ANNEX 10
HYDROLOGY AND HYDROGEOLOGY REPORT

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1 INTRODUCTION

The objective of this study is to establish the baseline from a hydrological and hydrogeological perspective of the area corresponding to the Project "Electricity Transmission Lines S/S Maitenes – S/S Alfalfal and Alfalfal II Power Plant – S/S Alfalfal."

The Project is to be implemented in the Colorado Canyon, which contains the river of the same name and is located in the northeast sector of the Municipality of San José de Maipo, within Cordillera Province in the Metropolitan Region.

2 OBJECTIVES

The objectives of this study were to:

- Characterize the existing drainage network in hydrological terms.
- Identify and characterize the hydrogeological units present in the area of study and the hydraulic properties present in the Project area.
- Identify potential impacts that the construction and operation of the Project could have on this environmental component.

3 METHODOLOGY

The stages undertaken to build the hydrological and hydrogeological characterization of the Project are described below:

3.1 Stage I: Office work

To conduct the hydrological characterization of the Project, rainfall and flow rate measurements taken at representative stations in the area of study were obtained from information provided by the Directorate General of Water (DGA).

The drainage network was defined to facilitate the field inspection of the watercourses that could be affected by the planned transmission line.

To carry out the hydrogeological characterization, information was gathered about geological and stratigraphic elements, survey drilling, water levels and hydraulic properties, as well as from some studies already conducted in the Project area. Based on this information, two control points were defined: the first at the "regional" level, which corresponds to high points where a general overview of the basin could be obtained, and the second at specific positions where the hydrogeological units defined in the preliminary analysis were identified, in order to verify their characteristics in the field.

The information used at this stage corresponded to a preliminary description of the Project that was provided by AES Gener S.A., IGM Base Cartography datum PSAD56 (on a scale of 1:50,000, digital and paper) and aerial photography from Google Earth.

3.2 Stage II: Field Inspection

Different control points defined in the office work stage were visited to conduct an on-site check of the hydrogeological units previously identified. Their location was defined by UTM coordinates through the use of a Garmin GPS satellite positioning device.
In order to define the stratigraphic correlations at the regional level of the different units inspected, the field team chose points with panoramic views of the proposed transmission line. Photographs were taken to obtain adequate graphic and spatial representations. The watercourses susceptible to impacts were also visited.

The information required for Stage III: Evaluation of the Information, was also collected at this time.

3.3 Stage III: Evaluation of the Information

From the hydrological information collected, the flow rates of the waterways crossed by the Project were calculated by transposing the basins.

To define the drainage network, IGM maps E60, E67 and E68 (1:50,000 scale) were used to carry out GIS arcview software analysis. Using information collected in the field and that contained in studies conducted in the zone analyzed, and based on geological information from the Alto Maipo Hydroelectric Project and the Santiago Segment of the Geological Map (*Mapa Geológico Hoja Santiago*, at a scale of 1:250,000), the hydrogeological units associated with the Project were positively defined.

4 HYDROLOGICAL CHARACTERIZATION

The Project will be located in the Colorado River subbasin and will extend from the Maitenes S/S to the Alfalfal S/S, and from there to the future Alfalfal II Power Plant in the basin of the Colorado River, one of the main tributaries of the Maipo River.

4.1 Drainage Network

The drainage network that exists along this relatively short transmission line is dendritic, in which the tributary currents are subdivided upriver in a manner similar to the branches of a tree. The Colorado River constitutes the main watercourse, and the Alfalfal S/S will be located on its eastern bank.

The Colorado River is a second order watercourse with headwaters high on the Tupungato Volcano. Its main tributary is the Olivares River. The basin of the Colorado River has three sections:

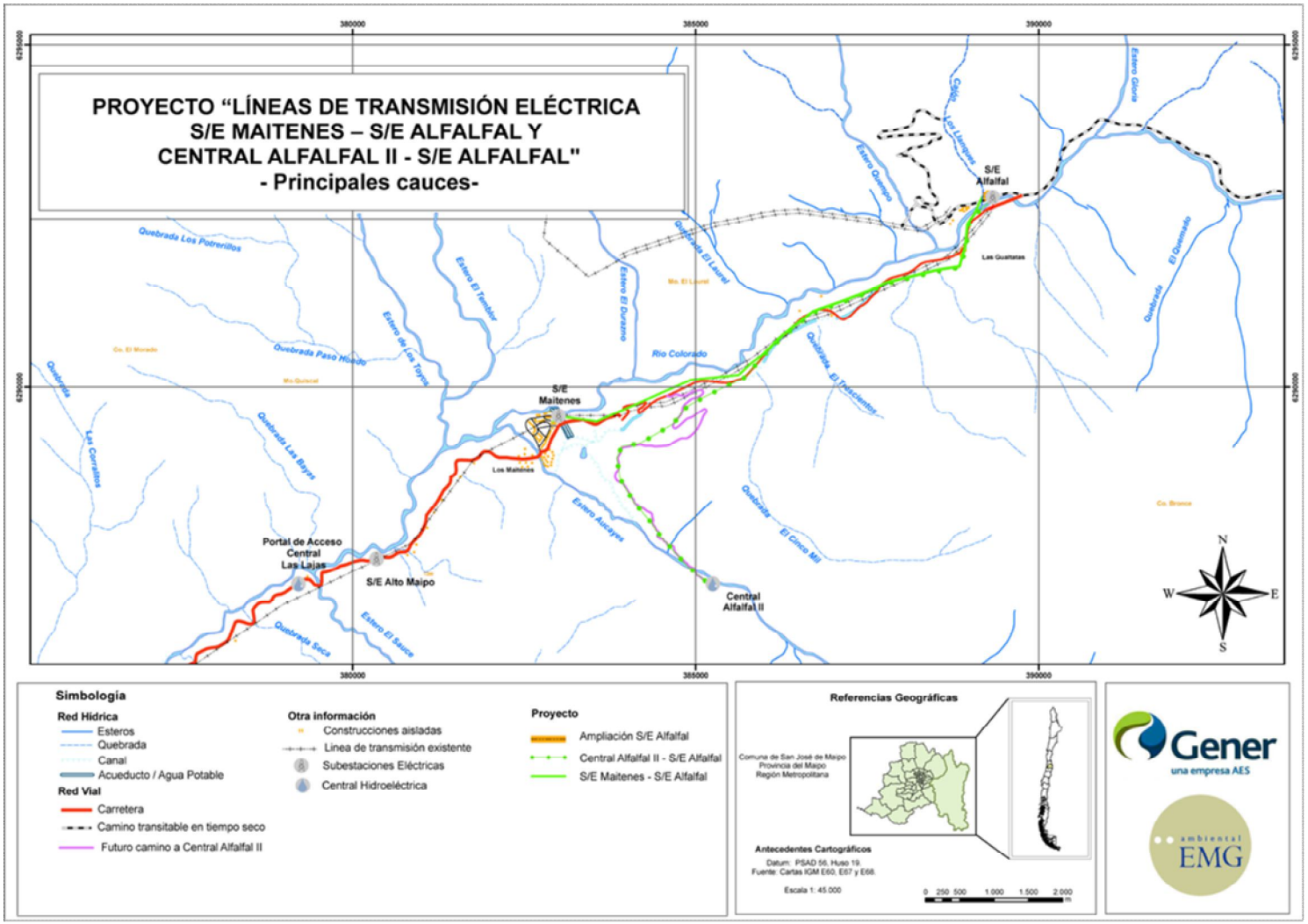
- Olivares River subbasin, with an annual mean flow rate of 10.1 m^3/s
- The Colorado River basin before its confluence with the Olivares River, with an annual mean flow rate of 25 m^3/s
- Colorado River basin before the confluence with the Maipo River, with an annual mean flow rate of 33 m^3/s.

The Colorado River displays an altered natural hydrological regime, meaning that it is regulated by human activity, in this case by the Maitenes and Alfalfal hydroelectric power plants.

The route of the transmission line runs through the lower and middle reaches of the Colorado River, a second order watercourse.

According to the information presented in Chapter 1 of the EIS, the lines cross the Colorado River once only and will not require the installation of structures in the waterway. This subbasin has an area of 507.2 km^2 and the average width of the waterway is 60 meters in this sector.

Figure 1: Principal waterways in the specific Project area



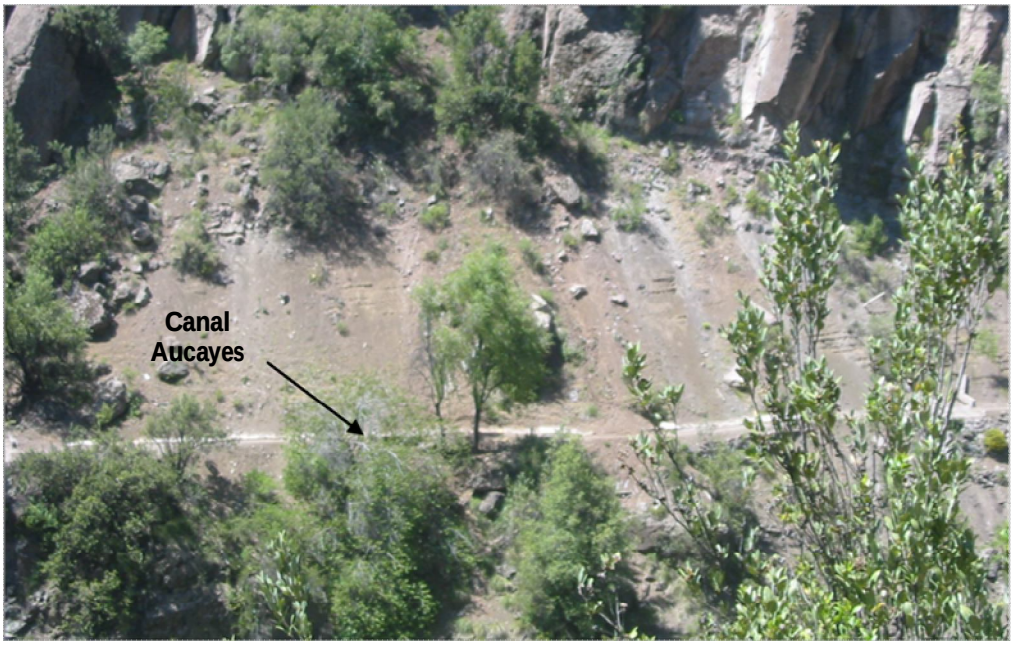
Source: Prepared by the authors based on IGM maps E60, E67 and E68, 1:50,000 scale.

- **Aucayes Stream**

This stream presents natural vegetation characteristic of the zone on the edges of the ravine but the banks are relatively free of vegetation because the year round flow is used mainly in the upper reaches for human consumption, irrigation and hydropower generation. It has an average gradient of 6%.

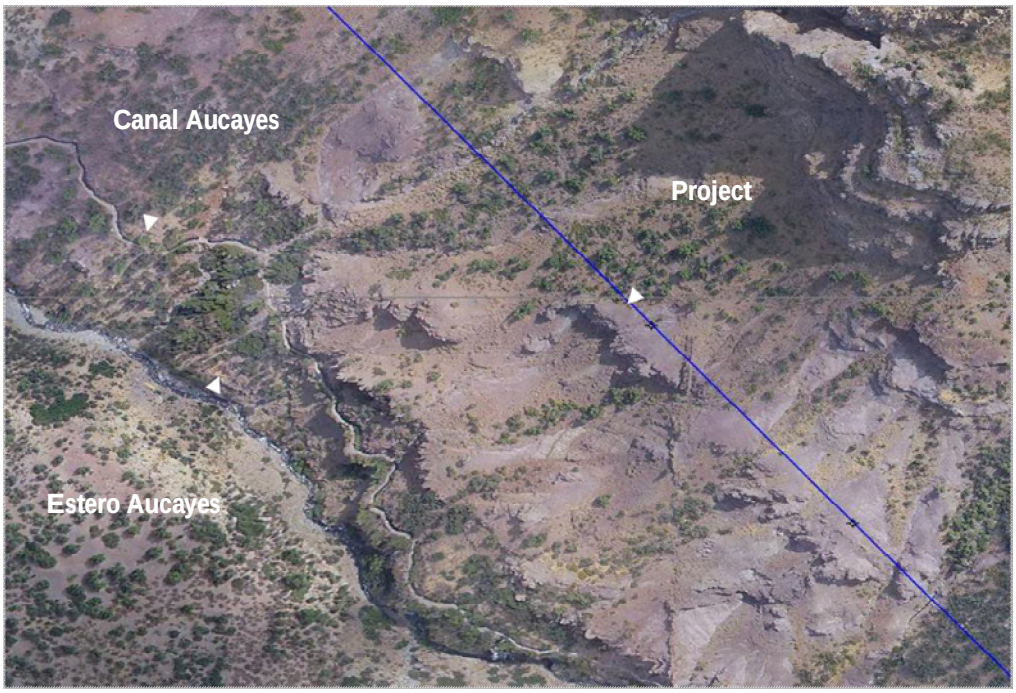
The Aucayes canal is located on the right hand bank of the stream (Figure 3).

Figure 2: Aucayes Canal



Source: Prepared by the authors.

Figure 3: Aerial view of the Aucayes canal to the right of Aucayes Stream



Source: Prepared by the authors, based on Google Earth image.

A water intake was installed on the Aucayes Stream at UTM coordinates N 6,287,477 and E 384,634, as shown in the figure below.

Figure 4: Water intake on the Aucayes Stream

Source: Prepared by the authors.

4.2 Flow Rates

The information on flow rates that was used in the characterization was obtained from the DGA, principally from the study "Assessment of Surface Water Resources in the Maipo River Basin" (Evaluación de los Recursos Hídricos Superficiales en la Cuenca del Rio Maipo, SDT Nº 145), dated May 2003. Gauging data was obtained from the National Water Bank of the DGA.

In regard to the drainage network, the characterization relied on IGM maps E60, E67 and E68 (1:50,000 scale), implemented for GIS arcview software analysis.

➢ **Colorado River**

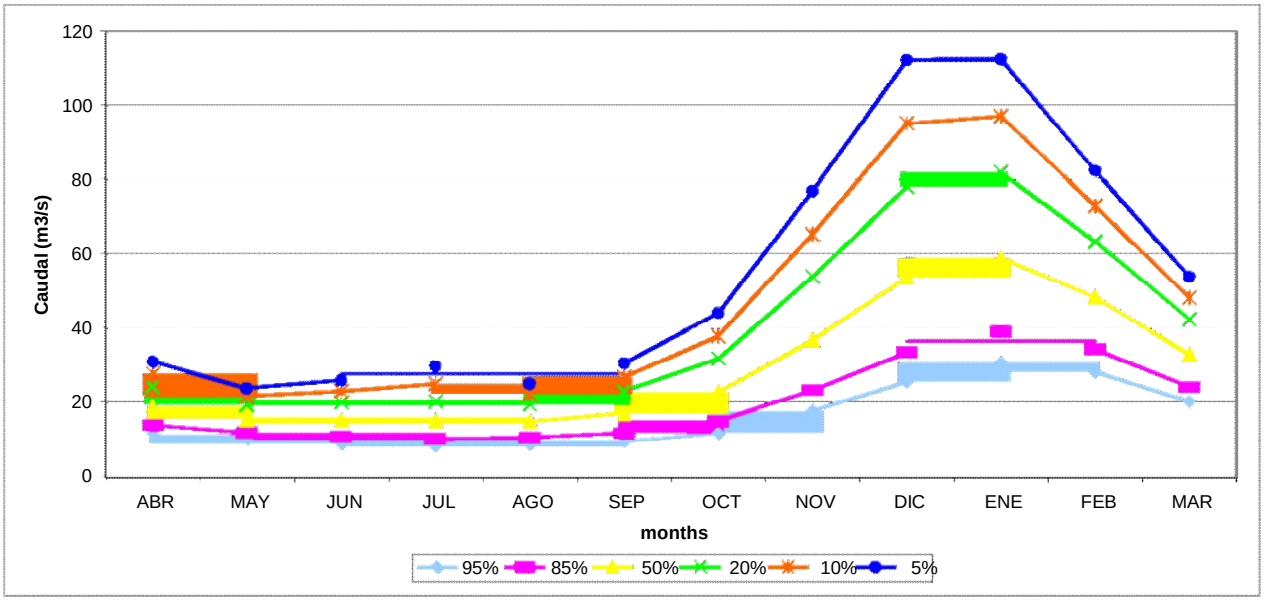
Hydrometric control of the Colorado River (distal section) is carried out at the gauging stations denominated: "Colorado River before the confluence with the Maipo River." The mean monthly flow rates for different exceedance probabilities are presented in the table below.

Table 1: Mean monthly flow rates of the Colorado River before its confluence with the Maipo River (m^3/s)

Exceedance Probability	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
95%	11.5	10.12	8.87	8.25	8.73	9.53	11.79	17.73	25.55	30.84	28.25	20.24
85%	13.84	11.87	10.82	10.27	10.62	11.83	15.04	23.26	33.59	39.17	34.42	24.26
50%	18.93	15.57	15.19	14.91	14.84	17.11	22.79	36.93	53.52	58.85	48.22	33.01
20%	24.42	19.42	20.01	20.17	19.46	23.09	31.93	53.75	78.14	81.91	63.38	42.39
10%	27.77	21.7	23.02	25.04	22.34	26.91	38.00	65.33	95.14	97.10	72.84	48.11
5%	31.13	23.97	26.03	29.92	25.21	30.74	44.06	76.90	112.13	112.29	82.30	53.82

Source: DGA.

Figure 5: Flow rates in the Colorado River basin (m^3/s)



Source: Prepared by the authors.

According to the results shown in Figure 6, it can be observed that the Colorado River has a flow regime that is strictly nival.

In summary, it can be said that the Colorado River displays a nival flow regime with a steep gradient and therefore a highly erosive power, which was a crucial aspect when choosing where to site the foundations of the transmission towers included in the Project. Therefore, the location of these supporting structures was defined to ensure they are sufficiently removed from the riverbeds. Therefore, the Project does not interfere with natural waterways (see details of the location of the tower structures in Plan 1 of Annex 1).

5 HYDROGEOLOGICAL CHARACTERIZATION

The hydrogeological units identified for the Project area correspond to a Rock Unit and a Fill Unit, each of which is briefly described below.

5.1 Rock Units

This unit displays lithological, structural, geomechanical and/or hydraulic features that make it unsuitable for the development of good aquifers. This type is represented by the Miocene Volcanic Unit (Tsf), corresponding to volcanic rock, specifically andesitic, ryolitic, and basaltic lavas and pyroclastic rocks alternating with sediment derived from the decomposition of these effusive rocks. The rocks in this unit have been dated isotopically, obtaining values ranging from 17.3 to 18.5 Ma, which allows them to be assigned to the Upper Tertiary (Miocene). They are distributed in a N-S band parallel to the Abanico Formation volcanic unit and immediately east of it, and cover a large portion of the Colorado River valley. This volcanic unit displays almost no permeability.

5.2 Fill Units

The area in which the transmission line running from the Maitenes S/S to the Alfalfal S/S will be located contains different fill units that, depending on the nature of their permeability, comprise different hydrogeological units, which are described below:

- Fluvial deposits (Qf).
- Ancient fluvial deposits (Qfa).
- Slopeside debris piles and/or alluvial fans (Qe).

5.2.1 Fluvial Deposits (Qf)

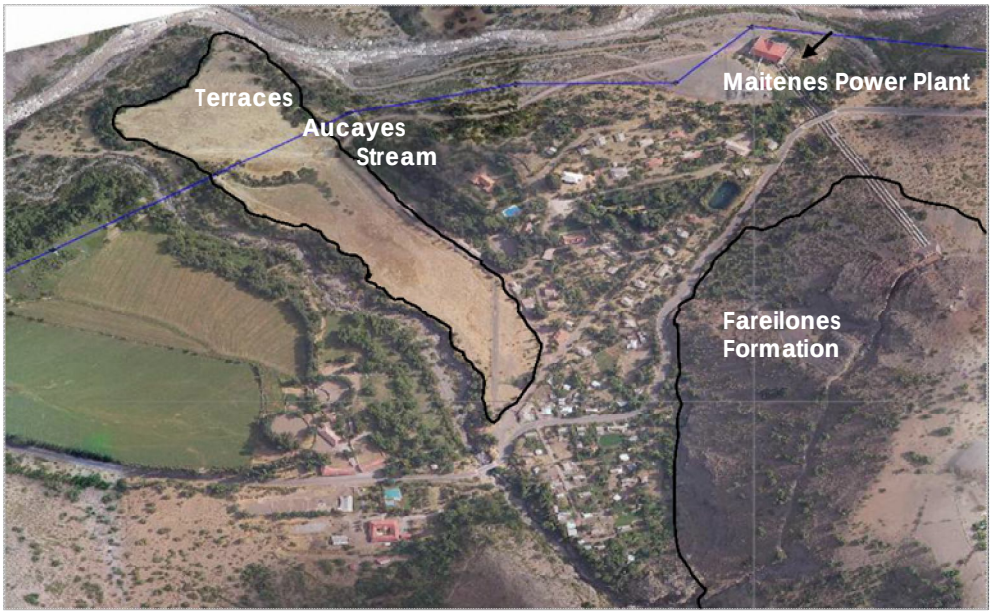
These includes clastic, coarse-grained sediments located on the edges of the present-day riverbeds of the larger rivers. They are sediments from the river channel that have been entrained and are composed mainly of well-selected gravel and sandy gravel that is virtually uncompacted. These constitute major free aquifers. The sediments of this unit display little compaction, good selection and high porosity and permeability.

5.2.2 Ancient fluvial deposits (Qfa)

These correspond to terraced deposits that adjoin the channel of a given waterway and that represent different states of the fluvial erosive cycle of that watercourse. They are very homogenous, weakly stratified polymictic deposits of rounded clasts up to 20 cm in diameter. These constitute aquifers of lesser importance. The sediments of this unit display moderate to high compaction, depending on the age of the terrace on which they are located, good selection, and low to medium permeability values.

The figures below show the terraced deposits of Aucayes Stream and the Colorado River. Figure 9 clearly shows the outcropping of volcanic deposits of the Farellones Formation, which act as a bank for the runoff of water.

Figure 6 Terraced deposits on the right bank of the Aucayes Stream, with impermeable vulcanite outcroppings of the Farellones Formation



Source: Prepared by the authors.

Figure 7 Terraced Deposits of the Aucayes Stream (Ta) and the Colorado River (Tc)

Source: Prepared by the authors.

5.2.3 Slopeside debris piles and/or alluvial fans (Qe)

The slopes of the mountains are covered with a discontinuous layer of fragmented material that has resulted from intense fragmentation and meteorization processes. Given their steep slope and permeability, these deposits favor pluvial recharge.

6 HYDRAULIC PROPERTIES

The hydraulic properties analyzed include the following, which are described further below:

- Permeability
- Static water level
- Movement of groundwater
- Well productivity

6.1 Permeability

Recent fluvial deposits display moderate to high permeability values (10^{-2} to 10^{-1}). Terraced fluvial deposits present lower levels of permeability owing to their higher degree of consolidation, mainly at upper levels.

6.2 Static Water Level

For the area of the Colorado River no information is available on water levels, but following the regional trend it is assumed that the water table is at the altitude of the river, for fluvial deposits, while on terraces it depends on the altitude of the terrace itself.

6.3 Movement of Groundwater

The movement of groundwater in recent and ancient (terraced) fluvial deposits of the Colorado River is determined by the flow lines, which are normal to the equipotential or piezometric lines. In the area of the Project they run predominantly northeast-southwest, in line with the regional surface runoff pattern.

6.4 Well Productivity

No information is available for the Project area on the construction of productive wells, and therefore a representative value will be assumed for yields on the order of 2 -3 l/s/m, based on zones with similar characteristics associated with recent fluvial deposits.

7 IDENTIFICATION AND ASSESSMENT OF IMPACTS

The works envisioned for the construction and operational phases of the Project do not generate any significant effects on this environmental component, as they don't modify the hydrological or hydrogeological characteristics existing in this sector. The following paragraphs outline the analysis that was carried out.

7.1 Construction Phase

The Project analyze herein does not envision the establishment or installation of structures in waterways or ravine beds in the area, and neither does it involve discharging water into those same watercourses.

In regard to pruning of vegetation along the buffer strip of the transmission line, this will be carried out according to forestry criteria (not cutting), which prevents:

- directly exposing the soil to the erosive effects of rainfall and its resulting washing away
- an increase in surface runoff into existing waterways

With these considerations in mind, the Project works will not have any relevant effects on the hydrological component, as they will not affect the features of the river courses or ravines present in the sector. Neither will they pollute surface or groundwater as they will not produce solid or liquid waste of any kind.

Additionally, it is important to note that the Project area contains a predominance of subsurface rock units with almost no permeability (practically impermeable). The only activities to be analyzed for the component studied herein are those related to the construction of anchored block foundations that will be 3 to 6 meters deep which, precisely because of the impermeability of the unit described, will have no impact. In the case of terraced fluvial deposits formed by the Colorado River and the Aucayes Stream, the level of groundwater is greater than 10 meters, and therefore there will be no impacts related to the hydrogeological component here, either.

7.2 Operational Phase

Given the operational nature of the Project, no interference is envisioned in the runoff of water into existing watercourses in the sector, and therefore no impacts associated with this environmental component have been identified.

8 CONCLUSIONS

The Project plan calls for towers sited at points outside of the riverbeds and sufficiently far from these, and therefore no intervention in natural waterways is expected. For this reason, the impact on surface water resources is also nil.

For recent fluvial deposits, the level of the water tables corresponds to the altitude of the rivers themselves. For terraced deposits in the Aucayes Stream ravine and the Colorado River, the water level is determined by the level of the terrace on which they are located.