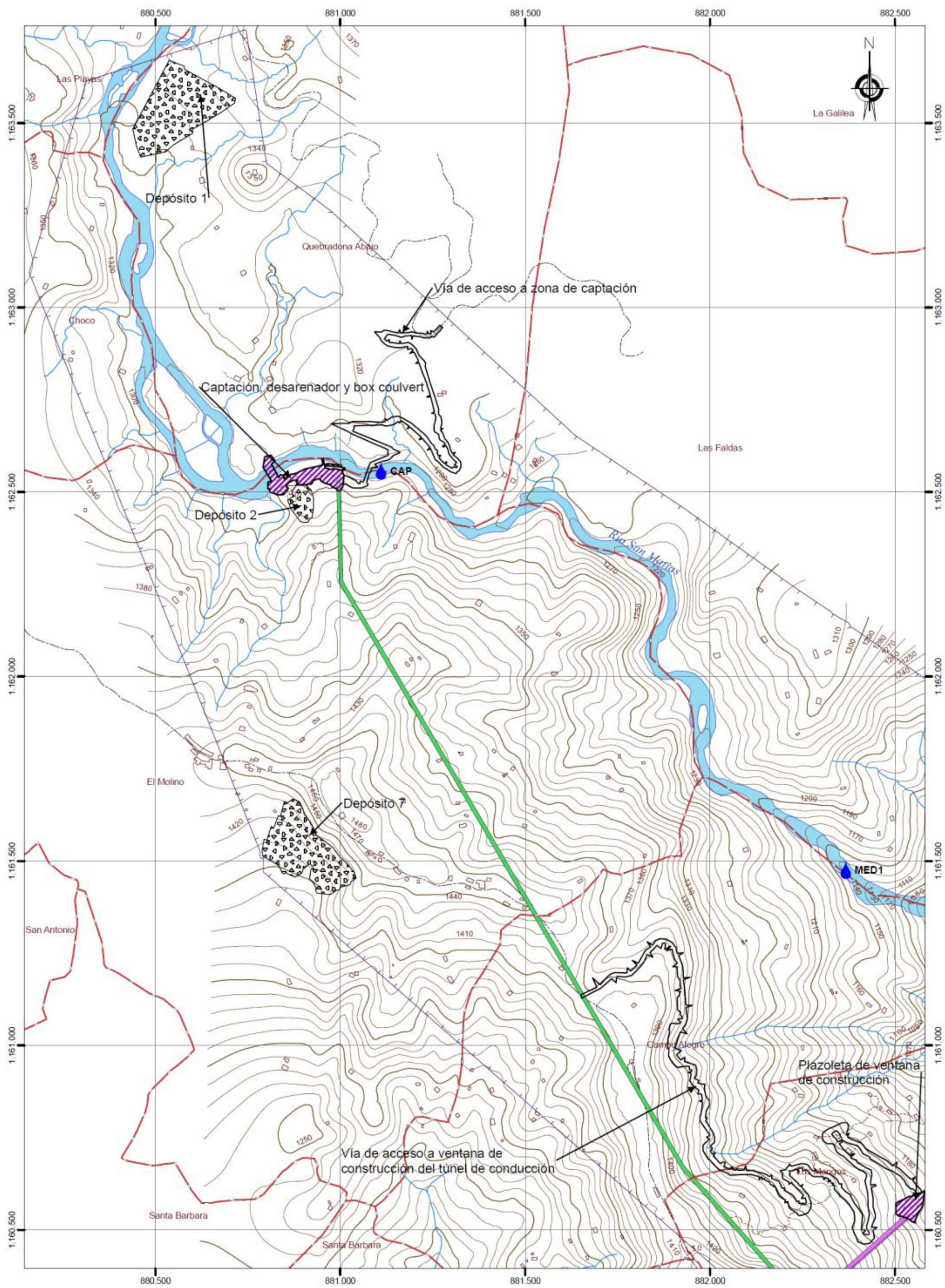

Figure 4 Alternative 2. Intake, sand trap, box coulvert, conduction tunnel and building window, access roads and deposits.

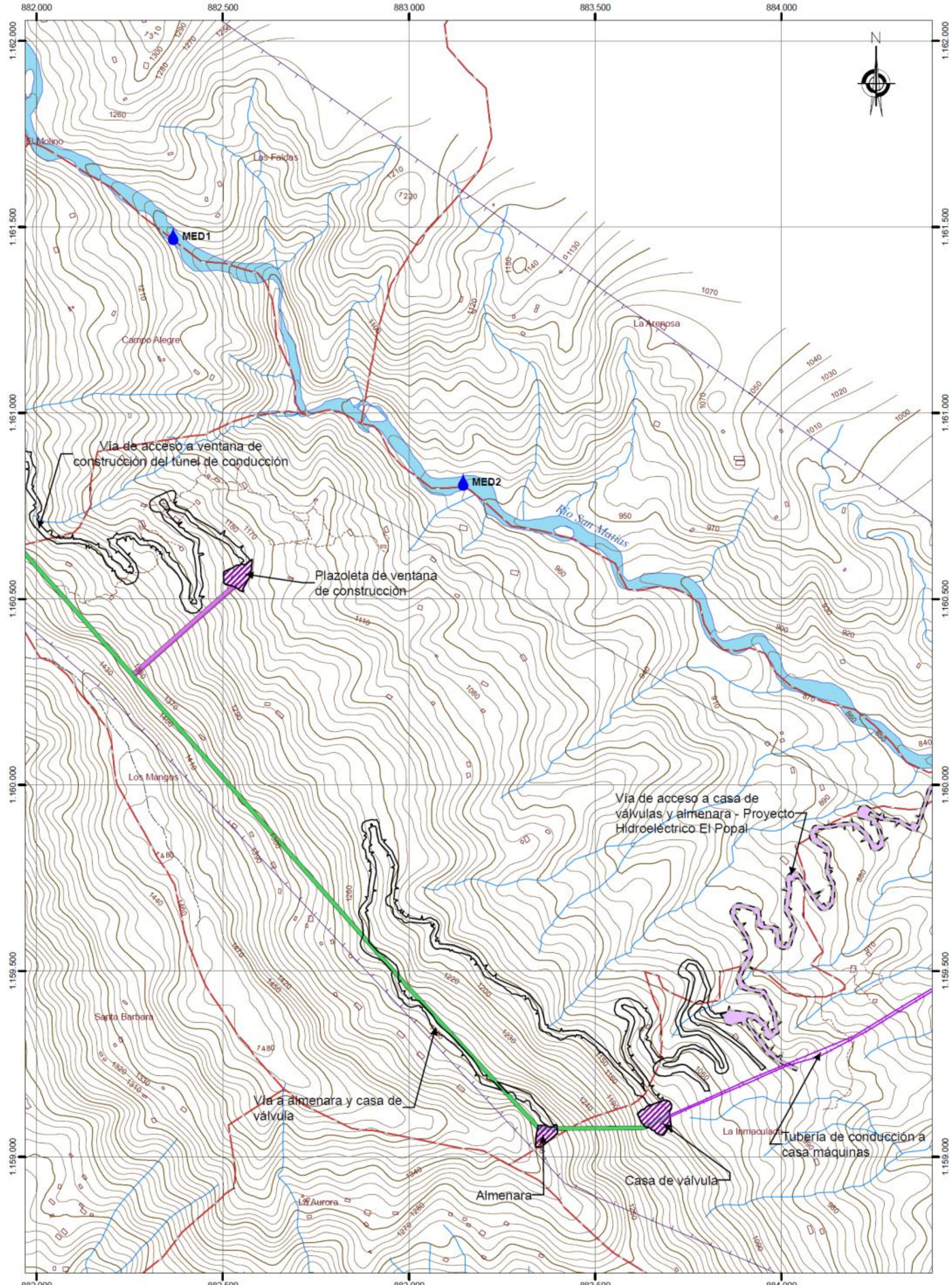
El Molino
Las Faldas
MED1
MED2
Campo Alegre
La Arenosa
Río San Matías
Vía de acceso a ventana de construcción del túnel de conducción
Plazoleta de ventana de construcción
Los Mangos
Vía de acceso a casa de válvulas y almenara - Proyecto Hidroeléctrico El Popal
Santa Barbara
Vía a almenara y casa de válvula
La Inmaculada
Tubería de conducción a casa máquinas
Casa de válvula
Almenara
La Aurora
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Figure 5 Alternative 2Conduction tunnel and building window, beacon, valves house, conduction lining to powerhouse, access roads and deposits.

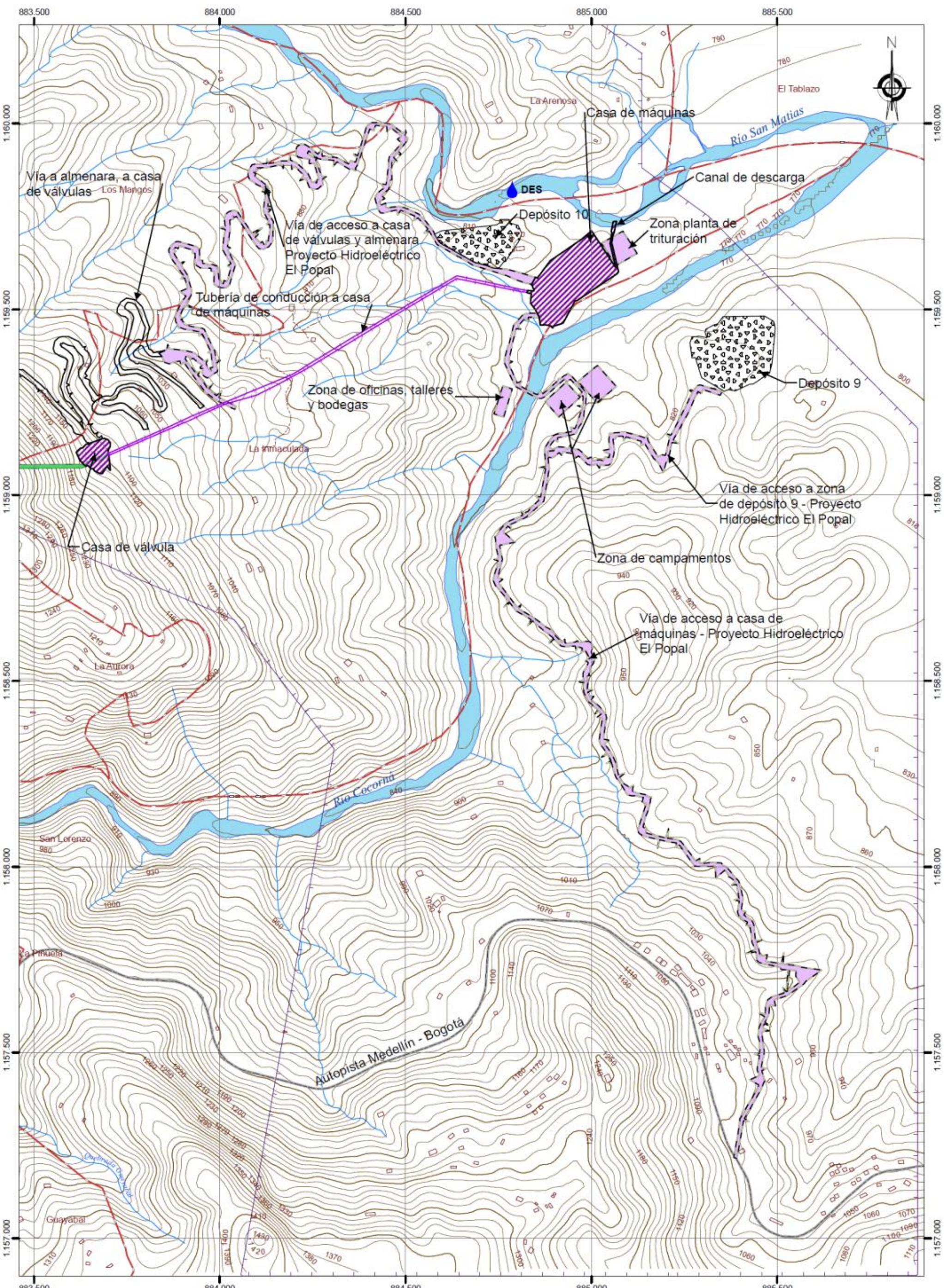


Figure 6 Alternative 2. Valves house, construction piping to powerhouse, discharge channel, crushing plant, offices, workshops and warehouses, camps, deposits and access roads.

5 CHARACTERIZATION OF THE AREA OF INFLUENCE

The area of influence of the project for the two alternatives correspond to those zones where the project will have some sort of direct or indirect environmental impact.

The two alternatives that have been studied share the same areas of influence, because the works for either of them will affect the same zones around the municipalities of Cocorná and Granada.

The project will affect the rural communities of El Molino, Campo Alegre, Los Mangos, La Inmaculada, San Lorenzo, Las Playas and Chocó in the municipality of Cocorná. The project will also affect the rural communities of Quebradona Abajo, Las Faldas y La Arenosa in the municipality of Granada.

5.1 ABIOTIC ENVIROMENT

The project is located in the basin of the San Matías River, tributaries of Cocorná River, which discharges its waters into the Calderas River. The main tributary of the San Matías River is Tafetanes which flows 1,000 meters before the intake site. The average flow at the intake site is 9.54 m3/sec while at the discharge the average flow is 11.41 m3 /s.

The waters of the San Matías River are qualified as good, given that the value of the Index NSF - WQI (National Sanitary Foundation -Water Quality Index) in the four sections that were monitored was greater than 71.

The sections of the river where there will be flow reduction have no use for the surrounding communities. Except from the rural communities Los Mangos and La Inmaculada the water supply for the population is an existing aqueduct that takes the waters from the tributaries of the San Matías and Cocorná rivers.

According to the results of the water balance, which take into account the comparison between precipitation, evaporation and the availability of water in the soil, in order to determine the deficit or surplus of water in the area, there is no water deficit in the study area.

5.2 BIOTIC ENVIORMENT

The area of influence of the project is located between 780 m and 1,280 m, with an average annual rainfall of 4,300 mm, in areas of tropical wet forest life (bmh-T) and montane rain forest (bp-PM). Both habitats are common to both alternatives.

In order to identify and locate the vegetation cover that could possibly be affected by the project, HMV analyzed the set of 1:20.500 scale aerial pictures of 2008 and previous field trips around the zone. A projection of the works on the maps was made establishing the categories and extension of each of them. After identifying sampling polygons, vegetation covers were measured and characterized through semi-permanent 4 m by 50 m rectangular plots type RAP (Rapid Assessment Plot) with two replications for each cover.

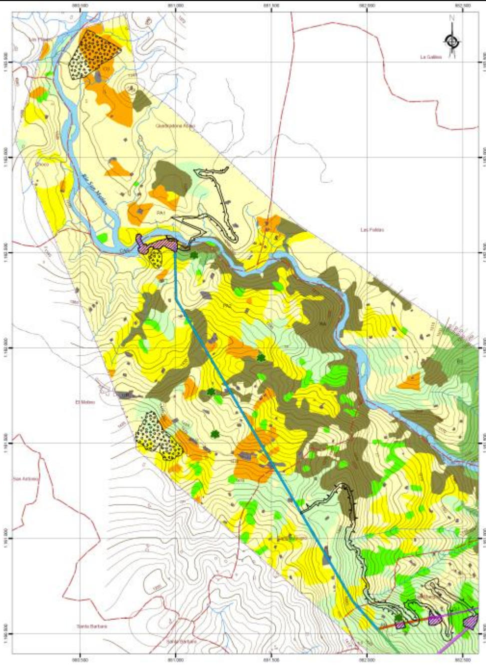
We identified and characterized the following vegetation cover categories: forest with average intervention (B2), forest with high intervention (B3), high stubble (RA), low stubble (RB), dense wooded pastures (PA1), sparse wooded pastures (PA2) and crop (C), which are described below.

The vegetation covers that were identified and the overall ecosystem of the area, exhibit great diversity despite the high level of intervention, which is not dependent on the number of species of commercial interest or timber (as in other forests), but of the great amount of grass and shrub, land forms and rock epiphytes, that thrive in this forest type (wet forest transition to rain) and its various successional stages.

The sampling results in different coverage and strata located in the area of influence of the two alternatives showed 74 morphospecies, 59 genera and 32 families, represented by 218 individuals, of which 56 species and 107 individuals were observed in the category of feedback (DBH <10 cm) and 37 morphospecies and 111 individuals were reported for trees and shrubs (DBH ≥ 10 cm).

An endemic mammalian species was identified in the study area, Saguinus leucopus (Gray marmoset), while two vulnerable species were recognized, Saguinus leucopus (Gray marmoset) and Lontra longicaudis (otter). Regarding birds, an endemic species to Colombia was identified, Melanerpes pulcher (chrysauchen) (nice carpenter), which is registered in the "Libro Rojo" of birds Colombia, national A4c category VU (vulnerable).

With respect to aquatic wildlife, it is important to highlight the fact that none of the species found is migratory. Low diversity of species occurs frequently in typical high mountain ecosystems, in which the strong efforts of dragging, the rugged topography, and the absence of native trophic supply are some of the main factors that determine the low diversity.



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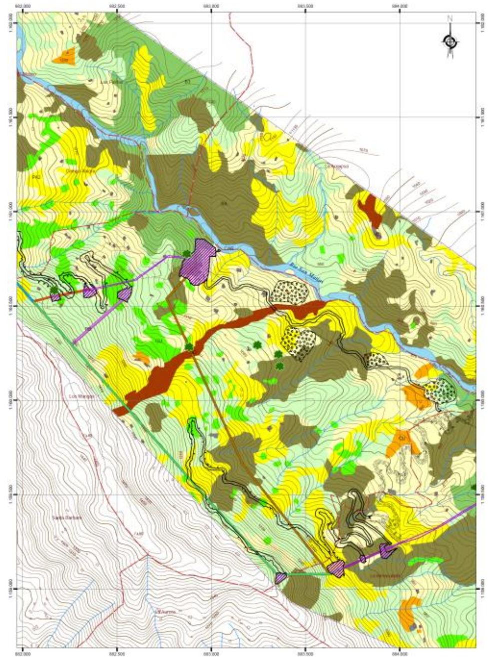

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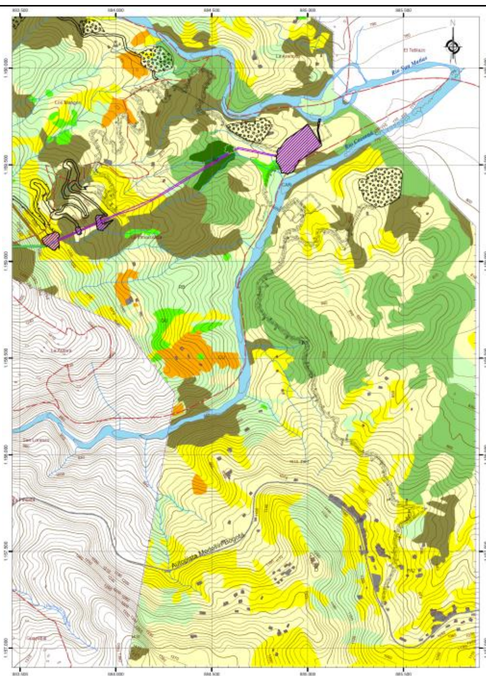

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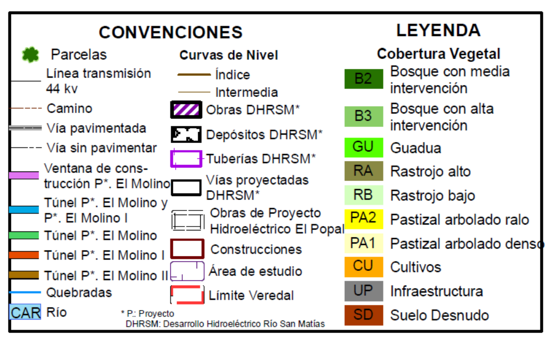


Figure 7 Vegetation Coverage

5.3 SOCIO-ECONOMIC ENVIRONMENT

Several important events that affected social, economic, political, cultural and environmental dynamics of the peopling of eastern Antioquia should be noted: The emergence in the seventeenth century in the context of the East "paisa"; economic decline, with political marginalization and social migration that occurred in the first half of the twentieth century; the re-integration of the East sub region in the development of the department thorough the execution of large road and hydro projects, exploiting labor, cheap raw materials and natural resources in the 1960´s were one of the causes that determined the location of the guerrillas and paramilitary groups in this area; and, in recent decades the rise of illicit economies, the development of the tourism sector, as well as a recent history framed by violence.

The execution of hydropower projects has directly affected the social dynamics of the municipalities of Cocorná and Granada in recent decades, given that part of the land suitable for agriculture was flooded, agricultural activity in smallholdings decayed, the socio-cultural relations were altered as tourism became the main economic activity, even though it declined in recent decades due to the armed conflict. It is a rich land in terms of availability of natural resources, where peasant and forest extraction activities are combined with informal trade, which like the rest of their dynamics have been affected by the military confrontation.

Another consequence of the conflict was the population decrease in these two municipalities, where between 1993 and 2005 they lost between 40 and 60% of its population, making it a worrying situation for the local authorities. Granada saw a 64% decrease of its population.

In the area of influence of the project, there are still villages with small populations in comparison to what they had eight years ago. This is the case of the rural communities like El Molino and Campo Alegre of the municipality of Cocorná; two years after the return started, the rural communities have recovered less than 40% of the population that used to habit the zone. As of today, rural communities La Inmaculada and Los Mangos of the municipality of Cocorná have only 10 and 15 families respectively. It is important to remark that most of the populations, nearly 83% of the habitants of Cocorná, are in a state of either poverty or misery.

Another outstanding feature of the rural communities situated within the area of influence of the project is the division of its territory, which is determined by the land tenure and the existence of small family production units. The studies of the area found that the trend is splitting the territory into smaller and smaller areas thorough time, what makes necessary to establish a minimum area, something that should be regulated by the Office of Planning and approved by the Municipal Council.

The economy of the rural communities of Granada Cocorná and depends exclusively on the agricultural sector, which has low productivity and low efficiency of the production processes, due to lack of technological development and scarce specialized technical assistance. Similarly, limited access to financial resources and almost no guidance in forming agricultural enterprises, in the form of associations of small producers, makes the rural sector not show any growth in economic terms.

Growing sugar cane has become a livelihood. In a study conducted to evaluate suitable areas for sugar cane crops, the Ministry of Agriculture and Rural Development found that the soils of Cocorná and Granada are not suitable for this type of crops. Conversely to the results of the study, it is evident that around the rural communities cane is one of the major crops in terms of planted area.

Due to the dramatic social living and the dynamic process of return of population, Cocorná and Granada have unprecedented institutional presence. The areas of influence are visited, assisted and accompanied by various organizations, ranging from local and national, to international humanitarian. Community organization in different rural communities of the area of influence of the project functions around the concept of Community Action Council-JAC, grassroots organization and the only one in most of these areas. In addition, the Association of Community Action Boards-ASOCOMUNAL operates as the first instance of participation at the municipal level. Agricultural producers are associated, sugarcane and coffee stand out.

Regarding the archaeological component of Eastern Antioquia region, including the sub region shed to the Magdalena, despite its importance as a communication path between the societies of the Aburrá Valley and settled in the valley of the Magdalena river, there is not enough research to give clarity on the processes of settlement and sociocultural dynamics of groups that habited this region in ancient times. The search for more accurate answers about the historical processes of settlement requires further archaeological research to enable the establishment of chronological sequences and the spatial and chronological spread of local pottery styles. Similarly, by ethno historical studies should clarify the different ethnic groups of the sixteenth century, their relationships with each other and with neighboring communities, as well as the dynamics of population in the colonial period.

5.4 ENVIROMENTAL ZONING

5.4.1 General Facts

The purpose of classifying is to identify the environmental aspects that enable delineation of “homogeneous areas" against factors that may induce or aggravate situations or undesirable states of the natural or human environment, based on the current conditions.

Such undesirable or unfavorable conditions may be related to limitations in the use of a natural resource or ecosystem, providing environmental goods and services, or may also refer to the generation of hazardous situations that threaten the health or physical integrity of the population, due to the introduction of contaminants or conditions caused by over-exploitation. In either case, the permanence of occupation and land use are threatened in the short, medium or long term.

5.4.2 Abiotic Environment

5.4.2.1 Environmental Water Zoning

To establish environmental zoning for water quality, the study takes into account current conditions according to the NFS - WQI index, the gradient of the stream and the current resource usage by the population.

Despite being an attribute of the stream, the reason for including the gradient as a key variable for the quality of water, is the increase in the biodegradability of organic materials in the turbulent flow streams. As the speed increases, the water can earn significant amounts of atmospheric oxygen, allowing the compensation for being consumed in the oxidation processes. Thus, a smooth flow of current compared to a turbulent, takes longer to regain its DO levels, therefore, being much more sensitive to the waste water drainage.

The proposed criteria are presented in Table 1 indicating the ranges and fact used for its interpretation.

Table 1 Zoning Criteria

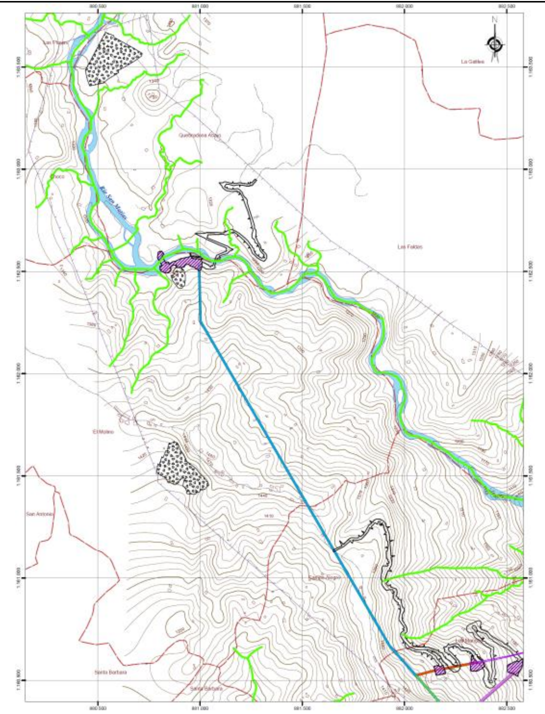
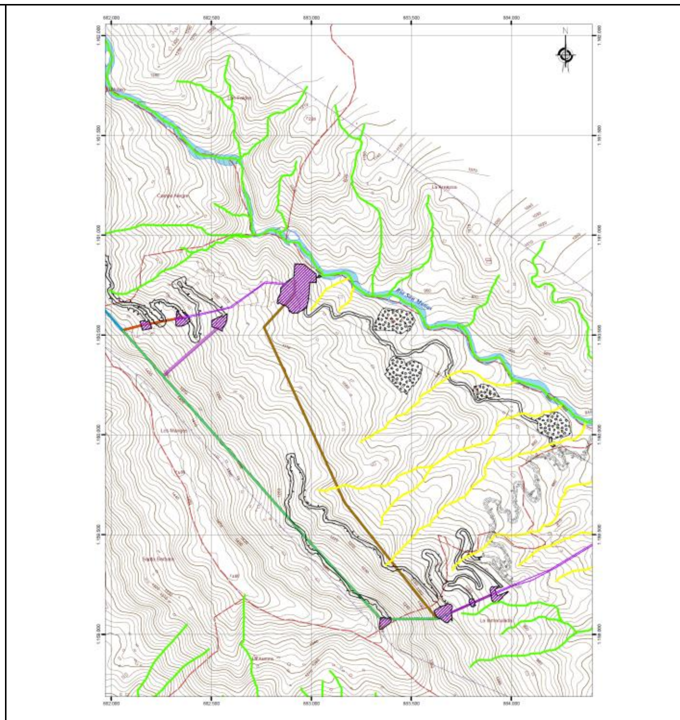
Characteristic	Possibilities	Description of the current
Current water quality	High	Streams of good quality (according to NFS – WQI)
	Mean	Streams of medium quality (according to NFS – WQI)
	Low	Streams of low quality (according to NFS – WQI)
Stream gradient	High	Streams with gradient greater than 10%
	Low	Streams with gradient with less than 10%
Supply aqueducts, irrigation and / or dispersed users	Irreplaceable - Caters at least one	Stream from which supply systems rely upon for drinking water supply, agricultural, recreational or industrial use of a community. Due to geographical, climatic or topographic features is not possible to obtain the resource from a different source, either by shortage or contamination thereof, or because their acquisition costs are unaffordable.
	Replaceable - It supplies at least one	In this case of scarce resources, water can be obtained from alternative sources at reasonable prices, so that the service is guaranteed to users.
	No current supplies	Does not supply water for any of the established uses or that works only for dilution of effluent applications.

Taking into account the criteria described above, environmental zoning for the water component is defined as follows:

- **Environmental Zoning – High**: Streams with any water quality and low gradients, which provide low oxygen, transfer and confer reduced capacity to absorb pollution loads. They are used by at least one user and are irreplaceable.

- **Environmental Zoning - Medium**: Streams with good water quality and any gradient or Media. They are used by the population, but they are replaceable.
- **Environmental Zoning - Low**: Streams with low water quality and a high gradient. Does not supply serves as supply for drinking or other uses.

The results of this zoning are presented in Figure 8, where it is evident that all the streams of the village Los Mango reach a medium value. The remaining streams on the area were classified as low.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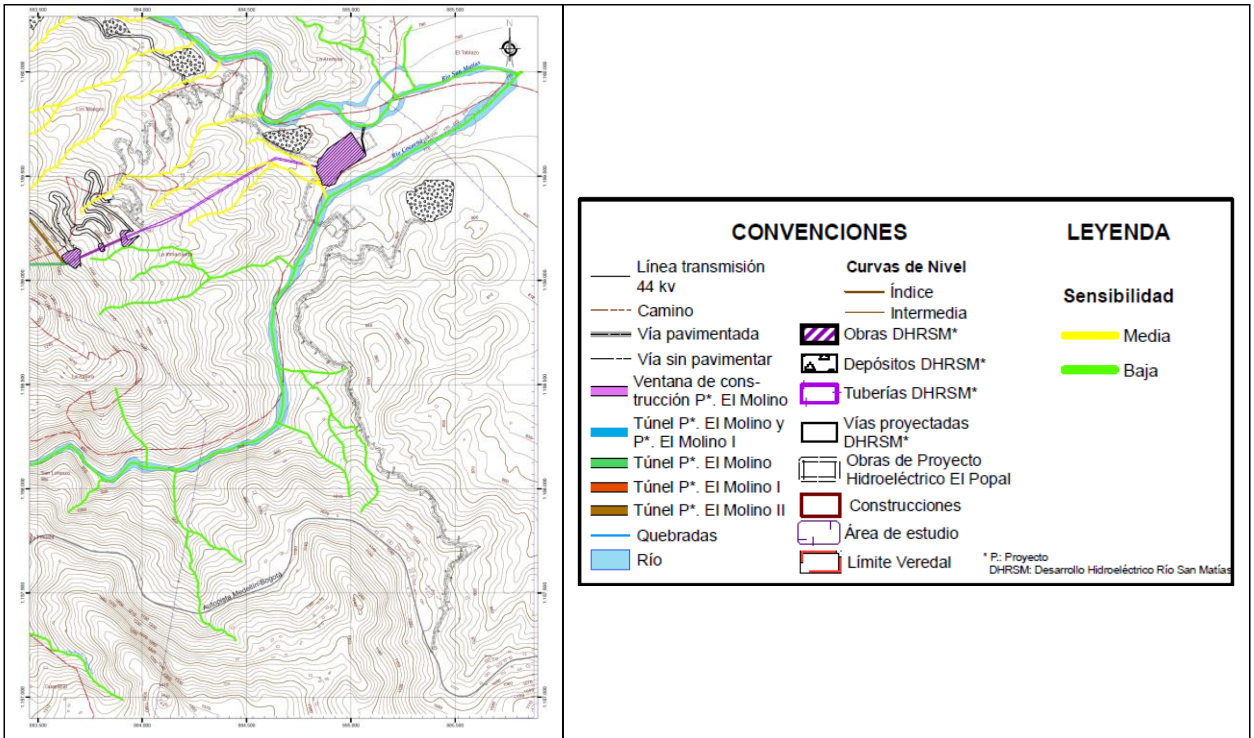

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Figure 8 Environmental water zoning

5.4.2.2 Environmental Soil Zoning.

Conflict analysis is used as an indicator of land use. These conflicts are determined taking into account the comparison between the current and the potential land use. Potential land use is defined according to the system of agrological classes. Environmental zoning is defined according to the presence or absence of conflict and its severity (see Table 2, Table 3, Table 4, Table 5 and Figure 9):

- **Environmental Zoning – High:** Soils with conflict in the severe range. Applies to areas that require strict selection of use or its use is restricted to protector and productive activities; however they currently have crops or pastures.
- **Environmental Zoning - Medium**: Conflict within the medium range. Refers to soils that are used without due practices and that these are complex, because they include the establishment of works for erosion control that can be for landowners and for the production technologies that are used in the region.
- **Environmental Zoning - Low**: No conflicts or minor conflicts involved. In the latter case uses are adequate but require simple and inexpensive practices to conserve as tracing crops and rotation of pastures.

Table 2 Pedological environmental zoning

Current use	Agrological class	Potential use	Type conflict	Environmental zoning
Forest with high Intervention	3s-2	Agriculture with clean, semi clean and dense crops, semi forest and livestock	No conflict	Low
	3s-7	Agriculture with clean, semi clean and dense crops, semi forest and livestock in improved pastures	No conflict	Low
	7p-5	Protective producer forests, conservation	No conflict	Low
	7p-7	Protective producer forests, agroforestry systems, conservation	No conflict	Low
Tall stubble	3pS-7	Agriculture with clean, semi clean and dense crops, semi forest, template climate; livestock in improved or cutting pastures	No conflict	Low
	3s-2	Agriculture with clean, semi clean and dense crops, semi forest and livestock	No conflict	Low
	3s-7	Agriculture with clean, semi clean and dense crops, semi forest and livestock in improved pastures	No conflict	Low
	6p-7	Productive forest plantations, agroforestry systems, extensive farming. Crops in semi forest and dense environments	No conflict	Low
	7p-5	Protective producer forests, conservation	No conflict	Low
	7p-7	Protective producer forests, agroforestry systems, conservation	No conflict	Low
Low stubble	3ps-7	Agriculture with clean, semi clean and dense crops, semi forest, template climate; livestock in improved or cutting pastures	Minor conflict[1]	Low
	3s-2	Agriculture with clean, semi clean and dense crops, semi forest and livestock	No conflict	Low
	3s-7	Agriculture with clean, semi clean and dense crops, semi forest and livestock in improved pastures	Minor conflict	Low
	6p-7	Productive forest plantations, agroforestry systems, extensive farming. Crops in semi forest and dense environments	No conflict	Low

Table 3 Pedological environmental zoning (continued)

Current use	Agrological class	Potential use	Type conflict	Environmental zoning
Low stubble	7p-5	Protective producer forests, conservation	Severe conflict[1]	High
	7p-7	Protective producer forests, agroforestry	Medium conflict[1]	Medium

		systems, conservation		
Dense woodland pastures	3ps-7	Agriculture with clean, semi clean and dense crops, semi forest, template climate; livestock in improved or cutting pastures	Minor conflict[2]	Low
	3s-2	Agriculture with clean, semi clean and dense crops, semi forest and livestock	No conflict	Low
	3s-7	Agriculture with clean, semi clean and dense crops, semi forest, livestock in improved pastures	Minor conflict	Low
	6p-7	Productive forest plantations, agroforestry systems, extensive livestock. Crops in semi forest and dense environments	No conflict	Low
	7p-5	Protective producer forests, conservation	Severe conflict[2]	High
	7p-7	Protective producer forests, agroforestry systems, conservation	Medium conflict	Medium
Wooded pastures Crops	3ps-7	Agriculture with clean, semi clean and dense crops, semi forest, template climate; livestock in improved or cutting pastures	Minor conflict[3]	Low
	3s-2	Agriculture with clean, semi clean and dense crops, semi forest and livestock	No conflict	Low
	3s-7	Agriculture with clean, semi clean and dense crops, semi forest and livestock in improved pastures	Minor conflict	Low
	6p-7	Productive forest plantations, agroforestry systems, extensive farming. Crops in semi forest and dense environments	No conflict	Low
	7p-5	Protective producer forests, conservation	Severe conflict[3]	High
	7p-7	Protective producer forests, agroforestry systems, conservation	Minor conflict	Low
Crops	3ps-7	Agriculture with clean, semi clean and dense crops, semi forest, template climate; livestock in improved or cutting pastures	No conflict[4]	Low

Table 4 Pedological environmental zoning (continued)

Current use	Agrological class	Potential use	Type conflict	Environmental zoning
Crops	3s-2	Agriculture with clean, semi clean and dense crops, semi forest and livestock	No conflict	Low
	3s-7	Agriculture with clean, semi clean and dense crops, semi forest and livestock in improved pastures	No conflict	Low
	6p-7	Productive forest plantations, agroforestry systems, extensive livestock. Crops in semi forest and dense environments	Minor conflict	Low
	7p-5	Protective producer forests, conservation	Severe conflict[4]	High
	7p-7	Protective producer forests, agroforestry systems, conservation	Severe conflict	High
Bamboo	3s-2	Agriculture with clean, semi clean and dense crops, semi forest and livestock	No conflict[5]	Low
	3s-7	Agriculture with clean, semi clean and dense crops, semi forest and livestock in	No conflict	Low

		improved pastures		
	6p-7	Productive forest plantations, agroforestry systems, extensive livestock. Crops in semi forest and dense environments	No conflict	Low
	7p-5	Protective producer forests, conservation	No conflict	Low
	7p-7	Protective producer forests, agroforestry systems, conservation	No conflict	Low
Constructions	3ps-7	Agriculture with clean, semi clean and dense crops, semi forest, template climate; livestock in improved or cutting pastures	No conflict[6]	Low
	3s-2	Agriculture with clean, semi clean and dense crops, semi forest and livestock	No conflict	Low
	3s-7	Agriculture with clean, semi clean and dense crops, semi forest and livestock in improved pastures	No conflict	Low
	6p-7	Productive forest plantations, agroforestry systems, extensive livestock. Crops in semi forest and dense environments	Severe conflict[6]	High
	7p-5	Protective producer forests, conservation	Severe conflict	High

Table 5 Pedological environmental zoning

Current use	Agrological class	Potential use	Type conflict	Environmental zoning
Constructions	7p-7	Protective producer forests, agroforestry systems, conservation	Severe conflict	High
Bare soil	3ps-7	Agriculture with clean, semi clean and dense crops, semi forest, template climate; livestock in improved or cutting pastures	Severe conflict	High
	3s-2	Agriculture with clean, semi clean and dense crops, semi forest and livestock	Severe conflict	High
	3s-7	Agriculture with clean, semi clean and dense crops, semi forest and livestock in improved pastures	Severe conflict	High
	6p-7	Productive forest plantations, agroforestry systems, extensive livestock. Crops in semi forest and dense environments	Severe conflict	High
	7p-5	Protective producer forests, conservation	Severe conflict	High
	7p-7	Protective producer forests, agroforestry systems, conservation	Severe conflict	High

(1) In the area of influence, zones with low stubble usually consist of pastures that have been left abandoned, because the landowner is restarting a production activity after being abandoned, or because although the land is highly productive but the landowner lack resources in order to perform periodic maintenance. Given that the area is suitable for livestock, the following potential conflicts should be considered: Minor, because there are no improved pastures; Medium, because there are tree in the pastures that are not being handled as Mostly though because there are associated with pasture trees, not handled as agroforestry systems and no protective forests have been identified; and severe, because the livestock is opposite to protected forests or protected areas.

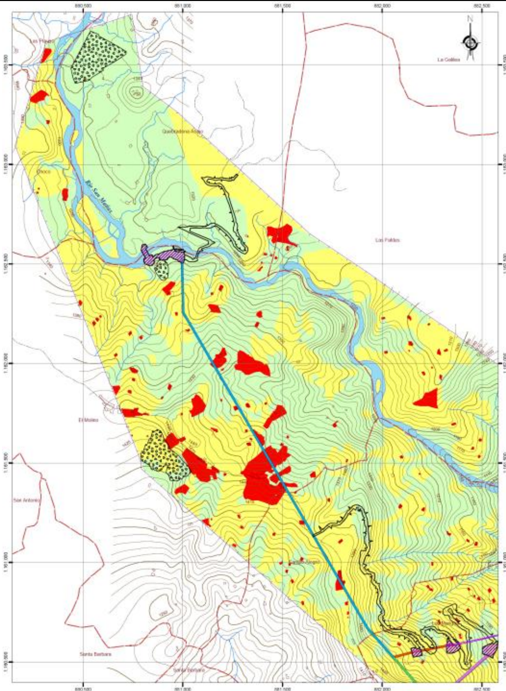
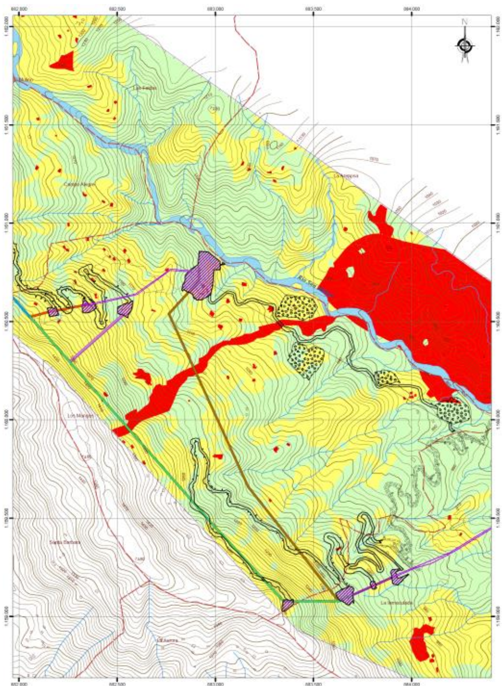
(2) For pastures, in general, minor conflict should be considered due to the lack of improved pastures; Medium to dense wooded pasture because the grass component has dominance over the tree and no conservation has been contemplated; and Severe for both dense and scarce, because producers are opposite to the recommended use for its protection.

(3) Determined as a minor conflict because in the sparse wooded pastures the tree component predominates over the grass, and thus, it should be considered as an agroforestry system. It is important to highlight that this activity has not been taken into account as a conservation practice.

(4) In the area of influence the dominant crop is the sugarcane, which is considered as a dense crop that is managed by harvesting by thinning without even cutting. Considering this feature, minor conflict should be considered for dense crops in areas that require simple practices to conserve soil resources (given the conditions of steep slopes and high susceptibility to erosion), and severe where is the potential use is for crops and not for protection.

(5) The bamboo is used locally as a protective cover

(6) For constructions a severe conflict is considered in case of steep hills that require strict restrictions of used due to susceptibility of erosion and likelihood of landslides. These areas are not suitable for housing or any other type of infrastructure. Minor conflict should be considered for areas where, although the recommended use is not construction, constraints are given by conditions like soil fertility and productivity risks.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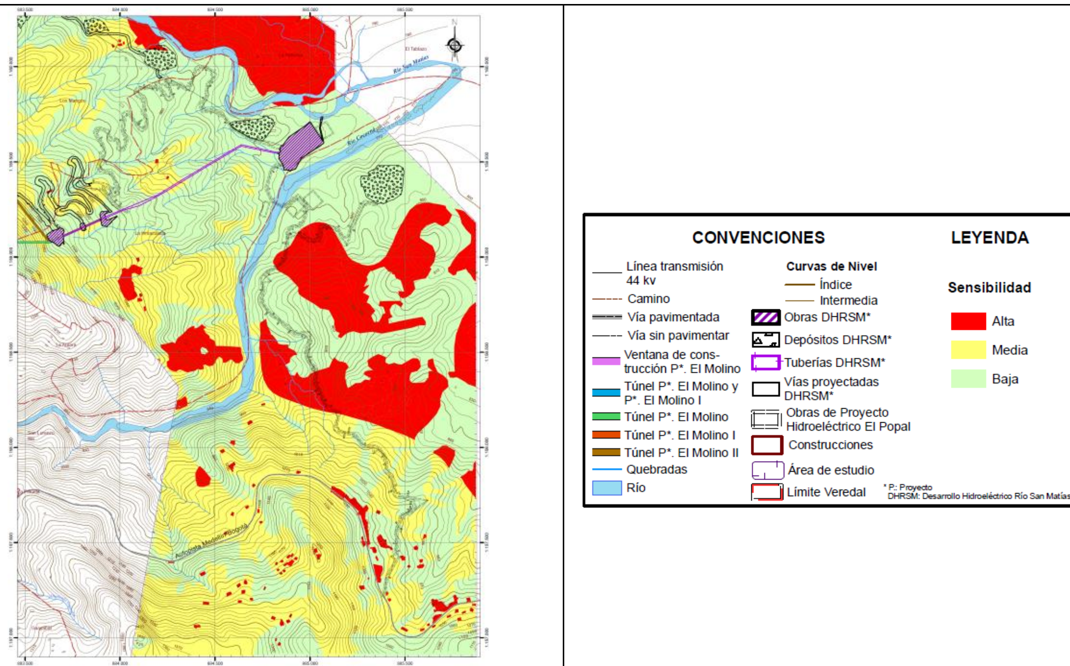

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Figure 9 Environmental soil zoning

5.4.3 Biotic Environment

Based on the opinion issued by Margales (1995), with respect to the rate of loss of vegetative cover in ecological niches and therefore the faunal diversity, biotic sensibility was determined from the types of coverage considering in the analysis their degree of structural complexity and resilience to shocks.

Bare soils and infrastructure where considered by default with a low environmental sensibility. For the remaining covers the following analysis was performed:

5.4.3.1 Structural Complexity

The structural complexity of an ecosystem refers to the development of different strata and biotopes which allows more complex food chains. For this criteria the following sensitivity ranges are established:

- **Sensibility Low.** Ecosystem with little variety of strata and environments, usually corresponds to open areas. For the area under study crops were considered in this category, because sugarcane is the main component forming a single layer: Dense woodlands and pastures are also in this category because the gramineous component predominates, the individual trees are occasional and there significant isn't variety of strata and environments.
- **Sensibility Media.** Presents combination of strata and environments in which species with different distributions and habits, which can be grouped or not in biotopes, are available.

  For the area under study the following covers are considered in this category: high stub, offering at the time of assessment, wildlife resources and contribute to the diversity of environments; wooded pastures in which the tree component predominates over the gramineous and forms strata in some sectors, and offers variety of environments; bamboo which has a vertical structure that offers environmental services related to the protection of soil and water.
- **Sensibility Alta.** Presents elements in lots of layers and biotopes, and environments with very different microclimates, allowing greater diversity of species (forest). Their structural complexity is greater than that presented by grasses and crops.

In the area under study the fragmented forests and high stub where classified under this category. The results of the field sampling show for the first cover, species typical of advanced successional forests and with some degree of conservation, such as palms (*Aiphanes aculeata*, *Euterpe precatoria*), ferns (*Cyathea cf. andina*), garrapatos (*Guatteria sp*) and majagua (*Rollinia edulis*).

In the high stub, similar to very fragmented forests, advanced successional species are found, among which are ferns (*Cyathea sp*), garrapatos (*Guatteria sp*) and several species form the Lauraceae family (*Cinnamomum triplinerve*, *Nectandra sp*, *Ocotea macropoda*), with a smaller structural development (diameters and heights) than those in the forests.

5.4.3.2 Resilience

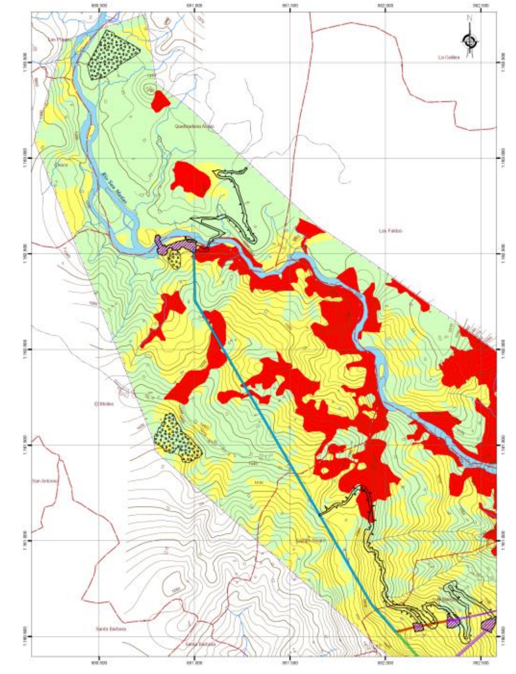
Refers to the resilience of a system, which is considered as the ability to reverse a disruptive processes and regenerate similar conditions to those that existed before the intervention, without substantially modifying the composition and diversity of species. Sensitivity ranges are defined as follows:

- **Low Sensitivity.** High recovery capacity; able to restore the existing species, but some colonizing species might arrive. Pasture, crops and bamboo are considered under this category.
- **Medium Sensitivity.** Average recovery capacity; incorporates new species, but also recovers those previously existing. Low and high stub were grouped into this category.
- **High Sensitivity.** Low recovery capacity; substantially modifies the composition and diversity of species. Forests are classified under this category.

After examining the elements for each ecosystem sensitivity was set as indicated in Table 6 and Figure 10.

Table 6 Biotic Sensitivity

Vegetative Cover	Vulnerability due to Structural complexity	Vulnerability due to Resilience	Sensibility
Very fragmented forest	High	High	High
High stub	High	Medium	High
Low stub	Medium	Medium	Medium
Crops	Low	Low	Low
Bamboo	Medium	Low	Medium
Dense wooded pastures	Low	Low	Low
Wooded pastures	Medium	Low	Medium



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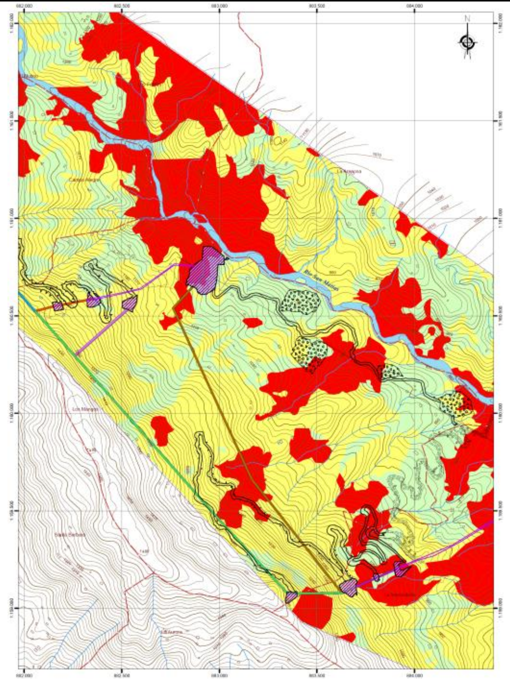

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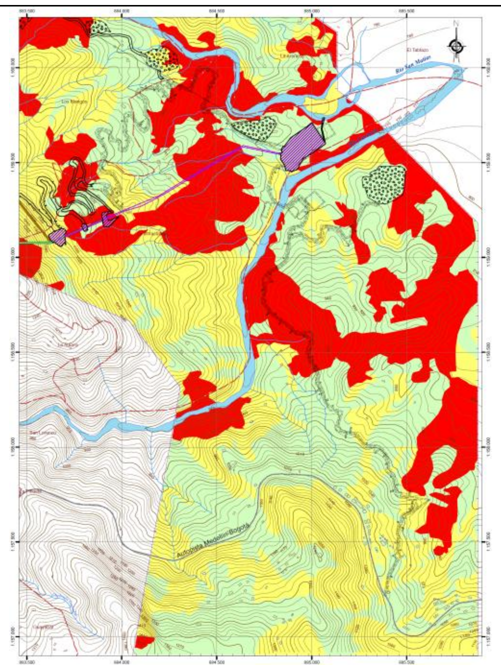

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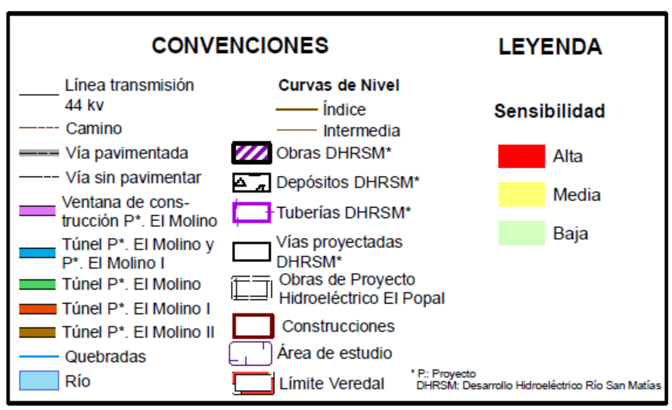


CONVENCIONES
Línea transmisión 44 kv
Camino
Vía pavimentada
Vía sin pavimentar
Ventana de construcción P*. El Molino
Túnel P*. El Molino y P*. El Molino I
Túnel P*. El Molino
Túnel P*. El Molino I
Túnel P*. El Molino II
Quebradas
Río
Curvas de Nivel
Índice
Intermedia
Obras DHRSM*
Depósitos DHRSM*
Tuberías DHRSM*
Vías proyectadas DHRSM*
Obras de Proyecto Hidroeléctrico El Popal
Construcciones
Área de estudio
Límite Veredal
LEYENDA
Sensibilidad
Alta
Media
Baja
* P.: Proyecto
DHRSM: Desarrollo Hidroeléctrico Río San Matías

Figure 10 Environmental biosphere zoning

5.4.4 Socioeconomic Environment

For the socio-economic environment of the project Central Hidroeléctrica El Molino the following variables were defined to identify the corresponding sensitivity as high, medium or low.

5.4.4.1 Demographic Variable

For this variable the relation between the area in km^2 and the total population of each rural community in the area under study was measured. This results must be analyzed taking into account that there is no geographical data regarding the distribution of the population. Meaning that a homogeneous distribution is assumed according to the number of inhabitants per square kilometer, this ratio is then given a rating presented in Table 7 and Table 8.

Table 7 Rating for Population Density

Description	Sensibility	Rating	Rural Communities
Less than 30 people/km^2	Low	1	Los Mangos and La Inmaculada from Municipio de Cocorná. La Arenosa from Municipio de Granada.
Between 30 and 80 people/km^2	Medium	2	El Molino, Campo Alegre, San Lorenzo from Municipio de Cocorná. Quebradona Abajo and las Faldas from Municipio de Granada.
More than 80 people/km^2	High	3	Las Playas, El Chocó and San Juan from Municipio de Cocorná.

Table 8 Rating for Number of Homes

Description	Sensibility	Rating	Rural Communities
Less than 20 homes per community.	Low	1	Los Mangos, La Inmaculada, and Campo Alegre from Municipio de Cocorná. La Arenosa from Municipio de Granada
Between 20 and 40 homes per community.	Medium	2	El Molino, and El Chocó, from Municipio de Cocorná. Quebradona Abajo and las Faldas from Municipio de Granada.
More than 40 homes per community.	High	3	Las Playas, San Lorenzo and San Juan from Municipio de Cocorná.

5.4.4.2 Economic activity

The municipalities where the project will be located are purely rural and a high percentage of the population depends on agriculture. This not only defines the rurality of the area, but the importance of natural resources as a basis of subsistence for the families.

As for agriculture, the cultivation of sugarcane is the most important crop in the agricultural activity of the municipality.

Livestock serves a dual purpose and is handled extensively. Due to the topography of the area, productivity is not high because animals must make a big effort to look for food, this makes the animal fattening time exceed three years.

Fish farming is an activity that has a small role because although there are many sources of water, there are few places suitable for mounting infrastructure due to the mountainous topography that dominates the area.

The exploitation activities of the forests are mainly directed to the consumption of wood for the brown sugar mill (it is said that 2 kilos of wood are necessary by 1 produced kilo of Brown sugar) and in small-scale for the production of stakes with common wood. Other areas covered in bamboo, are exploited commercially classifying economically like protector - producer, since bamboo is extracted for construction and furniture manufacturing.

The sensitivity due to economic activity is summarized in Table 9.

Table 9 Rating of the Economic Activity

Description	Sensibility	Rating
Agriculture with low levels of technification	3	High
Double purpose livestock farming	1	Low
Fish farming -ponds	3	High
Exploitation of producer-protective forests	2	Medium
Protective forest	2	Medium
Exploitation of producer forest	1	Low
Lacking Economic Activity	1	Low

5.4.4.3 Cultural Component

With the exception of the community of San Lorenzo, because of its close relationship with the Medellin - Bogota highway, and therefore, the presence of commercial activity and services, and the proximity to the urban area of some of the other rural communities, the rural communities of the area of influence of the project El Molino can be defined as a culturally homogeneous group, their relationship with the land is represented in their agricultural calling, the presence of kindred and permanence of events and cultural practices, characteristics strengthened by the existence of other common elements such as the phenomenon of socio political conflict, which also builds identity features.

Susceptibility to this component, according to the score established with respect to cultural adaptability and cultural sensibility of the communities in the area of influence of the project, are presented in Table 10.

Table 10 Rating of the Cultural Component

Description	Sensibility	Rural Communities	Rating
Rural Communities with certain identity, but high cultural diversity caused by the origin of its inhabitants and the presence of alternative means for survival, different to agriculture, such as trade and services.	Low	San Lorenzo	1
Rural Communities with cultural homogeneity, but with sectors with diversity, due to their proximity and contact with the main community or the accessibility to tertiary roads.	Medium	San Juan, El Chocó, Las Playas, El Molino, Las Faldas, Quebradona Abajo	2
Rural Communities with culturally homogeneous people with a close relationship and strong attachment to the land, very productive traditional agricultural calling, with the presence of kindred, village and neighborhood relations.	High	Campo Alegre, Los Mangos, La Inmaculada, La Arenosa	3

5.4.4.4 Political Component

Regarding the political component, no zoning variables are set as all communities of the area of influence have a high institutional presence and are assisted by various entities, ranging from local, to national, up to international entities with a humanitarian focus. Furthermore, all the communities have the Junta de Acción Comunal as their only first level organized group and it is through this entity that all the institutional management and community events take place.

5.4.4.5 Social Sensibility

Socioeconomic sensibility is the result of combining the population density, the number of homes and the cultural component (see Table 11) criteria, according to the ranges set forth in Table 12 with economic activity, which responds to different areas within communities of the area of influence and uses the data of Table 9 and the level of vegetative cover (Figure 7), the resulting combination is presented in Table 13 and Figure 11.

Table 11 Sensibility due to demographic and cultural criteria

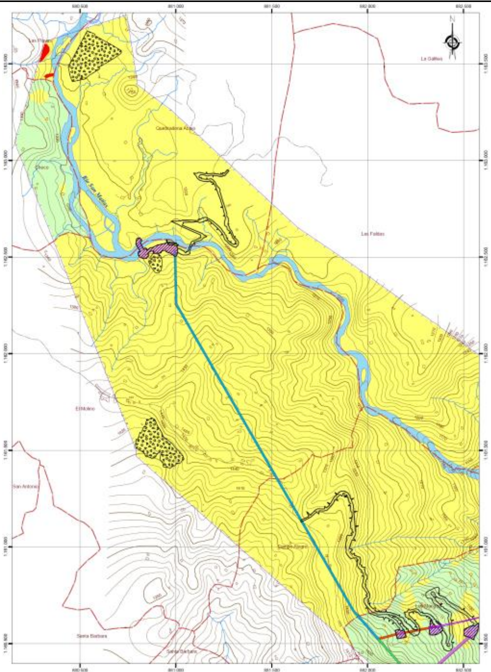
Rural Community	Density	Number of homes	Cultural Component	Total	Sensibility
San Lorenzo	2	3	1	6	Medium
San Juan	3	3	2	8	High
El Chocó	1	1	3	5	Medium
Las Playas	3	3	2	8	High
El Molino	2	2	2	6	Medium
Las Faldas	2	2	2	6	Medium
Quebradona Abajo	2	2	2	6	Medium
Campo Alegre	2	1	3	6	Medium
Los Mangos	1	1	3	5	Medium
La Inmaculada	1	1	3	5	Medium
La Arenosa	1	1	3	5	Medium

Table 12 Sensibility range for the demographic and cultural criteria

Sensibility	Rating Range
Low	1 to 3
Medium	3 to 6
High	More than 6

Table 13 Socioeconomic Sensibility

Description	Economic Activity Rating	Consolidated rating per community (demography and culture)	Socioeconomic Sensibility
Agriculture with low levels of technification	High	High	High
Double purpose livestock farming	Low	Low	Low
Exploitation of producer-protective forests	Medium	Medium	Medium
Protective forest	Medium	Low	Low
Infrastructure	High	Medium	Low
Lacking economic Activity	Low	High	Medium



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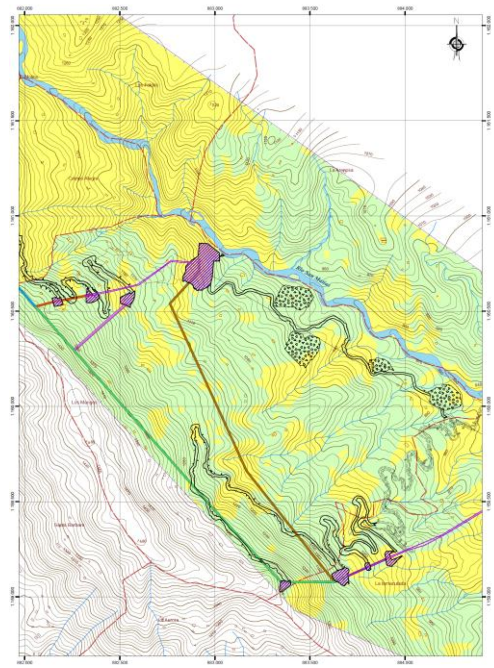

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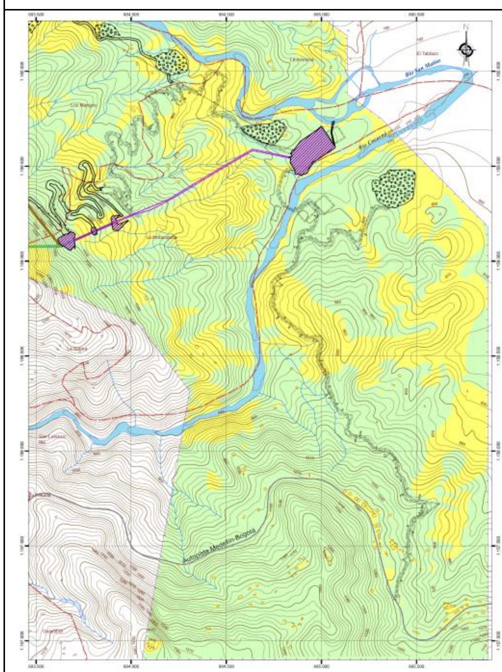

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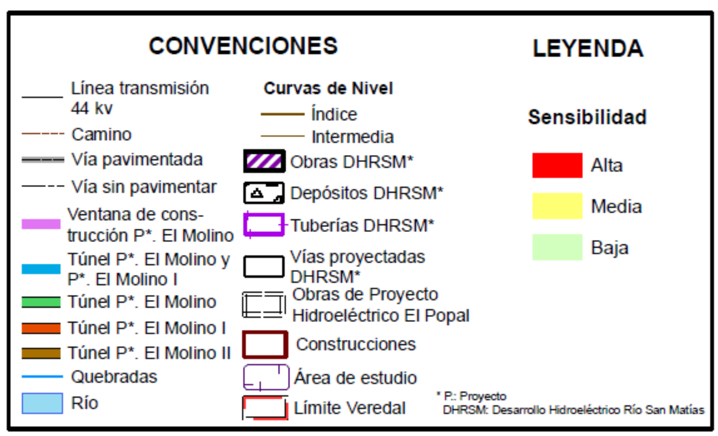


CONVENCIONES
LEYENDA
Línea transmisión 44 kv
Camino
Vía pavimentada
Vía sin pavimentar
Ventana de construcción P*. El Molino
Túnel P*. El Molino y P*. El Molino I
Túnel P*. El Molino
Túnel P*. El Molino I
Túnel P*. El Molino II
Quebradas
Río
Curvas de Nivel
Índice
Intermedia
Obras DHRSM*
Depósitos DHRSM*
Tuberías DHRSM*
Vías proyectadas DHRSM*
Obras de Proyecto Hidroeléctrico El Popal
Construcciones
Área de estudio
Límite Veredal
Sensibilidad
Alta
Media
Baja
* P.: Proyecto
DHRSM: Desarrollo Hidroeléctrico Río San Matías

Figure 11 Social Environment Zoning

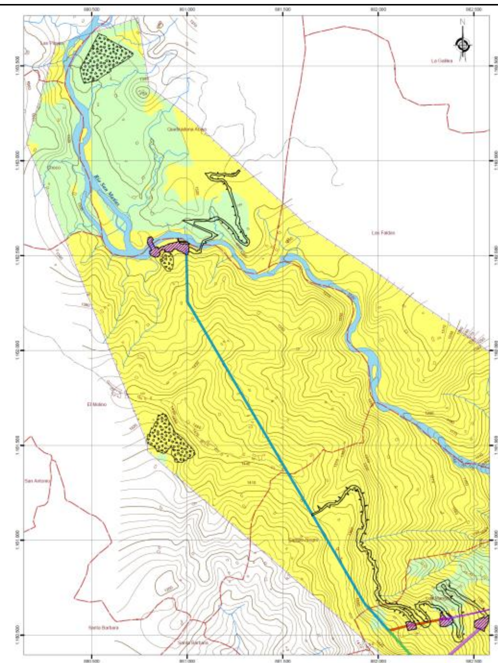
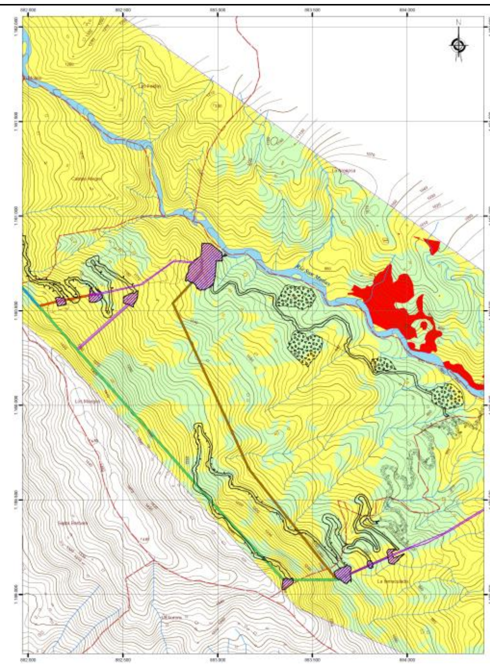
5.4.5 General Environmental Zoning

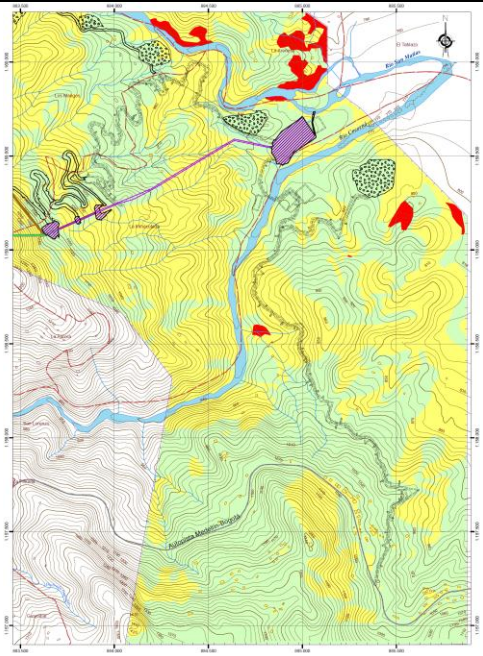
Based on the pedological, biotic and social environmental zoning and on criteria defined in Table 14, a general zoning of the area of influence of the hydroelectric project El Molino was constructed. The results are presented in Figure 12.

Table 14 Criteria for the general zoning of the area of influence

Sensibility	Weight of the Sensibilities (%)	Sensibility Values		General Sensibility[1]	
		Sensibility	Values	Value	Sensibility
Pedological	0,10	High	5	4 a 5	High
Biotic	0,45	Media	3	2,1 a 3,9	Media
Social	0,45	Low	1	1 a 2	Low

[1]: The general sensibility general is calculated as weighted average of the sensibilities.

	
A	**B**



C

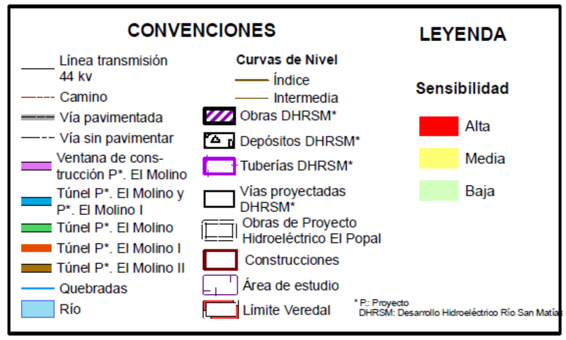


Figure 12 General Environmental Zoning

6 ENVIRONMENTAL EVALUATION

6.1 METHODOLOGY

The identification and evaluation of the impacts caused by the construction and operation of the project was developed using a double-entry matrix, where the environmental components (arranged in columns) intersect with those project activities that could potentially cause impacts (arranged in rows). If an activity can cause changes on an element of the environment, the respective box is marked using a sign "X". Project activities and environmental elements that were considered in this evaluation are presented in Table 15 and Table 16 to Table 18.

The matrix developed for the identification of the impacts generated by the project is presented in Table 19.

Once the environmental impacts are identified, a qualitative assessment will be made, for which the methodology developed by Conesa considering the parameters defined in Table 20 to Table 23 was used.

Table 15 Project Activities

Activity	Description
Preliminary Phase	
Previous Activities	Reconnaissance visits; surveying; perforations; project presentations, information and consultation process; negotiation of land for the construction.
Construction Phase	
Purchase of land	Acquisition of land for the construction of intake works, generation works, access roads and other related works.
Recruitment of labor	Selection and hiring of qualified and unqualified personnel for the construction and operation of the project.
Removal of vegetation and stripping	Cutting trees and shrubs, and removal of topsoil in areas of work.
Surface excavations	Cuts, loans and fills. Landfills for the adaptation of the work areas of the plant.
Underground excavation	Drilling, blasting and removal of materials during tunnel construction.
Excavation waste disposal	Adjustment and operation of storage sites, both temporarily and permanently, for the waste from surface and underground excavations.
Transport and haulage	Traffic of all kinds of vehicles for transportation of machinery, equipment, materials, supplies and debris within the construction area.
Operation of crushing and mixture plants	Sorting, crushing and stacking of sterile materials. Preparation of mixtures.
Pouring Concrete	Construction of plain concrete, reinforced, cyclopean and compacted.
Construction and operation of camps and workshops	Installation and operation of temporary facilities for the personnel working on the construction of the hydroelectric plant.
Operation Phase of the Project	

Plant operation	Power generation, unexpected electrical discharges due to high river flow, sediment tank operation, opening of the bottom discharge.

Table 16 Elements of the Environment

Element	Description
Air Component	
Concentration of particulate matter and gases	Air quality defined according to the existence of particulate material, CO, NO_2 and SO_2.
Sound Pressure Level	Sounds that can cause discomfort, reduction or total loss of hearing in people.

Table 17 Elements of the Environment. (Continuation)

Element	Description
Water Component	
Fluvial Dynamic	The equilibrium state of the currents depends on the geomorphology, geology, hydrology, water flow and sediment transport.
Physicochemical quality	Amount of biodegradable substances, inert suspended or carried by a stream of water.
Soil Component	
Physical and chemical properties	Physical characteristics of soil: grain size, permeability, porosity, friability and soil texture. Chemical or bacteriological properties of the soil, which may be modified by some sort of substance.
Landscape	Spatial perception between nature, topography and surface treatment, in specific places in the environment, constituting location and identity references.
Terrestrial Ecosystems Component	
Biocenosis	A group of living things that are characterized by their composition, number of species and individuals that have similar ecological requirements, through which species are related.
Biotopes	An area of uniform environmental conditions providing a living place for a specific assemblage of plants and animals.
Aquatic Ecosystems Component	
Biocenosis	A group of living things that are characterized by their composition, number of species and individuals that have similar ecological requirements, through which species are related; in this case with the bodies of water. Impaired trophic relationships.

Biotopes	An area of uniform environmental conditions providing a living place for a specific assemblage of plants and animals. Change of physiographic, hydraulic and physicochemical characteristics in bodies of water.

Table 18 Elements of the Environment. (Continuation)

Element	Description
Cultural Component	
Archaeology and cultural heritage	Value of the area for its archaeological, historical and cultural features.
Assembled Axes	Territorial models, paradigms, mythical forms, discourses that gather or cohere and allow groups or individuals to recognize themselves.
Demographic Component	
Population dynamics	Size, growth and distribution of territorial mobility as a result of economic, social, cultural and political processes that occur in an area, constituting factors that significantly determine the conditions of development of a locality and its economic, social and environmental sustainability.
Health	Health conditions regarding morbidity, mortality and endemic disease, prevention levels of risk factors, nutrition.
Spatial Component	
Social and public services	Equipment and resources for the satisfaction of basic needs (education, health, water supply, sewerage, power, telephone) in a given area.
Roads and transport	Road and road network from the point of view of their state, origin and destination points and frequency. Connections between settlements and transport type.
Economic Component	
Economic activities	Revenue generating activities.
Employment	Occupation or profession which is paid for.
Political Component	
Power Relations	Defined as the ability of some individuals or groups to influence, determine, condition, or to

	compel the behavior and thinking of other individuals or groups, a result of social interaction.
Structure of conflict	Presence of confronting forces and interests regarding adverse cohabitation phenomena.

Table 19 Impact Evaluation Matrix

Medio	Abiótico						Biótico				Social									
							Ecosistema		Ecosistema											
Componente	Aire		Agua		Suelo		Terrestres		Acuático		Cultura		Demografía		Espacial		Económico		Político	
Actividades / Elementos	Concentración de material particulado y gases	Nivel de presión sonora	Dinámica fluvial	Calidad fisicoquímica	Propiedades físicas y químicas	Paisaje	Biocenosis	Biotopos	Biocenosis	Biotopos	Arqueología y patrimonio cultural	Ejes articuladores	Dinámica poblacional	Salubridad	Servicios sociales y públicos	Vías y transporte	Actividades económicas	Empleo	Relaciones de poder	Estructura del conflicto
Etapa preliminar																				
Actividades previas											X								X	X
Etapa de construcción																				
Compra de predios											X	X	X					X	X	X
Contratación de mano de obra											X	X	X	X	X		X	X	X	X
Remoción de vegetación y descapote	X	X		X	X	X	X	X	X											
Excavaciones superficiales	X	X	X	X	X	X	X	X	X	X				X		X				
Excavaciones subterráneas		X	X						X	X										
Disposición de sobrantes de excavación	X	X		X	X	X								X		X				
Transportes y acarreos	X	X		X	X	X								X		X				
Operación de plantas de trituración y mezclas	X	X		X	X	X								X						
Vaciado de concretos	X	X		X	X	X								X		X				
Construcción y operación de campamentos y talleres				X	X	X					X	X	X	X	X		X	X	X	X
Etapa de operación del proyecto																				
Operación de la central		X	X			X			X	X	X	X	X	X	X		X	X	X	X

Table 20 Parameters for the qualitative assessment of the impacts

Criteria	Rating
Nature	Defines the direction of environmental change produced by a given action of the project. It can be positive (P, +) or negative (N, +), depending on whether it improves or degrades the current or future environment.
Extension (EX)	Refers to the theoretical influence area of impact in relation to the environment of the project (area % relative to the environment in which the impact occurs), and is evaluated according to the following discrete scale: • Punctual (1). If the impact is localized. • Partial (2). The impact occurs in fewer than 50% of the area of influence • Extensive (4). The impact occurs in more than 50% of the area of influence • Total (8). The impact does not affect a precise environment within the project location. It has a widespread impact throughout the area under study. If the impact occurs at a critical site, four (4) will be added to the zoning of

	the parameter.

Table 21 Parameters for the qualitative assessment of the impacts. (Continuation)

Criteria	Rating
Intensity (I)	Qualifies the dimension or size of environmental change caused by an activity or construction or operational process, which is expressed as follows: • Low (1). A minimal alteration is presented in the evaluated element. • Medium (4). Some of the characteristics of the element are changed completely. • High (8). The element changes its key features, but may still recover. • Total (12). Total destruction of the element
Momentum (MO)	The time between the beginning of an activity and the appearance of an impact upon an element in the environment, this time is classified in the following categories: • Long Term (1). If the impact takes more than five years to manifest. • Medium Term (2). If the impact takes between one and five years to manifest. • Short Term (4). If the impact takes less than one year to manifest. • Immediate (4). If the impact manifests as soon as the activity that causes it starts.
Duration (DU)	Evaluates the period during which the impact is active and its consequences. Is expressed in terms of duration of the impact (Fleeting, temporary or permanent): • Fleeting (1). If it lasts less than a year. • Temporary (2). If it lasts between 1 and 10 years. • Permanent (4). If it lasts more than 10 years.

Table 22 Parameters for the qualitative assessment of the impacts (Continuation)

Criteria	Rating
Reversibility (RV)	Refers to the possibility of returning the affected element to its initial state, in other words the possibility of returning to the conditions previous to the impact by natural means once the impact stops acting upon the environment. Evaluated under the following criteria and values: • Short Term (1). If the element returns to its initial conditions in less than a year. • Medium Term (2). If it takes between 1 and 10 years to recover to its initial conditions. • Long Term (4). If the recovery takes more than 10 years or is irreversible.
Synergy (SI)	This attribute contemplates the effect of two or more simple impacts acting upon the same area. The total impact of the two simple impacts provoked by two actions performed simultaneously is higher than the impacted cause when these actions are performed independently. • No synergy (1). When an action acting on a factor is not synergistic with other actions. • Synergic (2). Moderate synergism occurs, which means a bigger impact than that caused by the action. • Very synergistic (4). The action is highly synergistic, manifested in a much greater impact on the factor involved
Accumulation (AC)	When the effect is progressively increased, which is described as follows: • Simple (1). When the action does not produce cumulative impacts. • Cumulative (4). Accumulates impact.
Effect (EF)	Refers to the (direct or indirect) form of manifestation of the effect on the component, assigning the following values • Indirect (1). The impact is not a direct consequence of the action. • Direct (4). The impact is caused directly by the activity.

Table 23 Parameters for the qualitative assessment of the impacts (Continuation)

Criteria	Rating
Periodicity (PR)	Refers to the regularity with which the effect occurs, which is evaluated according to the following values • Irregular (1). The manifestation of the impact cannot be predicted. • Periodic (2). The manifestation occurs cyclically. • Continuous (4). The impact is constant since the beginning of the activity.
Recoverability (MC)	Refers to the possibility of reconstruction, total or partial, of the affected factor as a result of the project, i.e. the possibility of returning to the pre-action initial conditions, through human intervention (introduction of corrective measures). Is classified by the following ranges: • Immediate (1). Once the measure is taken, the element returns to its initial conditions • In the medium term (2). If the element returns to its initial state in less than 5 years • Mitigable (4). The initial conditions are recovered partially • Unrecoverable (8). The affected item cannot be repaired.

Based on the parameters described, the following expression calculates the "Importance of Environmental Impact"

$$IAI = \pm(3*I+2*EX+MO+DU+RV+SI+AC+EF+PR+MC)$$

Which is the expression of the interaction between the criteria that defines the environmental impact. This value varies between 13 and 100, and is classified according to the following scale:

Importance of Environmental Impact (IAI)	Variation
Irrelevant	IAI ≤ 25
Moderate	26 ≤ IAI ≤ 50
Severe	51 ≤ IAI ≤ 75
Critical	IAI ≥ 76

Each of the identified impacts are presented in the following section with the rating for each criteria used.

6.2 EVALUATION

In the following tables the summary of the qualifications of the environmental impacts caused by the construction and operation of Desarrollo Hidroeléctrico del río San Matías - El Molino is presented.

Table 24 Qualitative assessment of impacts for Alternative 1

Impacto	Extensión	Intensidad	Momento	Duración	Reversibilidad	Sinergia	Acumulación	Efecto	Periodicidad	Recuperabilidad	Calificación	Clasificación
Cambios en la calidad del aire	1,00	1,00	4,00	2,00	1,00	2,00	4,00	4,00	4,00	1,00	**27,0**	Moderada
Alteración de la dinámica fluvial	4,00	8,00	4,00	4,00	4,00	2,00	4,00	4,00	4,00	8,00	**66,0**	Severa
Cambios en la calidad y disponibilidad del agua	4,00	8,00	2,00	4,00	4,00	2,00	4,00	4,00	4,00	8,00	**64,0**	Severa
Cambios en las propiedades químicas y físicas del suelo	1,00	8,00	4,00	4,00	4,00	1,00	1,00	4,00	4,00	4,00	**52,0**	Severa
Modificación del paisaje	1,00	4,00	4,00	4,00	4,00	1,00	1,00	4,00	4,00	4,00	**40,0**	Moderada
Cambios en la cobertura vegetal	2,00	8,00	4,00	4,00	4,00	2,00	4,00	4,00	4,00	4,00	**58,0**	Severa
Pérdida o fragmentación de hábitats	4,00	8,00	4,00	4,00	4,00	2,00	4,00	4,00	4,00	4,00	**62,0**	Severa
Muerte y desplazamiento de fauna terrestre	4,00	8,00	4,00	4,00	4,00	2,00	1,00	4,00	1,00	4,00	**56,0**	Severa
Aumento de la presión sobre los recursos naturales	2,00	4,00	4,00	2,00	4,00	2,00	2,00	1,00	1,00	4,00	**36,0**	Moderada
Cambios en la comunidad íctica del río San Matías	1,00	4,00	2,00	4,00	4,00	1,00	1,00	4,00	4,00	8,00	**42,0**	Moderada
Cambios en la estructura del biotopo y biocenosis acuáticos	1,00	4,00	2,00	4,00	4,00	1,00	1,00	4,00	4,00	8,00	**42,0**	Moderada
Cambios en los niveles de gobernaiblidad	4,00	4,00	4,00	2,00	2,00	2,00	4,00	4,00	2,00	4,00	**44,0**	Moderada
Afectación del patrimonio cultural	4,00	4,00	4,00	4,00	4,00	2,00	4,00	4,00	1,00	4,00	**47,0**	Moderada
Potenciación de conflictos	8,00	1,00	4,00	2,00	2,00	4,00	4,00	4,00	2,00	4,00	**45,0**	Moderada
Desplazamiento de infraestructura y viviendas	6,00	8,00	4,00	4,00	4,00	2,00	1,00	4,00	4,00	1,00	**60,0**	Severa
Cambios en la dinámica poblacional	2,00	4,00	2,00	4,00	4,00	2,00	4,00	4,00	4,00	4,00	**44,0**	Moderada
Incremento en la demanda de bienes y servicios	2,00	4,00	4,00	2,00	2,00	2,00	4,00	4,00	4,00	2,00	**40,0**	Moderada
Cambios en el nivel de empleo	4,00	1,00	4,00	2,00	1,00	2,00	4,00	4,00	4,00	1,00	**33,0**	Moderada
Modificación de las finanzas municipales y de las corporaciones ambientales	8,00	1,00	2,00	4,00	4,00	2,00	4,00	4,00	4,00	8,00	**51,0**	Severa
Generación de expectativas	4,00	4,00	4,00	2,00	4,00	4,00	4,00	4,00	4,00	1,00	**47,0**	Moderada
Modificación de la movilidad local	4,00	4,00	4,00	4,00	4,00	2,00	4,00	4,00	4,00	8,00	**54,0**	Severa

Table 25 Qualitative assessment of impacts for Alternative 2

Impacto	Extensión	Intensidad	Momento	Duración	Reversibilidad	Sinergia	Acumulación	Efecto	Periodicidad	Recuperabilidad	Calificación	Clasificación
Cambios en la calidad del aire	1,00	1,00	4,00	2,00	1,00	2,00	4,00	4,00	4,00	1,00	**27,0**	Moderada
Alteración de la dinámica fluvial	4,00	8,00	4,00	4,00	4,00	2,00	4,00	4,00	4,00	8,00	**66,0**	Severa
Cambios en la calidad y disponibilidad del agua	4,00	8,00	2,00	4,00	4,00	2,00	4,00	4,00	4,00	8,00	**64,0**	Severa
Cambios en las propiedades químicas y físicas del suelo	1,00	8,00	4,00	4,00	4,00	1,00	1,00	4,00	4,00	4,00	**52,0**	Severa
Modificación del paisaje	1,00	4,00	4,00	4,00	4,00	1,00	1,00	4,00	4,00	4,00	**40,0**	Moderada
Cambios en la cobertura vegetal	2,00	8,00	4,00	4,00	4,00	2,00	4,00	4,00	4,00	4,00	**58,0**	Severa
Pérdida o fragmentación de hábitats	4,00	8,00	4,00	4,00	4,00	2,00	4,00	4,00	4,00	4,00	**62,0**	Severa
Muerte y desplazamiento de fauna terrestre	4,00	8,00	4,00	4,00	4,00	2,00	1,00	4,00	1,00	4,00	**56,0**	Severa
Aumento de la presión sobre los recursos naturales	2,00	4,00	4,00	2,00	4,00	2,00	2,00	1,00	1,00	4,00	**36,0**	Moderada
Cambios en la comunidad íctica del río San Matías	1,00	4,00	2,00	4,00	4,00	1,00	1,00	4,00	4,00	8,00	**42,0**	Moderada
Cambios en la estructura del biotopo y biocenosis acuáticos	1,00	4,00	2,00	4,00	4,00	1,00	1,00	4,00	4,00	8,00	**42,0**	Moderada
Cambios en los niveles de gobernaiblidad	4,00	4,00	4,00	2,00	2,00	2,00	4,00	4,00	2,00	4,00	**44,0**	Moderada
Afectación del patrimonio cultural	4,00	4,00	4,00	4,00	4,00	2,00	4,00	4,00	1,00	4,00	**47,0**	Moderada
Potenciación de conflictos	8,00	1,00	4,00	2,00	2,00	4,00	4,00	4,00	2,00	4,00	**45,0**	Moderada
Desplazamiento de infraestructura y viviendas	2,00	4,00	4,00	4,00	4,00	2,00	1,00	4,00	4,00	1,00	**40,0**	Moderada
Cambios en la dinámica poblacional	2,00	4,00	2,00	4,00	4,00	2,00	4,00	4,00	4,00	4,00	**44,0**	Moderada
Incremento en la demanda de bienes y servicios	2,00	4,00	4,00	2,00	2,00	2,00	4,00	4,00	4,00	2,00	**40,0**	Moderada
Cambios en el nivel de empleo	4,00	1,00	4,00	2,00	1,00	2,00	4,00	4,00	4,00	1,00	**33,0**	Moderada
Modificación de las finanzas municipales y de las corporaciones ambientales	8,00	1,00	2,00	4,00	4,00	2,00	4,00	4,00	4,00	8,00	**51,0**	Severa
Generación de expectativas	4,00	4,00	4,00	2,00	4,00	4,00	4,00	4,00	4,00	1,00	**47,0**	Moderada
Modificación de la movilidad local	4,00	4,00	4,00	4,00	4,00	2,00	4,00	4,00	4,00	8,00	**54,0**	Severa

There is no significant difference between the two alternatives from an environmental point of view. Some differences can be observed in the following impacts:

The only impact that differs in the rating is the displacement of infrastructure and housing, Alternative 1 received a score of Severe (60) and Alternative 2 received Moderate (44), this rating is due to the number of infrastructures that will be affected in each: 10 in Alternative 1 (three are crushers) and four in Alternative 2 (one is a crusher). This effect can be mitigated with proper management strategy.

Another impact which has a slight difference occurs in Changes in the Vegetative Cover which scored a Severe in both alternatives (55); difference, although minimal, is presented in the intervening area: 36.5 in Alternative 1 and 30.4 in Alternative 2. This impact can also be compensated with a management strategy.

The above explanation also applies to those impacts in which the cause is related to the area that will involve the works such as loss or fragmentation of habitats (Severe, 62) and death and displacement of terrestrial fauna (Severe, 56).

The difference between the alternatives is not perceivable, because the area that will be modified with respect to the total area is minimal. The area of indirect influence is estimated, for the subject of vegetative covers around 1,639 ha. The percentage of area modified in Alternative 1 is 2.2% and in Alternative 2 is 1.9%, which makes a difference of 0.3% between areas.

There is also a difference in the impact to Modification of municipal finance and environmental corporation due mainly to the installed capacity in the alternatives: 42 MW in Alternative 1 and 34 MW in Alternative 2. The annual cost of the transfers is $ 745.8 million for Alternative 1 and $ 704.4 million for Alternative 2; the rating obtained, for this positive impact, by the two alternatives is Severe, but there is no difference between the rating because the budget changes in CORNARE and in the management in Cosorná and Granada are very small: 1.65% in Alternative 1 and 1.56% in Alternative 2 for CORNARE (difference between alternatives 0.09%); 1.53% in the Alternative 1 and 1.45% in Alternative 2 for Corcorná (difference 0.08%); and 2.14% in Alternative 1 and 2.02% in Alternative 2 for Granada (difference of 0.12%).

Similarly, the impact in Changes in the Level of Employment has slight differences between Alternatives, although not enough to differ their rating (Moderate, 33): Alternative 1 will generate 400 jobs, including administrative staff, skilled and unskilled, of which 230 will be from area; Alternative 2 will employ 300 people, including administrative staff, skilled and unskilled, of which 180 will be from the area. However, the jobs of Alternative 2 will last 4 months longer. In addition, this number of jobs represent a very low stake in the growth of job opportunities in the area of influence of the project: 1.25% for Alternative 1 and 0.62% for Alternative 2.

Another effect that presents variations, but no difference in the rating is the Changes in local mobility, based on the length of new roads to be built in each Alternative: 6.37 km in Alternative 1 and 7.54 km in Alternative 2.

7 ENVIRONMENTAL MANAGEMENT STRATEGY

Table 26 presents the Environmental Management Strategies that should be implemented to control the impacts identified in the previous chapter, and costs.

Table 26 Environmental Management Strategies and their cost

Strategy	Impacts Handled	Alternative 1	Alternative 2
Environmental Supervision Group		420.500.000	478.500.000
Environmental Management Group		543.750.000	618.750.000
Soil Management	• Changes in air quality. • Changes in the quality and availability of water. • Changes in chemical and physical properties of soil.	Costs included in the civil works	
Water Management	• Changes in the quality and availability of water. • Generation of expectations	150.000.000	150.000.000
Air Management	• Changes in the quality and availability of water. • Generation of expectations	43.500.000	49.500.000
Removal of vegetation and stripping	• Changes in the vegetative cover. • Loss or fragmentation of habitats	16.100.000	13.340.000
Compensation for the affectation of wooded coverage	• Changes in the vegetative cover. • Loss or fragmentation of habitats. • Increased pressure on natural resources	214.200.000	92.400.000
Study of terrestrial vertebrate fauna	• Death and displacement of terrestrial fauna. • Loss or fragmentation of habitats. • Increased pressure on natural resources	369.892.871	369.892.871
Management of aquatic ecosystems	• Alteration of river dynamics • Change in the fish community of the river San Matias • Change in the structure of aquatic biotope and biocenosis	55.367.500	55.367.500
Information and community participation	• Generation of expectations • Changes in the level of employment • Changes in local mobility • Alteration of the cultural heritage • Increase in the demand for goods and services. • Changes in the population dynamics • Changes in the levels of governance • Strengthening of the conflict. • Modification of municipal finance and	30.450.000	34.650.000

Strategy	Impacts Handled	Alternative 1	Alternative 2
	environmental corporation		
Community education	• Generation of expectations • Changes in the level of employment • Alteration of the cultural heritage • Increase in the demand for goods and services. • Changes in the levels of governance • Modification of municipal finance and environmental corporation	42.534.000	48.400.000
Damage to third parties	• Alteration of the cultural heritage • Strengthening of the conflict.	Costs are included in the Environmental Management Group	
Relocation of infrastructure and housing	• Displacement of infrastructure and housing • Increase in the demand for goods and services • Changes in population dynamics • Generating expectations.	504.000.000	154.000.000
Recruitment of labor	• Generation of expectations • Changes in the level of employment • Displacement of infrastructure and housing • Increase in the demand for goods and services	27.550.000	31.350.000
Rural entrepreneurship	• Generation of expectations • Changes in the level of employment • Displacement of infrastructure and housing • Alteration of the cultural heritage	343.100.000	343.100.000
Memory and the cultural heritage	• Generation of expectations • Displacement of infrastructure and housing • Alteration of the cultural heritage • Changes in local mobility • Changes in the population dynamics	40.117.000	55.333.000
Survey, monitoring, archaeological rescue	• Generation of expectations • Alteration of the cultural heritage	18.198.200	18.198.200
Strategies to monitor		229.743.200	254.116.800
Total		3.049.002.771	2.766.898.371

Within these strategies are not considered measures for the management of the quarries, because of the loan materials will be the resultant materials from the excavation and fine materials will be bought at authorized quarry.

8 MONITORING STRATEGIES

Through the Follow up and Monitoring Strategies we wish to verify the efficiency and effectiveness of the Environmental Management Strategies, in order to adjust to the actual conditions that occur during the construction of the works. Monitoring strategies and a summary of the costs are presented in Table 27.

Table 27 Monitoring Strategies and their costs

Management Strategy	Follow up and Monitoring Strategy	Costs	
		Alternative 1	Alternative 2
Water Management	Wastewater Monitoring	41.815.200	47.788.800
	Monitoring of surface Water	41.588.000	41.588.000
	Monitoring of benthic comunities	34.300.000	34.300.000
Air Management	Emissions Monitoring	75.240.000	75.240.000
Cover Management	Habitat Monitoring	36.800.000	55.200.000
Information and community participation	Social Media Monitoring	Costs included in the Environmental Supervision	Costs included in the Environmental Supervision
Community education		Costs included in the Environmental Supervision	Costs included in the Environmental Supervision
Damage to third parties		Costs included in the Environmental Supervision	Costs included in the Environmental Supervision
Relocation of infrastructure and housing		Costs included in the Environmental Supervision	Costs included in the Environmental Supervision
Recruitment of labor		Costs included in the Environmental Supervision	Costs included in the Environmental Supervision
Rural entrepreneurship		Costs included in the Environmental Supervision	Costs included in the Environmental Supervision
Memory and the cultural heritage		Costs included in the Environmental Supervision	Costs included in the Environmental Supervision

Management Strategy	Follow up and Monitoring Strategy	Costs	
		Alternative 1	Alternative 2
Total Cost		**229.743.200**	**254.116.800**

9 ALTERNATIVE COMPARISON

9.1 ANALISIS OF THE ALTERNATIVES

As mentioned in Chapter 6 of this report, the differences from the environmental point of view are minimal, among which the following stand out:

- The only impact that differs in the rating is the Displacement of infrastructure and housing, Alternative 1 received a score of Severe (60) and Alternative 2 received Moderate (44). This effect can be mitigated with a proper management strategy, reflected in the costs of the Management Plan.
- In the impact Changes in the vegetative cover the affected area is very similar but is larger in Alternative 1 than Alternative 2, 36.5 ha and 30.4 ha, respectively.
- In the impact Changes in local mobility both alternative present the same rating but the length of the road in Alternative 2 is greater then Alternative 1 (7,54 km versus 6,37 km).
- Modification of municipal finance and environmental corporations also obtained the same qualification for both alternatives, although Alternative 1 generates a higher income than Alternative 2: CORNARE will receive $ 372.9 million for generation in Alternative 1 and $352.2 million for Alternative 2 annually; Cocorná will receive, $ 120.4 million for Alternative 1 and $ 113.8 million for Alternative 2. In Granada, the Alternative 1 will generate $ 214.4 while the Alternative 2 will generate $ 202.5 million.
- Alternative 1 will generate more jobs than Alternative 2: 400 people, including administrative staff, skilled and unskilled, of which 230 will be from the area in Alternative 1, and 300 people, including administrative staff, skilled and unskilled, of which 180 will be from the area in Alternative 2.

From a technical point of view there aren´t any big differences between both alternatives:

- Alternative 1 has a design flow of 11 m^3/s and Alternative 2 of 9 m3/s
- The intake works will be similar.
- The length of the conduction tunnels are similar: 4.868 m tunnel for Alternative 1 and 4,587 m of the Alternative 2.
- There is a slight difference in the installed capacity of the two Alternatives: 42 MW to 34 MW for 1 and 2, respectively.

9.2 SELECTION OF AN ALTERNATIVE

According to the previous paragraph, the alternatives present different values in the technical and environmental criteria which sets them apart. Being so this valuation does not define the selection of the best alternative because one alternative might have a higher rating in one impact of the environmental criteria but might have a lower rating in another environmental criteria. The same occurs for the technical criteria.

So selecting the best alternative depends on the importance the "decision maker" gives to each of the parameters analyzed, leading to the conclusion that this a scenario of group "decision making" for a project with multiple objectives. It is a process that not only involves the action of choosing among several alternatives, but reflects the way of thinking and prioritizing of the decision maker, which in this case is a group.

Because the decider is a group, different points of view are generated concerning the project, each of its members seek to optimize the most important aspects according to their personal opinion; for example, one of them can prioritize minimizing the environmental impacts, another member might prioritize optimizing costs, which can go against the firsts member objective; for a third decision maker it may be more important to maximize the profitability of the project, and a fourth will seek to maximize the social welfare and quality of life. Depending on the value given to these objectives the best alternative will be chosen.

Consequently, the selection of the best alternative, should use techniques that help groups make decision in a way that optimizes and objectifies the criteria of the actors involved in selection of the best project.

9.2.1 Methodology of the analysis

The problem that must be solved is: a group of decision-makers, who have different interests, which are reflected in the criterion they want to optimize, are interested in choosing the best alternative available in a set of them, therefore various objectives must be analyzed.

The importance that each of the people who decide give to the criteria that will be taken into account in making the decision is called "preference structure of the decision maker", which can vary over time. So when we refer to the "best" alternative it should be understood as the most reasonable at the time of making the decision.

Because selection involves multiple objectives, there is no single solution but the best alternatives or so-called "non-dominated solutions" are generated. For example, if two goals or criteria are assumed X, Y, and are drawn in a plane, as shown in Figure 13, we find that the shaded area is the set of "non-dominated solutions", as any point in it will always have a point that dominates it, meaning a point with a greater value. For example, point A has a higher value in the X objective than point B, which has more value in the objective Y.

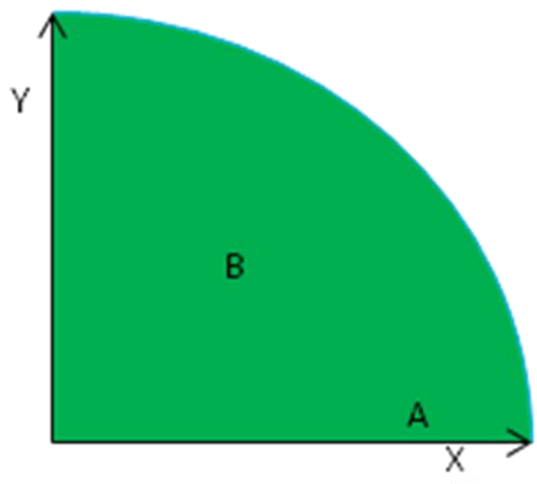


Figure 13 Non-Dominated Solutions

9.2.1.1 Methodology of the Evaluation

For evaluating the concept of utility function was used, a conversion rate of occurrence of each of the targets on a scale of determined values (Keenney and Rafia, 1976); that is, it is a mathematical formal representation in their value system of their preference structure.

To add them a multiattribute function is used, which is a rule by which the functions of each individual utility or objective criteria used for selection of Alternative are added:

$$U(G) = \sum_{i=1}^{p} k_i u_i$$, where

- u_i is the unit for the criteria i
- k_i is the weight or importance given to criteria i in the decision making, which depends on the structure of the decision maker.

For the selection of the best alternative in the hydroelectric project El Molino the following assumptions were made:

- Decision-makers are indifferent to risk, which means to find the value of each of the criteria to be used in the selection a straight line, defined by two points, is used:
    - The first point, the one with the highest utility (1), will be assigned to the higher value of the criterion.
    - The second, with the lowest utility (0) will be assigned to the lower value of the criterion.

– Because the structure of preferences of the decision maker is not known, a sensitivity analysis must be performed with different structures to see how utility varies in each of the alternatives analyzed, in order to take the "best" decision.

9.2.1.2 Evaluation criteria

The criteria with which the "best" alternative will be chosen for the hydropower plant El Molino are:

– Maximize financial returns. From the financial point of view a project can be done as long as the Internal Rate of Return (IRR) is above 10%.

  To define the utility curve of this criterion the following will be taken into account:

  - A value of 1 will be assigned to the Alternative with the highest IRR.
  - A value of 0 will be assigned to an Alternative with an IRR less than or equal to 10%.

– Minimize costs. A value of 1 will be assigned to the utility of the alternative with the lowest cost. The second point in the line will be assigned a value of 0 for the utility, for a cost equal to two times the cost of the cheapest alternative.

– Minimize negative impacts. From the mark of the environmental impacts presented in Chapter 6, the mark of negative impacts will be added and will have a zero value for the Alternative with the greatest negative impact. The second point of the curve, the greatest usefulness will have a zero value.

– Maximize the positive impacts. The utility curve is defined by the following two points: The highest utility (1) will be given to the alternative that generates the highest revenues to the municipalities and CORNARE. The lowest utility will be assigned to a project that does not generate revenue for the municipality and CORNARE.

9.2.1.3 Rating Criteria

a. Criterion, maximize the financial return

As an economic parameter for the decision of the installed capacity, the internal rate of return (IRR) of the project was calculated, varying over time the average cost of energy between 42 U.S.$ /MWh and 59 U.S.$ /MWh, according to marginal cost projections made by the Mining and Energy Planning Unit (UPME).

To calculate the IRR a financial projection of revenues and costs, which took into account the costs of energy sales like taxes and transfers for the use of water, and operating costs of administration, operation and maintenance, was made.

The average energy is estimated from the flow duration curve for the plant, considering an availability factor of 96% and typical efficiencies of the turbine and the generator.

The plant capacity factor was calculated as the ratio between the estimated mean energy and the energy that could produce the plant at full power without interruption. It is observed that the plant factor rapidly decreases as the installed capacity is increased.

Key energy and economic parameters such as the cost and IRR for each design flow of Alternative I, in the powerhouse of El Molino I and El Molino II are presented in **¡Error! No se encuentra el origen de la referencia.** and **¡Error! No se encuentra el origen de la referencia.**, respectively.

Table 28 Economic and Energy Parameters Alternative I – powerhouse El Molino I

Design Flow (m^3/s)	Effective Capacity (MW)	Average Annual Energy (GWh)	Plan Factor	Cost (´000 US$)	Unit Cost (US$/kW)	IRR
6,0	10,9	66,8	0,80	34.060	3.117	9,7%
6,5	11,9	72,3	0,78	34.962	2.950	10,0%
7,0	12,8	76,7	0,76	36.038	2.809	10,3%
7,5	13,6	81,3	0,75	36.758	2.702	10,5%
8,0	14,6	85,8	0,73	37.835	2.593	10,6%
8,5	15,5	88,9	0,71	38.716	2.494	10,8%
9,0	16,5	92,9	0,69	39.790	2.411	10,8%
9,5	17,3	96,2	0,67	40.485	2.343	10,9%
10,0	18,3	99,6	0,65	41.560	2.276	10,9%
10,5	19,2	101,8	0,63	42.423	2.211	10,8%
11,0	19,9	104,7	0,61	43.098	2.159	10,7%
11,5	20,9	105,6	0,60	44.203	2.111	8,0%
12,0	21,7	107,2	0,58	44.864	2.068	8,0%
12,5	22,7	109,5	0,57	45.938	2.026	7,9%
13,0	23,4	110,9	0,56	46.586	1.989	7,8%

Table 29 Economic and Energy Parameters Alternative I – powerhouse El Molino II

Design Flow (m^3/s)	Effective Capacity (MW)	Average Annual Energy (GWh)	Plan Factor	Cost (´000 US$)	Unit Cost (US$/kW)	IRR
6,0	10,8	76,2	0,80	26.522	2.452	12,5%
6,5	11,8	81,1	0,78	27.646	2.342	12,8%
7,0	12,7	85,4	0,77	28.514	2.239	13,1%
7,5	13,5	88,3	0,75	29.185	2.168	13,2%

Design Flow (m^3/s)	Effective Capacity (MW)	Average Annual Energy (GWh)	Plan Factor	Cost (´000 US$)	Unit Cost (US$/kW)	IRR
8,0	14,5	92,5	0,73	30.262	2.091	13,4%
8,5	15,2	94,9	0,71	30.912	2.036	13,4%
9,0	16,2	98,5	0,69	32.023	1.976	13,4%
9,5	17,2	101,7	0,68	32.878	1.916	13,5%
10,0	18,2	104,7	0,66	33.963	1.868	13,4%
10,5	18,9	104,9	0,63	34.600	1.830	13,2%
11,0	19,9	107,2	0,62	35.470	1.786	13,2%
11,5	20,7	109,0	0,60	36.340	1.759	9,9%
12,0	21,7	111,3	0,59	37.434	1.727	9,8%
12,5	22,6	113,2	0,57	38.274	1.691	9,7%
13,0	23,4	114,4	0,56	38.886	1.665	9,7%

As shown in the Tables above, one design flow area between 8.5 m3/s and 11 m3/s is presented as the optimum for take, the IRR being practically equal in this area. In order to maximize the resource and maximize energy production without changing the financial indicators, a design flow of 11 m3/s was selected for the Alternative 1 for an effective capacity of 19.9 MW and installed capacity of 21 MW.

Table 29 presents the key energy and economic parameters such as the cost and IRR for each design flow of Alternative 2.

As shown in Table 30, the design flow area occurring between 7.5 m3/s and 9 m3/s is the optimum, the IRR being practically equal in this area. In order to maximize the resource and maximize energy production without changing the financial indicators, a design flow of 9 m3/s was selected for Alternative 2 for an effective capacity of 33.3 MW and installed capacity of 34 MW.

Once you have set the power of the alternatives, the next step is to determine precisely the energy delivered to the system, for which a daily basis model of energy that takes into account the hydraulic losses; efficiencies of the turbine, generator and transformer is implemented. The demand for ancillary equipment services; losses due to the transmission line connecting the substation; minimum flow for the units to operate were also considered.

With the basic conditions of the model the results of energy power and energy were calculated and presented in Table 30.

Table 30 Economic and Energy Parameters Alternative 2

Design Flow (m³/s)	Effective Capacity (MW)	Average Annual Energy (GWh)	Plan Factor	Cost (´000 US$)	Unit Cost (US$/kW)	IRR
6,0	21,9	155,6	0,81	59.898	2.736	8,9%
6,5	23,9	165,4	0,79	62.181	2.607	9,1%
7,0	25,8	174,5	0,77	64.512	2.498	9,2%
7,5	27,8	183,0	0,75	66.926	2.407	9,2%
8,0	29,3	188,7	0,73	68.517	2.336	9,3%
8,5	31,3	196,1	0,71	70.985	2.265	9,3%
9,0	33,3	202,9	0,69	73.453	2.203	9,2%
9,5	35,4	209,4	0,68	75.954	2.149	9,2%
10,0	36,9	213,3	0,66	77.596	2.103	9,1%
10,5	38,9	218,9	0,64	80.148	2.059	9,0%
11,0	40,9	223,7	0,62	82.729	2.021	8,9%
11,5	42,5	226,9	0,61	84.399	1.986	8,8%
12,0	44,5	229,5	0,59	87.024	1.956	8,6%
12,5	46,0	232,0	0,58	88.705	1.927	8,5%
13,0	48,1	235,9	0,56	91.372	1.901	8,3%

Table 31 Power Parameters

Parameters	Alternative 1		Alternative 2
	El Molino I	El Molino II	El Molino
Average Flow (m³/s)	9,54	9,54	9,54
Design Flow (m³/s)	11	11	9
Gross Jump (m)	247,5	247,5	495,5
Net Jump (m)	215,7	215,7	441,1
Installed Capacity (MW)	21	21	34
Effective Capacity (MW)	19,9	19,9	33,3
Average Energy (GWh/year)	108	108	204
Plant Factor	0,62	0,62	0,70

In summary we have:

- Alternative 1 has an IRR of 11.1% (10.4% for the powerhouse El Molino I and 12% for the powerhouse El Molino II).
- Alternative 2 has an IRR of 8.7%.

b. Criteria minimize costs

The costs of each alternative are:

- Alternative 1: US$ 88.274.010.
- Alternative 2: US$ 74.358.790.

c. Criteria minimize negative impacts

To calculate this value ratings of negative impacts, obtained in Chapter 6 of this report, were added. The results are:

- Alternative 1: 867
- Alternative 2: 851

d. Criteria maximize positive impacts

To calculate the positive impacts, only the value proposed in the CORNARE budget and in the local governments for transfers of energy will be taken into account, as established in Article 45 of Law 99 of 1993.

The revenues generated by each alternative are:

- Alternative 1: $ 745.7 million annually
- Alternative 2: $ 704.8 million annually

9.2.2 Results

Based on the utility curves for each optimization criterion, defined in Section 9.2.1.2 and the values of each of them, which are summarized in Table 32, the value of each criterion is calculated and presented in Table 33.

Table 32 Value for each optimization criteria

Alternative	Financial IRR (%)	Costs (US$)	Negative Impacts	Positive Impacts (US$ million)
Alternative 1	11,1	88.274.010	867	745,7
Alternative 2	8,7	74.358.790	851	704,8

Table 33 Utility of the Criteria for Each Alternative

Alternative	Criteria

	Financial	Costs	**Negative Impacts**	**Positive Impacts**
Alternative 1	1	0,81	0	1
Alternative 2	0	1	0,01	0,95

Because the "preference structure" of the decision maker is not known, a sensitivity analysis with different weights of the criteria is performed, representing the different way of thinking of the people who will make the decision of which is the best Alternative. These weights are shown in Table 34.

Table 34 Possible weights of the preference structure

	Weight of the Criteria							
Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Financial	0.25	0.5	0.3	0.05	0.1	0.1	0.05	0.05
Costs	0.25	0.1	0.5	0.25	0.4	0.1	0.55	0.05
Negative impacts	0.25	0.2	0.1	0.6	0.4	0.3	0.05	0.3
Positive Impacts	0.25	0.2	0.1	0.1	0.1	0.5	0.35	0.6

The following aspects are analyzed under the previous preference structures:

- Within the deciding group there may be a person who believes that no criterion is more important than the others; all are equally important (Structure 1).
- For another member of the group the financial aspect might be the most important. This member would choose the alternative with a higher return (Structure 2).
- Another member might consider cost as the most important aspect of the project (Structure 3).
- There might also be members who regard environmental impacts or members who are interested in minimizing negative impacts (Structure 4) or maximizing positive impacts (Structure 6).

With the preference structures presented in Table 34 the utility of each alternative is obtained and presented in Table 35.

Table 35 Utility of each alternative for each preference structure

Structure	Alternative 1	Alternative 2
1	0,70	0,49
2	0,78	0,29
3	0,81	0,60
4	0,35	0,35
5	0,53	0,50

6	0,68	0,57
7	0,85	0,88
8	0,69	0,62

In the table above we may observe:

- Alternative 1 ranks first in seven of the eight preference structures. In one of them gets the same value as the Alternative 2 (Structure 4), which sets the highest weight to not generate negative impacts and cost, this structure is not interested at all the financial component.
- The only structure where Alternative 2 is better than Alternative 1 is number 7, which has no regard for the financial component instead giving it the greater weight to cost and to generating positive impacts.

9.2.3 Selection of an alternative.

According to the results obtained in the previous paragraph, taking into account the results of the identification and assessment of impacts, see Chapter 6, we recommend selecting the Alternative 1 to continue with the Environmental Impact Study, for the following reasons:

- There is no difference from an environmental point of view between the two Alternatives, as mentioned in Chapter 6.
- In the multi-objective analysis we found that it always achieves the highest utility, except for the preference structure 7, where the financial criterion is not important (given a weight of 0.05). This structure is very improbable, as the owners of a project, in this case a hydroelectric plant, make an investment only if an acceptable return, in this case an IRR higher than 10% is established.
- Moreover, one might think that without the multi-objective analysis, one can choose the Alternative 1 to continue the licensing process because the Alternative 2 does not have an IRR that will attract financing agent for the project.