CHAPTER III.

PROJECT BASE LINE

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A. PROJECT AREA DELIMITATION

Figure 3.A - 1 Development wells – Palagua Field

In 2001, the Incremental Production Contract (CPI) was signed between Ecopetrol and UT-IJP (Union Temporal-Ismocol, Joshi, and Parko). Since then, old wells have been activated and new wells have been drilled. This has allowed fulfilling the established base production and incremental production, which is the main objective of the contract.

Through the CPI contract, UT-IJP plans to drill 40 additional wells during the next two years. These wells will be drilled from the currently existing well locations.

(See: Appendix D, Map 1 - Geographic Location Development Wells and Map 2 - Slope)

A.1. LOCATION OF THE PROJECT

The Palagua – Caipal oil fields represent one of the population centers in the municipality of Puerto Boyacá. The fields are located 30 kilometers from the urban limits of the municipality of Puerto Boyacá, Department of Boyacá, in the basin of the Middle Magdalena Valley, approximately 7 kilometers east of ECOPETROL's Vasconia Station at an altitude of 137 meters above sea level. (See Figure 3.A-2).

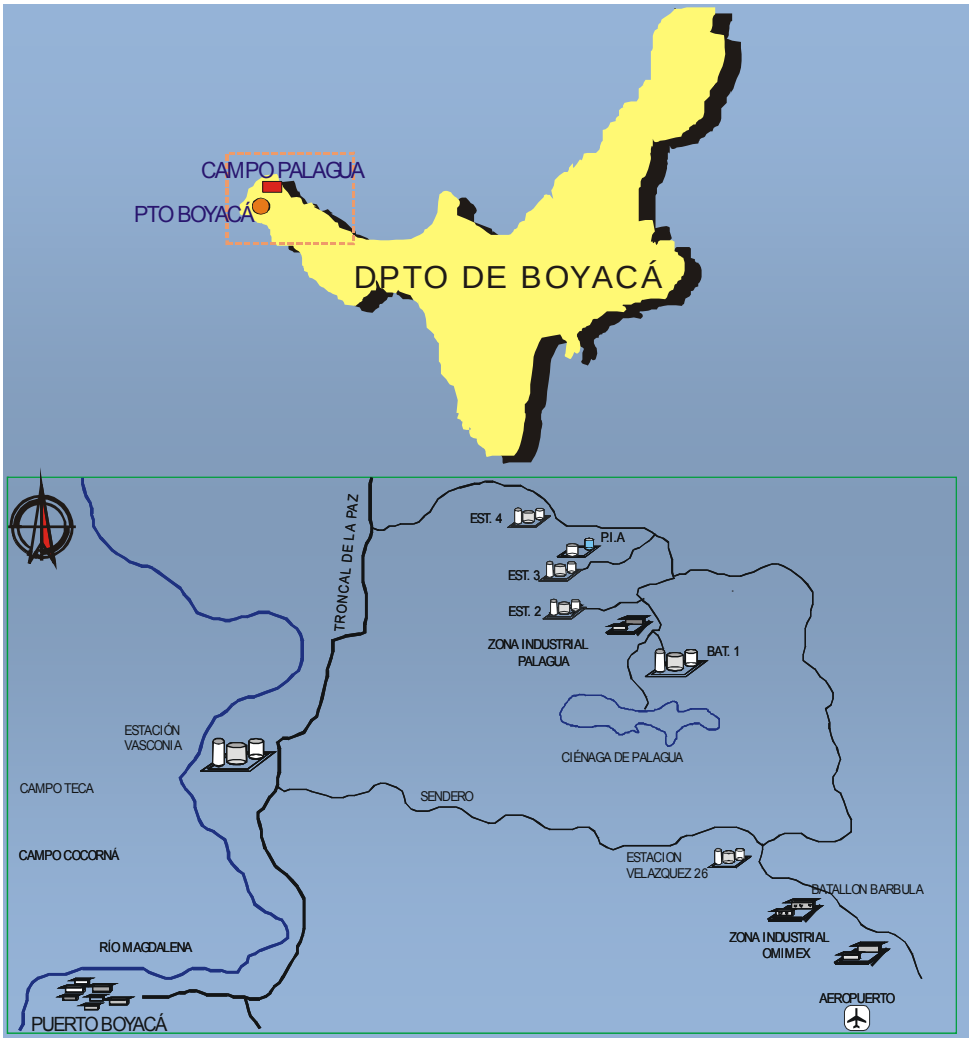


Figure 3.A-2 General Location of Palagua Field

SPANISH TO ENGLISH TRANSLATION KEY:

Top map: Campo Palagua: Palagua Field
Pto Boyacá: Puerto Boyacá
Dpto. De Boyacá: Department of Boyacá

Bottom map:

** Left hand side:*

Troncal de la Paz: Main road de la Paz
Estación Vasconia: Vasconia Station
Campo Teca: Teca Field
Campo Cocorná: Cocorná Field
Río Magdalena: Magdalena River

** Right hand side:*

Zona Industrial Palagua: Palagua Industrial Area
Est. #: Station #
PIA: Water Injection Plant
Bat. #: Battery #
Ciénaga de Palagua: Palagua Marsh
Sendero: Path
Estación Velázquez 26: Velázquez Station 26
Batallón Bárbula: Bárbula Battalion
Zona Industrial Omimex: Omimex Industrial Area
Aeropuerto: Airport

A.1.1. LOCATION OF THE WELLS TO BE DRILLED

Table 3.A-1 lists the preliminary coordinates of the 40 wells to be drilled and the existing surface locations from where they will be drilled.

Table 3.A-1 Coordinates of the new development wells

Coordinate System: Gauss-Kruger Bogota
Geographix Project: Palagua (N&E)
Data: Bogota Observatory

#	Name	Y	X	Drill Site(s)			
1	P-222	1165264	951999	P-220	P-185		
2	NWP13	1165588	952284	P-104	P-133		
3	C-15	1170095	954093	C-9			
4	C-14	1170157	953828	C-9	C-6		
5	C-17	1169778	953890	C-6			
6	NWP17	1164504	952364	P-27	P-115	P-157	
7	P-223	1163920	951544	P-175			
8	NWP39	1167136	951798	P-43	P-142	P-46	
9	NWP35	1167101	952187	P-142			
10	NWP12	1165748	952310	P-104			
11	NWP11	1165724	952485	P-133			
12	NWP41	1167084	951586	P-43	P-46	P-137	P-40
13	N017W010	1162637	952091.2	P-10	P-1		
14	N020W116	1162687	951841	P-196	P-18		
15	N021W116	1162887	952041.1	P-201	P-18		
16	N034W186	1163853	951309.1	P-206	P-140		
17	N045W155	1165336	950991.2	P-210	P-31		
18	N116W109	1167286	951840.7	P-142	P-46		
19	N143W109	1166736	950691	P-123	P-189		
20	N149W145	1167335	950586.3	P-41	P-135		
21	N153W145	1168536	950490.9	P-146	P-148		
22	N155W145	1168786	950741.2	P-148	P-113		
23	N197W155	1166037	951540.6	P-141	P-71		
24	N202W062	1164265	952123.4	P-172	P-169		
25	N203W062	1164037	952141	P-169	P-52		
26	N210W116	1162387	951890.6	P-138	P-201		
27	N211W116	1162237	951991.2	P-138	P-202		
28	N215W010	1162137	952290.7	P-139	P-138		
29	N219W155	1166137	951068.8	P-32	P-95		
30	N222W155	1165986	951091.3	P-32	P-212		
31	N233W155	1165436	951591.4	P-30	P-29		
32	N259W155	1167407	951789.8	P-142	P-46		
33	N269W116	1163428	952528.4	P-106	P-13		
34	N271WCPL	1170777	954180.6	C-9	C-14		
35	N272WCPL	1169766	953883.7	C-6	C-12		
36	N275W186	1165227	952326.4	P-82	P-157		
37	N284W155	1166474	952431.2	P-49	P-48		
38	NWP8	1166235	951760	P-53	P-34		
39	NWP31	1163077	952713	P-2	P-203		
40	NWP4	1166699	952346	P-49	P-48		

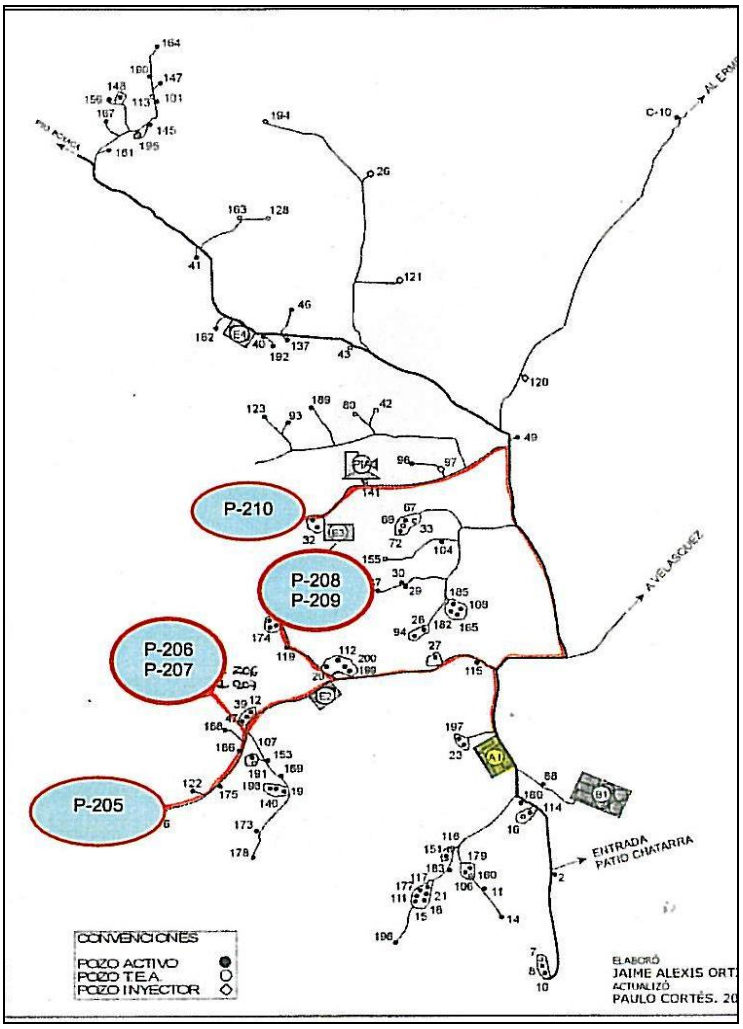
(1) Field Data gathered with GPS Garmin e map, Origin Coordinates Bogotá

The expected production for each new well is around 80 barrels of oil per day, which will increase the field oil production to 7,000 barrels per day.

A.1.2. TRANSPORTATION ROUTES

Access to well locations from the urban limits of Puerto Boyacá is through the main road, "Troncal de la Paz", heading to the North. About 3 km north of ECOPETROL's Vasconia Station, is a road (in good condition) approximately 12 km long, heading east, that takes one to the Palagua field.

The new wells will be drilled from the existing active well locations and all the locations have internal access roads. Therefore, there is no environmental effect in the areas where the new wells are to be drilled..



SPANISH TO ENGLISH TRANSLATION KEY:

Al Ermitaño	to Ermitaño
A Velasquez	to Velasquez
Desmantelada	Dismantled
Pozo Activo	Active Well
Pozo Tea	Flare Well
Pozo Inyector	Injection Well

Figure 3.A-3 Location Scheme and Mobilization Routes to the Wells

A.1.3. DESCRIPTION OF THE OPERATIONAL PROCESS

The crude oil produced by the wells comes together with water and gas in different proportions. All fluids produced are connected by flow lines to the main flow lines. Flow lines are pipelines of 4" or 6" diameter that collect the production all through the field and carry it to one of the three stations located in the Palagua Field. At each of the stations, chemicals are added to the crude oil and it is heated to break the emulsion facilitating separation by gravity of the oil, gas and water.

The separated gas is collected in gas lines. The gas is used to feed the power plant and process equipment in the Field. At the general separator, produced water is stored in gun-barrel tanks.

The crude oil from the stations is pumped to Battery No. 1 where the desalting process takes place, reducing the salt concentration in the oil to less than 20 lbs of salt per thousand barrels of crude oil. Likewise, the crude is de-watered, so that it contains less than 0.05% of water. The processed crude oil is measured in the three storage tanks and then pumped through the 7" pipelines to ECOPETROL S.A.´s Vasconia station for sale.

The produced water separated at each of the stations is collected and passes through oil-water separators to skim oil film. It is then sent to the Water Treatment Plant. Finally, the treated water is injected through the injector wells P-26, P-97, P-120 and P-121, in the formations of Tuné and Guaduas at a depth of about 4000 ft.

Station No. 2 will receive production from the new wells, and has the capacity to process the additional production.

A.2. DESCRIPTION OF THE PROJECT

The project consists of drilling forty (40) development (deviated) wells to reach areas of the oilfield that have not yet been drained by the existing wells. The drilling of the development wells of Palagua – Caipal Field requires a series of sequential activities to be performed, in order, described below:

1. Location of the well is decided based upon biotic, geologic, social and stratigraphic criteria.

2. Preparation of the Management Plan for approval of the Ministry of Environment, Housing and Land Development and the Regional Autonomous Corporation of Boyacá.

3. Improving existing roads so that the vehicles can transport the required equipment for the operation.

4. Creation and improvement of the well site to place the rig and related equipment. It should be stable enough since the equipment is quite heavy.

5. Building of perimeter channels to manage rainwater.

6. Installation of drilling equipment and waste management facilities.

7. Beginning of drilling work to a desired depth.

8. Dismantling of the drilling rig so as to continue the with completion tasks at the well.

9. Connection of the production pipelines to the existing infrastructure.

10. Removal of the mud from the well site and beginning of the recovery plan of the intervened area.

Table 3.A-2 contains the logic sequence with a short description of the activities that take place during the drilling of a development well. Figure 3.A-4 demonstrates the different stages in which the drilling project is developed.

Table 3.A-2 Activities during drilling

ACTIVITY	DESCRIPTION
Selection of the project area	• According to oilfield and geologic studies. • Low environmental impact area. • Easy execution of civil work according to topography.
Environmental Development Plan - EDP	• Submission of the document and respective management plan to the Environmental Authorities (CORPOBOYACÁ y MAVDT)
Road improvement	• Adaptation of the road to comply with technical specifications using motor graders. • Stabilization and compacting of the road using road rollers and compacters.
Location leveling	• Movement of land to re-level the soil. • Load-bearing capacity tests.
Equipment transport and installation	• Rig drilling equipment, control equipment and storage of solids, cementation equipment, electrical recording equipment, electrical generator, mud pumps, pipelines.
Drilling	• Drill to the depth where according to the design of the well the surface casing will set. • Take out the drilling pipes. • Install the surface casing. • Cementation of the surface coating. • Continue drilling to the desired depth. • Take electrical records to identify the interval of the productive formation. • During the whole drilling period the drilling cuttings are treated and dehydrated and the mud residue is treated to recover products and improve the quality of the liquid waste to be sent to the Water Injection Plant.
Equipment dismantling	• Dismantling of the equipment used in the operation. • Final disposal of the drilling cuttings. • Mud residue disposal.
Well completion	• Install the casing pipes. • Cementation of the casing. • Seat the shoe to for securing the casing. • Open by perforating the productive interval. • Install pumps. • Install pressure regulators.
Connection to existing infrastructure	• Installation of the production lines from the well to the nearest collector.

Source: UTIJP

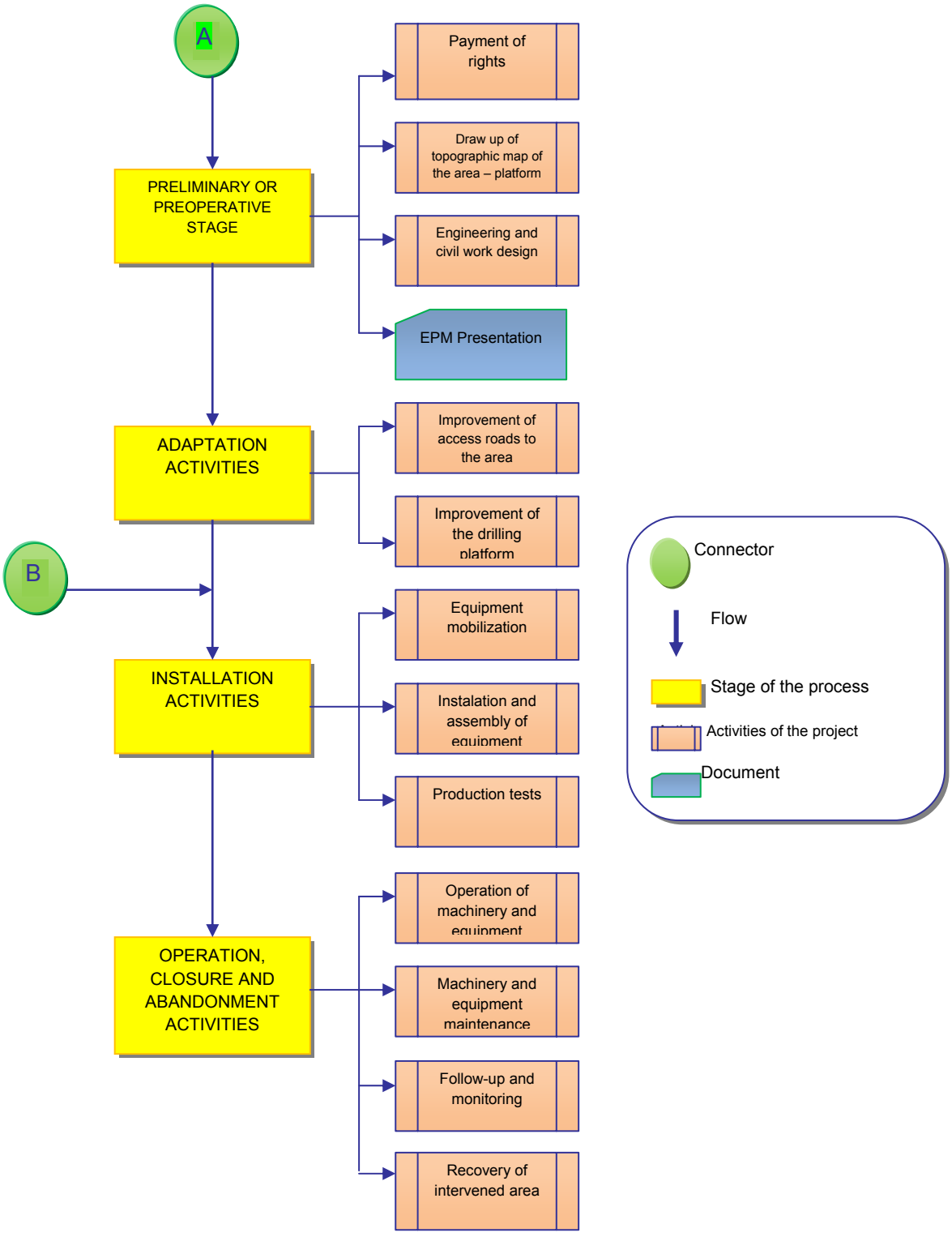


Figure 3.A-4 Stages of the execution and organization of the drilling project

A.2.1. ACCESS ROADS

The main access road to the Palagua Field from the Panamerican highway is periodically repaired using asphalt emulsion. Unpaved roads provide access to the wells and are in good condition for traffic of vehicles and the type of heavy machinery used during drilling.

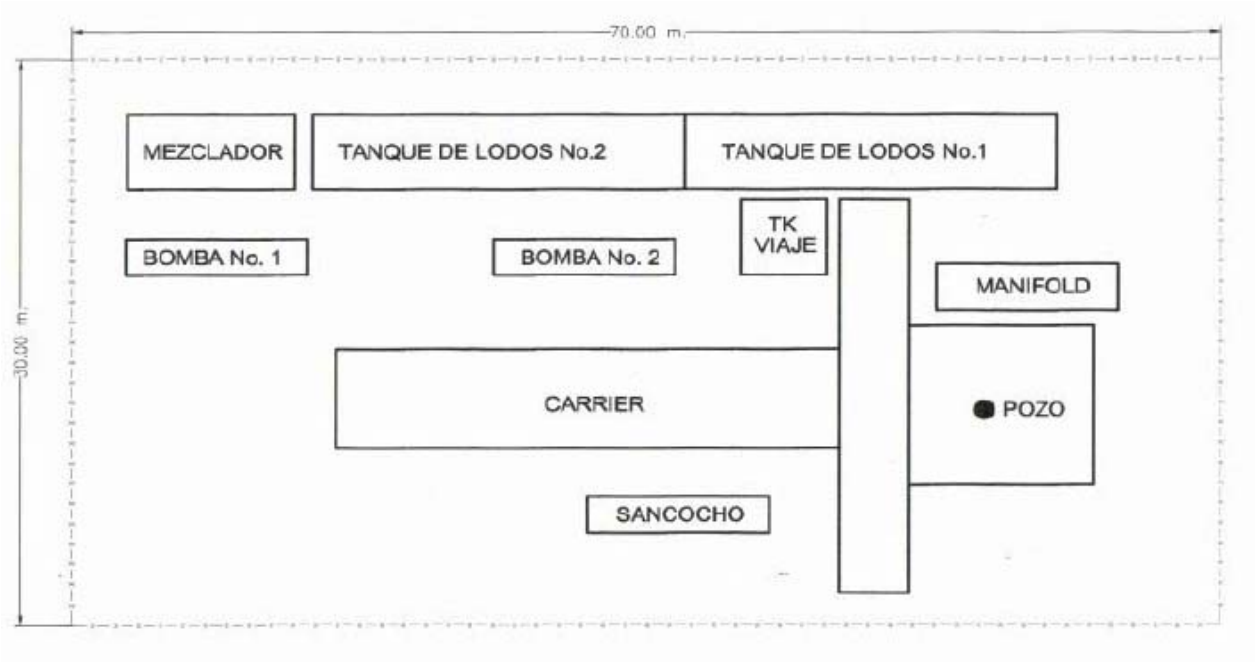
Figure 3.A-5 Access to wells in the Palagua-Caipal Field

Figure 3.A-6 Access to wells in the Palagua-Caipal Field

As noted earlier, there is no need to build new access roads for the drilling campaign since all the wells will be drilled from existing locations. It will only be necessary to perform some land-leveling works to the access roads. See Figures 3.A-5 and 3.A-6.

A.2.2. DRILLING LOCATIONS

All locations will be leveled and some civil work is required such as construction of channels to handle rainwater, stabilization of slopes, construction of grease traps, and construction of cellars and channels to handle oily water. The designs of each of the civil works depend on the condition of each location and the layout of the drilling equipment. Figure 3.A-7 shows a diagram of the distribution of the drilling equipment.



SOURCE: UT IJP

Figure 3.A-7 Placement of the drilling equipment

SPANISH TO ENGLISH TRANSLATION KEY:

- Ubicación del equipo de perforación: Placement of the drilling equipment
- Mezclador: Mixer
- Tanque de Lodos: Mud Tank
- Bomba: Pump
- TK Viaje: Trip Tank
- Pozo: Well
- Sancocho: Burner

The following equipment will be used for the improvement of the drilling locations: motor grader, back hoe, bulldozer, dump trucks, vehicles and other minor tools. No camp is required during these works because the required personnel will be from the Palagua rural area and from Puerto Boyacá.

A.2.2.1. Constructive Methods

The locations of the new wells will be prepared to offer the stability required during drilling. Other activities consist of compacting and leveling the ground.

The material extracted in the improvement at the locations, will be reused as a filler at the other locations, wherever it is needed.

The construction of concrete channels, drainages and other civil works will take place after the location is compacted and leveled.

The compacting and leveling work will be done with a vibro-compacter roller until it reaches the required compacting levels (modified proctor test minimum 95%).

Once the platform is leveled and compacted, a special, non-permeable layer of special material is installed over the drilling platform. Thus, during the drilling operation, the ground is protected from the fluids used in the operations. On the edges of the leveled ground, ditches and filters for runoff water are installed.

A.2.2.2. Temporary Facilities

Personnel lodging at the locations will be minimal. A dual purpose portable camp will be installed, i.e. for office space and lodging. Operation personnel will use hotels in Puerto Boyacá.

During the drilling activities there will be no need for special support facilities like heliports or workshops, since the work needed will be done at the Industrial Area of Palagua Field or, if needed, at specialized workshops in Puerto Boyacá.

Each of the facilities and systems required within the drilling are described below.

- **A retention area around the drill hole**. Will be built in reinforced concrete of 3000 psi. Its dimensions are 2 m x 2 m x 2 m (internal measures), with a wall thickness of 0.25 m reinforced with a double Q5 mesh.

- **Drilling rig base**. In reinforced concrete of 3000 psi and a thickness of 0.25 m reinforced with a double Q7 mesh. The drilling rig will be installed on this base.

- **Oily Water Handling System**. Around the drilling rig there will be rectangular type ditches of 0.2 m width, 0.15 m depth and a 0.25% slope, with wall thickness of 0.1 m in reinforced concrete of 3000 psi and Q4 mesh connected to the grease trap (See Figure 3.A-8)

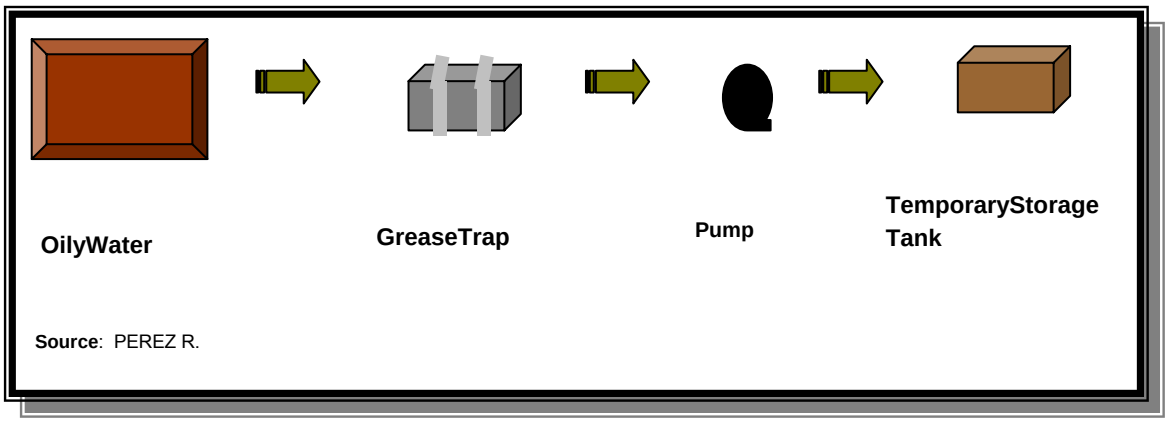


Figure 3.A-8 Flow Chart of Oily Water Handling

- **Edge Ditches for Rainwater Handling**. There are edge ditches all around the area; the ones to be built will have a trapezoid shape with 0.3 m in depth and 0.8 m top width, variable depth and a slope of 25% starting at 0.10 m. Built in concrete of 2500 psi and with a wall thickness of 0.08 m and corners reinforced with 3/8" rod. These ditches will take the water to the grease trap.

- **Treatment of drilling cuttings**. The drilling cuttings are initially passed through the dewatering system, where water is separated. Afterwards, they are taken in a sealed dump truck up to the treatment facility in the "land-farming" area in the Palagua-Caipal Field.

- **Grease trap**. This is a system to retain grease carried by industrial water. Inside it, there is a partition to retain greasy material. The effluent is sent to the water treatment tanks and later transported to the water treatment facility of Station No. 1, for disposal it the injection wells. The traps will be built in waterproof concrete of 3000 psi with double Q4 mesh and sika V-15 tape at the joints to avoid leakage. Its dimensions are 3.0 m length x 1.20 m width x 1.4 m depth.

- **Cuttings pool.** Not required. The drill cuttings will be taken to the land-farming area where they will get the treatment needed.

- **Waste Water Treatment**. The waste treatment equipment of the operation is a Red-fox system and its effluent will be taken to an 80 Bls capacity tank, and then to Battery No. 1 in the Palagua Field. Treated water could be used in irrigating roads or watering areas surrounding the locations, if the water quality is in compliance with the regulations set forth in Decree 1594/94.

- **Treatment tanks**. They are a series of portable tanks provided with shakers in which water coming from the well is collected. This water will be chemically stabilized and afterwards sent to the API in Station No. 1 at Palagua Field.

- **Fence.** There are no houses near the areas where drilling will take place. Therefore, a fence with linked mesh is not required. In some sectors a barbed wire fence will be installed to prevent livestock from entering the drilling area. This will be done with used pipes of 2 inches of diameter buried at 30 cms and at intervals of 2 meters, with 3 lines of barbed wire number 12.

A.2.2.3. Earthmoving

Earthmoving will be minimal and the moved soil will be used together with the available land-farming material for filling of slopes and conditioning of roads and placements.

A.2.2.4. Labor Force Requirements

In the construction stage, a civil engineer, a construction work supervisor, heavy machinery operators (motor grader, back hoe, bulldozer, motor graders, dump truck) and other workers will be needed. Around 20 unskilled laborers are to be hired from the Palagua rural area.

A.2.2.5. Equipment Requirements

Table 3.A-3 shows the equipment to be used during the work:

Table 3.A-3 Required Equipment to Adapt the Location and Access Roads

EQUIPMENT	QUANTITY
Back hoe	1
Bulldozer	1
Motor grader	1
6m3 dump truck	5
Motor pump	2
Vibro-compactor 10T	1
compactor FROG	2
Tank truck	1
Concrete vibrators	2
Concrete mixer sacks	2

Source: UT-IJP

A.2.2.6. Location of the final disposal place of material resulting from the drillings.

The location and road will be compacted and leveled with the removed material, i.e. cutting/filling. In the event that the removed material exceeds the material requirements of the leveling, it will then be used during the area restoration and/or to stabilize the slopes.

For the temporary storage of inert material, a place that does not pollute the soil will be developed far from water bodies (30 meters), so that they do not interfere in the natural re-vegetation and natural drainages. Also, it will be properly covered to avoid dragging of particles to the atmosphere and the draining to a body of water.

A.2.2.7. Use, Exploitation and Effect on Natural Resources

During the execution of this work, materials used are water resource, covering material and soil resource.

- **Water Resource**

Figure 3.A-9 Conduction of groundwater PW-1 – Administrative area of the Palagua Field

All the water required both for domestic and industrial use will be extracted from the groundwater well PW-1. The groundwater permit was granted by Corpoboyacá through Resolution 463 of June 8 of 2005, for a period of 5 years. It is estimated an average consumption of 0.3 liters per second.

- **Covering/filling material**

The material required for the conformation of locations will be acquired through trading companies located in Puerto Boyacá that have the environmental permit issued by the Regional Autonomous Corporation – CORPOBOYACA. The area of the old Station No. 3 will provide part of the filling material to be used.

- **Forest Resource.**

Figure 3.A-10 Forest component at the project area

The forest resource will not be affected since the drilling of new wells will be done in existing well locations.

- **Pouring.** While the construction work takes place no pouring will be generated, therefore, apouring permit will not be needed.
- **Use of River Water**. There is no need to get a permit for the use of river water, due to the fact that the needed water for the operation will be extracted in the field from well PW-1, that has an existing permit issued by CORPOBOYACA to take out 3.6 liters of water per second.

A.3. DRILLING ACTIVITIES, BASIC INFRASTRUCTURE AND EQUIPMENT

Development well drilling begins by erecting the drilling rig with all its accessories; drilling of the hole at the established depth, completing the well, and starting the production tests.

A.3.1. DRILLING EQUIPMENT

For the drilling of the development wells at Palagua-Caipal Field, conventional drilling equipment will be used.

A tri-cone bit with tungsten carbide teeth is used to break the underground rocks and to open the hole. The drilling bit is connected to the surface by a series of pipes known as drilling string, which provides the bit with energy generated at the rotary table by the engines.

The drilling string is composed of the kelly (square pipe), kelly bushings and the rotary table. The descent and ascent tasks of the drilling string are done by the winch.

To avoid collapse of the hole that has been drilled, a pipeline called "casing" is installed that protects the hole. This operation is repeated every time the drilling goes deeper, so that at the end the well is completely piped. This is a carbon steel pipe and it is supported around with concrete, between the wall of the hole and the outside of the pipe.

The following are short descriptions of the most important components of the equipment and drilling tools:

Drilling bits. Cutting or boring elements are used in drilling oil wells. Bits used in rotary drilling are roller-cone bits consisting of the cutting elements and the circulating element which permits the passage of drilling fluid. These bits use the hydraulic force of the fluid stream to drill more deeply, see Figure 3.A-11.

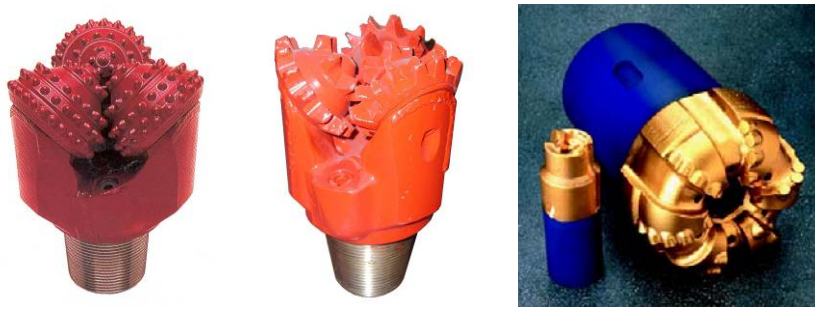
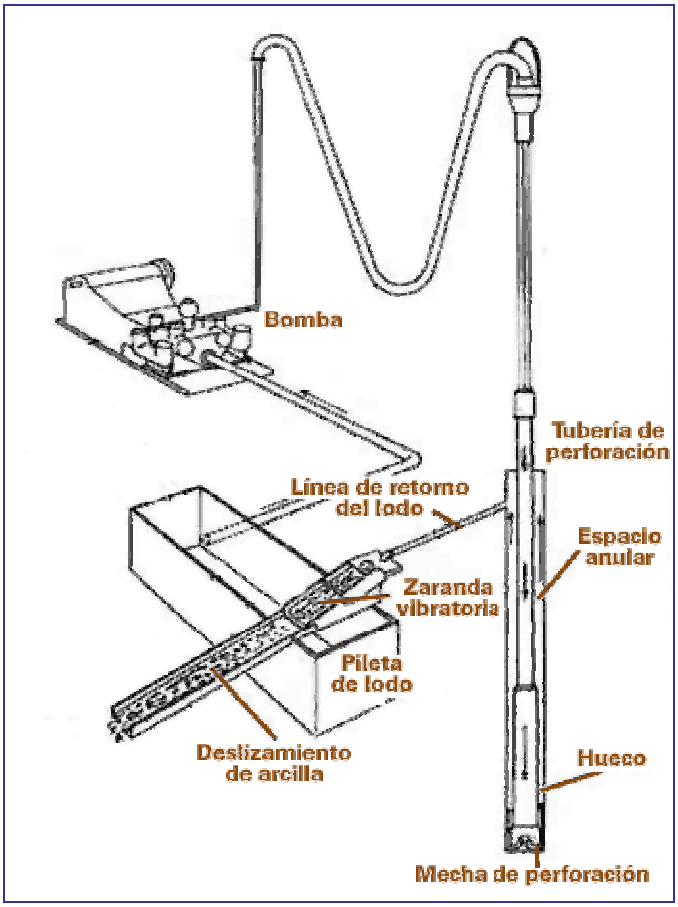


Figure 3.A-11 Types of Drilling Bits Used in Rotating Drilling

Drilling Pipe or "String": This is a column or string of drill pipe with attached tool joints that transmits fluid and rotational power from the Kelly to the drill collars and the bit. It is composed of pipes and heavy steel collars.

Winch: It is the drum in which the steel cable is rolled to allow lifting and lowering of the string according to the needs of the well.

Mud System: A set of hoses, pumps, accessories, and tanks used to circulate the drilling mud inside the drilling pipes. When the mud (drilling liquid) returns to the surface, it brings the underground cuttings that the bit has drilled. Mud also helps in lubricating the bit and in firmly supporting the walls of the well. (See Figure 3.A-12).



Source: Schlumberger Excellence Educational Development

Figure 3.A-12 Mud Cycle in Drilling

SPANISH TO ENGLISH TRANSLATION KEY:

- Bomba: Pump
- Línea de retorno del lodo: Mud return line
- Zaranda Vibratoria: Shale shaker
- Pileta de lodo: Sludge pool
- Deslizamiento de archilla: Clay sliding
- Tubería de Perforación: Drilling pipes
- Espacio anular: Anular space
- Hueco: Hole
- Mecha de perforación: Drill bit

The drilling mud is composed of fluids that are circulated in the oil and gas wells to clean the hole, to lubricate the drilling bit, and to balance the formation pressure so that the hole remains open.

The drilling mud that will be used is water based, and is recycled continuously, keeping the proper density and viscosity according to the well design.

The mud that reaches the surface passes through a series of shaking meshes (filters) known as "shale shakers", in which the liquid and solid phases of the mud are separated. The liquid fractions are pumped to the mud tanks to be reused. The solid phase is analyzed by the geologists to obtain information from each formation that has been drilled. It is then sent to the drying system (dewatering) from where it is taken to the land-farming area at the Palagua – Caipal Field.

- ***Cementation Equipment:*** This equipment injects the concrete that is used to adhere the casing to the well walls. The concrete is specially designed according to the depth and lithological composition of the well.

- ***Instrumentation:*** To monitor the progress of the drilling, the equipment has a series of accessories such as: a) Manometer, to measure the mud b) Tachometer, to measure the rotation speed of the string and the drilling bit; c) The indicator of weight on the drilling bit measures the weight that is on the bit and what part of that weight is on the steel wire that supports the string; d) Torsion indicator, to control that the torque on the pipeline; and e) The deviation indicator to show well inclination.

- ***Chemical substances and supplies:*** The mud under consideration to be used is water based, a mixture of water and clays (bentonite) with some additives such as barite and lignosulfonates that are used according to the drilling needs. These products are easily flocculated and stabilized.

A.3.1.1. General Drilling Design of the development wells

According to the prognosis of the new wells, the procedure for the drilling is as follows: Drill a hole with a 17-1/2" bit from the surface to a depth of 20 to 25 feet and install a pipe of 13-3/8" diameter to stabilize it, this pipe is called conductor pipe. Then, drill with a 12 1/4" bit to a depth of 800 feet and lower casing of 9 5/8" diameter. Afterwards drill with an 8 1/2" bit to the objective depth and lower the final production casing of 7" diameter. (See Table 3.A-4).

Table 3.A-4 General Drilling Design of the Development Wells

WELL DRILLING			
Stage	Diameter of the Hole (inches)	Diameter of the Casing (inches)	Depth (feet)
SURFACE COVERING	17 1/2	13 3/8	20
Middle covering	12 1/4	9 5/8	800
Production liner	8 1/2	7	4,600

SOURCE: PJV-IJP 2004.

A.3.1.2. Required Personnel

Two groups of personnel are needed for the drilling, one is a group that directly takes part in the drilling work, and another is a support group for certain activities related to the drilling.

Personnel from the region are classified as unskilled labor, and their selection will be coordinated by the representatives of the Community Action Council of the Rural District of Palagua, offering participation to neighbor rural towns such as Muelle Velásquez, El Chaparro and El Ermitaño. Table 3.A-5 is a list of the personnel that will work in the drilling activities.

Table 3.A-5 Required personnel during the drilling of the development wells

REQUIRED PERSONNEL			
DIRECT			
QUALIFIED	**No.**	**UNSKILLED**	**No.**
Well Manager	1	Oilfield Workers (4 per shift)	12
Well Manager Assistant	1	Cleaning Personnel	2
Geology Supervisor	1	Sample Picker (1 per shift)	3
Tool pusher	1	Security guard (1 per 12 hour shift)	3
Shift Managers (12 hour shifts)	2		
Driller	2		
Monkey Board Worker	2		
Logger	1		
Mechanical Floor Assistants	1		
Electrician	1		
Warehouseman Nurse	1		
Freight Elevator Operator	1		
Mud Engineer	1		
Environmental Auditor	1		
TEMPORARY			
Electric Record (3)	3		
Cementation Team (2)	3		
Core Pipe Operator (1)	1		
Pipeline Inspector (1).	1		

Source: UT-IJP.

A.3.1.3. Effect on Natural Resources

Considering that the wells will be drilled from the existing locations, and the fact that there will not be a cafeteria at the location, the additional impact on natural resources will be minimal.

Figure 3.A-13 Mains of drinking water for human consumption

- ***Water collection:*** Water is needed for both domestic and industrial use during the preparation of the drilling location (approximately 1.2 l/sec.). The water source is water well PW-1. The concession of underground water was set forth by Resolution 463 of June 8, 2005, and for a period of 5 years.

- ***Industrial and Domestic Liquid Waste:*** This includes run-off, domestic waters, industrial waters, and oily waste.

  - *Run-off Water.* To handle and control rainwater at the locations, there are border channels for drainage to channel water to the surrounding area without affecting the existing hydro dynamics. The rainwater that accumulates in the channels will be sent to the oil trap and then to the Waste Water Treatment System (PIA) of the Field.

  - *Domestic Water.* This results from the functioning of sanitary services and personal hygiene activities. This water will be treated at an activated Sludge aerobic treatment plant known as “Red Fox” Unit. Its effluent will be taken to a tank and from there it will be sent to the water treatment system of the Field. Occasionally, if required, the access roads will be sprinkled or irrigated. Before doing so, it will be verified if the effluent complies with all the established parameters in Decree 1594/84 and other applicable guidelines.

  - *Industrial Water.* These are liquids from mud and from the separation that takes place at the “Dewatering” unit. This water is taken to tanks where a conventional physical-

chemical treatment is used (with injection of coagulant, flocculants and clarifying chemicals). It is then stored in a sedimentation tank, from where it is taken by truck to the water injection plant in the field.

- *Oily Waste.* This is waste oil from the engines of various machinery and equipment. This is stored at the location in 55-gallon drums, and then taken to the sump of the Palagua battery for disposal. Contractors have been told to avoid doing engine maintenance at the location.

- *Waste Water Disposal:* All the domestic and industrial liquid waste will undergo primary treatment at the location to be sent afterwards to the water injection system at Battery No.1 (Station No. 1) Given the above, a surface discharge or pouring permit will not be needed for the drilling of these development wells.

- ***Domestic Solid Waste:*** This waste is composed of cartons, glass, food waste, paper and aluminum that comes from the offices, performance of personal hygiene, or food scraps. It will be classified at the source for easier handling. The domestic waste will be taken to the temporary storage place at the Industrial Area of Palagua Field to be collected afterwards by the Public Utilities Companies of Puerto Boyacá.

- ***Industrial Solid Waste:*** This includes cuttings or drilling waste at the dewatering system, the waste or remains of concrete from the cementations, scrap iron, wood, filters, unusable accessories, packaging and other materials resulting from maintenance of machinery and equipment.

  The cuttings and mud disposal collected from the location will be treated with lime for dehydration. Then it will be taken to the land-farming area for bio-remediation. Later it will be mixed with the soil available from the leveling work, and it will be used for erosion control.

  The scrap iron will be taken to the storage yard at the Palagua Battery. The contaminated soil will be sent to the bioremediation yard located next to the Water Injection Plant (PIA) in the landfarming area. The waste impregnated with hydrocarbons, will be stored at the warehouse at the Industrial Area of the Palagua Field to be sent for incineration at Holcim in Nobsa, Boyacá.

A.3.2. ARTIFICIAL LIFTING SYSTEM

Mechanical pumping units will be installed in the new wells. Four fundamental parts compose the mechanical pumping system: main engine, surface pumping unit, rods string and downhole pump. The engine provides the energy needed for the surface pumping unit; so that it can

perform the oscillatory movement that in turn is transmitted to the rods string to activate reciprocating movement at the downhole pump.

The downhole pump has two valves: one is the standing valve and the other one is the traveling valve. This last one is connected to the rods string. In the ascendant run of the string, the ball of the traveling valve seats lifting fluid above it and the valve of the standing valve floats, allowing the entry of a new fluid to the pump. Afterwards, during the descendent run of the string, the ball of the bottom valve seat as a result of the weight of the of fluid over it and prevents fluid exit from the valve, and the traveling valve floats allowing the exit of the fluid above the valve. This process repeats again as a result of the reciprocating movement of the pump, lifting the fluid from the bottom of the well to the surface.

There are three kinds of mechanical pumping units: Conventional, air balanced and special geometry. The conventional one uses a counterweight as an aid during the ascendant run and the air-balanced unit uses a pneumatic cylinder.

Figure 3.A-14 Air Balanced Pumping Unit at Palagua field

Figure 3.A-15 Conventional Pumping Unit at Palagua field

A.3.2.1. Production Tests

After completing the well and installing a pump, the connections on the surface are used to tie up the production line of the well to the existing network of flow lines, and then the well is tested. For testing the well, a tank and a separator are required to evaluate the well potential.

A.4. FLOW LINES

Figure 3.A - 16 Flow Lines with Manifold at the Palagua field

Figure 3.A - 17 Flow Lines with Manifold at the Palagua field

At the Palagua Field there are flow lines, branches and common flow lines to transport the crude oil. The flow lines are short pipelines of 2 ⅞" size that join the wellhead and the production branches, which in turn connect to the common flow lines that are connected to the gathering stations. After the primary treatment at the stations, the crude oil is sent to Battery No. 1 (Principal Battery or Station No. 1) via pipeline. All the pipelines are located along the access roads to monitor their physical conditions reducing the risk of leaks and failure.

Aditionally, parallel to the pipelines from the wells to the stations, there are flow lines, known as test lines, which transport the individual production of each well for the flow measurement.

As in all locations where proposed wells will be drilled, there are already existing production and test lines. It is only necessary to install a small 2 ⅞" flow line from the well-head to the flow lines and the test lines.

A.4.1. LOCATION OF PIPE RACKS, STORAGE OF MATERIALS AND WORKSHOPS

All the pipes, materials and accessories required to drill wells, will be temporarily stored at the gathering center of Battery No. 1 to be then taken to the drilling locations when they are needed.

A.4.2. LAND MOVEMENTS

To install the flow lines it will not be necessary to move land since flow lines are already installed on the ground surface.

A.4.3. CONSTRUCTIVE METHODS AND SUPPORT FACILITIES

All facilities and accessories for flow line installation will be done at the workshops of the Union Temporal IJP at the Palagua Field, and hence the laying of the flow lines will not require additional facilities.

A.4.4. LOCATION OF THE RUBBISH DUMPS

No rubbish dumps will be required.

A.4.5. USE, IMPACT AND MANAGEMENT OF NATURAL RESOURCES

The flow lines will be installed on the surface in areas that have been previously used and the lines will be very short, hence, there is no additional impact on the environment.

A.4.6. LABOR FORCE REQUIREMENTS

The following personnel are needed to install the flow lines:

- 1 Supervisor
- 1 API Welders
- 2 Welding helpers
- 1 Crane operator
- 2 Workers

A.4.7. PUMPING STATIONS AND TRAPS

It will not be necessary to install pumping stations, as the well head pressure is enough to transport the crude oil to Station No. 2 (Battery No. 2).

A.4.8. VALVES TO BE INSTALLED

A series of valves will be installed at the wellhead to control the flow of the well. This group of valves is commonly known as the Christmas tree.

A.5. DISMANTLING, ABANDONMENT AND RECUPERATION

The dismantling, abandonment and recovery stage is important to keep the balance between the oil production activity and the ecosystem. In this stage, the objective is to mitigate the impact of the drilling of the development well.

A.5.1. DISMANTLING

The dismantling of facilities and equipment consists of removing the portable structures used during drilling, such as: drilling rig, solids control equipment, portable tanks for mud preparation, "Dewatering" units, cementation unit, etc. Also, cement or concrete structures have to be demolished, such as: ditches and grease traps within the location. The fixed grease traps are cleaned and the drainages are emptied and sealed afterwards. In case the traps are not demolished, they are filled with excavation material. The pipes that are not removed have to be sealed to prevent the production of fluids that may affect the stability of the terrain. Additionally, all the oily waste has to be removed from the location, disposing of it at the bioremediation yards (land farming unit).

A.5.2. ABANDONMENT

The drilling project is made up of different activities, some of them are temporary (road and facilities construction, etc.) that require to be closed after the completion of the drilling activity. Production activities go on until the end of the project for productive wells. For the appropriate disposal of various environmental issues arising due to drilling of wells, one has to establish from the beginning, and keep during the execution, a restructuring and abandonment plan.

The abandonment activities include the dismantling of the pipes used in the management of waters from septic tanks, sanitary latrines or activated Sludge units (as is the case in the current project).

In the abandonment stage the affected areas have to be re-vegetated at the edges of the location. Before the reconstruction at the area takes place, the final stabilization works have to be carried out.

A.5.3. RECOVERY

The re-vegetation consists of the vegetal enrichment of the area. It is recommended to plow the terrain in order to aerate it and to help water infiltration. A layer of organic soil has to be set out in those areas that are more deteriorated or where there is a difficulty of re-vegetation.

A.5.3.1. Final Clean out

In this stage, all foreign material has to be removed from the area. Consequently, the clean out will cover all the places occupied by the facilities, as well as the other places that were used by the drilling project.

For the temporary activities like road construction and drilling installation, the final clean out will take place after the dismantling of the rig and the equipment. Also, clean-out will be done during the execution of the works along with the progress and development of the different stages and activities. A final inspection has to be done by the operator and the Environmental Inspector to confirm the final clean-up.

A.5.3.2. Recovery of Impacted Areas

The areas that have been impacted due to the drilling activities and that are not needed for the operation of the well, should undergo a recuperation process such as re-vegetation. Arboreal, bushy or herbaceous species can be selected for the recovery, depending on the vegetation cover that was removed and the characteristics of the area to be recovered. In general, during the first years for the recovery, if possible, species that grow fast should be selected, that can develop a good cover and foliage.

The recommended height to plant them depends on the species (between 50 cms to 1.5 m) and it is recommended to space out the arboreal species approximately every 10 to 15 m, place them in holes of 40 X 40 cms and should not be lower than 30 cms in height from the neck of the root.

It is recommended that the planting be done when the first rains fall, and hence the seedling can take advantage of all the humid time to adapt to their new place without dying or withering.

B. PHYSICAL GEOGRAPHY

To identify the environmental impact, it is necessary to establish the area of influence that refers to the sector that may alter the physical, biotic and socioeconomic surroundings, as a result of the **DEVELOPMENT WELL DRILLING IN THE PALAGUA-CAIPAL FIELD** (located in the municipality of Puerto Boyacá, Department of Boyacá). Hence, the area of influence was defined as the area that will have impact on its environment and social environment.

For the purpose of environmental impact, two main areas of influence were determined, one indirect (IAI) and one direct (DAI).

- Indirect Area of Influence (IAI)

According to the environmental requirements, the Indirect Area of Influence, IAI, is restricted to biotic, abiotic, socioeconomic and cultural aspects with respect to the area directly used by the project and that during its execution may have environmental impact

B.1. ABIOTIC MEDIUM

Figure 3.B-1 General view of the project area

B.1.1. CLIMATOLOGIC ASPECTS

To identify the climatologic behavior of the project's area of influence, weather records reported by IDEAM (Instituto de Hidrología, Meteorología y Estudios Ambientales – Hydrological, Meteorological and Environmental Studies Institute) Puerto Boyacá and Padilla stations, located close to the field in the Department of Boyacá were consulted.

Table 3.B-1 Meteorological Stations Used for Weather Characterization

CODE	TS	NAME OF THE STATION	ELEVATION (m.o.s.l.)	YEAR		COORDINATES	
				INST.	SUSP.	LATITUDE	LONGITUDE
2311501	OC	PUERTO BOYACÁ	350	AUG 1994	-	05º57` N	74º36` W
2311006	PG	PADILLA	100	MAY 1984	-	06º12` N	74º22` W

TS: Type of Station OC: Ordinary Climatologic PG: Rainfall
Source: IDEAM

The general conditions of the Mid-Magdalena Valley are determined mainly by the following factors: latitude, temperature, rainfall, relative humidity, winds, geomorphology and solar radiation.

The behavior of each of the climatic variables analyzed for the area where the project is located is presented below.

B.1.1.1. Precipitation

Atmospheric phenomenon consisting of a water precipitation in the form of liquid drops, whose diameter is found usually between 0.5 and 7 mm, and that falls at a speed of around 3 m/s.

The station of Puerto Boyacá shows an increase tendency of the precipitation from 1,398.9 mm in 1976 to 2,584 mm in 1,989; maintaining constant values in recent and current years. See Figures 3.B-2 and 3.B-3.

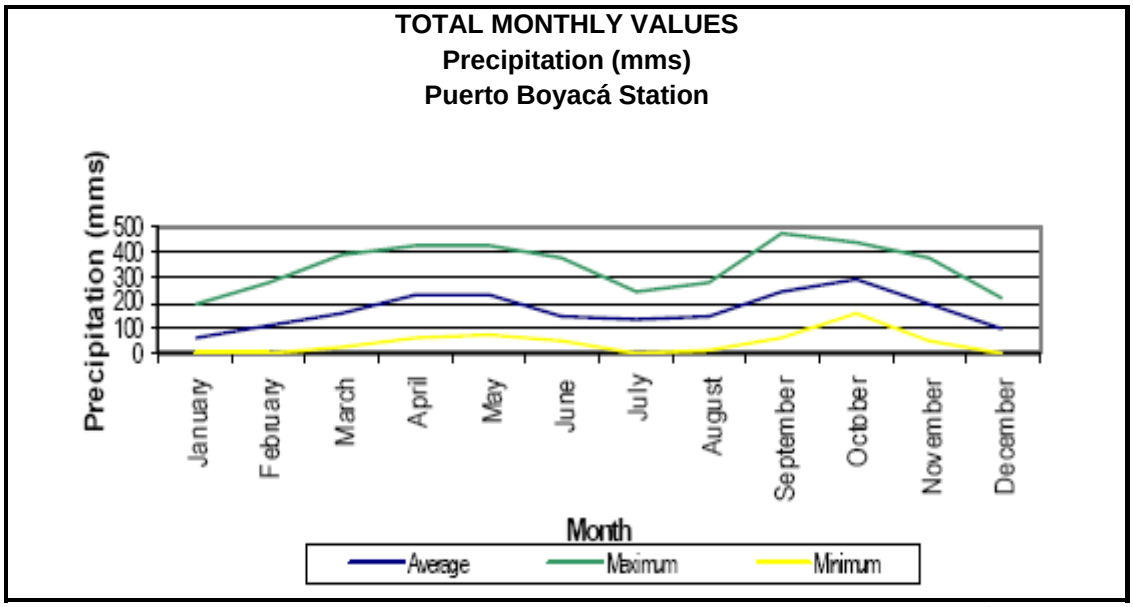


Figure 3.B-2 Total Monthly Values – Precipitation – Puerto Boyacá Station

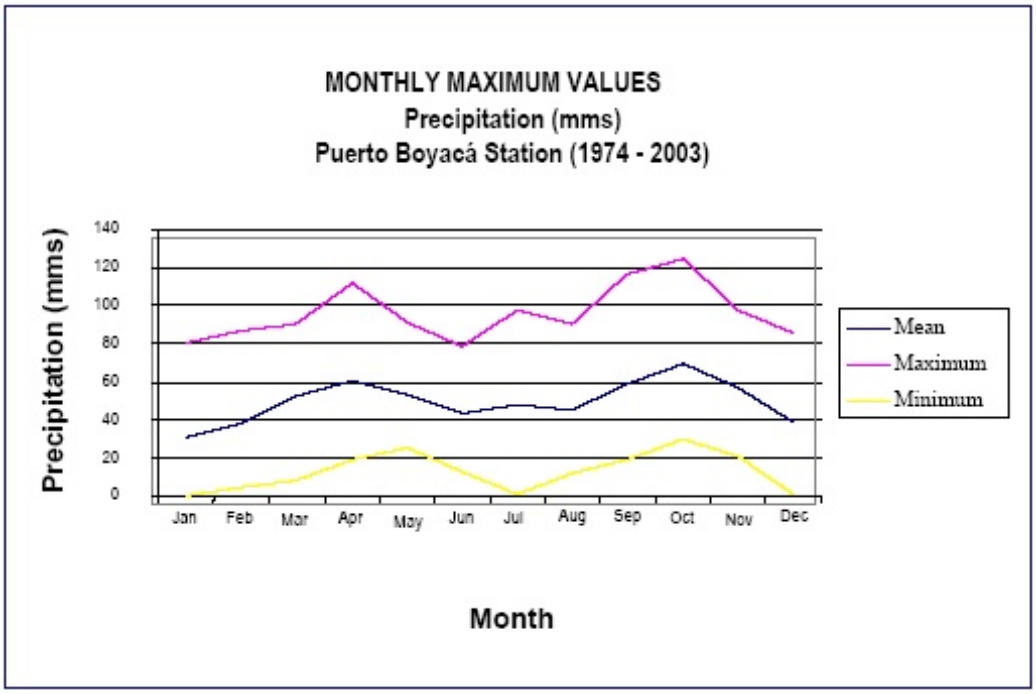


Figure 3.B-3 Monthly Maximum Values – Precipitation – Puerto Boyacá Station

The regional behavior presents two peaks and two valleys, showing a bimodal behavior, according to the monthly averages obtained. (See Figures 3.B-4 and 3.B-5).

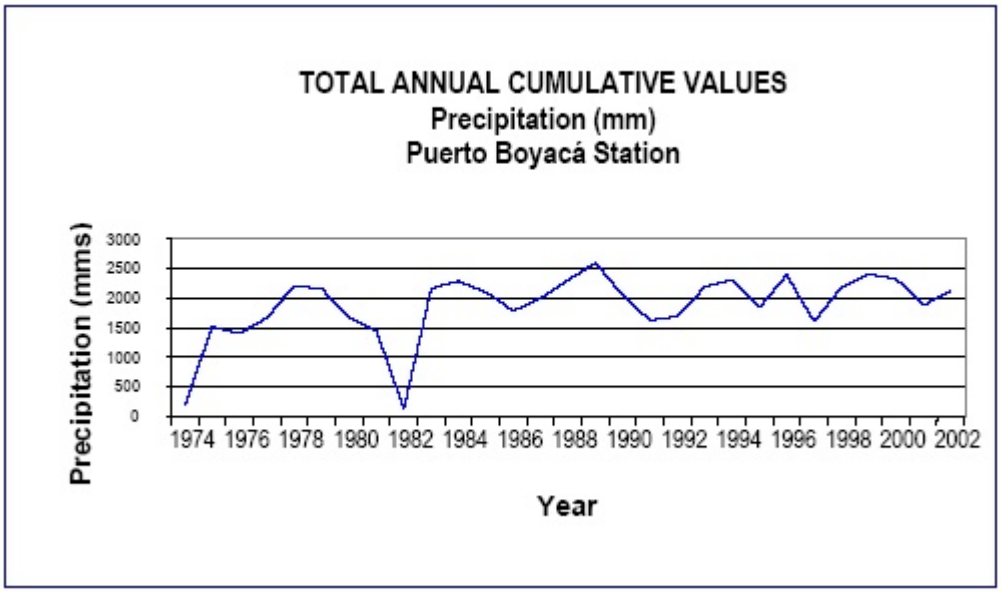


Figure 3.B-4 Total Annual Cumulative Values – Precipitation – Puerto Boyacá Station

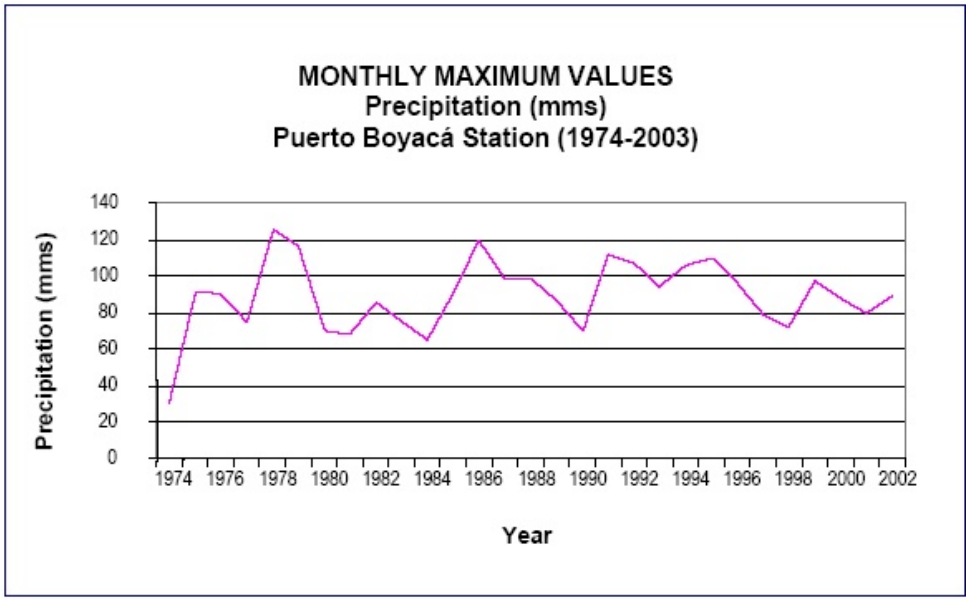


Figure 3.B-5 Monthly Maximum Values - Precipitation – Puerto Boyacá Station

The records at the Padilla Station show that the high precipitation periods correspond to the months of April to May (monthly precipitation of 220 and 290 mm) and from September to December with 360 mm of precipitation. (See Figures 3.B-6 and 3.B-7).

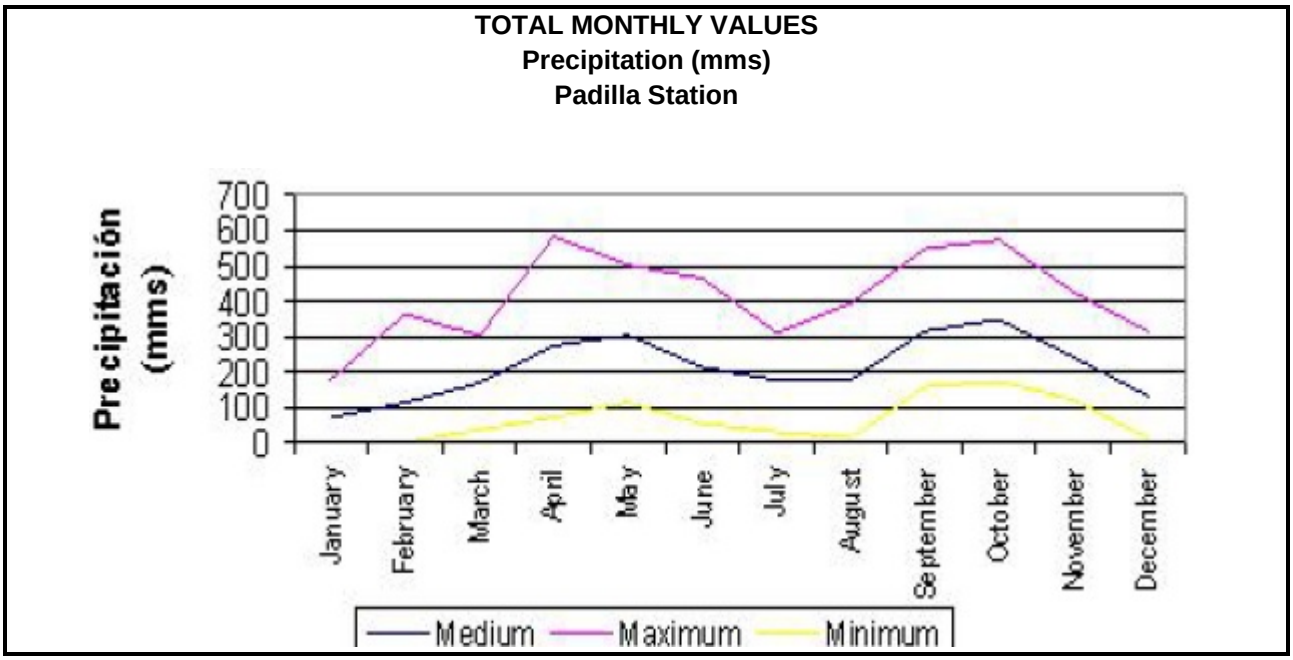


Figure 3.B-6 Total Monthly Values – Precipitation – Padilla Station

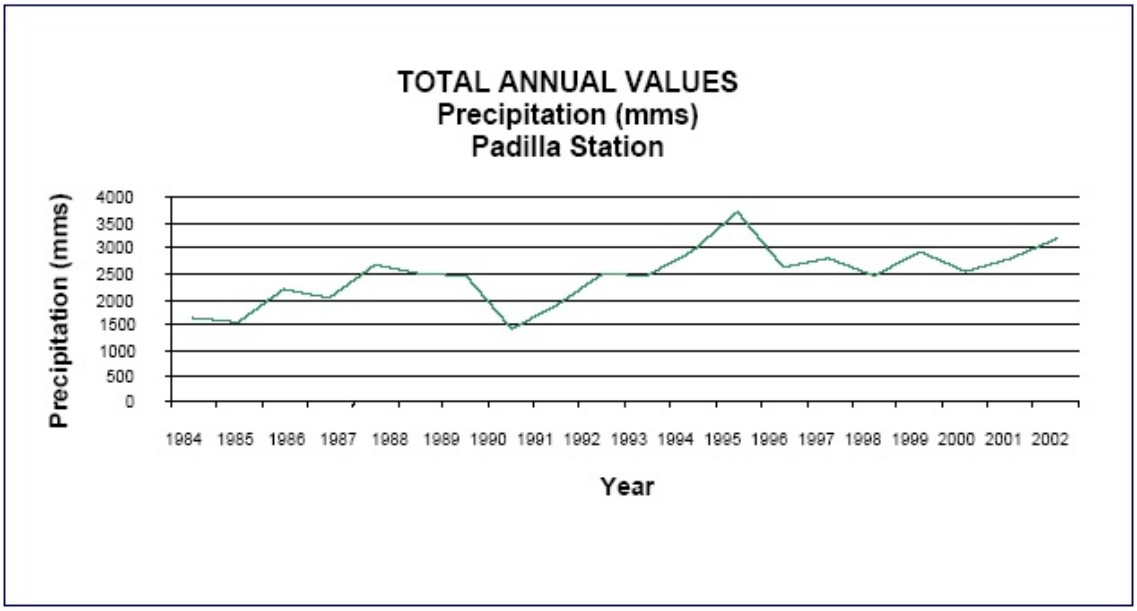


Figure 3.B-7 Total Annual Values – Precipitation – Padilla Station

B.1.1.2. Temperature

The mean annual temperature is between 26 ºC and 31 ºC with an average of 27.8 ºC. The period with highest temperature coincides with the dryest season, and the coldest period with the period of highest rains. (See Figures 3.B-8 through 3.B-10).

The minimum temperatures are during the months of April, May and September with values of 17.4 ºC, 16.8 ºC and 19.0 ºC respectively, related to the months of maximum precipitations in the area.

The mean temperature is characterized by the presence of the thermal levels, caused by the decrease of the temperature when the altitude above sea level increases. In the valleys of the most important rivers, like Magdalena, located within the area of the project, the highest values are recorded, between 24 and 28 ºC. Temperature keeps a close correlation with elevation, as it can be seen on the dispersion graphs. The mean temperature can be roughly determined, as well as its extremes (maximum mean and minimum mean) according to the relation shown below.

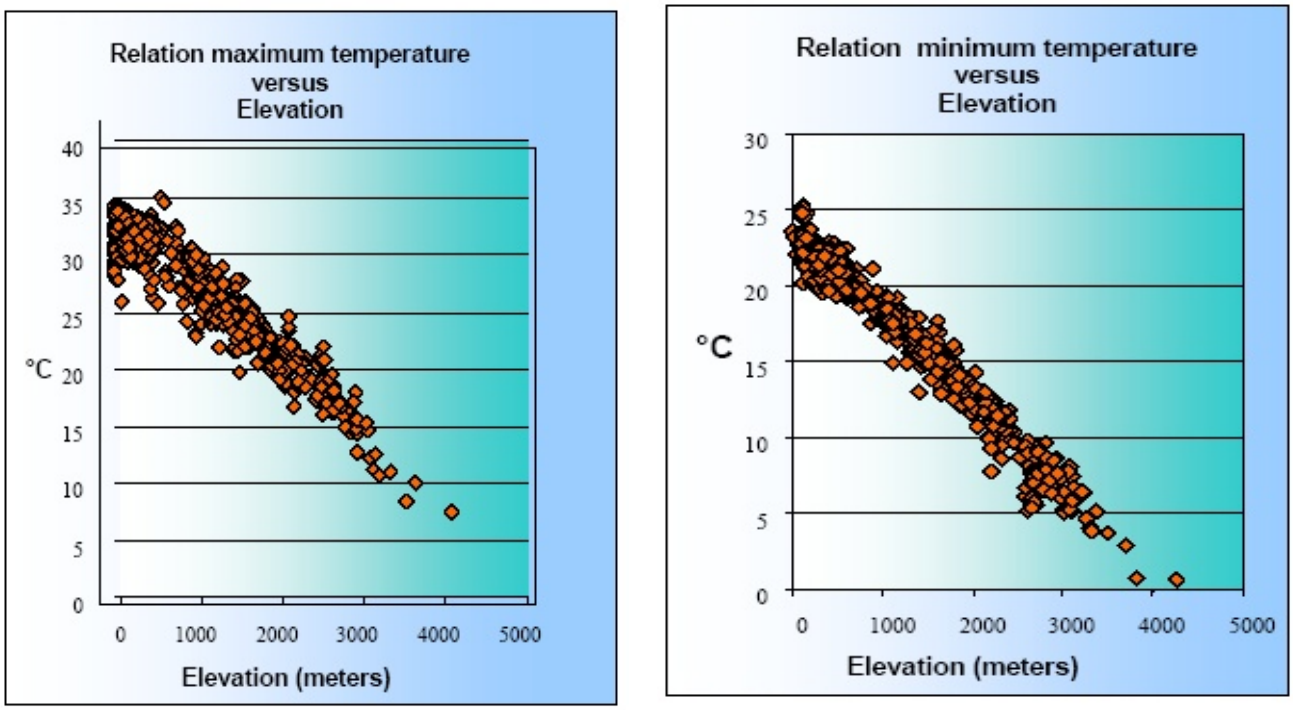


Figure 3.B-8 Ratio temperature to elevation

The maximum temperatures recorded are found during the months of March, July and August with a value of 40 ºC for the first month and of 41.2 ºC for the last two months.

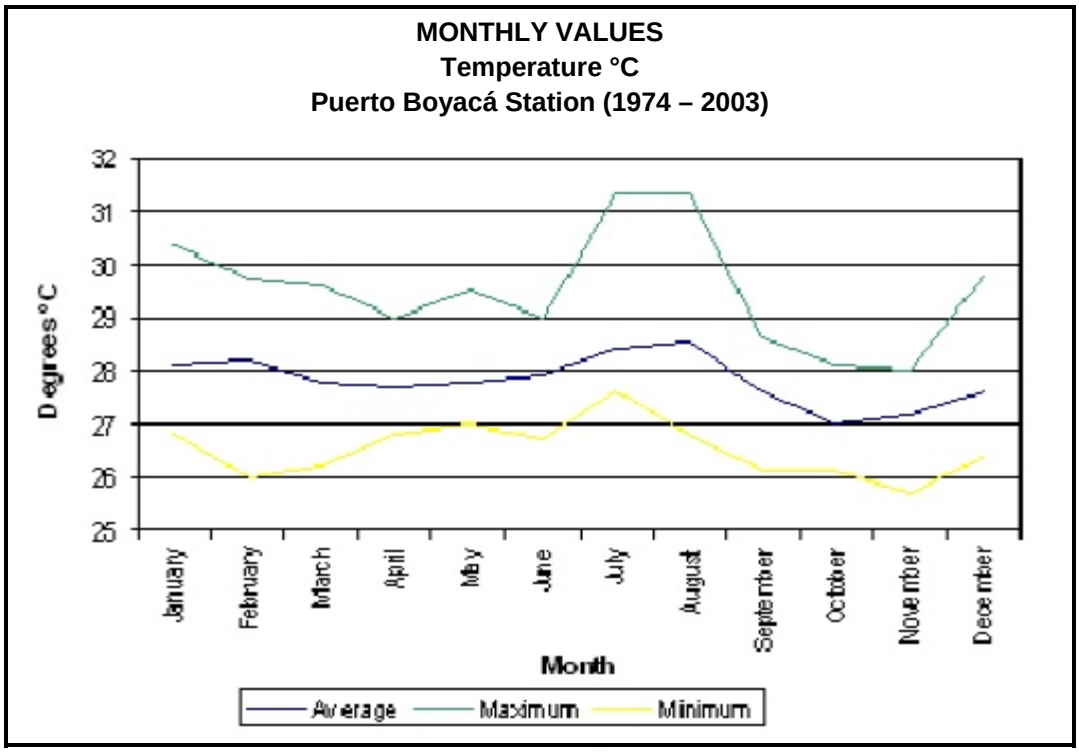


Figure 3.B-9 Temperature – Puerto Boyacá Station – Monthly Mean Values

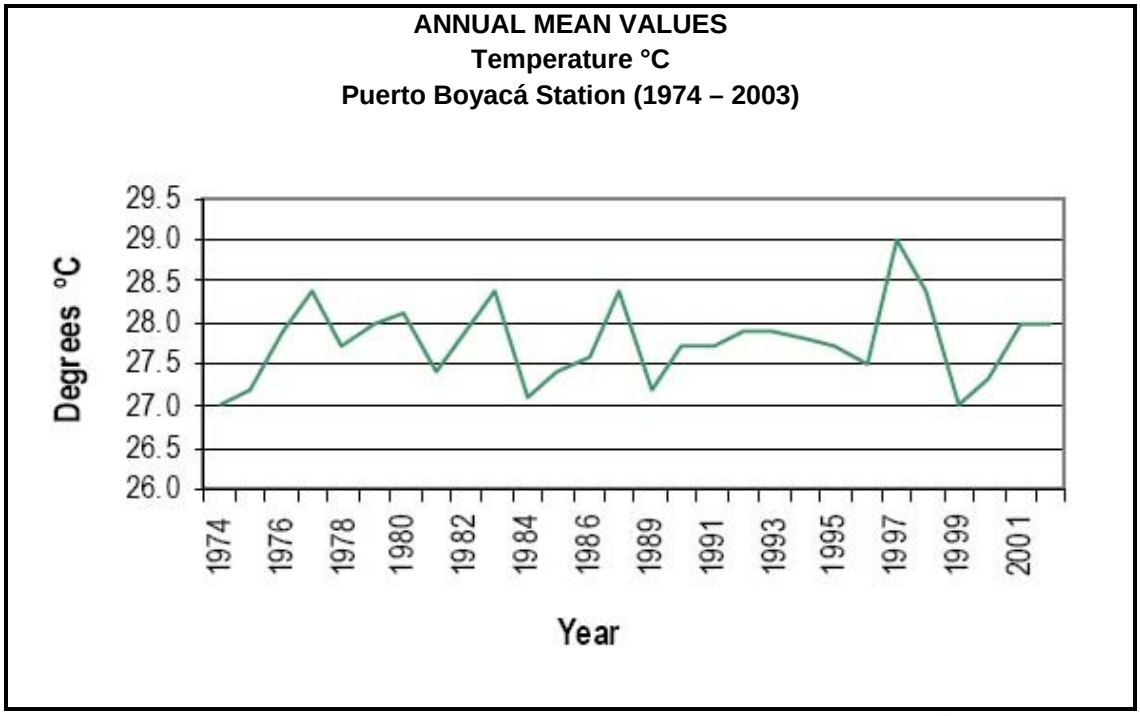


Figure 3.B-10 Temperature – Annual Mean Values – Puerto Boyacá Station

B.1.1.3. Relative Humidity.

This parameter has a similar behavior to the rain parameter.

The relative humidity in the area of influence of the project presents monthly variations through the year between 61% and 86%. The months of July and August have the lowest monthly average records, with monthly mean values of 65% and 61%, respectively. The months with highest relative humidity are March, September and October with a monthly mean value of 86% according to the records of the Puerto Boyacá Station. This parameter is determined by the ratio between temperature and precipitation.

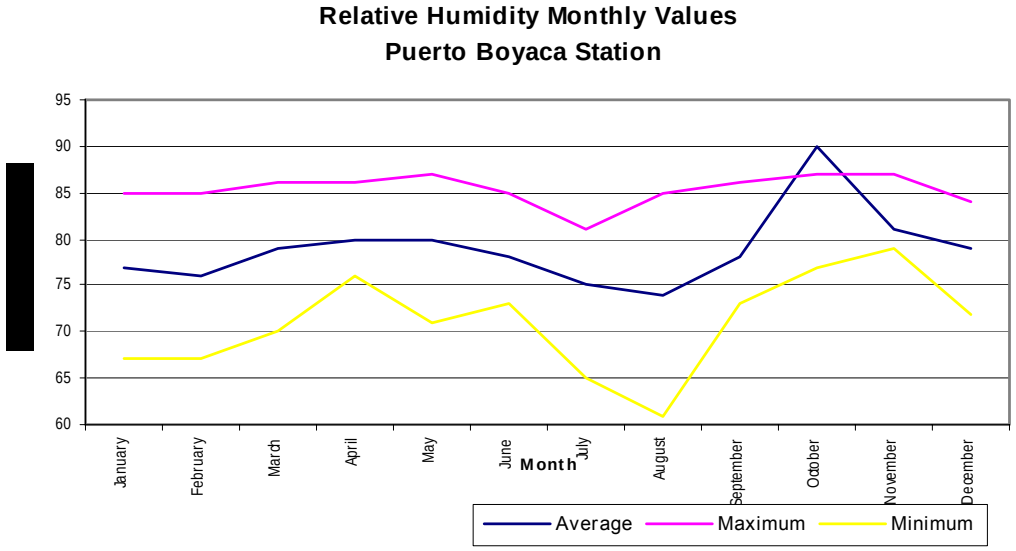


Figure 3.B-11 Relative Humidity – Monthly Mean Values – Puerto Boyacá Station

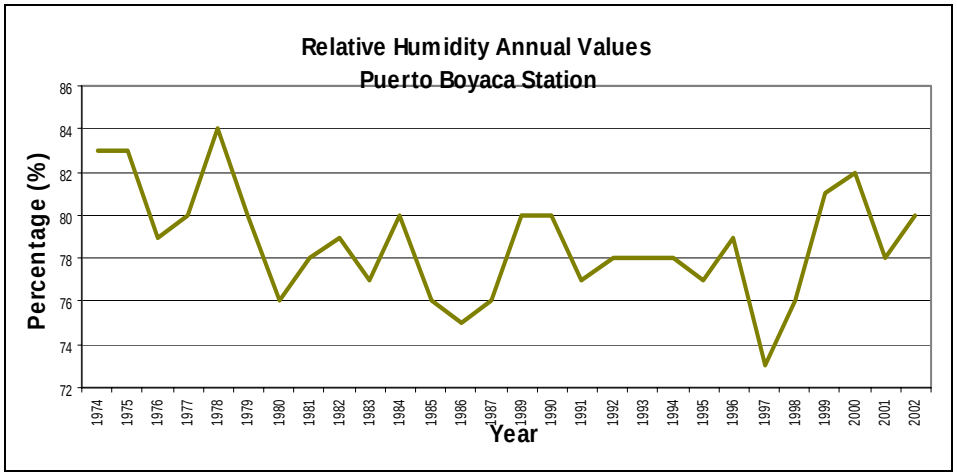


Figure 3.B-12 Relative Humidity – Annual Minimum Values – Puerto Boyacá Station

B.1.1.4. Cloud Cover.

According to records from Puerto Boyacá Station, the historic data by year and the monthly maximum, minimum and mean of cloud cover in the area of influence of the project vary through the year from 2 to 8 oktas with a mean value of 3 oktas. (See Figure 3.B-13). The months with the lowest mean records are from May to September and again from November to February, with a monthly mean value of 2 oktas. The months with the highest records are March, October and November with a monthly mean value of 8 oktas.

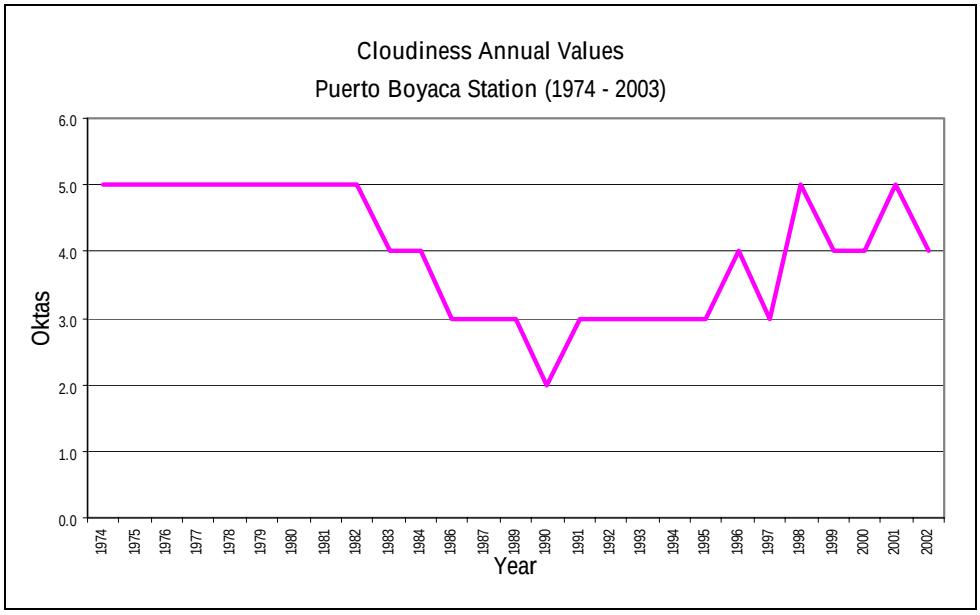


Figure 3.B- 13 Yearly Cloudiness Values

B.1.1.5. Winds.

At the Puerto Boyacá Station, the winds that come from the Northeast represent 15% of the annual total registered. Other data shows that winds from the East represent 10.6%, and winds from the North represent 8% of the annual total.

The predominant winds from the Northeast are trade winds that have high humidity and generate precipitation during the two rainy seasons.

Daily variations in the wind speed are a result of temperature changes in the different layers of the atmosphere that produce changes in pressure and air currents that alternate in the different strata.
The maximum speed of the wind occurs at mid-day, with averages of 2.5 m/s and minimum speed is usually in the early hours of the day with an average value of 0.8 m/s.

B.1.1.6. Hydric Balance.

To calculate the climatic hydric balance, the soil needs of humidity are quantified using the precipitation and temperature data recorded at the Puerto Boyacá Station. This establishes the availability of water in an area, and the temporary relationship between hydric supply and demand.

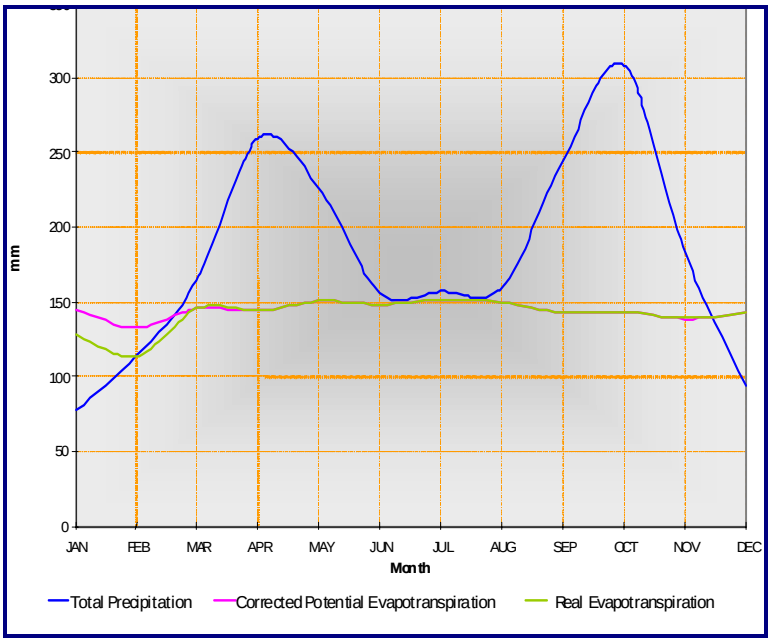
The potential evapotranspiration (mm) is calculated by using the theory of C. W. Thornthwaite (1948 in Socolmet), which is based on monthly temperature values (in degrees Celsius) and monthly total values of precipitation (in mm). Thornthwaite defines it as the quantity of water transferred to the atmosphere, under ideal conditions of soil humidity, and vegetation.

Table 3.B-2 and Figure 3.B-14, show the resulting potential evapotranspiration (PET) and the Hydric Balance. It can be observed that a considerable part of the year shows an excess of water in the soil (from April to November) with an annual total of 444.92 mm.

Table 3.B- Hydric Balance. Puerto Boyacá

PARAMETER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Mean Temperature (ºC)	28	28	27.6	27.6	27.8	28	28.1	28.2	27.6	26.9	27.1	27.6
Total Precipitation (mm)	77.2	113.5	164.6	259.6	226.4	156.2	157.1	159.6	244.4	308.6	184.1	93.4
Heat Index	13.58	13.5	13.28	13.28	13.43	13.58	13.65	13.74	13.28	12.78	13	13.28
Constant (a)	0.72	0.722	0.718	0.718	0.72	0.72	0.72	0.72	0.71	0.71	0.71	0.71
Potential Evapotranspiration (mm)	142.6	142.65	141.37	141.37	142	142.65	142.97	143.1	141.37	139.18	140.5	141.37
Coefficient (F)	1.02	0.93	1.03	1.02	1.06	1.04	1.06	1.05	1.01	1.03	0.99	1.01
Corrected Potential Evapotranspiration	145.5	132.6	145.6	144.2	150.5	148.3	151.5	150.2	142.8	143.3	139.09	142.78
Storage	0	0	18.99	100	100	100	100	100	100	100	100	50.62
Storage Variation	50.62	0	18.99	81.01	0	0	0	0	0	0	0	49.38
Excess	-	-	-	34.4	75.88	7.85	5.56	9.35	101.62	165.25	45.01	-
Deficit	17.68	19.16	-	-	-	-	-	-	-	-	-	-
Real Evapotranspiration (ETPr)	127.82	113.5	145.61	144.19	150.52	148.35	151.54	150.25	142.78	143.35	139.09	142.78

Source: Environmental Management Plan Palagua FIELD. ASETEC LTDA, 2001. – PBOT Municipality of Puerto Boyacá – Boyacá



Source: Environmental Management Plan Palagua field, ASETEC LTDA, 2001.

Figure 3.B-14 Hydric Balance, Puerto Boyaca Station

The first two months of the year (January and February) show a period of water deficit in the soil where the potential evapotranspiration (ETP) surpasses the precipitation values, causing a hydric deficit of 36.84 mm annually. In the remaining months of the year, there is water storage in the soil.

B.1.1.7. Climatic Classification

Climate is important, from a physical-biotic point of view due to its direct intervention in the evolution of soil and landscape. The temperature and precipitation parameters allow one to define, classify and zone the climate in a given region.

Based on the climatic classification by Koppen based on temperature, elevation and precipitation, in general, the area has a “humid warm climate; tropical rainy of savannah".

According to the ecological classification based on the life zones by L. R. Holdrige (IGAC 1977), who considers bio-temperature, precipitation and humidity as factors used in determining the life zones, the area under study corresponds to Basal Altitudinal Level (since it is located at an altitude of less than 200 meters above sea level), to the Tropical latitudinal region and to the Tropical humid forest (T-hf) Life Zone. The vegetation coverage of the area is located at the Mid-Magdalena Valley, according to Cuatrecasas, belongs to the Equatorial zone from 0 to 1100 meters above sea level.

Table 3.B-2 Temperature, Barometric Pressure, Humidity and Wind

Point	Temperature °C	Relative Humidity %	Speed of Wind (m/s)	Predominant Direction of the Wind	Barometric Pressure (mm Hg)
1	19,16	76,00	1,4	SE	553,36
2	20,38	49,27	2,23	ENE – ESE	553,36
3	21,05	44,88	2,06	S	564,35
4	20,61	45,65	2,58	N	563,58
5	21,92	39,67	2,94	NNE	562,94
6	22,67	35,88	2,65	N	562,47
7	23,1	33,7	2,41	SE	561,773
8	21,93	38,89	1,50	SE	561,296
9	19,65	49,83	2,44	S	560,345
10	20,91	47,65	1,94	S	556,224
11	20,67	46,37	2,74	SSW	563,711
12	14,96	76,71	0,06	WSW – WNW	553,299
13	17,07	59,41	2,94	S	546,557
14	15,97	61,65	0,65	SW	542,759
15	15,17	66,69	2,50	NNE	537,738
16	13,66	70,44	1,00	SE	533,908
17	12,92	76,69	0,94	SSE	533,906
18	13,66	72,18	2,24	SE	532,463
19	14,61	66,45	2,85	N	531,273
20	17,66	58,44	1,06	S	534,384
21	18,14	53,59	2,35	SSW	539,161
22	19,30	48,96	2,96	SE	542,020
23	19,40	48,79	2,84	S	544,656
24	21,70	44,67	2,98	S	547,977
25	21,96	43,28	2,78	SSE	553,089
26	24,00	37,07	2,11	SSE	558,154
27	23,17	39,18	2,71	SW	526,536
28	20,76	48,11	2,98	S	560,387
29	18,76	52,78	2,94	SSE	560,674
30	17,79	56,72	1,28	E – NNE	560,427
31	17,86	62,61	1,17	WSW	560,427

SOURCE: IDEAM

B.1.2. HYDROLOGY

Figure 3.B-14 Palagua Lake

From the regional point of view the area of Palagua and Caipal field is located in the Eastern margin of the middle Magdalena river basin. It is in the North sector of the Palagua sub-river basin and in the South margin of El Tambo sub-river. The Palagua and El Tambo sub-rivers merge in the Magdalena River, which is an important national fluvial artery.

The morphological characteristics of the zone, include permanent or lentic water deposits (like the Palagua lake), many natural depressions, and swamps.

The Palagua lake is located about 5 km east of the Magdalena river bank, with an area of approximately 170 Ha. This is a natural resource with hydrological and ecological functions due to its biological and scenic diversity. This lake is a part of the area of direct influence of the Palagua field and the Velasquez field to the south. The lake belongs to a lentic water body, located in the flood plain of the Magdalena River as part of the regulation systems of volume of flow of the river.

The Palagua lake fills up during the rainy season. In addition, it is possible to observe that the lake is in a process of filling rather than eutrophication considering the loss of vegetation coverage that protected it, and the constant and continuous addition of sediment.

According to the topographical characteristics, the zone is dominated by a series of hills and depressions that store water during the rainy seasons and the overflow of the Magdalena River.

B.1.2.1. Hydrogeology

Figure 3.B-15 Conduction system of water for human consumption

Figure 3.B-16 Conduction system of water for human consumption

The underground water is used mainly for human and domestic consumption, agriculture and livestock. In the Palagua – Caipal fields, there are two wells. The well supplying water for the Palagua district (PW-1), is in the installations of the operations base of UT- IJP duly licensed by CORPOBOYACA, located in the Alto Flores, at 850 meters North-East of the administrative office of the Palagua field. This water well has a total depth of 88.5 meters. Although reports show that close to 90% of the inhabitants of the rural area of Puerto Boyacá get their supply from similar wells, the density of the population in the area is low.

The geological units considered as aquifers correspond to non-consolidated units of conglomerates, sandstone, arcillites, and tuffs with high to moderate permeability, which represent aquifers of regional extension. These units correspond to conglomerates of La Mesa formation, that conform two levels as aquifer, a free one and a semi-confined one, and the recent alluvial deposits that conform an accumulated under-ground water level.

In La Mesa formation, water production wells have been drilled at a depth of between 110 and 283 meters, with a rate up to 10 litres per second of good water quality, suitable for human consumption. The recent alluvial deposits show a fluctuation in the water table at a regional scale of 8.8 to 13.93 meters, resulting in a free aquifer.

(See: Appendix D, Map 3 and Map 6.2).

B.1.3. REGIONAL GEOLOGY

The Palagua- Caipal field is located geologically in the basin of the Middle Valley of the Magdalena river, on the foothill of the Eastern mountain range. This region limits to the North-

East with the La Salina fault and to the South-East with the Cambras fault; to the West with the Palestina, Jetudo and Cocorná faults and belongs to a basin nestled amid the mountain range, tilted to the East, with homoclinal tendency, disturbed by some folds and faults. Its structural formation corresponds to an asymmetric Teutonic depression with two well defined margins. The Teutonic depression is shaped in the entire zone, mainly, by tertiary rocks which present some overlapped stratum dips which are quite vertical in the upper part, but as it deepens they slant to the West. The structures present in the region are:

- Couples of anticlines –synclines, asymmetric along the western Edge of the Eastern mountain range, to the South of Bucaramanga, East of Palagua of Miocene age, as the anticline and syncline of Jesús Maria, Cooper; anticlines of Pradera, Portones, and Pauna.

- A mega fault tending towards synestral, associated with marginal riding folds -- Bucaramanga fault.

- System of riding folds of La Salina, Fault of Dos Hermanos to the East of Palagua lake.

- Normal faults, short spaced, along the Eastern Edge of the Central mountain range. To these groups belong the faults of Casabe, Cimitarra, and Cantagallo.

A Group of minor elapsing faults that can clearly be seen in some areas, such as Opon and Las Monas, which are a result of the renewal of old foundation faults.

Figure 3.B-17 Geological shape of low rounded Hills within the area

Referring to the Teutonic evolution, the Middle Valley of the Magdalena River has been affected by expansive and compressive tectonic events. The expansive events cover a space between

the Old Triassic and the Upper Cretaceous. The Teutonic compressive phase began in the Palaeocene and continues until nowadays.

(See: Appendix D, Map 4 - Geological)

B.1.3.1. Stratigrafy

The geological formations from bottom to top, or from the most ancient to the most recent, are the following: Umir (Ksu) formation, Tertiary: Lizama (Tpl) formation, of the Chorro group: La Paz (Tel) formation and Esmeraldas (Tee) formation, of the Chuspas group: Mugrosa (Tom) formation and Colorado (Toc) formation, from Real Group (Tmr) and of the Tertiary-Quaternary: the Mesa Group (TQpm).

A description of the geological Formations or lithological units present in the area of the project and of its area of influence, such as the Real (Tmr) formation and the Mesa (TQpm) formation, are the formations of interest for the project:

- **Above Ground Stratigraphic Units**

Recent Alluvial Deposits (Qal): Deposits constituted by silt, sand, and in a smaller proportion by quartz gravel, metamorphic and volcanic rocks. They are located to the East of the area of interest. These deposits have different thickness depending on the shape of the area of deposit. These deposits are characterized by manifesting in its granulometry silts and clay with minor contributions of gravel and sand.

Alluvial Fan Deposits (Qcal): These are represented by alluvial fans deposited by the currents that originate in the sector, forming terraces of sand and gravel composition.

In the zone of influence, the alluvial deposits coming from fans due to its granulometric composition have gravel and sand horizons that can be can used as sources of material for the landfills.

Fluvial Lacustrine Deposits (Qfl): Fluvial Lacustrine deposits from swamps and sloughs conformed by silt and argil deposited on the lower and depressive zones of the area.

Figure 3.B-18 Low wetlands Zone, conformed of silt and argil

Due to the topographic characteristics and the system of wetlands, this unit is saturated; the thickness of these deposits varies from 2.5 meters to 6.0 meters.

Mesa Aquifer (Tsm): It consists of compact polimictic conglomerates with cherty edges, basalt, and andesine, openings, agglomerations, and tuffs. They are interpolations of shale, sandstone tuffs, and gravel with edges of volcanic Rocks in the valley of the Magdalena River. The thickness of this unit varies between 250 to 300 m. This formation is found locally covered by recent alluvial deposits. It sets itself up in an important regional aquifer, from the Plio-Pleistocene. It is located to the East of the area of interest.

Figure 3.B-19 Outcrop of Sand and Silt Horizons that Interpolate with Sandstones and Argyll, Representative of the Mesa Formation, in the area Surroundings the Palagua Field

This formation is affected by the Velazquez fault which is responsible for the depressions where the Palagua and El Tambo Swamps are located; the latter being outside the area of interest. Additionally, to the West of Puerto Boyacá the Cambras fault contacts the Mesa Formations. This is also located outside the area of study.

The Mesa Formation in the Middle Magdalena Valley: There is very little data on this unit of the Magdalena Valley. WHEELER (1935, p. 37) was the first to name this region that covers the area between the Rivers Sogamoso and Carare.

Figure 3.B-20 Hills belonging to the Mesa Formation which have been intervened and raised to form platforms for exploration labors

B.1.3.2. Structural Geology

Figure 3.B-21 General view of the geological formation of the zone

Regionally, the area of the Palagua field is dominated by a monocline. The layers are in the direction of N 10º E with a dip of 5-15º to the Southeast, presenting regional platforms towards the East. The monocline is affected by the Velázquez fault, which shows a Northeast-Southwest direction and a series of perpendicular faults to the main fault. This fault gives way to an alignment of depressions, which form the Palagua swamp.

The zone corresponds to a pseudo-geosincline, developed in the orogeny of the Andes mountain range. During the process of elevation of the Andes mountain range, these basins were formed.

B.1.3.3. Geomorphology

The area of study is characterized for presenting two Geological forms that are described below:

Low hills with flat top: They appear in the flat zones of the area of interest, as remnants of the old surface of the Mesa Formation. The erosive processes and the gradual transformation into rounded top hills. This unit presents a flat top and short slopes of medium inclination.

Rounded top hills: It is the predominant geomorphology of the zone characterized by interconnected hills of rounded top, with low slopes and little inclination; they show dendric to

subdendric drainage. The wetland system takes the dendric form of the characteristic drainage of the hills.

Figure 3.B-22 Geomorphologic unit of rounded top hills in the zone of the Project

B.1.3.4. Geotechnical Characteristics of the Zone

The area where the development wells are located is composed of sand and silt soils that belong to the Mesa Formation; these soils are of competent character, with a good capacity of support.

Figure 3.B-23 Presence of low consistency soils given an inadequate drain

The soils of fine character of La Mesa Formation are poorly drained soils and therefore retain rain water at surface level, generating local stagnation of water that could be detrimental for the exploration activities because of the loss of consistency of the soils due to the presence of water. Levelling and adjustment of the land is recommended in the places where this type of stagnation of water occurs.

To address this issue, as noted in Section A.3.13, drains are established around the drillsite to collect water and dispose of it in an environmentally safe manner.

B.1.4. SOILS

The Associations of the soils present in the area of the project were determined from the information registered in the General Study of Soils of the Western part of the Department of Boyacá.

- **Soils of Lacustrine-River Plain**

The landscape is homogenous and corresponds to the Marañal Association (MÑ). This unit of soils takes up the lacustrine plain of the Palagua Lake. The terrain of this landscape is flat with undulated micro-terrain and a slope of less than 3%.

The climate of the area of interest is humid warm and the vegetation formation (or Life Zone, according to the system of L.R. Holdridge), is Tropical rain forest (T-rf). The vegetation of the lacustrine zone (lowlands) has not been intervened by UT-IJP.

The soils that make up this formation have developed from the organic material, which rests on clayish or sandy material; and is characterized for being superficial, limited by the fluctuating under-ground water level, that at some times of the year can reach to the surface.

This Association is made up of the Marañal (Fibric Tropohemist), Peñoncito (Typic Tropaquept) and Palagua (Typic Psammaquent) groups. Their presence in the unit corresponds to 50, 30, and 20%, respectively.

- **Hill Soils**

They are elevations with less that 100m heights between hill tops, which were possibly terraces. However, due to their strong dissection, they were molded into hills.

The Associations SONORA (SO) and PIZZARRA (PI) belong to these soils.

✓ **SONORA ASSOCIATION (SO):**

This cartographic unit is found in strongly dissected low hills. The terrain of this landscape can be formed slightly undulated to highly broken, with slopes between 3 to 50%. The climate where this Association is found is warm-humid and the vegetable formation, according to L.R. Holdridge system, is Tropical rain forest (rf-T). The wooded vegetation has been almost completely destroyed to give way to extensive cattle ranching exploitations. The zone shows slight to severe laminar erosion and in some sections, one can see gullies.

The soils that make up this Association have formed from tufaceous sandstone and they are characterized for being moderately deep to superficial. The superficial horizons rest on a B to C alteration horizon.

This Association is made up of the Sonora (Typic Eutropept), Cadelsa (Typic Eutropept), with inclusions of Barlovento (Typic Tropaquept) and Estrella (Oxic Dystropept) soils. The Sonora represents 50% of the Association while Cadelsa represents 30%.

The following phases have been separated by inclines and erosion:

Sobc2: Slightly undulated to undulated terrain, inclines 3-7 and 7-12% and moderate erosion.

Socd2: Undulated to strongly undulated terrain, inclines 7-12 and 12-25%, moderate erosion.

Sode2: Strongly undulated to strongly broken terrain, inclines of 12-25% and 25-50%, moderate erosion.

Sode3: Strongly undulated to strongly broken terrain, inclines of 12-25 and 25-50% and severe erosion.

From the soils of this Association, the Sode3 phase can be seen near the area of the drilling project.

✓ **PIZARRA ASSOCIATION (PI):**

This unit is located in the middle hills of the Western Slope of the Eastern Cordillera. The terrain of this landscape varies between strongly undulated to broken, with inclines from 7 to 50%.

The climate of the region is warm humid and, according to the Holdridge system, is a tropical rain forest, in which the natural vegetation has been almost completely destroyed due to extensive livestock ranching.

The soils that make up this formation have formed from clays and compact sands from the Tertiary. They are moderately deep to superficial. The superficial horizons of dark colors rest on a B to a C alteration.

The limit of the unit is abrupt with the Carangal (CN), Porvenir (PV), Abarco (AB), Marañal (MÑ), San Felipe (SF), Cocomono (CC) and Trique (EB) associations, and with the Notora (NT), Balú (BL) and Alto Bonito (BT) associations. The soils are regularly distributed within the unit.

The groups Pizarra (Typic Eutropept) by 50%, and Tebaira (Typic Troporthent) by 40% make part of this association. There are also inclusions of the Estrella (Oxic Dystropept) and Barlovento (Typic Tropaquept) soils.

These soils show good development and are beginning to suffer degradation due to the lack of vegetable cover.

These soils have a high saturation of bases (alkaline) despite the shortage of total bases and the slightly acid reaction; the presence of carbon is very small in the entire outline.

B.1.4.1. Uses of the soil

In the study area, land use has been affected since 1929, by the presence of the TEXAS PETROLEUM COMPANY (TEXACO). Since then, the rain forest ecosystem was modified mainly by the commercial extraction and burning of valuable vegetation species. As a result of this exogenous factor, this area has little vegetation.

Aside from oil exploitation there were other activities such as deforestation (wood exploitation) and cattle ranching, which came along with the arrival of settlers to the area,that lead to reductions in vegetation.

Most of the homes have established a basic subsistence agricultural system, which implies the removal of marginal vegetation and drainage. Additional activity includes planting of species for domestic consumption such as cassava, plantains, corn, and in a fewer quantity lemon, guava, sour sop tree, and mango, among others.

Continued deforestation for the establishment of new pastures has reduced the supply and quality of the water, not only for animal consumption, but also for domestic use and human consumption. This situation turns worse during the days of lower rainfall or "summer" between June and August. Consequently, the supply and availability of good quality forage that meets the maintenance requirements for cattle production, is substantially reduced, and occasionally precarious. This situation requires producers to reduce livestock inventories during this time or simply move them to other farms, thus increasing deforestation and expanding the agricultural boundary.

B.1.4.2. Cattle Use

Figure 3.B-24 Areas for the use of stockbreeding

This area is used for breeding cattle, horses and minor species. Cattle are bread for both meat and milk. The mostly widespread species are: Zebu and Brownish-gray Swiss cattle. There is also a representative inventory of horses. Minor species include poultry, pigs, sheep and goats.

B.1.4.3. Agricultural Use

Figure 3.B-25 Areas of agricultural use

Figure 3.B-26 Areas of agricultural use

In the area of influence, there are only subsistence agricultural farms due to the hilly terrain or lowlands. Some of the local crops are plantain, corn, yucca, mango, sorghum, and citrus fruits.

B.1.4.4. Industrial Use

This area also has oil fields. The study area refers to the Palagua-Caipal fields and all the infrastructure related with the oil industry. (Tanks, flow lines, batteries, wells).

Figure 3.B-27 Sector of Industrial Use

Figure 3.B-28 Sector of Industrial Use

B.1.4.5. Exposed Areas

This refers to the area without a vegetable cover. In the area of the field, it relates to those places that are eroded mainly due to the flow of rain water. It is important to point out that most of the hills of the area of study show processes of slight to severe erosion, produced by the action of rainwater and further aggravated due to cattle ranching.

B.1.4.6. Hydric Use

Figure 3.B-29 Palagua Lake – Hydric source of greatest importance

The exposed area also includes the rivers, lakes, small lakes, creeks, bayous, streams, pools, and other natural or artificial bodies of still or fresh water. In the area of influence, this category mainly includes the Palagua Lake.

(See: Appendix D, Map 5 - Potential Land Use)

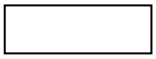
C. NATURAL THREATS AND RISK

Natural threats and risks are defined as those events that can cause harm to people and property. Threats are classified according to degree of intensity. There is high threat when the conditions for occurrence of the natural event are the most favorable, low threat when the conditions are less favorable, and medium threat when there are intermediate conditions between the first and the second.

C.1. HISTORY

As per the Basic Plan for Land Use Planning (PBOT) in the municipality of Puerto Boyacá for the area where the Palagua – Caipal field is located, possible natural hazards include landslides, seismic activity and floods. For the Palagua-Caipal well area, the possible natural threats are described in Table 3.C-1.

Table 3.C-1 Susceptibility to Geological Threats

THEMATICAL CONVENTION	SUSCEPTIBILITY	CHARACTERISTICS
	Areas of geological instability (susceptibility of Rotational and Transnational type sliding)	Landslide phenomena with rock or ground detachment.
	Areas susceptible of being flooded	Events that occur sporadically due to overflowing in the lower reaches of streams (flooding) brought on by heavy rains.
	Seismic risk areas	The Project area is an intermediate seismic risk area.
	Intervention Areas without restriction	Corresponds to the areas to be intervened by the project and where there is no restriction for its implementation.
	Intervention Area with restriction	Areas that will be intervened with the project's work and require special measures in order to protect some resource.

SOURCE: LAND MANAGEMENT PLAN – PBOT Puerto Boyacá – Boyacá

Natural Hazard Areas: The risks and threats that may affect the area's population are classified according to Table 3.C.2.

Table 3.C - 2 Natural Hazard Areas

TYPE	CHARACTERIZATION
Sliding	Corresponds to the immediate vicinity to the Magdalena River which presents erosions and landslides
Flooding	It is observed in the savanna zone, where the rivers expand in the winter time affecting the surrounding areas (especially the river bed and its banks).
Fire	Forest areas are susceptible to forest fires in summer time.
Geological Faults	The Municipality is classified as an intermediate seismic risk zone.

Source: Land Management Plan – PBOT Puerto Boyacá – Boyacá

Risk is the probability of harm or loss of property and people in case of the occurrence of a determined event. Due to its geomorphology, geology, climate, and hydrology the municipality of Puerto Boyacá is subject to different types and severity of natural hazards. The following natural hazards are possible in the Palagua-Caipal area:

- Climatic hazards/threats: Caused by water phenomena such as floods, drought, or climatic events such as hailstorms. In the Palagua – Caipal field, area there are sectors subject to flooding such as the area surrounding the Palagua Lake and in some lowlands as evidenced in the Map.#4-Amenazas Rural in Appendix D.

- Threats by erosion: Erosion is a constant threat in the municipality, mainly in the hillside areas devoted to agricultural activities. In the Palagua Field area, because of its flat to undulating topography, there is a threat of sheet erosion along the hillside.

- Mass movements: In the Palagua-Caipal area, as in most of the municipality's area this is a low impact phenomenon.

- Forest fires: The areas with the highest probability of occurrence of forest fires are located on the belt of forested hills where there are wooded areas corresponding to parts of the villages Puerto Gutiérrez, El Marañal, El Pescado, Puerto Niño, Ermitaño, and small areas of Palagua village.

- Within the Palagua – Caipal field area, as in the sectors of oil production, the risk of fire is present due to the fuel storage, but UT-IJP has taken actions and measures for the prevention and control of fires.

A map of the hazards and risks in Colombia can be found in Appendix D, Map 6.1.

C.2. POLICIES AND STRATEGIES FOR THREAT CONTROL

The municipality of Puerto Boyacá's policy is to monitor threatened areas in those sectors that require action so as to develop the guidelines and priorities in case of an eventuality.

Prevention as a pillar for national development and environmental protection is enshrined in Law 99 of 1993; the state as protector of life and property of the Colombian people (Political Constitution of Colombia) requires the Government to take actions to minimize the loss of people and property due to the occurrence of potentially harmful events.

C.2.1. STRATEGIES

1. Develop and implement a prevention and emergency care plan, according to the guidelines of the Department of the Interior and the Departmental Committee for Prevention of Risks and Disasters.

2. Develop studies to identify areas for the location of temporary shelters for the relocation of people whose homes are at risk.

3. Update the information (every 3 years) of the hazard and risk zones in the urban and rural areas.

C.3. POLICIES AND STRATEGIES FOR RISK CONTROL

- **Threat from Landslides**

Short and Medium Term Actions

Slope stabilization is recommended (gabions, retaining walls, etc.); having previously carried out the aforementioned studies.

- **Threat from Fire**

Medium Term Actions

Have adequate fire fighting equipment in the Palagua-Caipal oil fields.

- **Threat from Floods**

All the wells in the field are drilled from the top of the hills. Thus, the risk of flooding is absent in the drilling areas.

D. BIOTIC ENVIRONMENT

The following is a description of the vegetation and fauna diversity, natural habitats, renewable and nonrenewable resources related to the area of influence of the project for Development Well Drilling in the Palagua-Caipal field. The description is based on available information, the results of indirect photo interpretation, and field visits.

(See: Appendix D, Map 7 - Life Zones, Map 8 - Estrategics Ecosystem, and Map 9 - Wildlife and Natural Resources)

D.1. VEGETAL COVERAGE:

The soil studies carried out in the areas of influence were oriented towards identifying its physical and chemical characteristics, and its current status regarding degradation phenomena (erosion, denudation, flooding, and skeletization) in order to determine its quality, specifications and potential use.

The study of this area shows pastures and natural vegetation in low flood lands, mostly herbaceous, and areas with underbrush.

The forestry component (trees, forests and forestry activities) is scarce in the area. Forests or trees are located on the banks of rivers and streams in an early state of growth along the roads. A few scattered trees remain in the area.

The proposed new wells are to be drilled from the existing well locations, where no vegetation exists. Thus, proposed wells will not change the local vegetation.

D.2. VEGETATION UNITS

The following coverage units were identified and classified into four main areas: low flood land vegetation; stubble or underbrush; improved pastures, and those associated to natural [or dried (dissected) surface] savannahs and crops.

(See: Appendix D, Map 10 - Current Land Use)

D.2.1. LOW FLOOD LAND VEGETATION

The flood land is the lowest land in the area. It has surface soils to moderately deep soils. They are flat concave surfaces with slopes of less than 1%. They are located north of the Palagua Lake and Palagua Port. The plant population in this area is maintained throughout the year.

The species in the area include fixed and floating macrophytes, reeds, and some tree and shrub species which can be found around the drains. Some of the associated species include: *Potamogeton sp. Polyrrhiza Azolla, Pistia sp., Wolffia Colombian Sccirpus sp., Typha sp. Bidens sp., Eleocharis sp.*

The inhabitants of the region call this type of vegetation "plugs". These “plugs” are usually located in the surrounding hills. The predominant vegetation includes platanillo, bijao, (*Heliconia bihai L.*) rushes, and tree species with BHD (Breast Height Diameter) less than 10 centimeters such as cecropia, vara santa (*tripalis*), corozo palm, noli palm, chota lata (spiny palm), guayabillo (*Eugenia pachychlamys*), churimbo macho (Inga Sp), and olivon, among others.

Figure 3.D-1 Appearance of Flood land Areas

D.2.2. IMPROVED PASTURE AND NATURAL GRASSLANDS

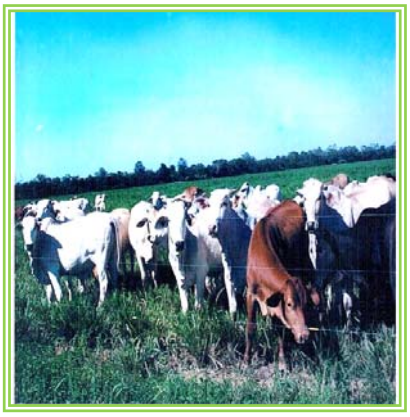
Native pasture lands are especially important. They are currently made up of natural enriched pastures and introduced grasses. Depleted pastures of native grasses are propagated with new grasses.

In the hills of the study area there are only a few isolated tree species such as palms *(Roystonea regia)*, guayacán *(Tabebuia roseae)*, hobo (*spondias mombin*), iguá (pithecellobium guachapele), algarrobillo (*Ceratonia siliqua)*, teak, guava *(Psidium guajava L.),* Lemon *(Citrius sp),* Aceituno (*Zanthoxylum flavum),* solera *(Tilia sp.),* Totumo (*Crescentia cujete),* Dindo *(Chlorophora tinctoria),* Chicalá, uvero, and tachuelo (*Picteti Aculeata),* among others. These trees and shrubs are usually planted by the settlers, to make live fences to provide shade for livestock, or they grow naturally.

The most common grass species in the area are: India *(Panicum maximum),* Pangola (*Digitaria decumbens),* Brachiaria *(Brachiaria spp.)* Carimagua *(Andropogon gayanus)*, and Pasto Aleman – German Grass*(Echinochloa polystachya*). The latter is very common in the floodlands.

Due to extensive cattle ranching, large portions of natural vegetation are disappearing.

The main use of this area is cattle ranching for meat and dairy industries.



D.2.3. CROPS

Both the field visit and the analysis of the area of the oil wells and their direct area of influence indicate that there are no established crops.

However, it is common, to find subsistence crops in areas adjacent to homes near water bodies (lentic, lotic or runoff), or in small isolated areas.

Some of the common species are: orange, lemon, tangerine, mango, papaya, guava, lemon, guanábana and mango fruit trees. Some give crops twice a year while others such as plantain, banana, and cassava, give an annual crop.

D.2.4. STUBBLE OR UNDERBRUSH

This classification corresponds to a type of vegetation in various stages. It arises as a result of tree cutting, forest burning, and turning the land into pastures and grasslands, which are later abandoned and recover naturally through different stages.

Units with shrubs and underbrush are located on the runoff draining areas. These units are usually surrounded by bushes and small trees with heights ranging from 2 to 15 m. In a few locations distant from the wells, they can be seen as dense spots of vegetation in low, humid lands that tend to flood. Some of the trees observed in the area were: caucho (*Ficus* sp.), hobo (*Spondias mombin*), palmas, Guásimo (*Guazuma ulmifolia*), Yarumo (*Cecropia peltata*), Gallinero o Payandé (*Pithecellobium dulce*), guamo (*Inga* sp.), samán (*Samanea saman*), iguá (*Pseudosamanea guachapele*) among others

- **Vegetation and Description of Strata**

The sector has three strata: arboreal, shrubs and herbaceous. The herbaceous layer, composed of grasses and weeds is predominant at different altitudes on the hills. The herbaceous strata are composed mostly of pasture to feed livestock. Among the grasses, we have: Brachiaria (*Braquiaria* sp.) and Carimagua (*Andropogon gayanus),* india (*Panicum maximum*), Pangola (*Digitaria decumbens*), and Pasto Alemán (*Echinochloa polystachya*).

The arboreal and shrub species were found scattered in the hills, forming part of a hedge of live barriers, or were found in floodable areas. They have different heights and stages of growth. Trees range in height from 5-15 m, shrubs grow up to 2 m and some herbaceous species are 1 m tall. The diameters of the tree trunks range from 30 to 80 cm.

Table 3.D - 1 Species of vegetation present in the Study Area

COMMON NAME	SCIENTIFIC NAME	COMMON NAME	SCIENTIFIC NAME
Java Plum	*Spondias mombin*	Yellow cedar	*Pseudosamanea guachapele*
Mango	*Mangifera indica*	Mimosa	*Mimosa* sp.
Western Cashew	*Anacardium occidentale*	Ficus	*Ficus* sp.
Guarita	*Astronium* sp.	Fustic tree	*Chlorophora tinctoria*
Wild sweet sop	*Annona* sp.	Myrsine	*Rapanea guinensis*
Monkey pepper	*Xylopia aromatic*	Sweet guava	*Psidium guajava*
Yagua palm	*Scheelea butyraceae*	Lathropopis	*Lathropopis* sp.
Lata palm	*Bactris minor*	Ant tree	*Triplaris americana*
American oil palm	*Elaeis oleífera*	West Indian elm	*Guazuma ulmifolia*
Coconut palm	*Cocos nucifera*	Teak	*Tectona grandis*
Calabash	*Crescentia cujete*	Miconia	*Miconia* sp.
Jacaranda	*Jacaranda* sp.	Mimosa	*Mimosa* sp.
Trumpet tree	*Tabebuia rosea*	Mastranto	*Hyptis brachyata*
Balsa	*Ochroma lagopus*	Panama hat plant	*Carludovica palmata*
Snake wood	*Cecropia* sp.	False bird of paradise	*Heliconia* sp.
Panama hat plant	*Carludovica palmata*	Calathea	*Calathea* sp.
Almendro	*Terminalia* sp.	Guinea grass	*Panicum maximum*
Leche leche	*Sapium marmieri*	Gamba grass	*Andropogon gayanus*
Gliricidia	*Gliricidia sepium*	German grass	*Echinochloa polystachya*
Colombian mahogany	*Cariniana pyriformis*	Thatching grass	*Hyparhenia rufa*
Monkey pod	*Pithecellobium dulce*		
Barbados cherry	*Bunchosia* sp.	Surinam grass	*Brachiaria decumbens*
Barbados cedar	*Cedrela odorata*	Golden leatherfern	*Acrostichum* sp.
Guamo plant	*Inga* sp.	Rain tree	*Samanea saman*

SOURCE: Palagua Field Observations

- **Endangered Species**

This area has been highly affected by deforestation throughout the years. As a consequence, secondary vegetation has developed, with species that adapt and tolerate disturbances in the natural environment.

One of the activities that has affected the vegetation is the tree cutting and burning of the forest done by the village settlers. Felling (tree cutting) is carried out mainly to obtain wood, and burning is practiced to preserve grasslands from weed invasion and extend the cattle ranching areas. However, these activities have been diminishing in the region due to the presence of Technical Assistance (Agricultural Technical Service Unit) and the vigilant presence of CORPOBOYACÁ (Corporación Autónoma Regional de Boyacá). The latter corporation controls the output of wood by farmers and traders to urban centers, in order to protect the forests from being completely cut down.

- **Vegetation of Economic and Cultural Importance**

These are important plant species used to obtain medicinal substances, edible fruits, timber, firewood, and other uses. These plants and trees are listed in the Table 3.D-2.

- **Vegetation in the areas of the development wells**

The development wells for which this study is conducted are located in high lands areas surrounded by flood lands. There is no vegetation in the proposed well site area.

The construction of each well site will not have a major technical and environmental relevance, since it does not require the construction of access roads and the existing fluid pipes tangentially cross the location. There is no need for a special type of engineering or forestry work.

Table 3.D - 2 Economically, Culturally and Ecologically important species in the Study Area

COMMON NAME	SCIENTIFIC NAME	USE AND ECOLOGICAL IMPORTANCE
Anón de monte/Golden Sugar Apple	*Annona* sp.	Timber tree with medicinal properties and edible fruit. Timber used to hold fishing nets and ropes because of its weight. It has been used in medicine to relieve ulcers, diarrhea in children, head aches, malignant tumors, etc..
Yarumo/Trumpet tree	*Cecropia peltata*	The cooking of their roots and leaves is antibilious. It is useful for colds and asthma. Source of fiber and paper pulp.
Samán/Rain Tree	*Samanea saman*	Provides protection to river banks and it is important because is gives shadow to cattle.
Abarco/Colombian Mahogany	*Cariniana pyriformis*	Timber tree. Its wood is used in bodywork.
Matapalo/Fig tree	*Ficus* sp.	Useful species to establish and initiate the process of recovery of vegetation in deforested riverbanks. The latex or milk is used as a parasite purgative.
Guamo/Ice Cream Bean	*Inga* sp.	Useful to protect riverbanks in areas low dissection. Its fruits are tasty.
Teak	*Tectona grandis*	Timber tree, used for hedges or live barriers.
Dinde/Gingerwood	*Chlorophora tinctoria*	Its wood is heavy and hard, it is very popular in construction. It produces a dye that is used in textiles. It is a useful species for erosion control.
Matarratón/Mouse Killer	*Gliricidia sepium*	It is used for production of forrage because of the large protein value in its leaves. It is used as a live barrier or hedge. The liquid produced from the cooked leaves is used in baths to relieve skin diseases. It is useful for erosion control and as nitrogen fixing, and suitable for soil remediation.
Guayacán/Ironwood	*Lignum vitae*	Timber tree. The wood is highly prized in fine furniture industry.

SOURCE: Green Mantle of the Earth. (Manto Verde de la Tierra) CAS. 1999.

D.3. FAUNA

The wildlife resource is of great importance in ecosystems due to the large contribution to the diversity of species inhabiting a geographic region, which depends on both abiotic factors (temperature, water availability, rainfall, elevation above sea level, etc.) and biotic factors.

Animal species are very sensitive to disturbances that alter their habitat and environment. This is corroborated by the extinction of several species in Colombia. Despite the existence of laws, resolutions, and decrees for their protection, such as the 2811, of 1974; and the existence of Ministry of the Environment, hunting and the indiscriminate destruction and illegal wildlife trade, remains a problem for the Colombian government and others worldwide. The natural wildlife has decreased mainly due to the logging of the forest, livestock farming, and thoughtless hunting in the past.

However, there are a few captive wildlife land mammals such as cerillo *(Tayassu spp),* tapir *(Tapirus terrestris),* capybaras *(Hodrochoerus hydrochaeris),* and reptiles such as the tortoise *(Geochelone denticulata*) and the Iguana (*Iguana iguana*) in thier natural environment.

- ***Danta or Tapirus*** is a mammal of the Perissodactyla Tapiridae family, commonly known as the tapir. Currently, it is the only variety of the family, which includes nine other extinct varieties.

The **tapir, sachavaca** or **anta** *(Tapirus terrestris)* is a mammal of the perissodactyle family of South American tapirs. It measures between 1.7 and 2.5 m long and weighs up to 270 kg, its tail is 5 to 10 cm long, measured at the cross, it is from 75 to 110 cm, its body varies from greyish-brown to dark brown and has white tips at the ears. Its upper lip ends with a trunk. It has a thin straight line of hair from the tail to the neck.

The tapir lives in forests with high rainfall, and near swamps and rivers, at an altitude ranging from sea level up to 1,700 meters above sea level. It is usually found near water since it is a good swimmer. It is herbivorous and uses its proboscis (motile nose) to eat leaves, branches, fruit, etc.

Capibara (*Hydrochoerus hydrochaeris***)** is a rodent species of the Caviidae family native of South America. It is currently the largest rodent (in size and weight) in the world, and lives in herds in savannas, rivers, marshes and wetlands of South America.

The capybara has a barrel shaped body, and a small head. Its reddish brown coat in the upper body turns brownish yellow at the bottom. It can grow to 130 centimeters long and weigh up to 65 kilograms. The capybara has slightly webbed feet, lacks a tail and has twenty teeth. Its hind legs are slightly longer than the front ones, and their muzzles are blunt. The eyes, nostrils and ears are at the top of the head. Females are slightly heavier than males.

The yellow-footed land motelo **tortoise** of the Amazon or jungle tortoise *(Geochelone denticulata)* is a turtle that lives in the tropical rainforest. It is native of South America, and can be found in the jungles of Colombia, Venezuela, Guiana, Brazil, Ecuador, Peru, Bolivia and Paraguay.

The shell of the jungle tortoise measures from 50 to 65 cm in males and between 65 cm and 75 cm in females, and its color is dark brown (not black) with clear or yellow circles. The under part of the shell (plastron) is brown with yellow squares and appears flattened in females while concave in males. It has multiple yellow spots on the legs and head.

In its natural habitat, it has a wide range of food available. Herbs, tropical fruits and leaves are its main food source. It also eats snails, worms and insects.

They mature sexually when they are between 5 and 7 years old. The male is usually very territorial. During foreplay, it follows the female continually and bites, taps and presses her until she accepts him. After that, the female lays 3 to 8 eggs. This happens up to 7 times a year. The eggs require an incubation period of about 4 to 5 months, at a temperature of 28 ° to 29 ° C and high humidity.

- **The Iguana**, teyú or green iguana *(Iguana iguana)* is a large arboreal lizard from Central and South America. It measures up to 2 m long from head to tail and can weigh over 15 kg. It belongs to the mayor and more complicated group of dinosaurs of the New World to which most species belong. It is included in the Iguana family

Iguana can measure from 1.5 to 2 meters. They are herbivores and reproduce by eggs, which are placed underground during the month of February (austral summer). They reach sexual maturity at 16 months of age, but are considered adults at 36 months, when they measure 70 cm in length.

The green color of their skin allows it to perfectly mimic vegetation that exists in their environment. Its skin is covered with small scales, with a dorsal ridge that runs from head to tail, and is quite visible in males.

All iguanas have short legs and five toes on each foot, which end in sharp claws. Its tail is long and thin and bordered by a row of sharp dorsal scales. This animal sometimes makes puffing sounds. It has scales, a gular pouch in the throat and a dorsal border, and saliva-like liquid, which males use to mark their territory.

According to information obtained from the villagers, other fauna in the flood lands consist of an abundant population of birds and reptiles which have maintained the ecological balance.

D.3.1. HYDRO BIOTIC POPULATION

In studies made in the existing surface water sources in the Palagua field regarding the identification of biotic communities, populations of Periphyton have been found as primary producers and Bentos as secondary consumers in the food chain.

Figure 3.D - 2 Hydrofauna sampling Palagua-Caipal Field

The samples taken help determine the water quality through the consideration of the composition and abundance of such species.

Aside from **Bentos,** (agents that remain or are fixed to the bottom of the sea or fresh waters, communities of animals or plants living on the ocean floor), and **Periphyton** (organisms that grow on surfaces free of objects submerged in water which it covers or wraps around with a slippery surface; a community of organisms that grows, settles down on an inanimate, organized or alive substrate, that is not part of the benthos complex whose members are tiny or microscopic). There are also abundant **Aquatic Macrophytes** which are macroscopic forms of aquatic vegetation. They include macroalgae, pteridophytes - mosses, ferns adapted to aquatic life - and angiosperms, which have also been detected. They have adapted to life in form of thin cuticles, non-functional stomata, and slightly lignified structures.

Species from the genus *Closterium (Mougeotia,* in greater abundance, *Euglenophyta (Euglena, Phacus, and Trachelomonas Lepocinclis)* have been identified. Among the aquatic macroinvertebrate communities present are Nekton, Neuston, and Benthos, species that respond rapidly to environmental pressure, and are susceptible to changes in water quality.

Regarding the predominant class Insect, the following orders have been identified in the area. **Diptera** (order of insects that have sucking mouthparts or stings and only two membranous wings like flies and mosquitoes), **Coleoptera** (order of chewing insects that has a hard exoskeleton and two hard wings called elytra, which cover in turn two membranous wings, like the beetle or ladybird), **Hymenoptera** (insect order with a chewing, sucking or licking mouth, complex metamorphosis, two pairs of wings and, in many species, social behavior) and **Odonata.** (The order **Odonata** includes insects such as dragonflies and damselflies. They are all Paleópter, insects that can not fold their wings. They live in association with aquatic environments which are necessary for the development of their larvae. They don´t have a pupal stage. They have two pairs of wings with complex venation, which is an important taxonomic character for classification).

E. HUMAN ENVIRONMENT

This analysis determines the influence of the proposed drilling and development of the Palagua-Caipal field oil wells on the community, located in the Palagua Rural area; in the municipality of Puerto Boyacá, Boyacá.

Figure 3.E-1 Social Structures and Housing in the Rural Area of Palagua field

E.1. INFLUENCE AREAS

The area of influence of the project refers to the area of social and environmental context which could be affected by the impacts (positive and / or negative) produced on the physical, biotic, and social variables by the activities of the project. For the Environmental Assessment of the Project, two areas of influence are defined, a Direct Influence Area (DIA) and an Indirect Influence Area (IIA).

E.1.1. DIRECT INFLUENCE AREA (DIA)

The direct influence area corresponds to the area where the work and activities required to drill the development will be carried since that they will cause the major environmental and/or social impacts. The Palagua Rural Area, in the municipality of Puerto Boyacá, is the area where new wells are proposed.

- **The Palagua Rural Area**

Located in the heart of the Middle Magdalena river basin, the Velasquez, Teca, Nare, Jasmine, Moriche and Chicalá oil fields are operated by Mansarovar. Cocorná field is also located here and it is operated by Ecopetrol.

The history of oil exploitation in the sub-region Middle Magdalena began with Velasquez field which is south of Palagua Lake. It was the first field discovered by the Texas Petroleum Company in the mid-50s.

The Texas Petroleum Company began the process of hiring unskilled labor from the village population. The community directly benefited from this through the provision food and housing improvement, among other things, which were provided directly by the company.

Towards 1979 and 1980, there was migration of a great part of the population of the rural area, due to existing conflicts over territorial control between armed groups, and in the end, only a few families and a store were left in the rural area of Palagua.

With the decrease of the conflict in the territory and the arrival of Empresa Colombiana de Petroleos, ECOPETROL in 1986, the displacement situation normalized and a new process of immigration to the sector initiated, which was attributed to the employment prospects in livestock farming and oil extraction activities.

Between 1995 and 2003, Ecopetrol and other oil field operators have paid for the operation of their oil fields in the Middle Magdalena Valley. The enhancement of social benefits for the area is greatly reflected in the more than $ 146,500 million in royalties, $1,645 million in taxes, and the $6,358 million in transportation taxes that have been collected by the government from Ecopetrol and others.

The social contribution to the communities surrounding these areas is reflected in health care provided to more than 3,500 people with paid doctors and the supply of free medicines.
.
Another of the contributions is the support given to education, including the reconstruction of old schools, and building of new ones, and the provision of books and school kits. Likewise, support has been given to the employment generation through support to micro companies. Businesses such as a recycling company, a corn flailer, production of ice cream, fast food and sewing shop are part of those that have been sponsored.


Figure 3.E-2 Educational Institutions existing in the Palagua Rural Area

E.1.2. INDIRECT INFLUENCE AREA (IIA)

The Indirect Influence Area is considered the area where the project activities are not performed; however, some indirect impacts rmay result from the drilling project. This area comprises the geographical coverage of the municipality of Puerto Boyacá, Boyacá.

- **Boyacá Department**

The department (state) of Boyacá is located in the central part of Colombia, limiting to the North with the departments of Santander and Norte de Santander, the departments of Arauca and Casanare to the East, the department of Cundinamarca to the South, and the department of Antioquia to the West.

Before the conquest, the Boyacá state was inhabited by numerous Indian tribes, especially belonging to the Caribbean linguistic families (Muzos and Citaráes) in the Magdalena Valley and Chibchas in the central territory. Many of these indigenous communities had a peaceful attitude. This situation facilitated racial mixing in this region.

The state's economy depends mainly on farming, food processing and mining.

- **Puerto Boyacá Municipality**

The municipality includes all the area known as the Vasquez Territory, which was named in honor of the Independence Martyr Cayetano Vasquez.

Surrounding the oil installations, large areas cultivate rice, maize, banana, and cassava (manioc). Wood logging was also developed. In late 1957, the village opened a road to Puerto Niño. The four kilometer road was built in 40 days by the Texas Petroleum Company. This was the first land road for the rising new city. Soon industries such as the first gas station, and the first transportation company also began to emerge.

- **Population Settlements**

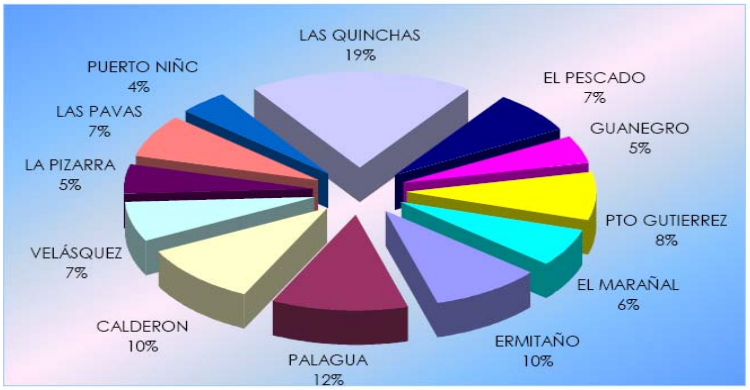
Currently the municipality of Puerto Boyacá has nineteen (19) settlements or population centers, which are distributed in the two main townships or administrative districts in the municipality. The following table is a summary of the above information.

Table 3.E - 1 – Administrative Division of the area

TOWN SHIP	RURAL AREA / Km²	POPULATION CENTER
1. Vasconia-Puerto Serviéz 465.99 Km.²	1.Palagua / 173.54	1.Cruce Palagua 2.Cruce El Chaparro
	2.Calderón / 150.78	3. Muelle Velásquez
	3. El Ermitaño / 141.67	4. El Ermitaño
2.Puerto Pinzón 1.017,45 Km²	3.Velásquez / 100.45	5.El Marfil
	4. Las Quinchas / 282.67	6. Puerto Pinzón
	5.La Pizarra / 72.09	7. La Pizarra 8. La Ceiba
	6.Las Pavas / 107.14	9. El Okal 10. Puerto Romero
	7.Guanegro / 70.35	11. Guanegro
	8.Puerto Gutiérrez / 118.92	12.Kilómetro 25
	9.El Marañal / 94.02	13. Unión Pto. Gutiérrez.
	10.El Pescado / 109.81	14. El Trique 15. El Pescado
	11.Puerto Niño / 62.01	16.Puerto Niño 17.Km. 1½ 18. Km. 2½ 19. Km. 11

Source: PBOT Basic Plan of Territorial Development, Municipality / Puerto Boyacá. 2005

The municipality of Puerto Boyacá consists of 12 rural areas which belong to the two townships of the Vasconia Territory - Puerto Serviez and Puerto Pinzón.



Source: PBOT Basic Plan of Territorial Development, Municipality / Puerto Boyacá. 2005

Figure 3.E-3 Division of the rural areas (by percentages)

E.2. SOCIAL SERVICES STRUCTURE

E.2.1. Population

The population of the municipality of Puerto Boyaca, according to the census of June 2005 is 50,301 inhabitants. .50% of the population is women and 50% is men. Thirty-three percent

(33%) of the population lives in rural areas and 67% in urban areas. On average, there are 34.17 inhabitants per square km.

Table 3.E - 2 Population - Puerto Boyacá Municipality

State (Departament)	Municipality	Surveyed Population – June 2005 Census		
		Total Population	Municipal Seat Population	Rural Population
Boyacá	Puerto Boyacá	50,301	33,806	16,495

Source: DANE (National Statistics Center) Census DANE. 2005

E.2.2. EDUCATION

According to the information stated in the PBOT, the Basic Plan of Territorial Development, (in Spanish - Plan Básico de Ordenamiento Territorial), for the Municipality of Puerto Boyacá, in 2005, the population has access to educational programs in pre-school, elementary school, academic, commercial, and/or technical high school as well as agricultural university and intermediate level. Adult training programs are offered by SENA and other non-governmental entities. There are also institutions offering informal education programs, job training, and preparation for high school.

There are 62 institutions of formal education in Puerto Boyacá. In the urban sector, coverage for school-age population reaches 82.6% in thirteen (13) schools; while in the rural sector this coverage reaches only 62% and is being provided by 48 government institutions.

The data recorded in the PBOT, shows that 16% of people who make up the population are illiterate. In terms of distribution by area, 13% of the illiterates live in the municipal seat. For the rest of the territory this percentage reaches 23%. The following table shows the illiteracy rates in the municipality.

Table 3.E-3 Illiteracy Indicators Puerto Boyacá Municipality

Area	Total Inhabitants %	Literate Persons %	Illiterate Persons %	No information Available %
Municipal Seat Population	69%	87%	13%	0
Rural Population	31%	76%	23%	1
Total	100%	84	16%	0

Source: Dane Evaluating Work Inspection Task Team PBOT Basic Plan of Territorial Development, Municipality, Puerto Boyacá

The elementary school Palaguas - Alliance, with eighty (80) students and three (3) teachers, is located in the area of direct influence. This school was built by the Texas Petroleum Comany in 1966, and upgrading and maintenance has been carried out by local governments with the support and participation of ECOPETROL, the community, and the Temporary Union IJP, the current oil and gas producer of the Palagua-Caipal field. The school is in good condition.

Figure 3.E-4 Palagua Alliance School

E.2.3. HEALTH

José Cayetano Vásquez Hospital, a State Social Enterprise, is currently the main provider of first and second level health services, and its coverage comprises entire urban area and twenty rural areas.

The municipality has 14 health posts in rural areas, of which only those located at the populated centers of La Pizarra, Puerto Serviez, and La Ceiba offer permanent services.

The environmental health office is a unit of the José Cayetano Vásquez Hospital responsible for developing related and planned activities under the PAB - Plan de Atención Básica Municipal - (Municipal Basic Health Plan). The development of programs for environmental sanitation and public health surveillance is funded by the state and the municipality's own resources, receiving municipal administration, counseling and coordination from the Health Department of Boyacá.

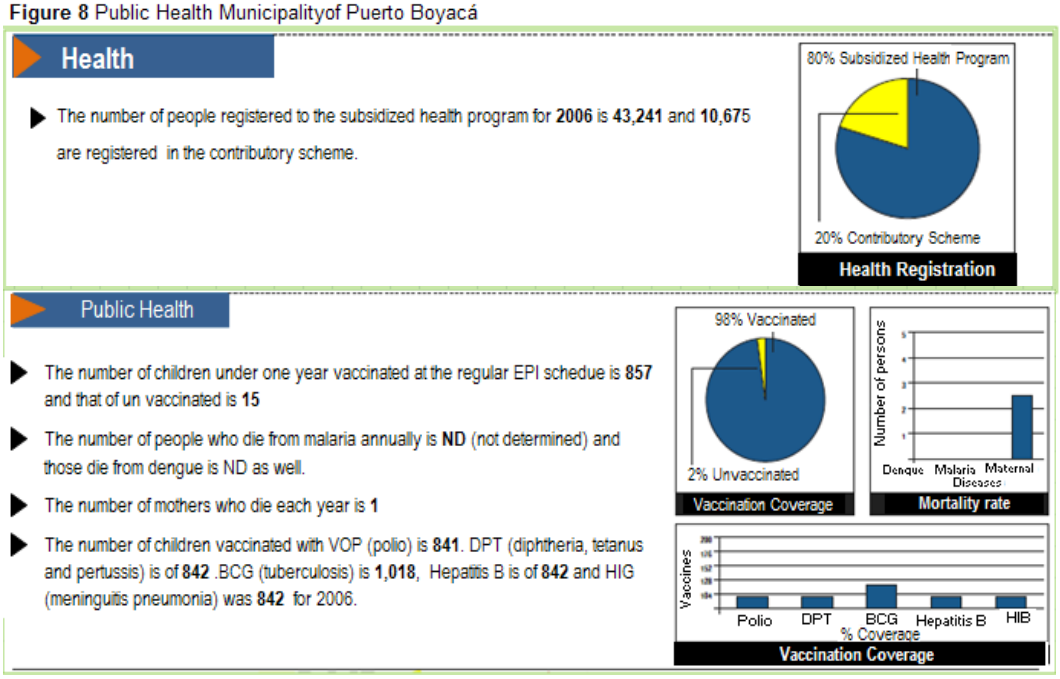
For 1993 the birth rate of the municipality was 2.2% Data shows the main causes of death are heart failure, vascular brain disease, sepsis, diabetes, intracranial trauma, among others; in addition to security problems and public order issues.

In the rural area, the health posts that provide the service and have supplies are: Puerto Serviez on the rural area El Ermitaño (The Hermit), Puerto Calderón in La Ceiba and La Pizarra (The Slate) in the rural area of La Pizarra (The Slate). These post offer health services to the central and northern areas of the municipality.

The low health service coverage in rural areas is manifested by higher rates of mortality. The main causes of this low coverage include: the sparsely populated areas, difficult road access, poor quality water supply and sanitation services, poor preventive health services, poor housing conditions and poor eating habits.

The figure below illustrates Public Health indicators including: Immunization Coverage, Mortality Rate, and the number of people registered or affiliated to the Health System at the Puerto Boyacá Municipality.

Figure 8 Public Health Municipalityof Puerto Boyacá



Source: Census 2005

Figure 3.E-5 Public Health Puerto Boyacá Municipality

The Palagua Rural Area has a health post, built in 1996, that was being served by a health promoter. Periodically health brigades and preventive medicine are carried out at the facility.

E.2.4. HOUSING

SISBEN, the Beneficiary Selection System for granting state subsidies, reports the existence of 5700 households at the rural areas, 8595 at the major town, and 425 households that are properties of the state.

The Rural Areas show a predominance of villages or settlements with zinc covered or thatched - roofed houses, rough walls, some with brick or cement blocks, and earthen floors. Only a few of the existing houses use concrete. A high percentage of these settlement houses and villages are located on roadsides (taking possession of land by poaching rights), where they border large estates, without following any type of urban planning or system.

At the Palagua municipality, most houses are built with wooden walls or crude lumber, palm or zinc roofs, and floors made mostly on natural earth or packed soil. Little concrete is used in the buildings.

E.2.5. RECREATION AND SPORTS

The municipality has as a coordinating office, the Municipal Institute of Recreation and Sports, a legal entity with administrative autonomy and independent assets. The resources are allocated to it by the Mayor in accordance with the plans, programs, and projects which are submitted by the entity to his office.

Among the sports scenarios available to the municipality may be included:

- Ramón Rapelo Municipal Stadium
- Cycling Schools
- Private Pools
- Private Motocross Track
- Chess Club
- Parks with games, rides, and other mechanical attractions
- Main Park

In addition, there are 14 municipal sports facilities, of which five are public, one is private and the others belong to educational institutions.

In the rural areas, most schools can boast one or multiple sports courts, but usually with inadequate infrastructure with access being limited to the most proximate residents. Therefore, most rural dwellers are not allowed to enjoy these benefits.

Mamagay Court is the most used sports facility by the inhabitants of the Palagua municipality, along with the multiple sports court at the school, which was completed in the year 1997. Its maintenance has been supported by ECOPETROL and the Temporary Union IJP, and is currently in good condition, frequently used by the school-age population.

E.2.6. CULTURE AND TOURISM

Figure 3.E-6 Tourist sites - Palagua Lake and La Cristalina Creek

Tourism has become one of the strategic lines for regional and local development given the comparative advantages of its unique location; its rich landscaping rising from its water sources.

Puerto Boyacá stands out as one of the main young municipalities of the country. In a short time, it has had a rapid development in the areas in which it operates.

There is an office in the municipality, Casa de La Cultura, which serves as a stage for dance events, a theater, and music concerts. Roughly 70% of the urban population benefits from the Casa de La Cultura.

E.2.7. JOB SOURCES

The Municipality has created alliances to generate sources of permanent employment, which includes:

1) Business Forum, showing the benefits of Puerto Boyacá and tax incentives for the establishment of companies.

2) Strengthening of the Microenterprise Fund, linking private sector companies, government agencies, and international organizations.

3) Creation of micro - enterprises of medium and short term productive projects.

For all the street vendors, shopkeepers, small traders and micro enterprises, there is a training program of job skills, production and marketing given by the National Learning Service, SENA.

The Municipality finances productive projects through the Fund Microenterprise and gives support to the project in the marketing and commercialization of its products or services to projects of food production and services.

E.2.8. PUBLIC UTILITIES

The identified domestic public services available are: water, sewage, electricity, public lighting, telephone (fixed and mobile), domestic gas, and TV communications.

E.2.8.1. Water

The municipality of Puerto Boyacá created the Public Services Company of Puerto Boyacá ESP, which is responsible for providing water supply services, sewerage, and trash collecting.

With regard to the rural supply of water, as stated by the municipal administration, the service has increased its coverage in recent years, meeting 65% of the rural area's water needs.. Nevertheless many places are lacking in water treatment plants and some of them are deficient due to malfunction or to an increase in the population that they must cover (as is the case of Puerto Serviez).

The Palagua Rural Area has had water supply service since 1987. In this same year, the INAS (Instituto Nacional de Agua y Saneamiento - National Institute of Water and Sanitation), at the request of the JAC (Junta de Acción Comunal), the Community Action Board, drilled the water well Flores 1 for human consumption, located on the right side of the road to the village of El Chaparro. In 1991, the City Administration provided the plumbing for the installation of distribution networks. In 1992, ECOPETROL built an elevated storage tank which increased the coverage of this service. Currently, the service is administered by the Aqueduct Board and covers about 74 homes. Other houses located in the area of the Palagua Lake get their water from artisan wells.

The Municipal Administration recently drilled a deep well with its respective elevated tank, located on the land on the Los Machines farm, covering the full water supply service to the entire rural area.

The Palagua Oil Field has the PW-1 Well located within the industrial area which provides the water for industrial and domestic activities.

Figure 3.E- 7 Well PW-1

E.2.8.2. Sewer System

In the year 1999, according to Public Enterprises of Puerto Boyacá ESP, the system should be providing service to 28,150 inhabitants. According to figures reported by the SISBEN for urban areas, the urban population for 2002 was 33,049 inhabitants and there were a total of 6,273 subscribers.

The municipal administration built seven (7) septic tanks and sewage networks for the Palagua Rural Area in 1997. Its coverage reaches at least 19 households out of which 12 are connected.

The homes that do not have septic tank and sewage service discharge wastewater directly to a distant lowland.

E.2.8.3. Trash Collection

For the utility company of Puerto Boyacá,, there are 6,273 registered subscribers distributed as follows: E-1 (1074), E-2 (2965), E-3 (1789), Small Farmers (30). In summary, there are 5,829 residential subscribers and 444 non-residential.

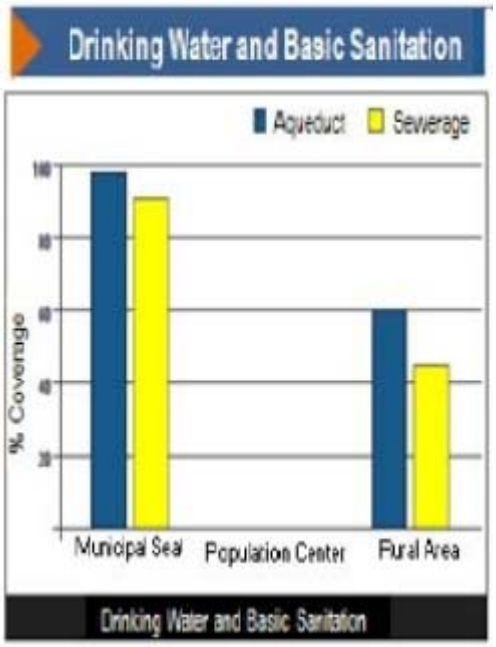
In relation to the rural area, the number of potential users is 5,700 houses. At the present time the service is provided in a very sporadic manner. This activity was carried out with the participation of the community, through environmental education work, and then it was delegated to the community action boards.
Twenty six (26) tons of municipal solid waste residues are generated per day, plus 3 Ton / day that arrive from rural areas. The generation rate of Urban Waste (Ru) is: Ru = 0.79 kg/person/day and the generation rate of Rural Waste (Rr) is: Rr = 0.14 kg/person/day.

The final disposal is a landfill that is located in the rural area. At the Palagua Oil Field, garbage collection is performed periodically throughout the rural area by the collection vehicle assigned

by the municipality. The area generates about ten (10) 55-gallon drums. Solid wastes are classified in advance, placed in bags for easier handling, and put into containers or bins.

Conclusion

The municipality of Puerto Boyacá has a water supply service that covers 97.57% in the urban area, 91% sewerage coverage in the urban area, and a landfill location for solid waste disposal.



- For 2005, the aqueduct has a coverage of 97.5% in municipal areas, ND for population centers and 60.30% for rural areas
- In 2005, the sewer system covers 91.10% of the areas of the municipal seats, ND for the population centers, and 45.45% for rural areas
- The number of sites for solid waste disposal in the municipality is 1.

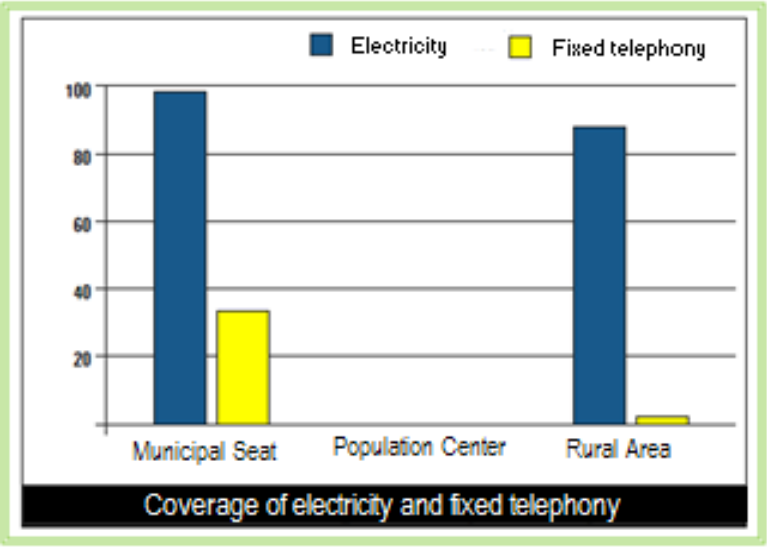
Source: Dane. (National Statistics Center) Census 2005

Figure 3.E-8 Drinking Water and Basic Sanitiation, Municipality of Puerto Boyacá

E.2.8.4. Electric Power

Based on Electric Power Company, Boyacá S. A.'s figures, there are 9,558 registered subscribers, of which 6,663 are urban, 2,895 are rural, and approximately 1,600 don't have legal access to public services. The number of potential users reaches 12,959.

Coverage rates are established according to census figures and SISBEN (96.13 % is for urban areas and 82,36 % for rural areas). Coverage in the Palagua Rural Area does reach to about 95% of the homes.



Source: Dane. (National Statistics Center) Census 2005

Figure 3.E-9 Coverage of Electricity and Fixed Telephony

E.2.8.5. Household Gas

The company ALCANOS DE COLOMBIA S.A., E.S.P, with headquarters based in Neiva is responsible for the provision of service in the urban area .Currently it serves about 4,000 users from different sectors of the municipality.

For rural areas the supply of gas is carried by trucks that have permanent routes and some rural area distribution sites. The service is maintained constantly.

E.2.8.6. Telephone

Similarly to the rest of the country, two systems provide telephone communication services in the municipality. The first provides telephone services using a physical phone through the (Empresa Nacional de Telecomunicaciones) TELECOM ESP National Telecommunications Company, and the second is private business Mobile telephone services such as: COMCEL, MOVISTAR and TIGO.

(See: Appendix D, Map 11 - Public Service Infrastructure)

E.3. ECONOMICS FACTORS

The municipality of Puerto Boyacá currently has an economic structure based on livestock, agriculture, fisheries, timber, mining, and hunting industries.

E.3.1. Agriculture Development

The Municipal Unit for Agricultural Technical Assistance UMATA (Unidad Municipal de Asistencia Técnica Agropecuaria); shows the following statistics: the planted area is around 1,035 hectares. This activity generates only 6% of the available employment. The bulk of production is for subsistence utilization and consumption markets in the nearby area. Only a small surplus is taken to markets in other locations.

(See: Appendix D, Map 12 - Agrological Classification)

E.3.2. Farming and Livestock Exploitation

Eighty point seven percent (80.7%) of the productive land in the municipality is covered with grassland, having natural or improved pastures. The town is widely recognized as a ranching location. The more recent livestock data reports 138,562 head of cattle, mainly from the Brahma and native breeds, 1,870 buffalo, 5,265 horses, 1,064 sheep, 639 pigs, and 163 goats.

Figure 3.E - 10 Cattle Ranching Puerto Boyacá

Farmers in the region maintain their dual purpose (meat & milk) herds in small to medium size premises, and destine large farms for cattle fattening.

The average cattle slaughter for consumption in urban areas is 270 heads per month and fifty (50) head for the rural sector.

The livestock business in the area generates 61.9% of rural employment

E.3.2.1. Fisheries Exploitation

Fishing is considered the oldest and the most widely spread economic activity in the area because of the many different water resources of the region, particularly near the Magdalena River.

In Puerto Boyacá, there are five (5) settlements of commercial fishermen clearly identified which are: Pueblo Nuevo Neigborhood, and the townships of Puerto Serviez, Puerto Niño, and three settlements around the area of Velásquez. In accordance with estimates of the INCODER territorial office, about 800 fishermen are devoted to this activity.

The main species caught are: bocachico, catfish, capaz, blanquillo, dorada, and comelón.

E.3.2.2. Tree Cutting

For several years, the increasing expansion of the agricultural frontier has been promoting major changes in the vegetation cover in the region, giving way to large cattle ranches and affecting some forests and fragile ecosystems.

The involvement of the Autonomous Regional Corporation (CAR), and the Instituto Colombiano Agropecuario (ICA), through controls on tree cutting (felling) and marketing, training farmers and settlers, and carrying out reforestation activities has decreased rates of extraction of forest species. The most common species of trees in the region are: caracoli, yellow, ceiba, hobo, charcoal, coco twine, Juana mestiza, abarco, carob, sapan and cedar.

E.3.2.3. Mining

The exploitation of hydrocarbons is exerted mainly in the municipality in the fields Velasquez, Jazmín and Palagua.
ECOPETROL's Vasconia station located close to Puerto Boyacá receives crude oils produced from different fields in the Country. These crudes are mixed in this station and are transported through the pipeline that runs to the oil refinery in Coveñas.

Other mining activities are related to the exploitation of gravel and sand for the building and construction industry carried out in the Magdalena River area. It is estimated that this activity involves about a hundred people in the municipality.

Livestock farming and oil drilling have been the most important economic activities for several years in the Palagua Rural Area.

F. ENVIRONMENTAL QUALITY OF THE AREA OF THE PROJECT

This section describes the evaluations of the environment in and around the Palagua field. This evaluation focuses in determining the presence of pollutants in the air, water, soil and sound pressure level (noise levels) that are commonly related with the hydrocarbon operation.
These parameters are compared with local and international regulations.

F.1. AIR QUALITY

Air quality determination is a complex activity due to the variation of weather conditions. Unlike water or soil contamination assessments, air quality measurements are more complex, more expensive and fixed site based, since variations are not constant in space and time. From October 9th to November 7th 2009, the main parameters associated with air quality were analyzed to establish the future variations during the Development Project in the Palagua Field.

The parameters analyzed were the following:

- Total Particulate Material (TPM´s).
- Particulate Material ((PM10)
- Nitrogen oxides (NOx)
- Sulfur oxides (SOx)
- Carbon Monoxide (CO).
- Ozone (O3)

The results obtained were compared with Resolution 601 of April, 2006, (601/2006) fulfilling the standards established by the Ministry of Environment and Territorial Development (M.A.V.D.T in Spanish) and the Environmental, Health, and Safety (EHS) Guidelines of the World Bank – used by the International Finance Corporation (IFC).

F.1.1. LOCAL CONDITIONS

The sampling sites for this project were established with the following location criteria:

- Far from high vehicular traffic routes and / or pathways that are not paved
- To a distance no less than 20 metes of vegetation or trees in the sampling area
- A radius of 270 ° unrestricted flow around the sampling equipment.

Table 3.F-1 lists the location of each sampling site.

Table 3.F-1 Sampling Locations

SITE	SAMPLING POINT	GEOGRAPHIC COORDINATE
PALAGUA FIELD IN THE STATE OF BOYACA, COLOMBIA	STATION 1 BATTERY 1	N 06º04'46,4" E 74º30'21,6"
	STATION 2 INDUSTRIAL AREA	N 06º04'58,6" E 74º30'30,3"
	STATION 3 BATTERY 2	N 06º05'06,0" E 74º30'53,8"
	STATION 4 BATTERY 4	N 06º06'32,0" E 74º31'17,0"

SOURCE: ANTEK S.A. (November, 2009)

Photo 3.F-1 Battery 1
SOURCE: ANTEK S.A. (November, 2009)

Photo 3.F-2 Industrial Area
SOURCE: ANTEK S.A. (November, 2009)

Photo 3.F-3 Battery 2
SOURCE: ANTEK S.A. (November, 2009)

Photo 3.F-4 Battery 4
SOURCE: ANTEK S.A. (November, 2009

The methodology used for the sampling can be found in Appendix A.

The maximum standard for local air quality is set by Resolution 601 of April 7th 2006 by the Ministry of Environment and Territorial Development. The local standard represents a correction for pressure and temperature taken over the concentration established in reference conditions of 298 K (25 ° C) temperatures and 760 mm Hg barometric pressure. The following equation is used to find the local standard of air quality:

$$N_L = N_{CR} \cdot \left(P_{BL} / 760\ mm\ Hg \right) \cdot \left(298\ K / T_L \right)$$

Where: NL = local standard (maximum allowable concentration) Ncr = reference Standard conditions PBL = local barometric pressure, mm Hg TL = local average temperature, K.

The different topographical conditions of the monitoring points that make up the stations can be found in the following table.

Table 3.F-2 Local conditions at the sampling points

SAMPLING POINT	Height (m)	Local Pressure (mm Hg)	Local Temperature °C/K
STATION 1 BATTERY 1	156	746.5	34.8 ° C or 308 K
STATION 2 INDUSTRIAL AREA	161	746.1	34.8 ° C or 308 K
STATION 3 BATTERY 2	163	745.9	34.9 ° C or 308 K
STATION 4 BATTERY 4	184	744.1	35.0 ° C or 308 K

F.1.2. AIR QUALITY RESULTS

- Regarding the Total Suspended Particles, the highest concentration of PST was found at Station 2 - Industrial Area with a value of 37.35 µg/m3 followed by Station 3 with a value of 24.98 µg/m3. The four monitoring stations comply with the annual local air quality standard and most of the levels reported in the Palagua field are low. This parameter is not reported in the Environmental Guidelines of the World Bank (IFC in the table)

- The highest concentrations of PM10 were indicated in Station 2 with a value of 15.56 µg/m3. This concentration is below the local standard as well as the guidelines form the World Bank. Therefore, the four monitoring points meet the annual standard for air quality.

- The nitrous oxide concentrations have no significant variations from one station to another. The Station 2 – Industrial Area has a higher concentration; however, this concentration represents only 25% of the World Bank Guidelines.

- Similar to the concentrations of particulates and nitrogen oxides, the concentration of sulfur oxides fully comply with local and international regulations established for the annual and daily local air quality in the area. Variations between stations are minimal. Station 2 has the highest recorded average concentration, and the lowest is found at Station 4.

- No presence of carbon monoxide was found, which verified the compliance for air quality, according to Article 4 of Resolution 601 of 2006 established by the Ministry of Environment, Housing and Territorial Development.

- Ozone measurements show very low concentrations in all the stations in the area of the project.

Table 3.F-3 Air Quality in Battery 1

PARAMETER	UNITS	MEASURE			RESOLUTION 601/06 AT LOCAL CONDITIONS	IFC Guideline
		Min	Max	Average		
Total Suspended Particles						
Daily Value	**µg/m3**	**4.82**	**21.60**	**14.92**	**285,12**	**NR**
Annual Geometric Average	**µg/m3**				**95,04**	**NR**
Coarse Particles (PM10)						
Daily Value	**µg/m3**	**1.76**	**8.33**	**5.58**	**142,56**	**50**
Annual Geometric Average	**µg/m3**				**66,53**	**20**
Coarse Particles (PM2.5)						
Daily Value	**µg/m3**	**NR**	**NR**	**NR**	**NR**	**10**
Annual Geometric Average	**µg/m3**				**NR**	**25**
Sulfur Oxides						
Annual mathematical Average	**µg/m3**	**6.67**	**10.48**	**8.74**	**76,03**	**NR**
Daily Value	**µg/m3**				**237,60**	**20**
3 hours	**µg/m3**				**712,80**	**NR**
10 minute	**µg/m3**				**NR**	**500**
Carbon Monoxide						
1 hour	**mg/m3**	**ND**	**ND**	**ND**	**38,02**	**NR**
8 hours	**mg/m3**				**9,50**	**NR**
Ozone						
8-hour daily	**mg/m3**	**ND**	**ND**	**ND**	**NR**	**100**
Nitrogen oxides						
Annual mathematical Average	**µg/m3**	**4.74**	**7.87**	**6.24**	**95,04**	**40**
Daily Value	**µg/m3**				**142,56**	**NR**
1 hour	**µg/m3**				**190,08**	**200**

NR: Not reported
ND: Not Detectable
SOURCE**:** ANTEK S.A. (November, 2009) and EHS Guidelines World Bank Group, IFC

Table 3.F-4 Standard Local Air Quality in Industrial Area

PARAMETER	UNITS	MEASURE			RESOLUTION 601/06 AT LOCAL CONDITIONS	IFC
		Min	Max	Average		Guideline
Total Suspended Particles						
Daily Value	**µg/m3**	**8.68**	**80.49**	**37.35**	**284,98**	**NR**
Annual Geometric Average	**µg/m3**				**94,99**	**NR**
Coarse Particles (PM10)						
Daily Value	**µg/m3**	**2.93**	**27.69**	**15.56**	**142,49**	**50**
Annual Geometric Average	**µg/m3**				**66,5**	**20**
Coarse Particles (PM2.5)						
Daily Value	**µg/m3**	**NR**	**NR**	**NR**	**NR**	**10**
Annual Geometric Average	**µg/m3**				**NR**	**25**
Sulfur Oxides						
Annual mathematical Average	**µg/m3**	**7.89**	**10.81**	**9.6**	**76**	**NR**
Daily Value	**µg/m3**				**237,49**	**20**
3 hours	**µg/m3**				**712,46**	**NR**
10 minute	**µg/m3**				**NR**	**500**
Carbon Monoxide						
1 hour	**mg/m3**	**ND**	**ND**	**ND**	**38**	**NR**
8 hours	**mg/m3**				**9,5**	**NR**
Ozone						
8-hour daily	**mg/m3**	**ND**	**ND**	**ND**	**NR**	**100**
Nitrogen oxides						
Annual mathematical Average	**µg/m3**	**6.03**	**8.43**	**7.4**	**94,99**	**40**
Daily Value	**µg/m3**				**142,46**	**NR**
1 hour	**µg/m3**				**189,99**	**200**

NR: Not reported
ND: Not Detectable
SOURCE: ANTEK SA (November, 2009) and EHS Guidelines World Bank Group, IFC

Table 3.F-5 Air Quality in Battery 2

PARAMETER	UNITS	MEASURE			RESOLUTION 601/06 AT LOCAL CONDITIONS	IFC Guideline
		Min	Max	Average		
Total Suspended Particles						
Daily Value	**µg/m3**	**18.98**	**32.48**	**24.98**	**284,98**	**NR**
Annual Geometric Average	**µg/m3**				**94,99**	**NR**
Coarse Particles (PM10)						
Daily Value	**µg/m3**	**8.13**	**12.40**	**9.23**	**142,41**	**50**
Annual Geometric Average	**µg/m3**				**66,46**	**20**
Coarse Particles (PM2.5)						
Daily Value	**µg/m3**	**NR**	**NR**	**NR**	**NR**	**10**
Annual Geometric Average	**µg/m3**				**NR**	**25**
Sulfur Oxides						
Annual mathematical Average	**µg/m3**	**7.93**	**10.89**	**9.45**	**75,95**	**NR**
Daily Value	**µg/m3**				**237,49**	**20**
3 hours	**µg/m3**				**712,05**	**NR**
10 minute	**µg/m3**				**NR**	**500**
Carbon Monoxide						
1 hour	**mg/m3**	**ND**	**ND**	**ND**	**37,98**	**NR**
8 hours	**mg/m3**				**9,49**	**NR**
Ozone						
8-hour daily	**mg/m3**	**ND**	**ND**	**ND**	**NR**	**100**
Nitrogen oxides						
Annual mathematical Average	**µg/m3**	**6.48**	**8.01**	**6.91**	**94,94**	**40**
Daily Value	**µg/m3**				**142,41**	**NR**
1 hour	**µg/m3**				**189,88**	**200**

NR: Not reported
ND: Not Detectable
SOURCE: ANTEK SA (November, 2009) and EHS Guidelines World Bank Group, IFC

Table 3.F-6 Air Quality in Battery 4

PARAMETER	UNITS	MEASURE			RESOLUTION 601/06 AT LOCAL CONDITIONS	IFC Guideline
		Min	Max	Average		
Total Suspended Particles						
Daily Value	µg/m3	8.04	27.78	22.47	284,08	NR
Annual Geometric Average	µg/m3				94,69	NR
Coarse Particles (PM10)						
Daily Value	µg/m3	2.52	11.12	8.4	142,04	50
Annual Geometric Average	µg/m3				66,29	20
Coarse Particles (PM2.5)						
Daily Value	µg/m3	NR	NR	NR	NR	10
Annual Geometric Average	µg/m3				NR	25
Sulfur Oxides						
Annual mathematical Average	µg/m3	6.61	11.11	8.57	75,75	NR
Daily Value	µg/m3				236,73	20
3 hours	µg/m3				710,20 37,88	NR
10 minute	µg/m3				NR	500
Carbon Monoxide						
1 hour	mg/m3	ND	ND	ND	9,47	NR
8 hours	mg/m3				94,69	NR
Ozone						
8-hour daily	mg/m3	ND	ND	ND	NR	100
Nitrogen oxides						
Annual mathematical Average	µg/m3	5.12	8.68	6.12	189,39	40
Daily Value	µg/m3				284,08	NR
1 hour	µg/m3				94,69	200

NR: Not reported
ND: Not Detectable
SOURCE: ANTEK SA (November, 2009) and EHS Guidelines World Bank Group, IFC

F.1.3. SMALL COMBUSTION FACILITIES EMISSIONS

The equipment used in the field where combustion occurs, includes gas-fueled electrical generators, drilling rigs, and curde oil heaters. The quality of combustion-exhaust gases meets all the regulations including Colombian Resolution 909/2008 and the IFC Guidelines as listed below.

Table 3.F-7 Small Combustion Facilities Emissions

SMALL COMBUSTION FACILITIES EMISSIONS										
Pollutant / Source	Gas Generator No.1	Gas Generator No.2	Drilling Rig	Wells Service Rig No.1	Wells Service Rig No.2	Battery No.1	Station No.2	Station No.4	Colombia Resolution No.909/2008	IFC Guidelines
Particulate Matter (PM) mg/Nm^3	3	3	6	6	6	5.86	9.71	8.87	50	N/A
Sulfur Dioxide (SO_2) mg/Nm^3	0	0	112	112	112	8.74	9.45	8.57	400	N/A
Nitrogen Oxides (Nox) mg/Nm^3	44	44	63	63	63	6.24	6.91	6.12	300	200

N/A: No emissions guideline

F.1.4. GREENHOUSE EMISSIONS

For 2009, the oil production in Palagua Field averaged 4,615 bpd (barrels per day) with a water production of 11,085 bpd and 1,385 MSCFD (thousands of standard cubic ft per day) of gas. The amount of gas that was not used was flared. Considering the activities related to the oilfield operation: drilling, work-overs, mobile sources, etc., the total calculated emissions for 2009 are 46,073 ton eq CO2/year.

The method used for the present calculation was based on the “COMPENDIUM OF GREENHOUSE GAS EMISSIONS METHODOLOGIES FOR THE OIL AND GAS INDUSTRY”, published by the American Petroleum Institute in August, 2009.

Other resources used were the “ENVIRONMENTAL, HEALTH, AND SAFETY GENERAL GUIDELINES” from the World Bank Group; the “ENVIRONMENTAL, HEALTH, AND SAFETY GUIDELINES FOR ONSHORE OIL AND GAS DEVELOPMENT” from the World Bank Group, and its Guidance Notes.

Table 3.F-8 Production and consumption data for 2009

FUEL	Natural gas	mole %	MW	wt %	# atoms C	Wt%C
	CO2	0.20	44.00	0.53	1	0.14
	CH4	97.15	16.04	94.10	1	70.40
	C2H6	0.68	30.07	1.23	2	0.99
	C3H8	0.20	44.10	0.53	3	0.43
	C4H10	0.10	58.12	0.35	4	0.29
	N2	1.54	28.00	2.60	0	0.00
	Total fuel	**99.87**	**16.56**	**99.35**		**72.25**
		Diesel			**Gasoline**	
	Density	7.07	lb/gal		6.2	lb/gal
	LHV*	5.53E+06	BTU/bbl		4.99E+06	BTU/bbl
	Wt% C	0.8634	lbc/lb diesel		0.866	lbc/lb gasoline

CONSUMPTION					
	Process	435000	scf/day		
	Flared	870000	scf/day		
	LHV	905	BTU/scf		
	Electricity	90000	scf/day		
	Drilling rig	Diesel		Gasoline	
	Consumption	800	gal/day	200	gal/day
	# days per well	14	day/well	14	day/well
	# wells	10	well	10	wells
	Workover Rig	Diesel		Gasoline	
	# workovers/year	146		146	
	Consumption	250	gal/day	40	gal/day
	# days per workover	2		2	

FIELD DATA					
	Oil production	4651	bbl/day		
	Water production	11085	bbl/day		
	Vehicles	Diesel		Gasoline	
	Consumption	130	gal/day	60	gal/day
	pick-ups	13	ea		
	trucks	5	ea		
	Electricity Imports	625000	W-HR		
	Number of active wells	100			
	Number of separators	3			
	Miles of gas pipeline	5.6			
	Mile gas pipeline for transmission	0.00			

* LHV = low heating value

Table 3.F-9 Total Greenhouse Emmisions

CATEGORY	CO2	CH4	NO2
	ton/year	ton/year	ton/year
COMBUSTION SOURCES			
Stationary devices with 100% efficiency			
Includes: Heaters			
Generator			
Total Facilities:	*9,182*	*0.2*	*1.7E-02*
Generator	*1,900*	*3.9*	*3.5E-03*
Well drilling	*1529*	*2.9E-02*	*5.2E-03*
Workovers	*932*	*1.6E-02*	*2.5E-03*
Stationary devices with 98% efficiency			
Flares combusted 98%	17,998	0.3	3.3E-02
non-combusted 2%		130.5	
Total Flares	*17,998*	*131*	*3.3E-02*
Total stationary sources	**31,541**	**135**	**6.1E-02**
Mobile sources			
Diesel vehicles	*531*	*7.3E-03*	*7.3E-04*
Gasoline vehicles	*216*	*9.1E-03*	*1.8E-03*
Total mobile sources	**747**	**0**	**0**
TOTAL COMBUSTION SOURCES	**32,288**	**135**	**0**
INDIRECT SOURCES			
Electricity Imports	*802.7*	*4.6E-02*	*1.5E-01*
TOTAL INDIRECT SOURCES	**802.7**	**4.6E-02**	**1.5E-01**
VENTED SOURCES			
Dehydration processes		*6.7*	
Storage tanks and drain vessels			
Workovers		*0.3*	
Mud degassing	17	33.8	
Process equipment		*1.4E-03*	
Gathering pipeline		3.0E-02	
TOTAL VENTED SOURCES	**17.3**	**40.7**	**0.0**
FUGUTIVE SOURCES			
Oil production		438	
Pipeline gas	0.0E+00	0.0E+00	
Oilwellheads	3.6E-03	6.4E-01	
Separators	1.1E-04	2.0E-02	
TOTAL FUGUTIVE SOURCES	**3.7E-03**	**439**	**0.0**
SUBTOTAL EMISSIONS, tons	33,108	614	2.1E-01
SUBTOTAL EMISSIONS, tons CO2eq		12,900	65
TOTAL EMISSIONS, tons CO2eq/year		**46,073**	

F.2. WATER QUALITY

In July 2001, the National Oil Company ECOPETROL handed over the Palagua and Caipal oil fields to the UT-IJP for their operation under an incremental production contract. The field was operated by Texaco from 1957 onwards. Thus, Ecopetrol and Texaco operated the Palgua Caipal field from 1957 till 2000.

Prior to taking over the field, UT-IJP did environmental base study. As per the agreement between Ecopetrol and UT-IJP, it is Ecopetrol's responsibility to pay for and arrange to remedy, environmental damage, if any, prior to the year 2000. Thus, as per the contract ECOPETROL is responsible of the environmental liabilities and the required monitoring and remediation/elimination activities for the non-recovered environmental impacts prior to year 2000.

F.2.1. DRINKABLE WATER

The source of the drinkable water is the shallow, active aquifers significantly above the Tune formation (2800' below subsea level in average for Palagua-Caipal area). There is one water-well, PW-1, that produces from an aquifer at 180' (88 m) below the surface.

Drinkable water aquifers are identified by resistivity measurements taken with electric logs every time a well is drilled.

Oil wells at the field are completed with steel casing from the bottom to the surface, guaranteeing no communication between oil bearing zones and drinkable water zones.

F.2.2. SURFACE WATER IN THE PALAGUA LAKE

One important conclusion of the 2000 Environmental Base line study was that Lake Palagua water lacked oxygen. To this effect, Ecopetrol took over the responsibility of correcting the situation. They annually cut the plants "Tarulla" from the lake. This has resulted in an increase in oxygen in the lake water and fish have returned to the Lake. Thus, there is a significant improvement in the quality of lake water from the year 2001 to 2010.

Ecopetrol, appointed ICP, "Instituto Colombiano del Petróleo" to monitor the progress of lake remediation. This report focuses on the results obtained from the monitoring activities carried out by "Instituto Colombiano del Petróleo" during the second semester of 2009, using the standards methods to determine the quality and conditions of the natural resources in Palagua Lake.

Samples were taken from Point 1 to Point 7 shown in Figure 3.F-1 and as shown in the pictures that follow.

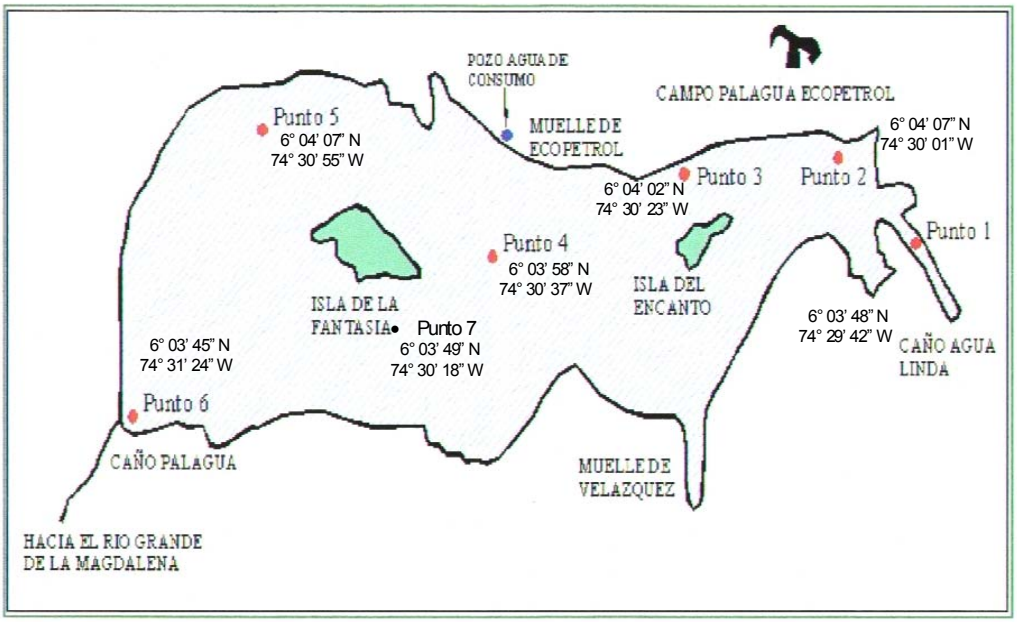


Figure 3.F-1 Location of Sampling Points

SPANISH TO ENGLISH TRANSLATION KEY:

- Punto:	Point
- Hacia el Rio Grande de La Magdalena	To the Grand River of the Magdalene
- Caño Palagua	Palagua Creek
- Isla de la Fantasia	Fantasy Island
- Pozo agua de consumo	Consume water well
- Muelle de Ecopetrol	Ecopetrol's dock
- Caño Agualinda	Agualinda Creek
- Muelle de Velazquez	Velazquez's dock

-

Table 3.F-10 Geographic coordinates of surface water sampling locations

Matrix	Location	Coordinates	
		N	W
PALAGUA LAKE	Point 1 Exit of the Agualinda creek into the Palagua Lake	06°03'46.0"	074°29'42.0"
	Point 2 Opposite to the exit of Agualinda Creek	06°03'55.5"	074°29'47.9"
	Point 3 At the shoreline of Palagua Lake	06°03'54.1"	074°30'04.7"
	Point 4 Central of Palagua lake in front of Ecopetrol's dock	06°03'52.1"	074°30'15.0"
	Point 5 North Fantasy Island	06°04'00.9"	074°30'38.9"
	Point 6 Entrance to the Palagua creek.	06°03'34.9"	074°31'10.9"
	Point 7 Between Palagua creek and Velazquez port	06°04'00.9"	074°30'15.5"

Palagua Lake-Point 1

Palagua Lake-Point 2

Palagua Lake-Point 3

Palagua Lake-Point 4

Palagua Lake-Point 5

Palagua Lake-Point 6

F.2.2.1. LAKE PALAGUA SURFACE WATER ANALYSIS RESULTS

Based on the National Law-Decree 1594/1984, Art. 38 and the results obtained, it can be concluded that:

- The pH values as well as the concentrations of cyanides, anions like chlorides, sulphates, nitrites and nitrates; ammonia-nitrogen, and metals like cadmium, chromium, lead, zinc and barium from the water samples taken in all the monitored places of Palagua Lake and also in the Agualinda, Palagua and El Tambo creeks, meet Article 38 of Decree 1594/84 of the Colombian Environment Law.

- The real color of the water bodies ranges between 87.7 and 150 Upt-Co levels which are out the range value of 75 UPt-Co permitted by the Law. However, the coloration of natural water is due to humic substances and tannic acids (due to vegetation in the lake).

- Hardness in the range of 17.9 mg CaCO3/l and 36.4 mg CaCO3/l indicates that the water of the Palagua Lake is soft, based on the range of 0-75 mgCaCO3/l .

- The concentrations of phenol compounds and polyaromatic hydrocarbons (PHAs) registered at each of the monitored points of Palagua Lake and in the Agualinda, Palagua and El Tambo creeks are not detectable by the methods used in the laboratory, demonstrating that PHA does not exist in these water bodies from compounds derived from the oil exploitation.

- Palagua Lake shows concentrations of oil, greases, and total hydrocarbons to be less than 1.07 mg/l corresponding to the minimum amount detectable by the methods used in the laboratory.

- The water of Palagua Lake and Agualinda, Palagua and El Tambo creeks have similar physical and chemical characteristics making the water suitable for domestic use.

The historical data at each measured point (Point 1 through Point 7), is listed in Appendix E.

Table 3.F-11 Analysis Results of Surface Water in the Palagua Lake (Part 1/2)

PALAGUA LAKE	SAMPLE IDENTIFICATION	POINT 1	POINT 2	POINT 3	POINT 4	POINT 5	POINT 6	POINT 7	DECREE 1594/84 ART 38
	POINT DESCRIPTION	Exit of the Agualinda creek into the Palagua Lake	Opposite to the exit of Agualinda Creek	At the shore exit line that unifies Palagua Lake with Enchanted Island	Central Part of the Palagua lake in front of Ecopetrol bridge	Behind Fantasy Island divergence Palagua Creek	Entrance to the Palagua creek.	Between Palagua creek and Velasquez port	
SUBMISSION: 100089101	DATE OF SAMPLING	24-Sep-09	9/24/2009	9/24/2009	9/24/2009	9/24/2009	9/24/2009	9/24/2009	
Component	UNITS								
ANALYSIS IN SITU									
CONDUCTIVITY/º T	micromhos/cm	67.5/31.9	68.6/32.6	64.4/32.9	63.5/34.4	64.4/35.5	66.7	65.4/34.4	NR
DISSOLVED OXYGEN	mg O2/L	2.28	3.76	4.00	5.46	5.02	2.84	4.68	NR
TURBIDITY	NTU	12.8	14.8	15.7	14.1	14	14.9	13.6	NR
LABORATORY									
pH /º T	Uni. pH	6.48/23.8	6.6/122.9	6.71/23.6	6.62/22.5	6.98/22.8	6.63/22.5	6.67/23.3	5.0-9.0
TEMPERATURE	°C	24.0	23.0	24.0	23.0	23.0	23.0	23.0	NR
TOTAL ALKALINITY	mg CaCO3/l	36.9	28.8	32.9	26.9	25.5	26.3	24.7	NR
TOTAL HARDNESS	mg CaCO3/l	108.0	91.5	91.2	91.1	87.7	88.5	89.1	NR
TOTAL ACIDITY	mg CaCO3/l	-18600	-14100	-13600	-14500	-12400	-12700	-13300	NR
COLOR	U Pt-Co	106.0	91.5	91.2	91.1	87.5	88.5	89.1	75.0
DISSOLVED CYANIDES	mg Cn/l	70.8	67.3	76.7	70.6	73.3	70.6	77.3	0..20
BOD	mg O2/l	2.0	<1.81	2.89	<1.81	2.77	<1.81	<1.81	NR
COD	mg O2/l	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	NR
DISSOLVED PHOSPOROUS	mg P/l	0.42	2.66	2.23	2.34	3.55	3.38	2.39	NR
DISSOLVED PHOSPHATE	mg PO4/l	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	NR
TOTAL PHOSPHOROUS	mg/L	1.09	1.02	2.07	1.74	1.03	0.73	0.56	NR
TOTAL PHOSPHATE	mg PO4/l	<0.031	<0.031	<0.031	m<0.031	<0.031	<0.031	<0.031	NR
CHLORIDES	mg/L	0.82	<0.59	0.62	<0.59	<0.59	<0.59	<0.59	250
SULPHATES	mg SO4/l	<1.0	<1.0	<1.0	<1.0	1	1.08	1.33	400
NITRATES NO3	mg NO3/l	1.93	1.72	1.98	1.88	1.72	1.73	1.94	44.3
NITRITES (NO2)	mg NO2/l	0.22	0.022	0.16	0.15	0.13	0.16	0.085	3.28
AMMONIA-NITROGEN	mg NH3/l	0.67	0.067	0.51	0.46	0.41	0.51	0.26	1.21
KJELDAHL NITROGEN	mg/L	0.32	0.23	0.25	0.39	0.16	0.2	0.17	NR
TOTAL NITROGEN	mg/L	1	0.7	0.77	1.19	0.49	0.61	0.52	NR
OIL AND GREASES	mg/L	<1.07	<1.07	<1.07	<1.07	<1.07	<1.07	<1.07	Non Visible Film
TOTAL HYDROCARBONS	mg/L	<1.07	<1.07	<1.07	<1.07	<1.07	<1.07	<1.07	NR
DISSOLVED SOLIDS	mg/L	82.8	83.6	75.6	58.4	64.4	78.8	76.4	NR
SUSPENDED SOLIDS	mg/L	15.5	13.5	12	12.5	16.9	9.8	14.8	NR
TOTAL SOLIDS	mg/L	126	119	90.4	96.4	91.6	104	100	NR
METALS									
SILICON	mg/L	10.77	9.089	8.487	8.444	7.228	7.872	7.965	NR
IRON	mg/L	0.972	1.252	1.236	0.833	1.214	1.048	0.9619	NR
CADMIUM	microg/L	0.044	0.034	0.036	0.053	0.063	0.034	0.038	10.0
CHROMIUM	microg/L	0.955	1.161	0.829	0.841	0.928	0.706	0.963	50 (Cr^{+6})
LEAD	microg/L	0.560	0.491	0.466	0.458	0.710	0.415	0.614	50.0
VANADIUM	microg/L	2.551	3.197	2.676	1.910	2.964	2.363	2.231	NR
ZINC	microg/L	7.22	43.74	23.58	<3.145	4.85	<3.145	43	15000
BARIUM	microg/L	70.6	59.04	61.98	59.37	67.99	59.52	59.64	1000
MOLYBDENUM	microg/L	0.536	1.666	0.395	0.366	0.366	0.499	0.401	NR

Table 3.F-12 Analysis Results of Surface Water in the Palagua Lake (Part 2/2)

PALAGUA LAKE	SAMPLE IDENTIFICATION	POINT 1	POINT 2	POINT 3	POINT 4	POINT 5	POINT 6	POINT 7	DECREE 1594/84 ART 38
	POINT DESCRIPTION	Exit of the Agualinda creek into the Palagua Lake	Opposite to the exit of Agualinda Creek	At the shore exit line that unifies Palagua Lake with Enchanted Island	Central Part of the Palagua lake in front of Ecopetrol bridge	North of the Fantasia Island	Entrance to the Palagua creek.	Between Palagua creek and Velasquez port	
SUBMISSION: 100089101	DATE OF SAMPLING	9/24/2009	9/24/2009	9/24/2009	9/24/2009	9/24/2009	9/24/2009	9/24/2009	
Component	UNITS								
PHENOLS ANALYSIS									
PHENOL	mg/l	<1.70E-4	<1.70E-4	<1.70E-4	<1.70E-4	<1.70E-4	<1.70E-4	<1.70E-4	0.002
2-CHLORO-PHENOL	mg/l	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	0.002
2-METHYLPHENOL	mg/l	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	0.002
3-METHYLPHENOL+4-METHYLPHENOL	mg/l	<1.70E-4	<1.70E-4	<1.70E-4	<1.70E-4	<1.70E-4	<1.70E-4	<1.70E-4	0.002
2-NITROPHENOL	mg/l	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	0.002
2-4-DIMETHYLPHENOL	mg/l	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	0.002
2-4-DICHLOROPHENOL	mg/l	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	0.002
2-6-DICHLOROPHENOL	mg/l	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	0.002
4-CHLORO-3-METHYLPHENOL	mg/l	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	0.002
2.3.5-TRICHLOROPHENOL	mg/l	<3.40E-4	<3.40E-4	<3.40E-4	<3.40E-4	<3.40E-4	<3.40E-4	<3.40E-4	0.002
2.4.6-TRICHLOROPHENOL	mg/l	<3.30E-4	<3.30E-4	<3.30E-4	<3.30E-4	<3.30E-4	<3.30E-4	<3.30E-4	0.002
2.4.5-TRICHLOROPHENOL	mg/l	<3.50E-4	<3.50E-4	<3.50E-4	<3.50E-4	<3.50E-4	<3.50E-4	<3.50E-4	0.002
2.3.4-TRICHLOPHENOL	mg/l	<3.40E-4	<3.40E-4	<3.40E-4	<3.40E-4	<3.40E-4	<3.40E-4	<3.40E-4	0.002
2.3.6-TRICHLOPHENOL	mg/l	<3.40E-4	<3.40E-4	<3.40E-4	<3.40E-4	<3.40E-4	<3.40E-4	<3.40E-4	0.002
4-NITROPHENOL	mg/l	<4.70E-4	<4.70E-4	<4.70E-4	<4.70E-4	<4.70E-4	<4.70E-4	<4.70E-4	0.002
2.3.4.6-TETRACHLOROPHENOL	mg/l	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	0.002
2.3.4.5-TETRACHLOROPHENOL	mg/l	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	0.002
2.3.5.6-TETRACHLOROPHENOL	mg/l	<4.20E-4	<4.20E-4	<4.20E-4	<4.20E-4	<4.20E-4	<4.20E-4	<4.20E-4	0.002
3.4.5-TRICHLOROPHENOL	mg/l	<3.90E-4	<3.90E-4	<3.90E-4	<3.90E-4	<3.90E-4	<3.90E-4	<3.90E-4	0.002
2-METHYL-4.6-DINITROPHENOL	mg/l	<9.90E-4	<9.90E-4	<9.90E-4	<9.90E-4	<9.90E-4	<9.90E-4	<9.90E-4	0.002
PENTACHLOROPHENOL	mg/l	<5.80E-4	<5.80E-4	<5.80E-4	<5.80E-4	<5.80E-4	<5.80E-4	<5.80E-4	0.002
DINOSEB	mg/l	<5.60E-4	<5.60E-4	<5.60E-4	<5.60E-4	<5.60E-4	<5.60E-4	<5.60E-4	0.002
PAH's ANALYSIS									
NAPHTALENE	mg/l	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	NR
ACENAPHTHILENE	mg/l	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	NR
ACENAPHTHENE	mg/l	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	NR
FLUORENE	mg/l	<2.00E-4	<2.00E-4	<2.00E-4	<2.00E-4	<2.00E-4	<2.00E-4	<2.00E-4	NR
PHENANTHRENE	mg/l	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	NR
ANTHRACENE	mg/l	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	NR
FLUORANTHENE	mg/l	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	NR
PYRENE	mg/l	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	NR
BENZ(A)ANTHRACENE	mg/l	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	NR
CHRYSENE	mg/l	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	NR
BENZO(B)FLUORANTHENE	mg/l	<2.60E-4	<2.60E-4	<2.60E-4	<2.60E-4	<2.60E-4	<2.60E-4	<2.60E-4	NR
BENZO(K)FLUORANTHENE	mg/l	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	NR
BENZO(A)PYRENE	mg/l	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	NR
DIBENZ(A,H,)ANTHRACENE	mg/l	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	NR
BENZO(G,H,I)PYRELENE	mg/l	<4.00E-4	<4.00E-4	<4.00E-4	<4.00E-4	<4.00E-4	<4.00E-4	<4.00E-4	NR
INDENO(1,2,3CD)PYRENE	mg/l	<3.60E-4	<3.60E-4	<3.60E-4	<3.60E-4	<3.60E-4	<3.60E-4	<3.60E-4	NR

F.2.2.2. ANALYSIS OF SEDIMENTS IN LAKE PALAGUA

Samples were taken from Point 1 to Point 7, shown in Figure 3.F-1. These points correspond to the surface water sampling points, also. The oilfield operations of the Palagua-Caipal field are located at the north of Palagua Lake. At the south portion of the Lake, the Velazquez field is located. This field is operated by Mansarovar Energy Colombia Limited (MECL), a joint venture comprising ONGC, Amazon Alaknanda Limited (OALL), and a subsidiary of Sinopec International Petroleum Exploration and Production Corporation (SIPC).

- **Conclusions**

Poly-aromatic hydrocarbon (PHA) pollution was not found at any of the seven sampling points. The concentrations were found to be below the detectable minimum amount as per the measurement technique employed. This represents a total concentration lower than the target value for the Dutch Standard.

The concentrations of metals (barium, cadmium and vanadium) have decreased from 2005 to 2009. Also, the concentrations are lower than the intervention value established by the Dutch Standard.

These conclusions are outlined in the following tables where the lab results of 2009 are shown in comparison to prior years, as well as in comparison to the Dutch Standard.

Table 3.F-13 Analysis of Sediments in Palagua Lake – Sampling Point 1

PALAGUA LAKE	SAMPLE IDENTIFICATION	POINT 1			DUTCH STANDARD (Criteria for contaminated soil mg/kg Table 1.a)		
		Opposite to the exit of Agualinda Creek			National Background concentration (BC)	Target value (incl. BC)	Intervention value
	DATE OF SAMPLING	14-Oct-05	23-Aug-07	24-Sep-09			
Component	UNITS						
ANALYSIS IN SITU							
METALS							
BARIUM	microg/Kg	500.9	334	418.5	160	160	625
VANADIUM	microg/Kg	156.7	47.1	87.93	42**	42**	250**
CADMIUM	microg/Kg	2.47	<2.5	9.405	0.8	0.8	12.0
PAH's ANALYSIS							
NAPHTALENE	mg/kg	ND	ND	<0.016	NR	1	40
PHENANTHRENE	mg/kg			<0.020	NR		
ANTHRACENE	mg/kg			<0.022	NR		
FLUORANTHENE	mg/kg			<0.022	NR		
CHRYSENE	mg/kg			<0.025	NR		
BENZO(K)FLUORANTHENE	mg/kg			<0.028	NR		
BENZO(A)PYRENE	mg/kg			<0.028	NR		
DIBENZ(A,H,)ANTHRACENE	mg/kg			<0.036	NR		
BENZO(G,H,I)PYRELENE	mg/kg			<0.041	NR		
INDENO(1,2,3CD)PYRENE	mg/kg			<0.040	NR		

NR: Not Reported
** From Table 2a of the Dutch Standard
ND: Not Detected
NT: Not Tested

Table 3.F-14 Analysis of Sediments in Palagua Lake – Sampling Point 2

PALAGUA LAKE	SAMPLE IDENTIFICATION	POINT 2			DUTCH STANDARD (Criteria for contaminated soil mg/kg Table 1.a)		
		At the shore exit line that unifies Palagua Lake with Enchanted Island			National Background concentration (BC)	Target value (incl. BC)	Intervention value
	DATE OF SAMPLING	14-Oct-05	23-Aug-07	24-Sep-09			
Component	UNITS						
ANALYSIS IN SITU							
METALS							
BARIUM	microg/Kg	500.9	288.0	457.30	160	160	625
VANADIUM	microg/Kg	156.70	38.50	62.890	42**	42**	250**
CADMIUM	microg/Kg	2.470	3.900	6.937	0.8	0.8	12.0
PAH's ANALYSIS							
NAPHTALENE	mg/kg	0.203	ND	<0.016	NR	1	40
PHENANTHRENE	mg/kg			<0.020	NR		
ANTHRACENE	mg/kg			<0.022	NR		
FLUORANTHENE	mg/kg			<0.022	NR		
CHRYSENE	mg/kg			<0.025	NR		
BENZO(K)FLUORANTHENE	mg/kg			<0.028	NR		
BENZO(A)PYRENE	mg/kg			<0.028	NR		
DIBENZ(A,H,)ANTHRACENE	mg/kg			<0.036	NR		
BENZO(G,H,I)PYRELENE	mg/kg			<0.041	NR		
INDENO(1,2,3CD)PYRENE	mg/kg			<0.040	NR		

NR: Not Reported
** From Table 2a of the Dutch Standard
ND: Not Detected
NT: Not Tested

Table 3.F-15 Analysis of Sediments in Palagua Lake – Sampling Point 3

PALAGUA LAKE	SAMPLE IDENTIFICATION	POINT 3			DUTCH STANDARD (Criteria for contaminated soil mg/kg Table 1.a)		
		At the shore exit line that unifies Palagua Lake with Enchanted Island			National Background concentration (BC)	Target value (incl. BC)	Intervention value
	DATE OF SAMPLING	14-Oct-05	23-Aug-07	24-Sep-09			
Component	UNITS						
ANALYSIS IN SITU							
METALS							
BARIUM	microg/Kg	611.90	413	470.10	160	160	625
VANADIUM	microg/Kg	252.6	46	64.190	42**	42**	250**
CADMIUM	microg/Kg	7.37	<2.5	7.988	0.8	0.8	12.0
PAH's ANALYSIS							
NAPHTALENE	mg/kg	0.522	ND	<0.016	NR	1	40
PHENANTHRENE	mg/kg			<0.020	NR		
ANTHRACENE	mg/kg			<0.022	NR		
FLUORANTHENE	mg/kg			<0.022	NR		
CHRYSENE	mg/kg			<0.025	NR		
BENZO(K)FLUORANTHENE	mg/kg			<0.028	NR		
BENZO(A)PYRENE	mg/kg			<0.028	NR		
DIBENZ(A,H,)ANTHRACENE	mg/kg			<0.036	NR		
BENZO(G,H,I)PYRELENE	mg/kg			<0.041	NR		
INDENO(1,2,3CD)PYRENE	mg/kg			<0.040	NR		

NR: Not Reported
** From Table 2a of the Dutch Standard
ND: Not Detected
NT: Not Tested

Table 3.F-16 Analysis of Sediments in Palagua Lake – Sampling Point 4

PALAGUA LAKE	SAMPLE IDENTIFICATION	POINT 4			DUTCH STANDARD (Criteria for contaminated soil mg/kg Table 1.a)		
		Central Part of the Palagua lake in front of Ecopetrol bridge			National Background concentration (BC)	Target value (incl. BC)	Intervention value
	DATE OF SAMPLING	14-Oct-05	23-Aug-07	24-Sep-09			
Component	UNITS						
ANALYSIS IN SITU							
METALS							
BARIUM	microg/Kg	485.90	367	437.60	160	160	625
VANADIUM	microg/Kg	194.200	42.1	85.900	42**	42**	250**
CADMIUM	microg/Kg	6.120	6.5	6.945	0.8	0.8	12.0
PAH's ANALYSIS							
NAPHTALENE	mg/kg	0.382	ND	<0.016	NR	1	40
PHENANTHRENE	mg/kg			<0.020	NR		
ANTHRACENE	mg/kg			<0.022	NR		
FLUORANTHENE	mg/kg			<0.022	NR		
CHRYSENE	mg/kg			<0.025	NR		
BENZO(K)FLUORANTHENE	mg/kg			<0.028	NR		
BENZO(A)PYRENE	mg/kg			<0.028	NR		
DIBENZ(A,H,)ANTHRACENE	mg/kg			<0.036	NR		
BENZO(G,H,I)PYRELENE	mg/kg			<0.041	NR		
INDENO(1,2,3CD)PYRENE	mg/kg			<0.040	NR		

NR: Not Reported
** From Table 2a of the Dutch Standard
ND: Not Detected
NT: Not Tested

Table 3.F-17 Analysis of Sediments in Palagua Lake – Sampling Point 5

PALAGUA LAKE	SAMPLE IDENTIFICATION	POINT 5			DUTCH STANDARD (Criteria for contaminated soil mg/kg Table 1.a)		
		Behind Fantasy Island divergence Palagua Creek			National Background concentration (BC)	Target value (incl. BC)	Intervention value
	DATE OF SAMPLING	14-Oct-05	23-Aug-07	9/24/2009			
Component	UNITS						
ANALYSIS IN SITU							
METALS							
BARIUM	microg/Kg	542.10	247.00	449.20	160	160	625
VANADIUM	microg/Kg	238.8	37.2	70.350	42**	42**	250**
CADMIUM	microg/Kg	5.440	3.400	6.218	0.8	0.8	12.0
PAH's ANALYSIS							
NAPHTALENE	mg/kg			<0.016	NR		
PHENANTHRENE	mg/kg			<0.020	NR		
ANTHRACENE	mg/kg			<0.022	NR		
FLUORANTHENE	mg/kg			<0.022	NR		
CHRYSENE	mg/kg	0.3	ND	<0.025	NR	1	40
BENZO(K)FLUORANTHENE	mg/kg			<0.028	NR		
BENZO(A)PYRENE	mg/kg			<0.028	NR		
DIBENZ(A,H,)ANTHRACENE	mg/kg			<0.036	NR		
BENZO(G,H,I)PYRELENE	mg/kg			<0.041	NR		
INDENO(1,2,3CD)PYRENE	mg/kg			<0.040	NR		

NR: Not Reported
** From Table 2a of the Dutch Standard
ND: Not Detected
NT: Not Tested

Table 3.F-18 Analysis of Sediments in Palagua Lake – Sampling Point 6

PALAGUA LAKE	SAMPLE IDENTIFICATION	POINT 6			DUTCH STANDARD (Criteria for contaminated soil mg/kg Table 1.a)		
		Entrance to the Palagua creek.			National Background concentration (BC)	Target value (incl. BC)	Intervention value
	DATE OF SAMPLING	14-Oct-05	23-Aug-07	24-Sep-09			
Component	UNITS						
ANALYSIS IN SITU							
METALS							
BARIUM	microg/Kg	586.3	247	407.10	160	160	625
VANADIUM	microg/Kg	227.3	37.2	78.110	42**	42**	250**
CADMIUM	microg/Kg	8.120	3.4	5.688	0.8	0.8	12.0
PAH's ANALYSIS							
NAPHTALENE	mg/kg			<0.016	NR		
PHENANTHRENE	mg/kg			<0.020	NR		
ANTHRACENE	mg/kg			<0.022	NR		
FLUORANTHENE	mg/kg			<0.022	NR		
CHRYSENE	mg/kg	0.247	ND	<0.025	NR	1	40
BENZO(K)FLUORANTHENE	mg/kg			<0.028	NR		
BENZO(A)PYRENE	mg/kg			<0.028	NR		
DIBENZ(A,H,)ANTHRACENE	mg/kg			<0.036	NR		
BENZO(G,H,I)PYRELENE	mg/kg			<0.041	NR		
INDENO(1,2,3CD)PYRENE	mg/kg			<0.040	NR		

NR: Not Reported
** From Table 2a of the Dutch Standard
ND: Not Detected
NT: Not Tested

Table 3.F-19 Analysis of Sediments in Palagua Lake – Sampling Point 7

PALAGUA LAKE	SAMPLE IDENTIFICATION	POINT 7			DUTCH STANDARD (Criteria for contaminated soil mg/kg Table 1.a)		
		Between Palagua creek and Velasquez port			National Background concentration (BC)	Target value (incl. BC)	Intervention value
	DATE OF SAMPLING	14-Oct-05	23-Aug-07	24-Sep-09			
Component	UNITS						
ANALYSIS IN SITU							
METALS							
BARIUM	microg/Kg	509.30	369.00	447.5	160	160	625
VANADIUM	microg/Kg	117.200	36.6	82.970	42**	42**	250**
CADMIUM	microg/Kg	13.300	4.4	7.367	0.8	0.8	12.0
PAH's ANALYSIS							
NAPHTALENE	mg/kg	0.754	ND	<0.016	NR	1	40
PHENANTHRENE	mg/kg			<0.020	NR		
ANTHRACENE	mg/kg			<0.022	NR		
FLUORANTHENE	mg/kg			<0.022	NR		
CHRYSENE	mg/kg			<0.025	NR		
BENZO(K)FLUORANTHENE	mg/kg			<0.028	NR		
BENZO(A)PYRENE	mg/kg			<0.028	NR		
DIBENZ(A,H,)ANTHRACENE	mg/kg			<0.036	NR		
BENZO(G,H,I)PYRELENE	mg/kg			<0.041	NR		
INDENO(1,2,3CD)PYRENE	mg/kg			<0.040	NR		

NR: Not Reported
** From Table 2a of the Dutch Standard
ND: Not Detected
NT: Not Tested

F.2.3. UNDERGROUND (3 to 4m deep) WATER TESTING

In the year 2000, prior to UT-IJP taking over the field, the Colombian Environmental Ministry asked Ecopetrol to install ground water monitoring stations and correct the ground water problems, if any. The objective of testing is to stop the spreading of contamination by the removal of contaminated soil to the land farming area for bioremediation.

To comply with the order, Ecopetrol installed 19 monitoring shallow wells (3 to 4 meters deep) to monitor ground water. Some of the problems found have been fixed by Ecopetrol over time. In the last 10 years there has been a significant improvement in the ground water quality. Most of the ground water problems were found near Battery No 1, where there was a spill and a fire in 1996. There are three ground-water monitoring stations in Battery No1. Two stations out of three stations are now free of any hydrocarbons.

Table 3.F-20 contains the results of the laboratory analysis of samples during the second semester of 2009 for each of the monitor wells.

F.2.3.1. UNDERGROUND WATER (3 to 4m deep) ANALYSIS RESULTS

Based on these measurements and the Colombian National Law-Decree 1594/1984, Article 38, we draw the following conclusions:

- The pH values as well as the concentrations of sulphates, nitrates and nitrites in all the monitored wells meet the Article 38 of Decree 1594/84 of Colombian Environment Law.

- The concentrations of cadmium, chromium, copper, lead, zinc and mercury in all the monitored wells are lower than the maximum value allowed by the law.

- The concentrations of barium in PM-18 and PM-19; arsenium in PM-3, PM-4, PM-6 and PM-12, and selenium in PM-18 and PM-19 are high, but these values are consistent with the local levels in the area.

- The alkalinity values are in the range of 163 mg CaCO3/L to 1539 mg CaCO3/L, and the bicarbonates values are in the range of 199 mg HCO3/L to 1878 mg HCO3/L, whereas carbonates were not found in monitoring stations. This indicates that the underground water's alkalinity is due to presence of bicarbonates in the soil.

- The concentrations of dissolved oxygen are lower than 3.66 mg O2/L which are considered to be normal for this type of waters in which the contact with the atmospheric oxygen is minimal.

- The concentrations of BTEX's (benzene, toluene, ethylbenzene,xylenes) are lower than the minimum amount detectable by the methods used in the laboratory, and also meet the quality criteria established in Alberta Risk Management Guidelines for Petroleum Storage Tanks Sites, 2001.

- The concentrations of polyaromatic hydrocarbons (PAHS) registered at each of the monitored wells are lower than the minimum amount detectable by the laboratory methods with the exception of wells PM-17, PM-18 and PM-19 which registered higher values of fluorine and phenantrene.

- The concentrations of total phenol registered at each of the monitored wells are lower than the minimum amount detectable of 0.029 mg/L by the laboratory methods inferring minimal to no effect on the water byr these compounds which are typically found in the liquid residue of the oil industry.

- Out of the 19 total stations, wells at 5 of the stations show detectable hydrocarbons in the laboratory. This needs further monitoring.

- In general, the ionic balance of the majority of the monitored piezometers is in the admitted range of the Standard Methods, with the exception of piezometers PM-6, PM-7 and PM-12.

- Three out of 19 wells (PM-4, PM-13, and PM-19) have chloride concentrations higher than 250 mg NH3/L.

- The concentrations of ammonia-nitrogen in 8 of the 19 wells (PM-1, PM-3, PM-4, PM-6, PM-7, PM-13, PM-17, PM-18 and PM-19) is higher than the 1.21 mg NH3/L. This is mainly due to the use of fertilizers by the farmers.

PM1


PM2


PM3

PM4

PM5

PM6

PM7

PM8

PM9

PM10

PM11

PM12

PM13

PM14

PM16

PM17

PM18

PM19

Table 3.F-20 Physical – Chemical Analysis of the underground water samples (PM 1 through PM 8)

UNDERGROUND WATERS	SAMPLE IDENTIFICATION	PM 1	PM 2	PM 3	PM 4	PM 5	PM 6	PM 7	PM 8	DECREE 1594/84 ART. 38	Alberta Risk Management guidelines for Petroleum storage tank sites 2001 Table 4. Generic Hydrocarbon Criteria for the Groundwater Ingestion Pathway
	POINT DESCRIPTION	LOCATED IN THE BATTERY No. 1 BEHIND THE TK-12000	LOCATED IN THE OLD JUNK YARD ("CEMETERY")	LOCATED NEAR TO PALAGUA LAKE	LOCATED IN WELL P-211 ("MIRADOR DE LOS MICOS")	LOCATED NEAR TO WELL P-153	LOCATED IN WELL P-187	LOCATED IN THE LANDFARMING AREA	LOCATED NEAR TO PALAGUA LAKE BEHIND THE WELL P-10		
	DATE OF SAMPLING	22-Sep-09	25-Sep-09	23-Sep-09	22-Sep-09	22-Sep-09	21-Sep-09	23-Sep-09	22-Sep-09		
Component	UNITS										
ANALYSIS IN SITU											
DEPTH	m	4.38	3.63	3.72	2.40	3.54	2.94	1.64	2.5	NR	NR
DISSOLVED OXYGEN	mg O2/L	1.61	1.72	2.25	1.70	2.62	1.85	0.99	1.22	NR	NR
TURBIDITY	NTU	535	137	464	56.4	355	415	610	107	NR	NR
pH/T	Uni. pH	NT	7.33/32.0	NT	NT	NT	NT	NT	NT	5.0 - 9.0	NR
TEMPERATURE	°C	NT	32	NT	NT	NT	NT	NT	NT	NR	NR
LABORATORY											
PHYSICAL CHEMICAL ANALYSIS											
CONDUCTIVITY	micromhos/cm	436/24.9	392/22.0	546/24.9	1847/25.1	837/24.7	2382/24.8	4420/24.9	496/24.7	NR	NR
pH/T	Uni. pH	6.45/24.2	NT	6.74/24.4	6.98/24.1	6.75/24.3	7.87/24.0	7.12/24.0	8.23/24.1	5.0 - 9.0	NR
TEMPERATURE	°C	24	NT	24	24	24	24	24	24	NR	NR
TOTAL ALKALINITY	mg CaCO3/L	257	195	224	547	176	1280	866	259	NR	NR
CARBONATES	mg CO3/L	0	0	0	0	0	0	0	0	NR	NR
BICARBONATES	mg HCO3/L	314	238	273	667	215	1562	1056	316	NR	NR
OIL & GREASES	mg/L	52.6	<1.07	<1.07	<1.07	<1.07	<1.07	4.85	64.5	Not allowed	NR
TOTAL HYDROCARBONS	mg/L	25.8	<1.07	<1.07	<1.07	<1.07	<1.07	<1.07	<1.07	NR	NR
TOTAL PHENOLS	mg/L	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	0.002	NR
CHLORIDES	mg/L	10.8	3.07	52.4	282	122	84.8	1450	9.56	250	NR
SULPHATES	mg SO4=/L	<0.45	12.5	<0.45	11.8	58.0	19.0	8.39	<0.45	400	NR
NITRATES	mg NO3/L	0.33	1.75	41.7	9.73	4.33	<0.059	0.29	1.84	44.3	NR
NITRITES	mg NO2/L	0.17	<0.031	<0.031	<0.031	<0.031	<0.031	<0.031	<0.031	3.28	NR
AMMONIA-NITROGEN	mg NH3/L	5.58	<0.59	8.25	2.58	0.74	1.57	3.13	<0.59	1.21	NR
DISSOLVED SOLIDS	mg/L	306	267	329	1055	499	1587	2492	350	NR	NR

UNDERGROUND WATERS	SAMPLE IDENTIFICATION	PM 1	PM 2	PM 3	PM 4	PM 5	PM 6	PM 7	PM 8	DECREE 1594/84 ART. 38	Alberta Risk Management guidelines for Petroleum storage tank sites 2001 Table 4. Generic Hydrocarbon Criteria for the Groundwater Ingestion Pathway
	POINT DESCRIPTION	LOCATED IN THE BATTERY No. 1 BEHIND THE TK-12000	LOCATED IN THE OLD JUNK YARD ("CEMETERY")	LOCATED NEAR TO PALAGUA LAKE	LOCATED IN WELL P-211 ("MIRADOR DE LOS MICOS")	LOCATED NEAR TO WELL P-153	LOCATED IN WELL P-187	LOCATED IN THE LANDFARMING AREA	LOCATED NEAR TO PALAGUA LAKE BEHIND THE WELL P-10		
	DATE OF SAMPLING	22-Sep-09	25-Sep-09	23-Sep-09	22-Sep-09	22-Sep-09	21-Sep-09	23-Sep-09	22-Sep-09		
Component	UNITS										
ION BALANCE											
ION BALANCE	NA	1.0	1.0	0.9	1.0	0.9	1.3	0.8	1.0	NR	NR
CALCULATED TDS/CONDUCTIVITY	NA	0.7	0.6	0.6	0.5	0.5	0.7	0.7	0.6	NR	NR
MEASURED TDS/CALCULATED TDS	NA	1.1	1.2	0.9	1.1	1.1	1.0	0.9	1.2	NR	NR
BTEX'S											
BENZENE	microg/L	<2.76	<2.76	<2.76	<2.76	<2.76	<2.76	<2.76	<2.76	NR	5.00
TOLUENE	microg/L	<2.23	<2.23	<2.23	<2.23	<2.23	<2.23	<2.23	<2.23	NR	24.0
ETHYLNENZENE	microg/L	<1.82	<1.82	<1.82	<1.82	<1.82	<1.82	<1.82	<1.82	NR	2.40
M+P-XYLENE	microg/L	<1.85	<1.85	<1.85	<1.85	<1.85	<1.85	***3.17***	<1.85	NR	300
O-XYLENE	microg/L	<2.30	<2.30	<2.30	<2.30	<2.30	<2.30	<2.30	<2.30	NR	300

UNDERGROUND WATERS	SAMPLE IDENTIFICATION	PM 1	PM 2	PM 3	PM 4	PM 5	PM 6	PM 7	PM 8	DECREE 1594/84 ART. 38	Alberta Risk Management guidelines for Petroleum storage tank sites 2001 Table 4. Generic Hydrocarbon Criteria for the Groundwater Ingestion Pathway
	POINT DESCRIPTION	LOCATED IN THE BATTERY No. 1 BEHIND THE TK-12000	LOCATED IN THE OLD JUNK YARD ("CEMETERY")	LOCATED NEAR TO PALAGUA LAKE	LOCATED IN WELL P-211 ("MIRADOR DE LOS MICOS")	LOCATED NEAR TO WELL P-153	LOCATED IN WELL P-187	LOCATED IN THE LANDFARMING AREA	LOCATED NEAR TO PALAGUA LAKE BEHIND THE WELL P-10		
	DATE OF SAMPLING	22-Sep-09	25-Sep-09	23-Sep-09	22-Sep-09	22-Sep-09	21-Sep-09	23-Sep-09	22-Sep-09		
Component	UNITS										
EXTRACTABLE HC'S											
OCTANE	mg/L	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	NR	NR
NONANE	mg/L	**0.0002**	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	NR	NR
DECANE	mg/L	**0.0007**	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	NR	NR
UNDECANE	mg/L	**0.0011**	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	NR	NR
DODECANE	mg/L	**0.0010**	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	NR	NR
TRIDECANE	mg/L	**0.0038**	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	NR	NR
TETRADECANE	mg/L	**0.0101**	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	NR	NR
PENTADECANE	mg/L	**0.0102**	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	NR	NR
HEXADECANE	mg/L	**0.0067**	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	NR	NR
HEPTADECANE	mg/L	**0.0101**	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	NR	NR
PRISTANE	mg/L	**0.0210**	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	NR	NR
OCTADECANE	mg/L	**0.0070**	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	NR	NR
PHYTANE	mg/L	**0.0219**	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	NR	NR
NONADECANE	mg/L	**0.0132**	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	NR	NR
EICOSANE	mg/L	**0.0077**	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	NR	NR
HENEICOSANE	mg/L	**0.0016**	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	NR	NR
DOCOSANE	mg/L	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	NR	NR
TRICOSANE	mg/L	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	NR	NR
TETRACOSANE	mg/L	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	NR	NR
PENTACOSANE	mg/L	**0.0006**	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	NR	NR

UNDERGROUND WATERS	SAMPLE IDENTIFICATION	PM 1	PM 2	PM 3	PM 4	PM 5	PM 6	PM 7	PM 8	DECREE 1594/84 ART. 38	Alberta Risk Management guidelines for Petroleum storage tank sites 2001 Table 4. Generic Hydrocarbon Criteria for the Groundwater Ingestion Pathway
	POINT DESCRIPTION	LOCATED IN THE BATTERY No. 1 BEHIND THE TK-12000	LOCATED IN THE OLD JUNK YARD ("CEMETERY")	LOCATED NEAR TO PALAGUA LAKE	LOCATED IN WELL P-211 ("MIRADOR DE LOS MICOS")	LOCATED NEAR TO WELL P-153	LOCATED IN WELL P-187	LOCATED IN THE LANDFARMING AREA	LOCATED NEAR TO PALAGUA LAKE BEHIND THE WELL P-10		
	DATE OF SAMPLING	22-Sep-09	25-Sep-09	23-Sep-09	22-Sep-09	22-Sep-09	21-Sep-09	23-Sep-09	22-Sep-09		
Component	UNITS										
EXTRACTABLE HC'S											
HEXACOSANE	mg/L	**0.0023**	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	NR	NR
HEPTACOSANE	mg/L	**0.0029**	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	NR	NR
OCTACOSANE	mg/L	**0.0024**	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	NR	NR
NONACOSANE	mg/L	**0.0145**	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	NR	NR
TRIACONTANE	mg/L	**0.0048**	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	NR	NR
HENTRIACONTANE	mg/L	**0.0068**	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	NR	NR
DOTRIACONTANE	mg/L	**0.0037**	<1.00E-04	<1.00E-04	<1.00E-04	<1.00E-04	<1.00E-04	<1.00E-04	<1.00E-04	NR	NR
TRITIACONTANE	mg/L	**0.0023**	<1.00E-04	<1.00E-04	<1.00E-04	<1.00E-04	<1.00E-04	<1.00E-04	<1.00E-04	NR	NR
TETRATRIACONTANE	mg/L	**0.0028**	<1.10E-04	<1.10E-04	<1.10E-04	<1.10E-04	<1.10E-04	<1.10E-04	<1.10E-04	NR	NR
PENTATRIACONTANE	mg/L	<1.20E-04	<1.20E-04	<1.20E-04	<1.20E-04	<1.20E-04	<1.20E-04	<1.20E-04	<1.20E-04	NR	NR
HEXSATRIACONTANE	mg/L	<1.30E-04	<1.30E-04	<1.30E-04	<1.30E-04	<1.30E-04	<1.30E-04	<1.30E-04	<1.30E-04	NR	NR
HEPTATRIACONTANE	mg/L	<1.40E-04	<1.40E-04	<1.40E-04	<1.40E-04	<1.40E-04	<1.40E-04	<1.40E-04	<1.40E-04	NR	NR
OCTATRIACONTANE	mg/L	<1.70E-04	<1.70E-04	<1.70E-04	<1.70E-04	<1.70E-04	<1.70E-04	<1.70E-04	<1.70E-04	NR	NR
TETRACONTANE	mg/L	<2.50E-04	<2.50E-04	<2.50E-04	<2.50E-04	<2.50E-04	<2.50E-04	<2.50E-04	<2.50E-04	NR	NR

UNDERGROUND WATERS	SAMPLE IDENTIFICATION	PM 1	PM 2	PM 3	PM 4	PM 5	PM 6	PM 7	PM 8	DECREE 1594/84 ART. 38	Alberta Risk Management guidelines for Petroleum storage tank sites 2001 Table 4. Generic Hydrocarbon Criteria for the Groundwater Ingestion Pathway
	POINT DESCRIPTION	LOCATED IN THE BATTERY No. 1 BEHIND THE TK-12000	LOCATED IN THE OLD JUNK YARD ("CEMETERY")	LOCATED NEAR TO PALAGUA LAKE	LOCATED IN WELL P-211 ("MIRADOR DE LOS MICOS")	LOCATED NEAR TO WELL P-153	LOCATED IN WELL P-187	LOCATED IN THE LANDFARMING AREA	LOCATED NEAR TO PALAGUA LAKE BEHIND THE WELL P-10		
	DATE OF SAMPLING	22-Sep-09	25-Sep-09	23-Sep-09	22-Sep-09	22-Sep-09	21-Sep-09	23-Sep-09	22-Sep-09		
Component	UNITS										
PAHs											
NAPHTALENE	mg/L	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	NR	NR
ACENAPHTILENE	mg/L	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	NR	NR
ACENAPHTENE	mg/L	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	NR	NR
FLUORENE	mg/L	<2.00E-4	<2.00E-4	<2.00E-4	<2.00E-4	<2.00E-4	<2.00E-4	<2.00E-4	<2.00E-4	NR	NR
PHENANTRENE	mg/L	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	NR	NR
ANTHRACENE	mg/L	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	NR	NR
FLUORANTHENE	mg/L	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	NR	NR
PYRENE	mg/L	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	NR	NR
BENZO(A) ANTHRACENE	mg/L	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	NR	NR
CHRYSENE	mg/L	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	NR	NR
BENZO(B) FLUORANTHENE	mg/L	<2.60E-4	<2.60E-4	<2.60E-4	<2.60E-4	<2.60E-4	<2.60E-4	<2.60E-4	<2.60E-4	NR	NR
BENZO(K) FLUORANTHENE	mg/L	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	NR	NR
BENZO(A) PYRENE	mg/L	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	NR	NR
DIBENZ(A,H) ANTHRACENE	mg/L	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	NR	NR

UNDERGROUND WATERS	SAMPLE IDENTIFICATION	PM 1	PM 2	PM 3	PM 4	PM 5	PM 6	PM 7	PM 8	DECREE 1594/84 ART. 38	Alberta Risk Management guidelines for Petroleum storage tank sites 2001 Table 4. Generic Hydrocarbon Criteria for the Groundwater Ingestion Pathway
	POINT DESCRIPTION	LOCATED IN THE BATTERY No. 1 BEHIND THE TK-12000	LOCATED IN THE OLD JUNK YARD ("CEMETERY")	LOCATED NEAR TO PALAGUA LAKE	LOCATED IN WELL P-211 ("MIRADOR DE LOS MICOS")	LOCATED NEAR TO WELL P-153	LOCATED IN WELL P-187	LOCATED IN THE LANDFARMING AREA	LOCATED NEAR TO PALAGUA LAKE BEHIND THE WELL P-10		
	DATE OF SAMPLING	22-Sep-09	25-Sep-09	23-Sep-09	22-Sep-09	22-Sep-09	21-Sep-09	23-Sep-09	22-Sep-09		
Component	UNITS										
BENZO(G,H,I) PYRELENE	mg/L	<4.00E-4	<4.00E-4	<4.00E-4	<4.00E-4	<4.00E-4	<4.00E-4	<4.00E-4	<4.00E-4	NR	NR
INDENO(1,2,3-D) PYRENE	mg/L	<3.60E-4	<3.60E-4	<3.60E-4	<3.60E-4	<3.60E-4	<3.60E-4	<3.60E-4	<3.60E-4	NR	NR

UNDERGROUND WATERS	SAMPLE IDENTIFICATION	PM 1	PM 2	PM 3	PM 4	PM 5	PM 6	PM 7	PM 8	DECREE 1594/84 ART. 38	Alberta Risk Management guidelines for Petroleum storage tank sites 2001 Table 4. Generic Hydrocarbon Criteria for the Groundwater Ingestion Pathway
	POINT DESCRIPTION	LOCATED IN THE BATTERY No. 1 BEHIND THE TK-12000	LOCATED IN THE OLD JUNK YARD ("CEMETERY")	LOCATED NEAR TO PALAGUA LAKE	LOCATED IN WELL P-211 ("MIRADOR DE LOS MICOS")	LOCATED NEAR TO WELL P-153	LOCATED IN WELL P-187	LOCATED IN THE LANDFARMING AREA	LOCATED NEAR TO PALAGUA LAKE BEHIND THE WELL P-10		
	DATE OF SAMPLING	22-Sep-09	25-Sep-09	23-Sep-09	22-Sep-09	22-Sep-09	21-Sep-09	23-Sep-09	22-Sep-09		
Component	UNITS										
METALS											
CALCIUM	mg/L	24.14	2.410	9.205	104.3	37.61	34.14	110.8	10.39	NR	NR
SODIUM	mg/L	47.56	85.84	89.07	167.2	71.40	677.229	740.0	100.7	NR	NR
POTASSIUM	mg/L	1.956	1.005	2.063	5.186	3.889	0.453	4.844	1.229	NR	NR
MANGANESE	mg/L	2.835	0.00340	0.997	7.095	1.532	0.110	2.813	0.00173	NR	NR
MAGNESIUM	mg/L	13.03	2.078	10.40	69.82	29.92	55.56	67.44	5.192	NR	NR
IRON	mg/L	22.77	0.218	0.8761	6.724	0.5426	0.2378	2.803	0.0697	NR	NR
BARIUM	mg/L	0.314	0.0252	0.0541	0.395	0.160	0.332	0.682	0.0330	1.00	NR
ALUMINUM	mg/L	0.00289	0.106	0.00621	0.00302	0.0280	0.0463	0.0154	0.0441	NR	NR
CADMIUM	microg/L	0.0400	0.033	<0.260	0.484	0.432	<0.260	<0.260	0.056	10.0	NR
CHROMIUM	microg/L	0.463	1.181	<1.150	1.957	2.331	<1.150	1.436	1.636	50 (Cr^{+6})	NR
COPPER	microg/L	1.201	<2.102	<21.02	<21.02	<21.02	<21.02	<21.02	<2.102	1000	NR
LEAD	microg/L	0.294	<0.284	<2.840	2.922	<2.840	<2.840	<2.840	<0.284	50.0	NR
NICKEL	microg/L	2.290	1.846	<2.490	4.305	3.952	3.434	8.249	0.898	NR	NR
VANADIUM	microg/L	0.593	44.27	1.200	0.899	3.058	58.0955	0.830	41.01	NR	NR
ZINC	microg/L	6.879	3.503	<31.45	<31.45	<31.45	<31.45	<31.45	3.682	15000	NR
ARSENIUM	microg/L	9.621	4.296	61.20	204.4	11.00	119.7	6.416	3.409	50.0	NR
SELENIUM	microg/L	<0.860	<0.860	<8.600	<8.600	<8.600	<8.600	9.316	<0.860	10.0	NR
MERCURY	microg/L	<0.123	<0.123	<0.123	<0.123	<0.123	<0.123	0.159	<0.123	2.00	NR

Table 3.F-21 Physical – Chemical Analysis of the underground water samples (PM 9 through PM 19)

UNDERGROUND WATERS	SAMPLE IDENTIFICATION	PM 9	PM 10	PM 11	PM 12	PM 13	PM 16	PM 17	PM 18	PM 19	DECREE 1594/84 ART. 38	Alberta Risk Management guidelines for Petroleum storage tank sites 2001 Table 4. Generic Hydrocarbon Criteria for the Groundwater Ingestion Pathway
	POINT DESCRIPTION	LOCATED NEAR TO PALAGUA LAKE	LOCATED IN BATTERY No.1, BEHIND THE GAS TREATMENT ZONE	LOCATED BEHIND THE STATION No. 2	LOCATED BEHIND THE WELLS P-112 AND P-20	LOCATED NEAR WELL P-32 IN THE API SEPARATOR AREA	LOCATED IN THE WELL P-125 LOCATION	LOCATED OUT THE BATTERY No.1 FENCE NEAR TO PM-14	LOCATED NEAR TO PM-14	LOCATED NEAR TO PM-18		
	DATE OF SAMPLING	23-Sep-09	22-Sep-09	22-Sep-09	21-Sep-09	22-Sep-09	21-Sep-09	25-Sep-09	25-Sep-09	25-Sep-09		
Component	UNITS											
ANALYSIS IN SITU												
DEPTH	m	3.21	3.31	3.68	3.76	3.56	1.90	0.33	0.31	0.22	NR	NR
DISSOLVED OXYGEN	mg O2/L	3.64	1.40	3.66	0.90	1.14	1.73	0.74	0.95	1.06	NR	NR
TURBIDITY	NTU	552	561	628	528	117	158	685	860	769	NR	NR
pH/T	Uni. pH	NT	NT	NT	NT	NT	NT	6.42/29.2	6.06/30.2	6.15/29.3	5.0 - 9.0	NR
TEMPERATURE	°C	NT	NT	NT	NT	NT	NT	29	30	29	NR	NR
LABORATORY												
PHYSICAL CHEMICAL ANALYSIS												
CONDUCTIVITY	micromhos/cm	369/25.0	401/25.0	393/25.1	811/25.3	1913/25.1	2753/25.2	395/21.4	11870/21.9	7720/22.3	NR	NR
pH/T	Uni. pH	7.49/24.2	7.11/23.8	7.71/23.7	7.21/23.8	6.60/23.8	7.99/23.6	NT	NT	NT	5.0 - 9.0	NR
TEMPERATURE	°C	24	24	24	24	24	24	NT	NT	NT	NR	NR
TOTAL ALKALINITY	mg CaCO3/L	194	182	163	410	299	1539	174	279	293	NR	NR
CARBONATES	mg CO3/L	0	0	0	0	0	0	0	0	0	NR	NR
BICARBONATES	mg HCO3/L	236	222	199	500	365	1878	213	340	357	NR	NR
OIL & GREASES	mg/L	11.0	36.5	27.0	6.08	<1.07	4.00	78.1	41.1	189	Not allowed	NR

UNDERGROUND WATERS	SAMPLE IDENTIFICATION	PM 9	PM 10	PM 11	PM 12	PM 13	PM 16	PM 17	PM 18	PM 19	DECREE 1594/84 ART. 38	Alberta Risk Management guidelines for Petroleum storage tank sites 2001 Table 4. Generic Hydrocarbon Criteria for the Groundwater Ingestion Pathway
	POINT DESCRIPTION	LOCATED NEAR TO PALAGUA LAKE	LOCATED IN BATTERY No.1, BEHIND THE GAS TREATMENT ZONE	LOCATED BEHIND THE STATION No. 2	LOCATED BEHIND THE WELLS P-112 AND P-20	LOCATED NEAR WELL P-32 IN THE API SEPARATOR AREA	LOCATED IN THE WELL P-125 LOCATION	LOCATED OUT THE BATTERY No.1 FENCE NEAR TO PM-14	LOCATED NEAR TO PM-14	LOCATED NEAR TO PM-18		
	DATE OF SAMPLING	23-Sep-09	22-Sep-09	22-Sep-09	21-Sep-09	22-Sep-09	21-Sep-09	25-Sep-09	25-Sep-09	25-Sep-09		
Component	UNITS											
TOTAL HYDROCARBONS	mg/L	1.46	2.04	<1.07	4.08	<1.07	2.31	28.5	8.81	59.4	NR	NR
TOTAL PHENOLS	mg/L	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	0.002	NR
CHLORIDES	mg/L	1.32	4.36	17.9	27.0	402	44.1	38.9	4926	2864	250	NR
SULPHATES	mg SO4=/L	3.53	11.4	7.40	5.32	58.9	76.9	<0.45	<1.00	<1.00	400	NR
NITRATES	mg NO3/L	1.98	15.2	6.92	0.81	19.5	<0.059	<0.031	NT	NT	44.3	NR
NITRITES	mg NO2/L	<0.031	<0.031	<0.031	<0.031	<0.031	<0.031	<0.059	0.047	<0.019	3.28	NR
AMMONIA-NITROGEN	mg NH3/L	<0.59	<0.59	<0.59	<0.59	4.62	<0.59	4.72	39.6	28.8	1.21	NR
DISSOLVED SOLIDS	mg/L	290	269	255	437	1112	1922	261	7884	4873	NR	NR

UNDERGROUND WATERS	SAMPLE IDENTIFICATION	PM 9	PM 10	PM 11	PM 12	PM 13	PM 16	PM 17	PM 18	PM 19	DECREE 1594/84 ART. 38	Alberta Risk Management guidelines for Petroleum storage tank sites 2001 Table 4. Generic Hydrocarbon Criteria for the Groundwater Ingestion Pathway
	POINT DESCRIPTION	LOCATED NEAR TO PALAGUA LAKE	LOCATED IN BATTERY No.1, BEHIND THE GAS TREATMENT ZONE	LOCATED BEHIND THE STATION No. 2	LOCATED BEHIND THE WELLS P-112 AND P-20	LOCATED NEAR WELL P-32 IN THE API SEPARATOR AREA	LOCATED IN THE WELL P-125 LOCATION	LOCATED OUT THE BATTERY No.1 FENCE NEAR TO PM-14	LOCATED NEAR TO PM-14	LOCATED NEAR TO PM-18		
	DATE OF SAMPLING	23-Sep-09	22-Sep-09	22-Sep-09	21-Sep-09	22-Sep-09	21-Sep-09	25-Sep-09	25-Sep-09	25-Sep-09		
Component	UNITS											
ION BALANCE												
ION BALANCE	NA	0.9	1.0	0.9	0.5	1.0	1.0	1.0	0.9	0.9	NR	NR
CALCULATED TDS/CONDUCTIVITY	NA	0.5	0.6	0.5	0.5	0.6	0.7	0.6	0.7	0.6	NR	NR
MEASURED TDS/CALCULATED TDS	NA	1.4	1.2	1.2	1.2	1.1	1.1	1.1	1.0	1.0	NR	NR
BTEX'S												
BENZENE	microg/L	<2.76	<2.76	<2.76	<2.76	<2.76	<2.76	<2.76	<2.76	<2.76	NR	5.00
TOLUENE	microg/L	<2.23	<2.23	<2.23	<2.23	<2.23	<2.23	<2.23	<2.23	<2.23	NR	24.0
ETHYLNENZENE	microg/L	<1.82	<1.82	<1.82	<1.82	<1.82	<1.82	<1.82	<1.82	<1.82	NR	2.40
M+P-XYLENE	microg/L	<1.85	<1.85	<1.85	<1.85	<1.85	<1.85	<1.85	<1.85	<1.85	NR	300
O-XYLENE	microg/L	<2.30	<2.30	<2.30	<2.30	<2.30	<2.30	<2.30	<2.30	<2.30	NR	300

UNDERGROUND WATERS	SAMPLE IDENTIFICATION	PM 9	PM 10	PM 11	PM 12	PM 13	PM 16	PM 17	PM 18	PM 19	DECREE 1594/84 ART. 38	Alberta Risk Management guidelines for Petroleum storage tank sites 2001 Table 4. Generic Hydrocarbon Criteria for the Groundwater Ingestion Pathway
	POINT DESCRIPTION	LOCATED NEAR TO PALAGUA LAKE	LOCATED IN BATTERY No.1, BEHIND THE GAS TREATMENT ZONE	LOCATED BEHIND THE STATION No. 2	LOCATED BEHIND THE WELLS P-112 AND P-20	LOCATED NEAR WELL P-32 IN THE API SEPARATOR AREA	LOCATED IN THE WELL P-125 LOCATION	LOCATED OUT THE BATTERY No.1 FENCE NEAR TO PM-14	LOCATED NEAR TO PM-14	LOCATED NEAR TO PM-18		
	DATE OF SAMPLING	23-Sep-09	22-Sep-09	22-Sep-09	21-Sep-09	22-Sep-09	21-Sep-09	25-Sep-09	25-Sep-09	25-Sep-09		
Component	UNITS											
EXTRACTABLE HC'S												
OCTANE	mg/L	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	NR	NR
NONANE	mg/L	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	**0.001**	**0.001**	**0.001**	NR	NR
DECANE	mg/L	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	<8.00E-05	**0.001**	**0.001**	**0.002**	NR	NR
UNDECANE	mg/L	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	**0.003**	**0.002**	**0.004**	NR	NR
DODECANE	mg/L	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	**0.005**	**0.001**	**0.018**	NR	NR
TRIDECANE	mg/L	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	**0.011**	**0.001**	**0.012**	NR	NR
TETRADECANE	mg/L	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	**0.008**	**0.001**	**0.016**	NR	NR
PENTADECANE	mg/L	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	**0.018**	**0.002**	**0.029**	NR	NR
HEXADECANE	mg/L	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	**0.026**	**0.002**	**0.030**	NR	NR
HEPTADECANE	mg/L	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	**0.027**	**0.001**	**0.037**	NR	NR
PRISTANE	mg/L	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	**0.032**	**0.001**	**0.040**	NR	NR
OCTADECANE	mg/L	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	**0.001**	**0.045**	NR	NR
PHYTANE	mg/L	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	**0.056**	**0.002**	**0.040**	NR	NR
NONADECANE	mg/L	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	<9.00E-05	**0.035**	**0.002**	**0.041**	NR	NR
EICOSANE	mg/L	<9.00E-05	<9.00E-05	<9.00E-05	**0.0002**	<9.00E-05	<9.00E-05	**0.010**	**0.001**	**0.024**	NR	NR
HENEICOSANE	mg/L	<8.00E-05	<8.00E-05	<8.00E-05	**0.0014**	<8.00E-05	<8.00E-05	**0.022**	**0.001**	**0.035**	NR	NR
DOCOSANE	mg/L	<9.00E-05	<9.00E-05	<9.00E-05	**0.0040**	<9.00E-05	<9.00E-05	**0.027**	**0.002**	**0.050**	NR	NR
TRICOSANE	mg/L	<8.00E-05	<8.00E-05	<8.00E-05	**0.0074**	<8.00E-05	<8.00E-05	**0.035**	**0.001**	**0.059**	NR	NR
TETRACOSANE	mg/L	<8.00E-05	<8.00E-05	<8.00E-05	**0.0100**	<8.00E-05	<8.00E-05	**0.027**	**0.001**	**0.014**	NR	NR
PENTACOSANE	mg/L	<8.00E-05	<8.00E-05	<8.00E-05	**0.0107**	<8.00E-05	<8.00E-05	**0.014**	**0.002**	**0.017**	NR	NR
HEXACOSANE	mg/L	<8.00E-05	<8.00E-05	<8.00E-05	**0.0109**	<8.00E-05	<8.00E-05	**0.033**	**0.002**	**0.059**	NR	NR
HEPTACOSANE	mg/L	<8.00E-05	<8.00E-05	<8.00E-05	**0.0103**	<8.00E-05	<8.00E-05	**0.035**	**0.003**	**0.051**	NR	NR

UNDERGROUND WATERS	SAMPLE IDENTIFICATION	PM 9	PM 10	PM 11	PM 12	PM 13	PM 16	PM 17	PM 18	PM 19	DECREE 1594/84 ART. 38	Alberta Risk Management guidelines for Petroleum storage tank sites 2001 Table 4. Generic Hydrocarbon Criteria for the Groundwater Ingestion Pathway
	POINT DESCRIPTION	LOCATED NEAR TO PALAGUA LAKE	LOCATED IN BATTERY No.1, BEHIND THE GAS TREATMENT ZONE	LOCATED BEHIND THE STATION No. 2	LOCATED BEHIND THE WELLS P-112 AND P-20	LOCATED NEAR WELL P-32 IN THE API SEPARATOR AREA	LOCATED IN THE WELL P-125 LOCATION	LOCATED OUT THE BATTERY No.1 FENCE NEAR TO PM-14	LOCATED NEAR TO PM-14	LOCATED NEAR TO PM-18		
	DATE OF SAMPLING	23-Sep-09	22-Sep-09	22-Sep-09	21-Sep-09	22-Sep-09	21-Sep-09	25-Sep-09	25-Sep-09	25-Sep-09		
Component	UNITS											
OCTACOSANE	mg/L	<8.00E-05	<8.00E-05	<8.00E-05	**0.0098**	<8.00E-05	<8.00E-05	**0.021**	**0.002**	**0.038**	NR	NR
NONACOSANE	mg/L	<8.00E-05	<8.00E-05	<8.00E-05	**0.0128**	<8.00E-05	<8.00E-05	**0.026**	**0.004**	**0.076**	NR	NR
TRIACONTANE	mg/L	<9.00E-05	<9.00E-05	<9.00E-05	**0.0084**	<9.00E-05	<9.00E-05	**0.013**	**0.003**	**0.027**	NR	NR
HENTRIACONTANE	mg/L	<9.00E-05	<9.00E-05	<9.00E-05	**0.0080**	<9.00E-05	<9.00E-05	**0.010**	**0.004**	**0.014**	NR	NR
DOTRIACONTANE	mg/L	<1.00E-04	<1.00E-04	<1.00E-04	**0.0069**	<1.00E-04	<1.00E-04	**0.038**	**0.004**	**0.021**	NR	NR
TRITIACONTANE	mg/L	<1.00E-04	<1.00E-04	<1.00E-04	**0.0052**	<1.00E-04	<1.00E-04	**0.013**	**0.002**	**0.009**	NR	NR
TETRATRIACONTANE	mg/L	<1.10E-04	<1.10E-04	<1.10E-04	**0.0035**	<1.10E-04	<1.10E-04	**0.017**	<1.10E-04	**0.018**	NR	NR
PENTATRIACONTANE	mg/L	<1.20E-04	<1.20E-04	<1.20E-04	**0.0023**	<1.20E-04	<1.20E-04	**0.007**	<1.20E-04	**0.004**	NR	NR
HEXSATRIACONTANE	mg/L	<1.30E-04	<1.30E-04	<1.30E-04	**0.0019**	<1.30E-04	<1.30E-04	**0.007**	<1.30E-04	**0.005**	NR	NR
HEPTATRIACONTANE	mg/L	<1.40E-04	<1.40E-04	<1.40E-04	<1.40E-04	<1.40E-04	<1.40E-04	**0.001**	<1.40E-04	<1.40E-04	NR	NR
OCTATRIACONTANE	mg/L	<1.70E-04	<1.70E-04	<1.70E-04	<1.70E-04	<1.70E-04	<1.70E-04	<1.70E-04	<1.70E-04	<1.70E-04	NR	NR
TETRACONTANE	mg/L	<2.50E-04	<2.50E-04	<2.50E-04	<2.50E-04	<2.50E-04	<2.50E-04	<2.50E-04	<2.50E-04	<2.50E-04	NR	NR

UNDERGROUND WATERS	SAMPLE IDENTIFICATION	PM 9	PM 10	PM 11	PM 12	PM 13	PM 16	PM 17	PM 18	PM 19	DECREE 1594/84 ART. 38	Alberta Risk Management guidelines for Petroleum storage tank sites 2001 Table 4. Generic Hydrocarbon Criteria for the Groundwater Ingestion Pathway
	POINT DESCRIPTION	LOCATED NEAR TO PALAGUA LAKE	LOCATED IN BATTERY No.1, BEHIND THE GAS TREATMENT ZONE	LOCATED BEHIND THE STATION No. 2	LOCATED BEHIND THE WELLS P-112 AND P-20	LOCATED NEAR WELL P-32 IN THE API SEPARATOR AREA	LOCATED IN THE WELL P-125 LOCATION	LOCATED OUT THE BATTERY No.1 FENCE NEAR TO PM-14	LOCATED NEAR TO PM-14	LOCATED NEAR TO PM-18		
	DATE OF SAMPLING	23-Sep-09	22-Sep-09	22-Sep-09	21-Sep-09	22-Sep-09	21-Sep-09	25-Sep-09	25-Sep-09	25-Sep-09		
Component	UNITS											
PAHs												
NAPHTALENE	mg/L	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	<1.60E-4	NR	NR
ACENAPHTILENE	mg/L	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	NR	NR
ACENAPHTENE	mg/L	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	<1.90E-4	NR	NR
FLUORENE	mg/L	<2.00E-4	<2.00E-4	<2.00E-4	<2.00E-4	<2.00E-4	<2.00E-4	**0.0034**	**0.0010**	**0.022**	NR	NR
PHENANTRENE	mg/L	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	**0.0053**	**0.0024**	**0.012**	NR	NR
ANTHRACENE	mg/L	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	NR	NR
FLUORANTHENE	mg/L	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	NR	NR
PYRENE	mg/L	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	<2.20E-4	NR	NR
BENZO(A) ANTHRACENE	mg/L	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	NR	NR
CHRYSENE	mg/L	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	<2.50E-4	NR	NR
BENZO(B) FLUORANTHENE	mg/L	<2.60E-4	<2.60E-4	<2.60E-4	<2.60E-4	<2.60E-4	<2.60E-4	<2.60E-4	<2.60E-4	<2.60E-4	NR	NR
BENZO(K) FLUORANTHENE	mg/L	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	NR	NR
BENZO(A) PYRENE	mg/L	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	<2.80E-4	NR	NR
DIBENZ(A,H) ANTHRACENE	mg/L	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	<4.10E-4	NR	NR
BENZO(G,H,I) PYRELENE	mg/L	<4.00E-4	<4.00E-4	<4.00E-4	<4.00E-4	<4.00E-4	<4.00E-4	<4.00E-4	<4.00E-4	<4.00E-4	NR	NR
INDENO(1,2,3-D) PYRENE	mg/L	<3.60E-4	<3.60E-4	<3.60E-4	<3.60E-4	<3.60E-4	<3.60E-4	<3.60E-4	<3.60E-4	<3.60E-4	NR	NR

UNDERGROUND WATERS	SAMPLE IDENTIFICATION	PM 9	PM 10	PM 11	PM 12	PM 13	PM 16	PM 17	PM 18	PM 19	DECREE 1594/84 ART. 38	Alberta Risk Management guidelines for Petroleum storage tank sites 2001 Table 4. Generic Hydrocarbon Criteria for the Groundwater Ingestion Pathway
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	DATE OF SAMPLING	23-Sep-09	22-Sep-09	22-Sep-09	21-Sep-09	22-Sep-09	21-Sep-09	25-Sep-09	25-Sep-09	25-Sep-09		
Component	UNITS											
METALS												
CALCIUM	mg/L	33.30	66.77	40.46	16.13	77.38	15.83	23.23	531.7	356.9	NR	NR
SODIUM	mg/L	42.76	11.92	33.27	54.75	258.8	735.8	47.49	1723	1083	NR	NR
POTASSIUM	mg/L	0.219	0.511	2.679	0.299	2.875	0.956	1.290	13.94	12.84	NR	NR
MANGANESE	mg/L	0.0143	0.208	0.0113	2.965	4.955	0.0555	0.9933	8.764	2.966	NR	NR
MAGNESIUM	mg/L	2.009	3.168	2.207	16.90	36.60	28.01	8.843	207.5	80.04	NR	NR
IRON	mg/L	0.3471	0.2366	0.1624	0.174	13.48	<0.100	9.852	173.4	42.42	NR	NR
BARIUM	mg/L	0.0277	0.124	0.0910	0.0583	0.212	0.0673	0.415	10.31	6.72	1.00	NR
ALUMINUM	mg/L	0.367	0.00902	0.0200	0.0118	0.00573	0.0188	0.0162	<0.03508	<0.03508	NR	NR
CADMIUM	microg/L	0.193	0.289	0.095	0.278	<0.260	<0.260	<0.026	<0.260	<0.260	10.0	NR
CHROMIUM	microg/L	5.183	0.366	0.627	<1.150	2.228	<1.150	0.898	<1.15	2.450	50 (Cr^{+6})	NR
COPPER	microg/L	<2.102	<2.102	7.286	<21.02	<21.02	<21.02	<2.102	<21.02	<21.02	1000	NR
LEAD	microg/L	<0.284	0.335	0.424	<2.840	<2.840	<2.840	<0.284	<2.84	<2.84	50.0	NR
NICKEL	microg/L	2.713	6.499	4.616	3.543	5.811	3.699	3.363	15.28	12.11	NR	NR
VANADIUM	microg/L	13.69	7.183	16.68	3.7555	<0.800	38.18	3.313	<0.80	<0.80	NR	NR
ZINC	microg/L	10.31	72.45	8.725	<31.45	<31.45	<31.45	<3.145	<31.45	<31.45	15000	NR
ARSENIUM	microg/L	0.991	0.411	2.654	108.1	4.088	12.49	7.766	11.30	9.839	50.0	NR
SELENIUM	microg/L	<0.860	<0.860	<0.860	<8.600	<8.600	<8.600	1.045	26.76	21.40	10.0	NR
MERCURY	microg/L	<0.123	<0.123	<0.123	0.203	<0.123	<0.123	<0.123	0.737	0.706	2.00	NR

NT-No Test, NR-Not Reported, NA-Not Allowed

F.2.4. WASTE MANAGEMENT

There are two kinds of so called ”Waste Water” in Palagua-Caipal oil field, domestic waste water and industrial (produced) waste water. All the industrial waste water (about 11,100 barrels per day) is reinjected into the Tune reservoir.

F.2.4.1. Domestic Waste Water

Water used in human activity such as bathrooms, kitchens and sinks comes from a drinkable water source. This water is treated in a septic system which includes several tanks and filters. Approximately 150 gallons of domestic waste water are generated on a daily basis. This represents a minimum amount in comparison with the 11,100 barrels per day of industrial waste water.

F.2.4.2. Industrial Waste Water

- Water from hydrostatic tests

The equipment and the flow lines are pressure tested with water to detect leakage and check their integrity. Chemical additives like corrosion inhibitors, oxygen scavengers, and colors can be added to the water to prevent internal corrosion or identify leakage places. This water is taken to the water injection system for its final disposal.

- Other industrial wastewaters

Other wastewaters generated continuously in the oil and gas installations on land include sewage water, drainage water, and water from the bottom of the tanks, fire extinguishing water, waters resulting from washing the equipment and vehicles, and generic oily water. This water is transported to the water injection system (where oily water is separated) and is injected into the 3200-ft deep reservoir for its final disposal.

- Produced Water

This water is produced in conjunction with oil as an emulsion from the oil bearing sands of Tune and Guaduas formations. UT-IJP produces about 11,100 barrels of water per day. The oil-water emulsion is produced and separated by physical and chemical processes in which heat is applied along with demulsifier, allowing oil and water to be segregated by gravity in storage tanks.

Water produced with oil is treated and is then re-injected into the oil bearing zones. Chemical characteristic of this water does not change in the process of oil-water separation. At the end of the process the water returns to the formation from where it was initially extracted.

The typical well design of an injection well is shown in Figure 3.F-2. Based on the nature of our operation, compliance with World Health Organization guidelines for Drinkable Water is not applicable, since sources of drinkable water are not being affected or contaminated. World's Bank guidelines for Oil and Gas Development protect sources of fresh/drinkable water from contamination or from over demand. At no point in the process of production, separation and injection, does produced water get in contact with any drinkable water source or the environment.

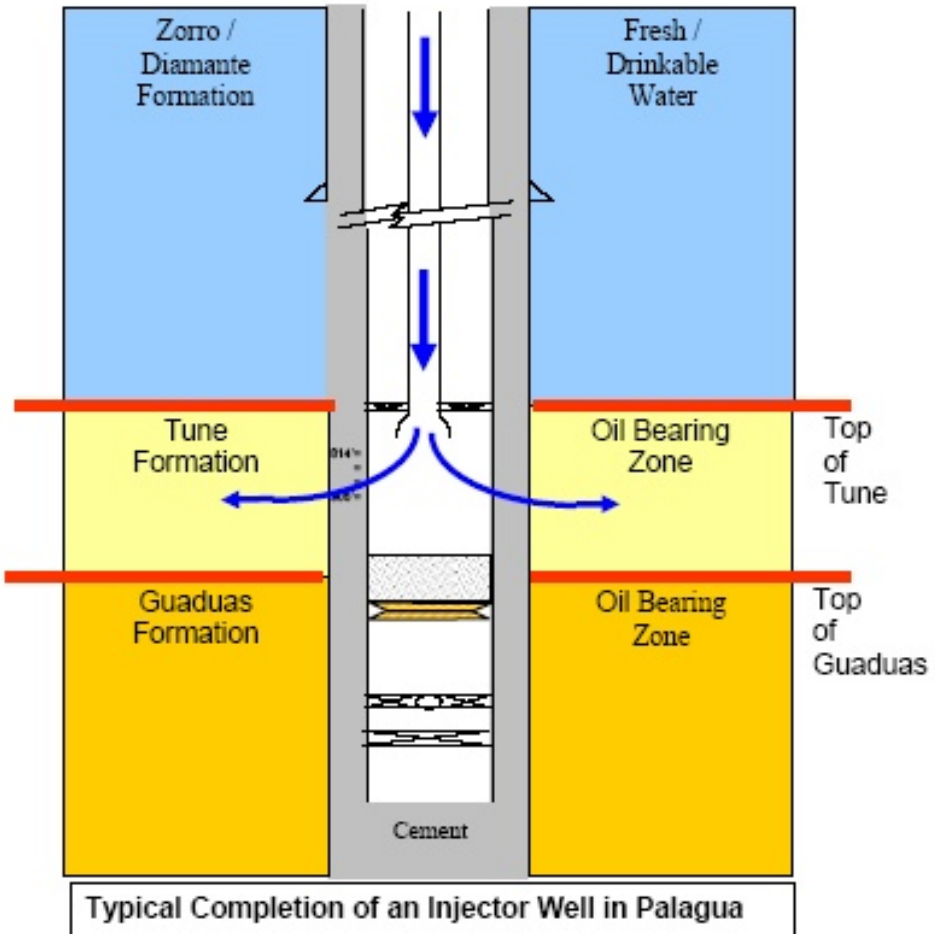


Figure 3.F-2 Typical Completion of fan Injector Well in Palagua field

F.2.4.3. INJECTION PLANT OF RESIDUAL WATER

Since the construction of the water injection plant in 1994, all produced water at the field is injected, after physico-chemical treatment.

The injection of residual waters system consists of the following stages:

Clarification: solids removal

- Skimming: residual oil removal
- Filtration: solids / oil removal
- Injection: To the reservoir - Tune Formation

Palagua-Caipal field produces approximately 11,100 BWPD (barrels of water per day). The produced water is first treated in general separators (commonly known as API separators) by injecting coagulants and flocculants to precipitate the solids that are in suspension. The separated water and oil are taken to different storage tanks in Battery No. 1 and in Stations 2 and 4. Water is then taken to the water injection plant near Battery No. 1 (most commonly known as PIA) using a P-100 A/B/C pump.

Photo 3.F-5 API Separator

Once water enters the plant, treatment continues with the injection of oxygen scavengers and biocide. The water will continue through a stabilizer tank (TK- 100), and then it is sent to a skimmer tank (TK- 101) using a P-101 A/B/C pump where gravity helps to trap suspended solids and oil. All these processes are designed to achieve a good quality of water for reinjection into the Tune formation.

Photo 3.F-6 Water Treatment Plant at Palagua field

Once the clean water is obtained, it goes directly to the hydrostatic head tank (TK-103) from where water is pumped by three pumps P-109 A/B/C for re-injection in the Palagua Field. The injection is carried out by these three (3) pumps that transport the water through 8" tubing (coated with green color) towards the four injection wells. The water is injected into the Tune formation at 3,200' of average depth. Presently about 11,100 bbl of water are being injected daily into wells P-26, P-120 and P-121. Well P-97 is an additional well that can be used for contingencies.

The operating conditions of the water injection plant are tabulated in Table 3.F-21.

Table 3.F-22 Operating conditions of Water injection Plant

Capability of design:	12,000 bpd
Maximum Injection Pressure:	2,000 psi
Normal Operation Flow rate:	11,100 bpd
Actual Operation Pressure:	700 psi

Bpd: barrels / day

Figure 3.F-3 depicts a schematic of the water injection plant. Here, the tanks, the filtration system and injection pumps can be observed.

The quality of the injected water is controlled daily by measuring the suspended solids, dissolved oxygen and oil in water at the entrance and also at the exit of the plant. Corrosion coupons have also been installed to determine the corrosion and scale formation.

Table 3.F-23 Operational Parameters of the Water Injection Plant (PIA)

OPERATING PARAMETERS		
Parameters	Concentration	
	Entrance	Exit
Dissolved Oxygen	200-500 ppb	0-50 ppb
Greases and oils	11 ppm	4 ppm
Suspended soils	30 ppm	5 ppm
Temperature	100 °F	100 °F
Carbon Dioxide	18 ppm	18 ppm

The chemicals used in the treatment of residual water are listed in the table below.

Table 3.F-24 Chemicals used in the treatment of residual water

CHEMICAL	Consumption, gpd	Concentration, ppm
Scale inhibitor	2.0	8
Oxigen scavenger	2.0	7
Flocculant (polymer)	0.5	1
Coagulant (polymer)	0.1	5
Biocide	1.4	80

gpd: gallons per day

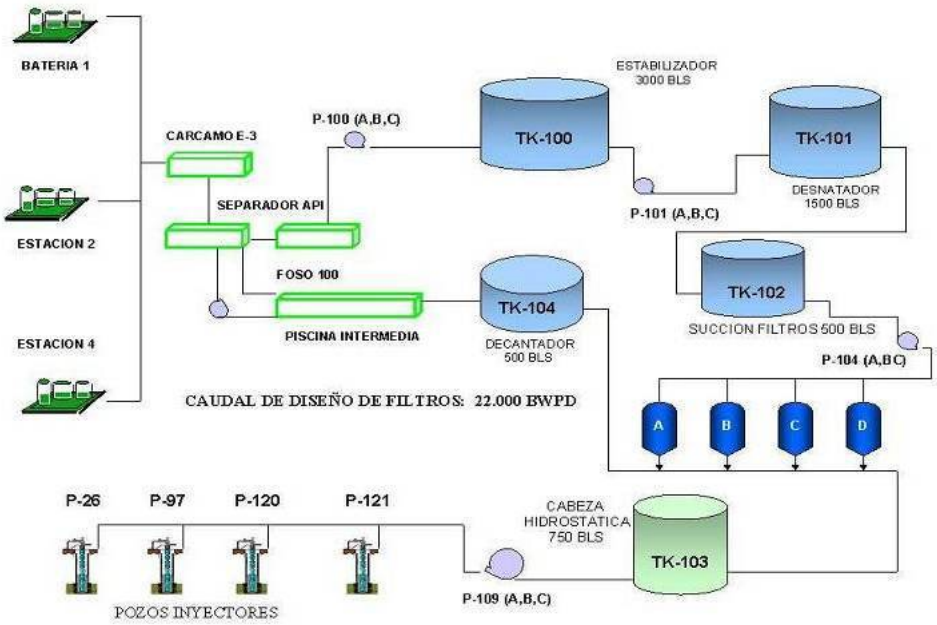


Figure 3.F-3 Schematic of the water injection plant

SPANISH TO ENGLISH TRANSLATION KEY

Bateria 1	Battery 1	P	Pump
Estación 2	Station 2	Caudal de diseño de filtros	Filters design rate
Estación 4	Station 4	Estabilizador	Stabilization tank
Pozos injectors	Injection wells	Desnatador	Skimmer tank
Cárcamo	Sump	Decantador	Precipitation tank
Separador API	API Separator	Suction filtros	Suction Filters
Foso	Ditch	Cabeza hidrostática	Hydrostatic Head
Piscina intermedia	Intermediate pool		

Should an operational emergency occur, the field has a pool with extra storage capacity that can be used until the injection plant is commissioned again. The following photo shows the industrial water storage pools available in the field.

Photo 3.F - 7 Industrial pools of Water Storage

Table 3.F-25 Water Analysis of the Residual water treatment plant

RESIDUAL WATERS TREATMENT PLANT LABORATORY ANALYSIS - 2nd SEMESTER 2009					
PARAMETERS	**UNITS**	**API OIL SEPARATOR**	**TANK-100 INLET**	**FILTERS OUTLET**	**PUMPS OUTLET**
PHYSICALS					
Temperature	° C	40	38	38	34
Pressure	psi	14.7	20	20	950
IONS					
Total hardness	ppm CaCO3	5840	5720	5700	5720
Hardness as calcium carbonate	ppm CaCO3	4950	4850	4820	4810
Alkalinity	ppm CaCO3	420	450	420	420
Chlorides	ppm	14000	14000	13980	13950
Sulfites as SO4	ppm	18	18	20	16
Barium	ppm	40	42	45	28
Iron, soluble	ppm	4.2	3.9	4.2	3.98
Iron, total	ppm	7.8	6.4	6.2	6.2
GASES					
Carbon dioxide	ppm	22	20	20	22
H2S	ppm	0.2	0.1	0.1	0.1
Dissolved oxygen	ppm	1000	50	30	10
ELECTROCHEMICALS					
pH		7	6.5	6.8	6.9
Conductivity	uS/cm	33.3	35.1	34.5	32.9
TDS	ppm	19850	19820	19830	19750
CORROSION					
Index/Pit index	MPY				
Amine	ppm	2	2	2	2
OTHERS					
TSS	ppm	152	20	6	4.2
Oil carryover	ppm	498	19	4	3
Turbidity	ppm	315	21	8	5

F.3. SOIL QUALITY

Due to previous hydrocarbon operations in the field, the Colombian Petroleum Institute (ICP from Ecopetrol) provides technical advice for the landarming of this field. ICP performed a physic-chemical characterization of the soil and (in the absence of local regulations) uses the Louisiana Administrative Code, which establishes the criteria for quality of bioremediation soils, as the comparison standard.

F.3.1. PRINCIPLES OF BIODEGRADATION OF HYDROCARBONS

The biodegradation is a process of oxidation by means of the metabolic action and chemical interaction with microorganisms such as bacteria, actinomycetos and others. Molecular oxygen is important for fast biodegradation of hydrocarbons.

Worldwide, the oil industry has utilized microorganisms for over 50 years for the biodegradation of hydrocarbons in the treatment of residual waters and oily residues. The biodegradation of hydrocarbons is an acceptable treatment for final disposal of oily residues produced in the oil fields. The hydrocarbon molecule is turned into innocuous substances with the oxidation of the hydrocarbon using minimum energy and cost.

The success in the bio treatment requires a specific and healthy microorganism population, oxygen, nutrients and an environment with balanced pH. Figure 3.F-4 illustrates this process.

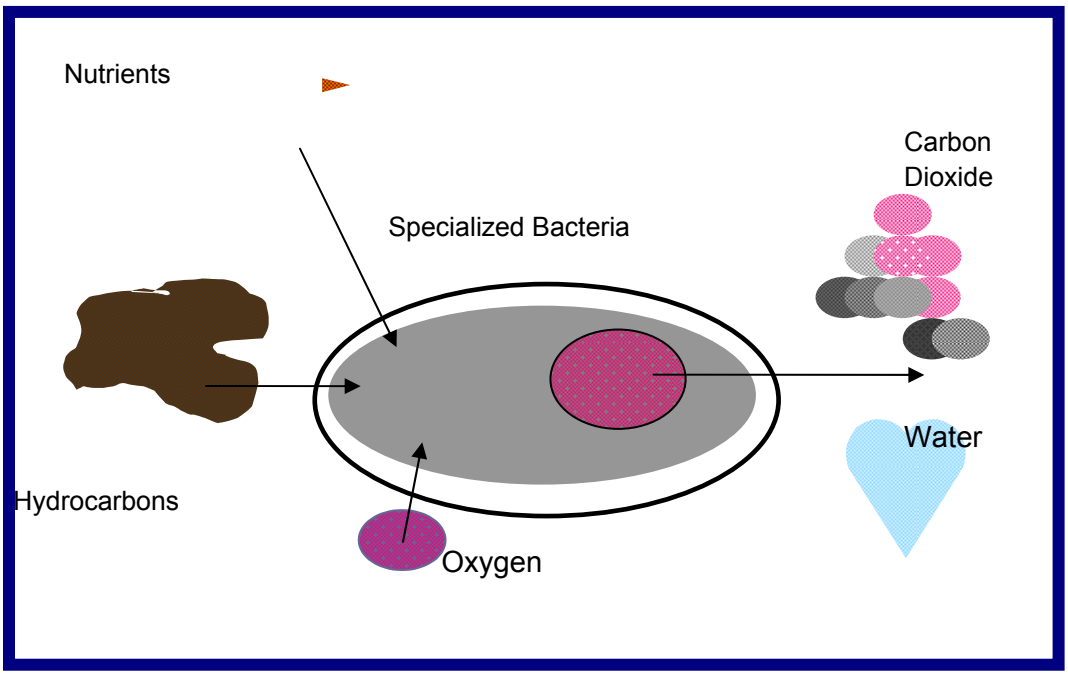


Figure 3.F - 4 Biodegradation process

Ecopetrol since 1991, through the Colombian Institute of Oil (ICP) has developed and applied successful bioremediation technology along with intensive aeration for the treatment and disposal of oily residues, treatment of residual waters and environmental restoration of grounds impacted by hydrocarbons.

F.3.2. TREATMENT UTILIZING THE TECHNOLOGY OF LAND FARMING

The technology known as land farming, land treatment or land application, is a method for the aerobic biodegradation of hydrocarbons.

This method is applicable to soil that contains oil, water and solids. Its effectiveness depends upon the physical-chemical characteristics of the soil, characteristics and composition of the oily residue, climatic conditions, and humidity.

A representative scheme of the application of the process of biodegradation is shown in Figure 3.F-5.

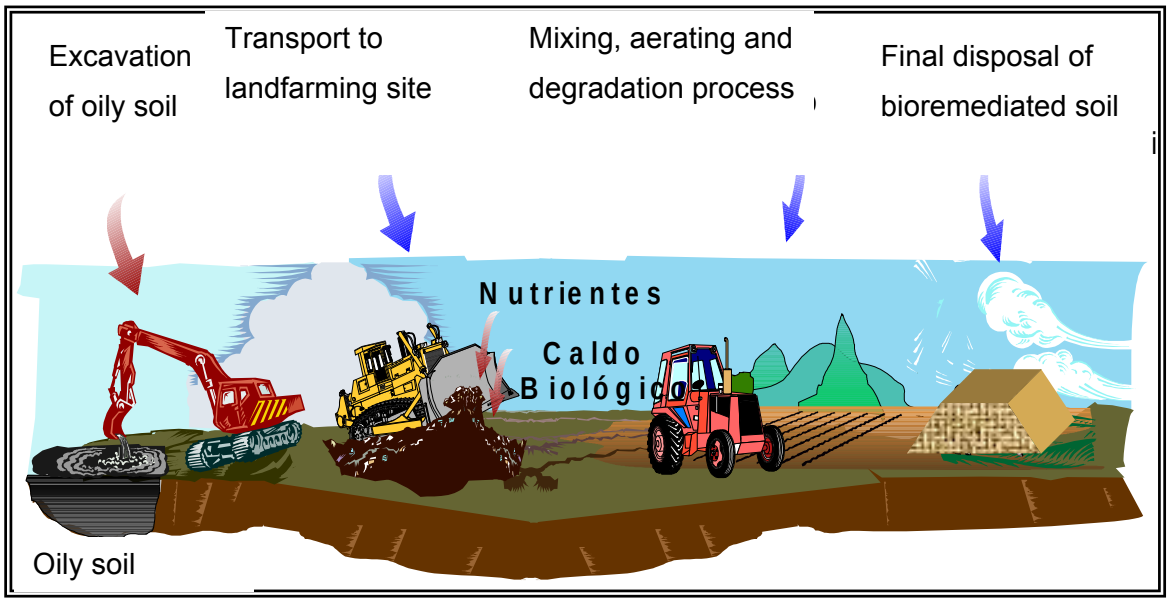


Figure 3.F-5 Scheme of the mixture for the treatment

F.3.3. BIOREMEDIATION TREATMENT

F.3.3.1. Bio nutrients

For the process of biodegradation, macro bio nutrient concentrations are utilized in a proportion C:N:P (Carbon:Nitrogen:Phosphorus) of 200:10:1:0.1 or 100:10:1:0.1.

When Carbon, Nitrogen and Phosphorus are not in balance, then commercial inorganic fertizers are added to the mixture. These fertilizers contain salts like ammonium nitrate (NH4NO3), potassium chloride (KCl), potassium nitrate (KNO3), di-ammoniac sulphate or Super phosphates (P202), and others.

The micronutrients are necessary to maintain adequate environmental conditions for the metabolism of the microbiota in the ground and facilitating the decomposition of organic material. These nutrients are generally found in natural grounds forming compounds like Sulfates, hydroxides or iron, manganese, calcium, magnesium, zinc, cobalt, copper, aluminum oxides, etc.

F.3.3.2. Conditioning of the mixture

In bioremediation, microorganisms use the hydrocarbon as a source of carbon. For efficient land farming at the Palagua field, the mixture of the material to be treated is prepared with an initial concentration of total hydrocarbons between 6 to 10% of TPH (Total Petroleum Hydrocarbon) in dry weight (w/w). To achieve the proper pH, agricultural lime (CaOH) and magnesium lime were used to adjustment of acidity of the mixture in treatment. The humidity of the mixture is adjusted with addition of water to achieve humidity between 80 and 90% in the treatment system.

F.3.3.3. Process of bio remediation

This process consists of increasing the microorganism's population in the treatment mixture to improve the efficiency of biodegradation. The harvesting of microorganism is accomplished in bioreactors under appropiate environmental conditions to proliferate bacteria in a range of 10E +06 to 10E +09 Ufc/ml.

Once the cultivated microbial is obtained in high concentrations of microorganisms, then the microbial broth is added directly to the mixture of soil and hydrocarbons.

The processes for native microorganisms were developed by Ecopetrol. The certified laboratories of Biotechnologies provide technical support for the application in bioremediation of oily residues.

F.3.3.4. Preparation of the mixture of treatment

For the Palagua Field, the initial mixture of oily residues shows TPH around 21%. The homogenization process is accomplished using excavators. The following actions were taken to carry out the bioremediation.

- Movement and mixing of the contaminated material: The areas show different hydrocarbon concentration, so mixing with excavators to achieve a uniform hydrocarbon concentration in the area is required..
- Preparation and sprinkling of the microbial broth:
- Addition of nutrients and lime: The addition of nutrients and the pH control are applied in each zone.
- Aeration: The aeration is carried out by intensive mixing with two excavators.

Figure 3.F-6, shows a scheme of the bioremediation plant.

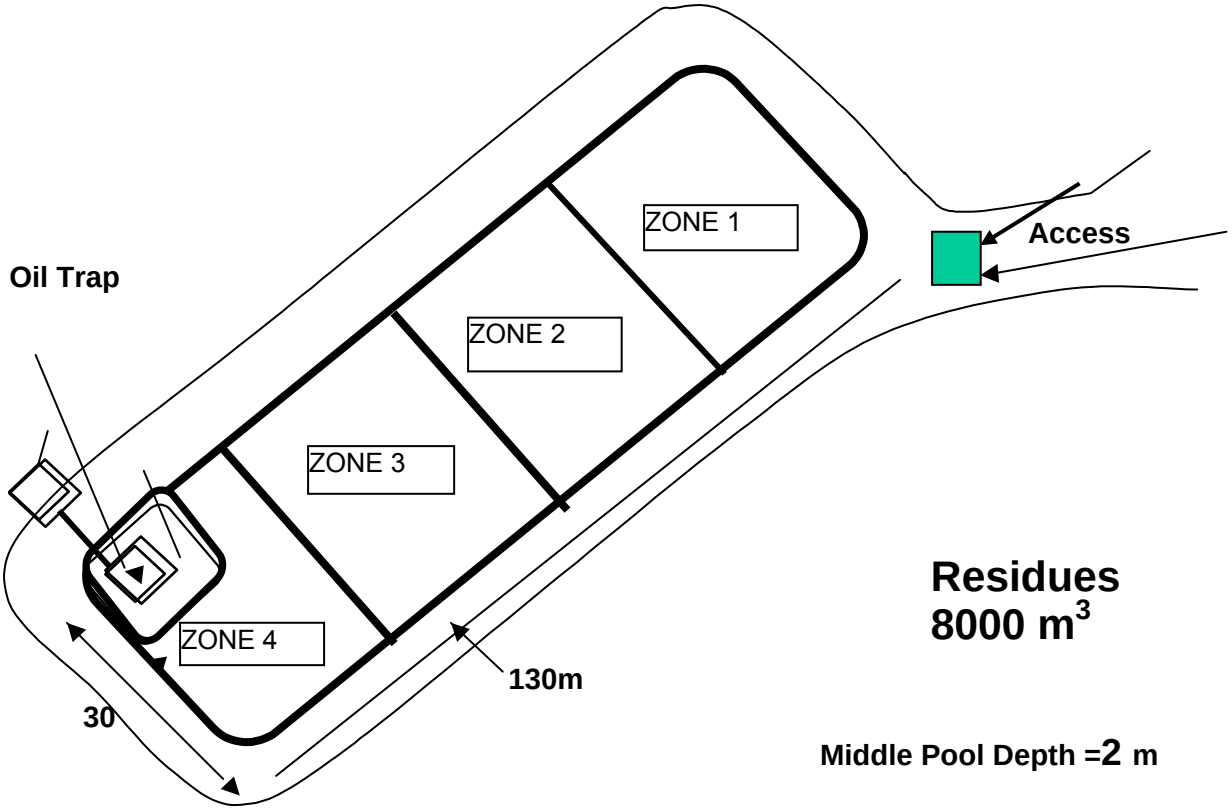


Figure 3.F-6 Sample zones of the Land Farming in Palagua Field

The soil mixing, aeration, and sprinkling of microbial and nutrients broth for the removal of hydrocarbon continues until reducing the average TPS to 9% w/w. With the excavator, the mixture is aired to improve the homogenization and the porosity of the system.

F.3.3.5. Completion of the bioremediation process

The process of bioremediation for land farming is completed when TPH reaches less than 3% w/w, representing a removal up to 80% of the initial TPH.

According to the experience in Palagua region, the time for the bioremediation process of Land farming is about six (6) to ten (10) months.

The treated material is reused as refill material for the contruction of road slopes and for the reforestation of industrial areas.

F.3.4. SOIL SAMPLING FROM THE PALAGUA FIELD LANDFARMING AREA

In 2009, about 1,540 mts3 of drilling cuttings and 2,900 mts3 of oily sludge were treated in the landfarming area using the bioremediation technique. The area was sampled and tested in different places as shown in the figure below (Table 3.F-24 gives the geograhic coordinates of the sampling sites).

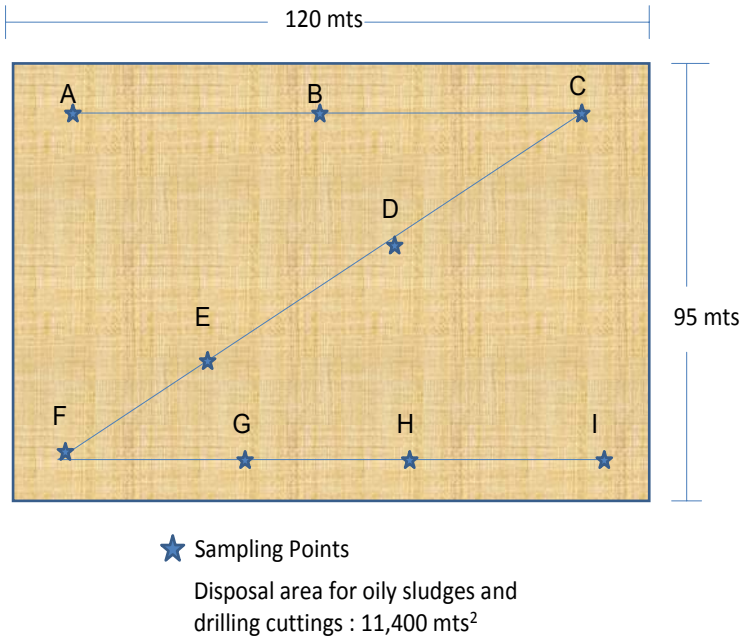


Figure 3.F-7 Sampling Points

Table 3.F-26 Geographical locations of the sampling points for soil analysis

Material	Location	Coordinates	
		N	W
SOIL	POINT A	06º05'49.5"	074º30'47.9"
	POINT B	06º05'44.9"	074º30'48.1"
	POINT C	06º05'50.1"	074º30'48.2"
	POINT D	06º05'50.2"	074º30'47.9"
	POINT E	06º05'50.3"	074º30'47.5"
	POINT F	06º05'50.3"	074º30'47.2"
	POINT G	06º05'50.4"	074º30'46.6"
	POINT H	06º05'50.6	074º30'46.8"
	POINT I	06º05'51.0"	074º30'47.0"

F.3.5. PARAMETERS EVALUATED

- pH:
- Conductivity
- Humidity:
- Greases and oils:
- Sodium Adsortion Ration (SAR)
- Cationic Interchange Capability (CIC):
- Interchangeable cations (calcium, magnesium, sodium, potassium):
- The percentage of interchangeable sodium (PSI):
- Metals (Ba, V, Cd, Zn, Pb, Ag, Se, As):

F.3.6. SOIL QUALITY RESULTS

The soil in the Palagua Field was evaluated according to the legislation in the Louisiana Administrative Code, Natural Resources, Subsection 1, and state-wide Order No. 29b. This norm contains the requisites for *in-situ* storage, treatment, and disposal of non-hazardous residues.

The conductivity and concentrations of grease, oil, and metals (silver, arsenic, barium, cadmium, lead, selenium, zinc and mercury) in the measured soil samples are below the permitted limits in the Louisiana norm.

A summary of these analyses is shown in Table 3.F-25.

Table 3.F-27 Palagua Field soil tests results

	Sampling location	Point A	Point B	Point C	Point D	Point E	Point F	Point G	Point H	Point I	Louisiana Administrative Code. Natural resources, Subpart 1. State-wide order 29B
	Date	Sept. 25/09	Sept. 25/09	Sept. 25/09	Sept. 25/09	Sept. 25/09	Sept. 25/09	Sept. 25/09	Sept. 25/09	Sept. 25/09	
PHYSICOCHEMICAL PROPERTIES	Units	**200461692**	**200461693**	**200461694**	**200461695**	**200461696**	**200461697**	**200461698**	**200461699**	**200461700**	
Conductivity/ºT	µomhs/cm-T	192/25.4	179/25.3	229/23.4	164/25.7	187/25.2	207/24.0	167/23.3	176/25.6	225/26.0	8000
pH/ºT		9.09/21.5	9.49/22.1	9.48/22.3	9.25/21.8	9.05/22.1	8.62/22.4	9.02/22.7	9.10/22.7	9.35/22.3	6.0-9.0
Greases and oil	mg/kg	4802	3641	2221	1880	3993	5847	9717	7434	3483	10000
Humidity	%weight	2.25	3.60	2.53	2.28	2.28	2.98	2.16	2.84	2.06	NR
Exchangeable sodium	%	39.6	33.9	47.8	85.4	42.1	37.1	125	74.3	209	25
Exchangeable cations											NR
Calcium	meq/100g	24.4	28.6	29.4	14.6	20.8	19.1	17.6	20.7	21.2	NR
Magnesium	meq/100g	3.29	1.13	1.65	3.11	2.13	2.93	2.65	4.01	1.80	NR
Potassium	meq/100g	0.38	0.49	0.56	0.39	0.56	1.19	0.69	0.39	0.67	NR
Sodium	meq/100g	5.77	6.34	6.27	6.08	5.35	4.20	4.20	5.03	5.50	NR
RAS		6.87	6.91	6.40	6.73	6.07	4.85	5.53	5.48	6.60	14
Calcium	meq/L	1.61	2.06	3.41	1.23	2.88	3.94	1.97	1.80	2.69	NR
Magnesium	meq/L	0.60	0.14	0.18	0.43	0.58	1.37	0.67	0.78	0.29	NR
Sodium	meq/L	7.21	7.24	8.56	6.13	7.99	7.89	6.36	6.23	8.06	NR
Cation exchange capacity	meq/100g	14.6	18.7	13.1	7.12	12.7	11.3	3.37	6.77	2.63	NR
METALS											
Silver	mg/kg	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	200
Arsenic	mg/kg	4.168	4.743	4.087	4.180	<1.570	<1.570	<1.570	3.892	3.793	10
Barium	mg/kg	440.7	408.4	415.5	428.3	385.0	7140.2	1551.2	480.2	470.8	20000
Cadmium	mg/kg	1.069	1.208	1.061	1.143	1.081	1.577	1.249	1.485	1.197	10
Lead	mg/kg	20.73	8.839	6.369	8.352	10.32	85.11	25.71	23.85	8.755	500
Selenium	mg/kg	<0.399	<0.399	<0.399	<0.399	<0.399	<0.399	<0.399	<0.399	<0.399	10
Zinc	mg/kg	57.27	56.67	53.01	57.54	57.5	80.88	57.77	62.93	51.89	500
Mercury	microg/kg	38.90	29.20	34.30	38.70	34.50	75.70	54.10	39.10	35.70	10000

NR: Not reported

F.4. LOWLANDS IN THE PALAGUA FIELD

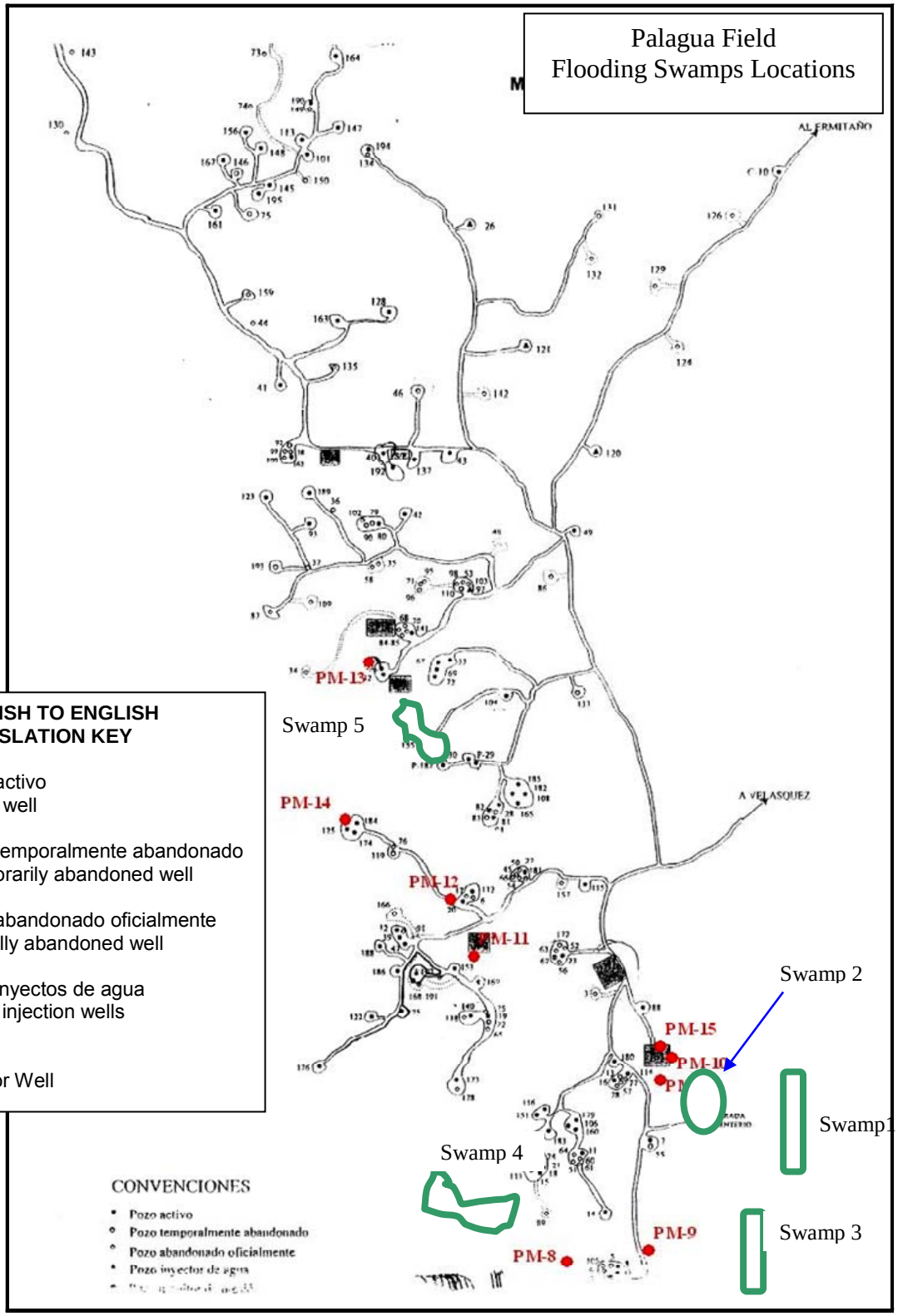
The Environmental Diagnosis Study of Palagua and Caipal Fields done during the second semester of 2001 measured soil samples in five lowland flooding areas:

Since 2006, a bioremediation process, ECOBIOL, has been implemented in the lowlands by application of microorganisms to accelerate and improve the process of natural decontamination. This process is monitored every year, and in 2009 the “Instituto Colombiano del Petróleo (ICP)” sampled and tested the five lowland areas.

The following tables show the results of such sampling with a comparison to the results from 2007, and also with different standards including the Dutch Standard for oil samples.

According to the table, since 2007, the concentration of hydrocarbon has decreased in all the lowlands and for 2009 the figures are below 1% of hydrocarbon concentration, which is acceptable as per the Canadian Law and Louisiana Regulations for environmentally sensitive areas that have been impacted by hydrocarbon spills.

Also, the concentrations of metals like cadmium and chromium meet all the standards.



SPANISH TO ENGLISH TRANSLATION KEY

Pozo activo
Active well

Pozo temporalmente abandonado
Temporarily abandoned well

Pozo abandonado oficialmente
Officially abandoned well

Pozo inyectos de agua
Water injection wells

PM
Monitor Well

Figure 3.F-8 Critical Lowland Areas

Table 3.F-28 Lowland Flooding Area 1

PARAMETER	PCTTL Tender No 0229 Based on Canadian and American Standards	LOUISIANA 29B	DUTCH STANDARDS Values		LAB. RESULTS	
			Target	Intervention	2007	2009
Cadmium	20 mg/l Cd	10 (mg/Kg)	0.8 (mg/Kg)	12 (mg/Kg)	1.27mg/kg	<0.077mg/kg
Chromium	500 mg/l Cr	500 (mg/Kg)	100 (mg/Kg)	380 (mg/Kg)	11.5mg/kg	15.5mg/kg
TPH	3%	2%	–	–	2.70%	1.79%

Table 3.F-29 Lowland Flooding Area 2

PARAMETER	PCTTL Tender No 0229 Based on Canadian and American Standards	LOUISIANA 29B	DUTCH STANDARDS Values		LAB. RESULTS	
			Target	Intervention	2007	2009
Cadmium	20 mg/l Cd	10 (mg/Kg)	0.8 (mg/Kg)	12 (mg/Kg)	0.470mg/kg	<0.077mg/kg
Chromium	500 mg/l Cr	500 (mg/Kg)	100 (mg/Kg)	380 (mg/Kg)	9.109mg/kg	19.8mg/kg
TPH	3%	2%	–	–	0.96%	0.05%

Table 3.F-30 Lowland Flooding Area 3

PARAMETER	PCTTL Tender No 0229 Based on Canadian and American Standards	LOUISIANA 29B	DUTCH STANDARDS Values		LAB. RESULTS	
			Target	Intervention	2007	2009
Cadmium	20 mg/l Cd	10 (mg/Kg)	0.8 (mg/Kg)	12 (mg/Kg)	1.24mg/kg	<0.077mg/kg
Chromium	500 mg/l Cr	500 (mg/Kg)	100 (mg/Kg)	380 (mg/Kg)	18.6mg/kg	12.2mg/kg
TPH	3%	2%	–	–	0.06%	<0.03%

Table 3.F-31 Lowland Flooding Area 4

PARAMETER	PCTTL Tender No 0229 Based on Canadian and American Standards	LOUISIANA 29B	DUTCH STANDARDS Values		LAB. RESULTS	
			Target	Intervention	2007	2009
Cadmium	20 mg/l Cd	10 (mg/Kg)	0.8 (mg/Kg)	12 (mg/Kg)	1.32mg/kg	<0.077mg/kg
Chromium	500 mg/l Cr	500 (mg/Kg)	100 (mg/Kg)	380 (mg/Kg)	17.1mg/kg	<11.5 mg/L
TPH	3%	2%	–	–	0.05%	<0.03%

Table 3.F-32 Lowland Flooding Area 5

PARAMETER	PCTTL Tender No 0229 Based on Canadian and American Standards	LOUISIANA 29B	DUTCH STANDARDS Values		LAB. RESULTS	
			Target	Intervention	2007	2009
Cadmium	20 mg/l Cd	10 (mg/Kg)	0.8 (mg/Kg)	12 (mg/Kg)	0.457mg/kg	<0.077mg/kg
Chromium	500 mg/l Cr	500 (mg/Kg)	100 (mg/Kg)	380 (mg/Kg)	18.3mg/kg	14.7mg/kg
TPH	3%	2%	–	–	3.41%	0.05%

F.5. NOISE

Noise is defined as sound or other unpleasant or unwanted alteration, or a random sound of a general nature, whose spectrum does not exhibit clearly defined frequency components (Harris, 1995).

The listening range can be divided into four areas according to their potential for hearing loss (See Figure 3.F-9).

Area I is below the threshold of auditory acuity. Area II is limited by noise levels below the threshold of auditory acuity and the higher levels on the risk threshold for hearing; this region includes sounds that are audible, but pose no risk of injury or loss of hearing, whatever is the duration of exposure. The sounds within the limits of Area III represent the region of "qualified risk". Acoustic injury and permanent hearing loss due to the sounds of this area depend on the

noise level, duration, and the biological variables of the person being exposed. The lower limit of Area IV is the threshold of discomfort; the upper limit is the threshold of pain. Exposure to sounds in this area (not including impulse or impact sounds) carries a high risk of causing injury and producing hearing loss, even when the sounds are of relatively short duration (seconds or minutes).

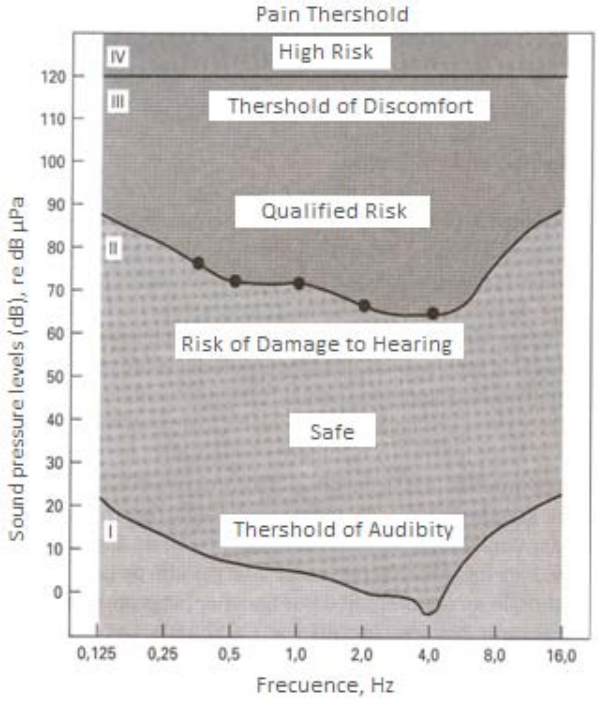


Figure 3.F-8 Human hearing and acoustics classified by injury and potential hearing loss

SOURCE: J.H. Mills, Seminars on hearing, vol. 9, 1988, p.260.

F.5.1. EVALUATION INDEXES AND NOISE STANDARDS

Resolution 627 of 2006 of the Ministry of Environment, SECTOR C: NOISE RESTRICTED INTERMEDIATE for the permitted uses in industrial areas allows a maximum of 75 dB in the daytime (7:01 to 21:00) and 70 dB in the night shift (21:01 to 7:00 hours). This Resolution regulates the noise component in the nation and it establishes the "rules concerning the protection and preservation of hearing health and welfare of people, because of the production and emission of noise." As set out in Article 14 of the reference standard, results in environmental noise measurements should be used to diagnose the noise environment. The results will lead to noise maps which allow visualization of the reality in regard to environmental noise, identification of critical areas and possible noise emission pollutants. The Maximum Permissible Standard of Ambient Noise Levels dB (a) can be observed in the following table.

Table 3.F-33 Maximum Permissible Standard of Ambient Noise Levels dBa

SECTOR	SUBSECTOR	Resolution 627 de 2006. Maximum Standard permissible ambient noise levels dB (a).	
		Day	Night
SECTOR A. PEACE AND SILENCE	Hospitals, libraries, kindergartens, clinics and nursing homes.	55	45
SECTOR B. PEACE AND MODERATE NOISE	Exclusively for residential areas for housing development, hotels and guesthouses.	55	45
	Universities, colleges, schools, study and research centers	65	50
	Parks in urban areas different from parks with outdoor mechanical attractions		
SECTOR C RESTRICTED INTERMEDIATE NOISE	Uses permitted in industrial areas such as industries in general, port areas, industrial parks, import/export zones.	75	70
	Areas with permitted commercial uses such as shopping centers, warehouses, commercial premises or shops, auto repair shops and industrial, recreational and leisure centers, gyms, restaurants, bars, taverns, nightclubs, bingo halls, casinos.	70	55
	Areas with office use allowed.	65	50
	Areas for institutional uses.	65	50
	Areas with other related uses, such as mechanical outdoor parks, areas for outdoor public events, crossroads, highways, arteries, main roads.	80	70
SECTOR D FIELD SUBURBAN OR RURAL QUIET AND MODERATE NOISE	Suburban Residential	55	45
	Rural housing for agriculture development		
	Recreation and rest areas, like natural parks and nature reserves		

SOURCE: MAVDT. Resolution 627 / 06

In accordance with the provisions of Resolution 627/06 Ministry of Environment, the final outcome of the measurements is given by the following equation:

$$L_{Aeq} = 10*Log\ ((1/5)*10^{LN/10} + 10^{LW/10} + 10^{LS/10} + 10^{LE/10} + 10^{LV/10}))$$

Where:

LAeq = Equivalent level measurement result
LN = Average equivalent level with the microphone placed in northbound position
LW = Average equivalent level with the microphone in westbound position
LS = Average equivalent level with the microphone in southbound position
LE = Average equivalent level with the microphone in eastbound position
LV = Average equivalent level with the microphone vertically oriented

According to the Environmental, Health, and Safety Guidelines from the World Bank Group, the limits for noise level are in the next table.

Table 3.F-34 Maximum Standard from World Bank guidelines (IFC)

RECEPTOR	One Hour LAeq (dBA)	
	Daytime	Nighttime
	07:00-22:00	22:00-07:00
Residential, institutional; educational	55	45
Industrial; commmercial	70	70

Source: Table 1.7.1. EHS Guidelines, April 30-2007

F.5.2. FIELD EVALUATION

Readings were conducted of the sound pressure level (SPL) during daytime and night, through measurements of 6 minutes in each direction: North, East, South, West and Vertical, for each of the six monitoring stations, to establish conditions of noise emission in Production Area - AP Palaguas FIELD. Importantly, this monitoring is primarily to establish the sound pressure level (SPL) in terms of environmental noise in each of the stations in the area.

Measurements were taken in a specific (punctual) manner to meet the sound pressure level (SPL) with duration of 6 minutes per sample/measurement for noise measurements and 15 minutes for ambient or environmental noise in each direction: (north, east, south, west, and vertical).

The result of these measurements was compared with the maximum permissible noise emission and environmental noise standards stated in Resolution 627 of 2006 Ministry of Environment, Housing, and Territorial Development (MAVDT) and the Environmental, Health and Safety (EHS) Guidelines from the World Bank and the International Finance Corporation (IFC in the tables).

Table 3.F-34 shows the location of monitoring points within the area of exploratory drilling and taking into account as a criterion to sensitive areas to drilling and/or exploitation of energy resources

Table 3.F-35 Location of Monitoring Points

Monitored Location Point	Geographic Coordinates	Map Coordinates
Location 1. Caipal 10	N 06º07'19,6"	N 1168446,54
	E 74º30'00,4"	E 953597,61
Location 2. Water treatment plant (PIA)	N 06º05'56,0"	N 1165879,97
	E 74º31'05,8"	E 951584,54
Location 3. Battery 2	N 06º05'06,7"	N 1164365,19
	E 74º30'54,2"	E 951940,03
Location 4. Industrial Area	N 06º05'01,5"	N 1164204,87
	E 74º30'30,6"	E 952665,63
Location 5. School	N 06º04'54,5"	N 1163989,82
	E 74º30'30,2"	E 952677,76
Location 6. Battery 1	N 06º04'45,9"	N 1163725,42
	E 74º30'21,2"	E 952954,31

SOURCE: ANTEK S.A. (November, 2009)

Readings from all location points monitored during the daytime measurements in a work day and during a holiday comply with the maximum limit established in Resolution 627/06 article 17 SECTOR C: restricted medium noise. Only at the water treatment plant, the value is slightly higher when compared with the IFC guidelines.

Some of the location points monitored (Points 1, 2, and 6) during the nighttime measurements registered values that exceed the maximum limit established in resolution 627/06 article 17 SECTOR C: restricted medium noise and the IFC guidelines.

In the majority of the location points monitored during the daytime and nighttime measurements, for a work day as for a holiday, an increase of the equivalent levels in the nighttime measurements was evidenced, mainly due to the **presence of elevated animal populations** that live in the area.

Table 3.F-36 Noise Levels in six location in Palagua Field

Location	COORDINATES	Day Shift				Night Shift			
		EQUIVALENT READING LEVEL dB (A)		MAXIMUM PERMISSIBLE STANDARD (07:01-21:00)	IFC MAXIMUM PERMISSIBLE (07:00-22:00)	EQUIVALENT READING LEVEL dB (A)		MAXIMUM PERMISSIBLE STANDARD (21:.01 - 07:00)	IFC MAXIMUM PERMISSIBLE (22:00-07:00)
		Work Day	Holiday			Work Day	Holiday		
Oilwell Caipal 10	06º07'19,6" 74º30'00,4"	58,9	56,8	75	70	71,5	55,4	70	70
Water treatment plant (PIA)	06º 05' 56,00" 74º 31'	72,4	67,9			68,2	71,4		
Battery 2	06º05'06,7" 74º30'54,2"	68,0	56,8			69,5	60,3		
Industrial Area	06º05'01,5" 74º30'30,6"	63,3	59,4			67,9	65,5		
School	06º04'54,5" 74º30'30,2"	58,5	56,6			66,6	63,9		
Battery 1	06º04'45,9" 74º30'21,2"	58.4	58.2			78.2	69.2		

SOURCE: ANTEK SA (November, 2009)

G. ARCHEOLOGICAL, HISTORICAL AND CULTURAL RESOURCES

Following the current regulations on preservation of the Archaeological Heritage in Colombia, "The whole country is considered to have great archaeological potential richness" (Decree 833 of 2002). In this regard, Law 1185 of 2008 (art. 7, subsection 1.4) and Decree 763 of 2009 (Article 55, Subsection 8, and Paragraph fourth) foresee that in order to achieve adequate protection of this heritage in economic development projects, if required it is necessary to prepare an Archaeological Preventive Program.

The constitutional regulations that watch over the protection, handling and recovering of the cultural heritage, are found in articles 7, 8, 63 and 72, where it is referred to the protection of ethnical and cultural diversity, as well as to cultural and archeological heritage, being this, one of the responsibilities of the State. From the Political Constitution are derived Law 99 of 1983 (National Environmental System), Law 388 of 1997 (Territorial Development) and Law 397 of 1997 (General of Culture).

G.1. RESEARCH BACKGROUND

The archeological research that has taken place during the last four decades in the middle-high valley of the Magdalena River, allowed information gathering of different cultural aspects of the Panches Indians that lived in those areas through different periods of time. The main historical periods of time that have been studied are:

This evaluation begins with the archeological data that indicates that at the end of the Pleistocene (15,000 to 10,000 years before present time – b. P.) several hunter collector groups traveled through the valley of the Magdalena River. A complete record was gathered in the excavation of open places and rock shelters, under which those groups carried out their domestic activities and in some cases buried their dead, for more than five millenniums (Correal, 1977, 1991).

Agricultural-ceramic communities of the formative, prior to the communities known at times of contact with the European culture. These societies cohabited until the second millennium before the present and started consolidating with the continuous improvement of agricultural and pottery activities known in the archeological literature as belonging to the Formative cultural period.

Although there is no certainty as to when the first occupations of the middle high part of the Magdalena River occurred – and in general in the whole national territory – the archeological research allowed to establish that these occupations took place at least for around 15,000 years ago, whose evidence show a developed industry through work on stone as primary raw material to obtain resources, with technological, functional and morphological variations that prevailed even after the era of contact with the Spaniards. On the other hand it can be sensed, as a primary indicator to explain later cultural developments, the development of agriculture and its consequent material evidence represented by pottery.

G.2. METHODOLOGY

The current landscapes are the result of various historic landscapes that have been following in turn one to the other, being a part of the material culture of the societies that created them. In their creation, the interaction between humans and nature and the way a certain social formation has been expressing itself in its space have been of the outmost importance.

G.3. PRESENCE OF NATIVE AND/OR AFRICAN -COLOMBIAN-COMMUNITIES

According to the Palagua – Caipal Field jurisdiction, there is not record of native communities nor of communitarian councils of African- American communities in the area, as certified by the official letter OFI10-6514-GCP-0201, sent by the Ministry of the Interior and Justice. Thus, preservation of archeological artifacts is not applicable to the proposed campaign of drilling of 40 development wells in the Palagua-Caipal field.