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Las Pailas Geothermal Project: A 35 MW Plant

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ABSTRACT

The Costa Rican Electricity Institute (ICE) developed the Miravalles geothermal field in only one decade (1994-2004), reaching a geothermal installed capacity of 163 MW at present. Additionally, ICE is going to increase the installed geothermal capacity by 35 MW with the construction of a new plant called Las Pailas, located on the south-southwest slope of the Rinón de la Vieja volcanic complex.

So far, the contribution of geothermal energy in the country stands at 14% and it will increase during 2011 when this new project is finished. A brief description of the Las Pailas geothermal project, information on the drilled wells, the adjudication process, the financing scheme, as well as the civil works associated to the development is presented in this document.

The potential for future geothermal development in the Las Pailas area and in the rest of Costa Rica is very limited. The fact that Las Pailas geothermal project is located adjacent to Rincón de la Vieja National Park, and current laws in Costa Rica do not allow the exploration or exploitation of geothermal energy inside National Parks, represents an enormous limitation, which has increased the difficulties in looking for the optimal development of the project.

An update of the current drilled wells and the main characteristics of the separation station, the gathering system and the civil works are described in this document.

1. INTRODUCTION

Due to the excellent results in the production of geothermal energy at the Miravalles geothermal filed, ICE is now in the process of developing a new geothermal field on the south-southwestern slope of the Rincón de la Vieja volcano; see Figure 1.

The pre-feasibility study at Las Pailas was carried out by GeothermEx, Inc. in 2001. The objectives of the study were: a) describe and synthesize the exploration data and other pertinent technical information that had been collected within the project area, b) using the database, develop a conceptual model of the geothermal system(s) in the project area to serve as a base for interpreting the geothermal resource potential in the area, as well as for planning future exploration and development activities, c) make a preliminary estimate of the commercial geothermal energy reserves that could be present in the project area, and d) make recommendations and establish priorities for drilling sites: Moya and Yock (2007).

This study started in April of 1999 with a meeting of specialists from GeothermEx, Inc. and ICE, and finished with a final report in December 2001. The work performed consisted in: a) analyzing and synthesizing the available information from the disciplines of geology, geophysics and geochemistry, b) analyzing and interpreting the results of temperature gradient wells in the project area, including an estimation of the temperature regime at depth, based on projection of temperature gradients, c) constructing a conceptual model of the geothermal system by integrating the available data, including the heat and fluid sources, the probable position and extent of the system, the possible patterns of fluid flow, and the geologic and structural controls that affect these characteristics, d) preliminary estimation of the recoverable geothermal heat reserves, based on the conceptual model, and e) description of the sites recommended for the drilling and completion of deep wells to test and confirm the existence of the geothermal resource.

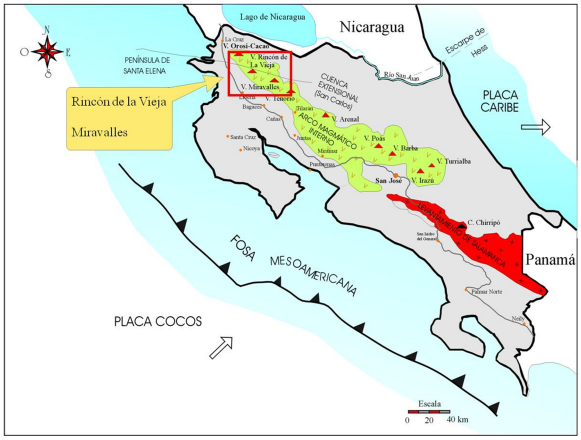

Figure 1: Location of the Las Pailas project.

Five sites were recommended in the Las Pailas area and five in the Borinquen area (another geothermal area on the Pacific slope of the Rincón de la Vieja volcano). For each area, four wells were programmed to confirm the existence of a geothermal reservoir that could produce commercially exploitable steam for electricity production; a fifth well was programmed as a development in the periphery of the Las Pailas field where residual geothermal fluid could be re-injected.

Based on the pre-feasibility report, ICE continued testing at Las Pailas to confirm the existence of a geothermal reservoir (with adequate temperature and permeability) in the area. To continue with these activities, ICE needed to consider that currently a great part of the area of known geothermal interest is within the limits of Rincón de la Vieja National Park, which was created as a result of the application of a national policy that protects and preserves the natural resources and the environment. Therefore, a large part of the area of geothermal interest is excluded from any possible future commercial development. The zone that is available in the Las Pailas geothermal area to

carry out the investigation is a stretch of land, oriented northeast (approximately 4 km long and 3 km wide).

ICE drilled five wells in the available area at Las Pailas. Three of the four production wells yielded positive results, making it possible to confirm the existence of a geothermal reservoir capable of commercial electricity production, with temperatures of 240ºC, 13 000 ppm of total dissolved solids, and low content of non-condensable gases. The fifth well proved to be unsuccessful, and therefore the existence of a zone where re-injection wells could be sited to dispose of residual geothermal water has yet to be found. However, better results were expected within the short term from a new injection well to be drilled in an area near the production zone. While drilling the deep commercial-diameter wells, ICE continued to reinforce the pre-feasibility project studies with additional electric resistivity soundings, geological studies, geochemical studies and the drilling of various temperature gradient wells, all of which supported the conclusion that a geothermal anomaly exists at Las Pailas.

Due to the good results obtained in the pre-feasibility study, ICE decided to continue the studies to demonstrate the feasibility of installing a geothermal unit and its capacity. The feasibility could be also used to seek funding for the project.

The consultants for the feasibility study were: GeothermEx, Inc. of Richmond California, USA for the development of the geo-scientific part and coordinator of the study, and Power Engineers of Hailey, Idaho, USA for the pre-design of the field-plant system proposed for the exploitation of the field. The study started in January 2000 with the signing of an assessment contract between ICE and the companies involved, and finished with a final report in September of 2005.

The purpose of the feasibility study was to: a) analyze the type of resource available (water-dominated, fluid enthalpy, temperature and chemical characterization of the fluid produced and injected), b) evaluate the field´s potential from reservoir engineering data, including the creation of a numerical reservoir model, and c) design the power plant and field installation based on the synthesis of the previous results, taking into account the applicable environmental restrictions throughout the process. The main result from the perspective of resource availability was that it was feasible to install a 35 MW power plant.

Under the Environmental Protecting Infrastructure for Economic Growth Utilizing Renewable Energy under the Puebla-Panamá Plan, the company West Japan Engineering Consultants, Inc., the Japan Bank for International Cooperation, and ICE conducted a second feasibility study in Las Pailas area. The activities of this study were very similar to the ones carried out by GeothermEx, and the conclusion was the same; namely, that "it is feasible to install a 35 MW power plant": ICE and West Japan Engineering Consultant, (2003).

While financing was being sought for Unit I at Las Pailas, ICE drilled two deep wells in the Borinquen area, finding a temperature of 278ºC (Table 1) but low permeability. Drilling activities in this zone have been postponed until the logistics of the area are improved. Meanwhile, geo-scientific studies continue in the area.

In mid-2007, an agreement was signed between the Ministry of Environment and Energy (MINAE), the Costa Rican Institute of Electricity (ICE) and the Guanacaste Dry Forest (Non-Governmental Organization), to carry out geo-scientific studies in the area called "Mundo Nuevo", which is a property of the Guanacaste Dry Forest, located between Las Pailas and Borinquen geothermal areas. The investigations of this area are currently in progress: Moya and Yock (2007).

Table 1: Parameters of Borinquen geothermal wells.

Well No.	Depth (m)	Maximum T (^{0}C)	Enthalpy (kg/kJ)	Flow (kg/s)	Est. Output (MW)
PGB-01	2 594	278	1 079	31.3	N. A.
PGB-03	2 082	203	N. A.	N. A.	N. A.

2. FINANCIAL SCHEME

For the Las Pailas project ICE received financial aid from the "Banco Centroamericano de Integración Económica" (BCIE) to build a plant of 35 MW on the slopes of the Rincón de la Vieja Volcano. The cost of the plant is around $160 million and should be in operation in October 2011. This plant should be constructed under the corresponding international quality standards in harmony with the social and natural environment, minimizing risk for the working personnel.

To develop the project, a leasing contract with an option to buy was prepared between ICE and BCIE in which, BCIE has the responsibility to develop and finance the construction of the geothermal plant for four years and then to lease it to ICE for 12 years (with an option to buy). The construction of the plant will be done by ICE and the structures to be built are: a) necessary infrastructure to build the main buildings, b) drilling of the geothermal wells, c) construction of all surface equipment (pipelines, separation station, shops, etc.), d) power house construction, e) auxiliary production buildings, and f) substation and transmission lines. Descriptions of the items are found next.

BCIE will carry out all the necessary acquisitions for all different works that are included in this development.

3. FIELD AND PLANT CONSTRUCTION

BCIE has allowed ICE to construct the power plant and field facilities taking into consideration the technical experience and efficiency that ICE has in these types of geothermal developments. Furthermore, this type of construction is not included in the bank's normal activities.

ICE will do all the design and will carry out the construction and installation of everything but the power house designs, which will be done by the equipment supplier. The construction activities in which ICE is involved are:

3.1 New Infrastructure

Construction of access roads, work camp, electricity lines and all it is required to begin the different constructions.

3.2 Geothermal Wells

All wells that need to be drilled (production, injection, observation wells) to operate the plant.

3.3 Surface Constructions

The main items are:

a. Gathering system: It consists in the fabrication and installation of 9 km of steel pipelines with a protective covering for the thermal insulation. The gathering system includes all the mechanical equipment required to transport the two-phase flow from the geothermal wells to the separation station, the steam lines from there to the power plant, and the brine lines to the injection wells (See Figure 2).

b. Cool injection system: Excavation and installation of 7 km of culverts. The concrete culverts will transport the brine from the geothermal wells and the separation station to the sedimentation pond or lagoon. The system also includes a pressure pipe from the lagoon to the injection wells.

c. Separation station: Everything related to the construction of the separation station, that is, all the civil works, the installation of the metal-mechanical, electrical, instrumentation and control equipment.

d. Aqueduct: It includes the intake and the secondary water lines to be transported to the different locations in the field. There will be two different aqueduct systems, one for industrial use (non-drinking water) and drinking water for all the common services required.

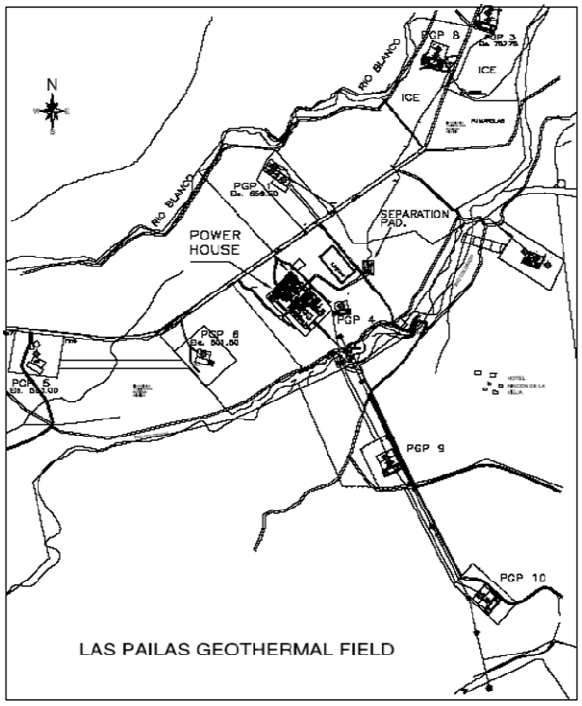

Figure 2: Las Pailas geothermal field

3.4 Power House Construction

Construction of the building where the main power equipment is going to be installed: turbine, generator, main transformers, auxiliary equipment of generation, internal pipelines, system against fire, security and watchman systems, and the cooling tower system (See Figure 3).

3.5 Auxiliary Buildings

These are the buildings required by ICE`s production department in order to have the necessary facilities to carry out the operation and maintenance of the power plant. They include the flammable materials warehouse, the spare parts warehouse, the shops (mechanical and electrical) and the administrative building.

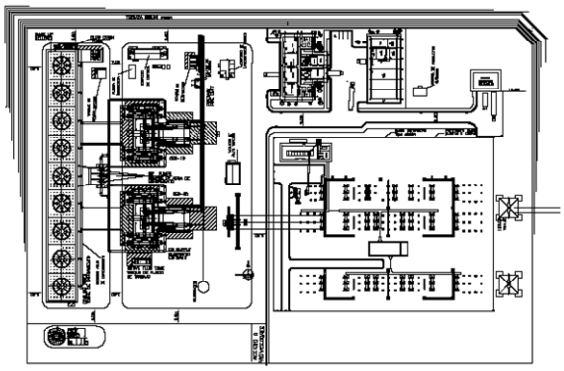

Figure 3: Power house and substation area at Las Pailas geothermal field

3.6 Substation and Transmission Lines

This includes the construction of the substation and the transmission lines between the new plant and the transmission line coming from substation Miravalles. After the interconnection of these two lines, the electricity is sent to substation Liberia where it is distributed.

4. BIDDING PROCESS

ICE prepared a bidding document "Concurso de Ofertas PGLP 001-08", published March 17, 2008 that allowed the participation of interested companies in two technologies, namely, single-flash (as used in Miravalles Units 1-3) and binary plants (as used in Miravalles Unit 5). The bank department in charge of this bid, invited companies to participate in the design, fabrication, transport to the site, installation supervision, preliminary tests, commissioning tests, and capacity and efficiency tests of the equipment for the power house of Las Pailas geothermal field.

On July 3, 2008, the bank opened the received bids, finding only one bid from: Consorcio Ormat Technologies Inc. y Ormat Systems Ltd.

4.1 Analysis of the Base Bid and Its Alternative

Each participating company was allowed to provide alternative proposals to the base bid. The alternative proposals can be evaluated after the base bid from a company has won the bidding process. Since there was only one participating company in this bidding process, ICE carried out the technical analysis of the base bid and its alternative, called Alternative 1. The only difference between them was related to the way the payment should be done. The evaluation of the bid consisted in: a) experience evaluation of the supplier, b) financial evaluation of the supplier, c) tender technical evaluation, and d) evaluation of the economic proposal and determination of the electricity cost.

4.2 Technical Analysis of the Base Bid

As mentioned before, ICE carried out the technical analysis of the bid and the main items are found in Tables 2 – 5: ICE, (2008).

Following the terms of reference, to compare the results, an evaluation of the base alternative and alternative 1 was

carried out. An estimation of the cost of a kilowatt-hour produced was made, taking into consideration the costs of steam and brine, construction and installation, equipment, and operations and maintenance, and the electricity generated during the lifetime of the unit, estimated to be 25 years from the beginning of its commercial operation. The results of this cost evaluation are shown in Table 6.

Table 2: Plant parameters

Item	Guarantee value by supplier	Units
Net power, 100% capacity	35 080	kW
Brine consumption, 100% capacity	377.8	kg/s
Steam consumption, 100% capacity	89	kg/s
Plant noise level	In agreement with bid standards	
Brine outlet temperature	140	ºC
Brine inlet pressure	740	kPa abs.
Brine outlet pressure	540	kPa abs.
Brine outlet pH	Same inlet and outlet pH values	
Water dischsrge for cooling tower	17.5	kg/s
Generation units (OEC)	2	
Number of turbines in each OEC	2	
Number of generators	2	

Table 3: Generator parameters

Item	Guarantee value by supplier	Units
GENERATOR		
Measured power at generator terminals	28 125	kVA
Power factor	0.8	
Frequency	60	Hz
Voltage	13.8	kV
Insulation type	VPI	

Table 4: Turbine parameters

Item	Guarantee value by supplier	Units
TURBINE		
Nominal power	20 800	kW
Working fluid	N-pentane	
Working fluid temperature at inlet turbine	150.1	ºC
Design pressure	93.8	kPa abs.
Rotational velocity	1 800	rpm
Moment of inertia of turbo-generator	1 860	t m^2

Table 5: Other parameters

Item	Guarantee value by supplier	Units
Required structural steel	130	metric tons
Steel for concrete works	722	metric tons
Pipelines	275	metric tons
Concrete	6 120	m^3
Geofluid specific consumption	0.013	kg/s/kWh
Time for commisioning tests	61	days

Table 6: Final cost of electricity

Item	Final cost of electricity	Units
Base Proposal	0.01764	US$/kWh
Alternative 1	0.01508	US$/kWh

Once the results of the final cost of electricity were completed, ICE recommended Alternative 1, taking into account the experience and the technical aspects for this development. The signature of the contract between the Banco Centroameriacano de Integración Económica and Ormat took place in January 2009.

5. GEOTHERMAL WELLS

So far ICE has drilled 9 vertical geothermal wells looking for production and injections areas. The parameters of these wells are shown in Table 7 (See also Figure 4 and Figure 5).

Table 7: Parameters of geothermal wells at Las Pailas geothermal project

Well Name	Depth (m)	Temp. (ºC)	Enthalpy (kJ/kg)	Power (MW)
PGP-01	1 418	246	1 052	8.1
PGP-02	1 764	240	N. A.	N. A.
PGP-03	1 772	243	1 128	3.7
PGP-04	1 418	232	1 011	4.5
PGP-05	1 827	160	N. A.	N. A.
PGP-06	1 327	200	N. A.	N. A
PGP-08	1 712	240	1 700	2.7
PGP-09	1 742	203	N. A.	N. A.
PGP-10	2 673	230	N. A	N. A

These wells have allowed ICE to define only the southern boundary of the reservoir. The eastern boundary is practically established since ICE is not planning to drill more production wells east of well PGP-02. To the east of well PGP-02 some injection wells might be drilled. New deviated wells are being drilled to find the northern and western boundaries of the field as well as the production and injection required for the 35 MW plant.

The geothermal area at Las Pailas is next to the Rincón de laVieja volcano National Park. The boundary of this park sets the northern boundary of the exploitable geothermal area at Las Pailas. Since in Costa Rica is not possible to establish any industrial or commercial activity inside a national park, it is not possible to obtain permission to extract energy inside the national park yet. The western boundary is set by a Non-Governmental Organization (NGO) called Guanacaste Dry Forest. This NGO has signed a contractual agreement in which some geothermal development may be allowed, provided the two parties are in agreement.

ICE still needs to drill more wells to reach the amount of fluids (steam and brine) that are required by the 35 MW plant. To date (July 2009) there are between 16 and 19 MW on reserve for production (See Table 7); the missing megawatts will be sought towards the northern and western zones of the current production area.

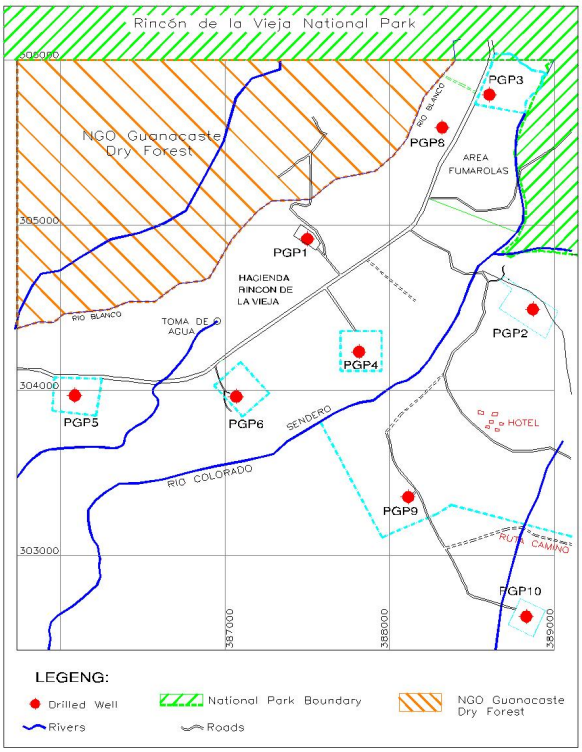

Figure 4: Drilled wells at Las Pailas geothermal field.

Figure 5: Well PGP-01 at Las Pailas geothermal field. Photo by P. Moya.

The power plant that will be built at Las Pailas geothermal filed is a binary plant, which is composed of two modules (Figure 6) where the steam is sent to the vaporizers and the brine is sent to the preheaters. The corresponding working fluid is N-pentane as indicated in Table 4.

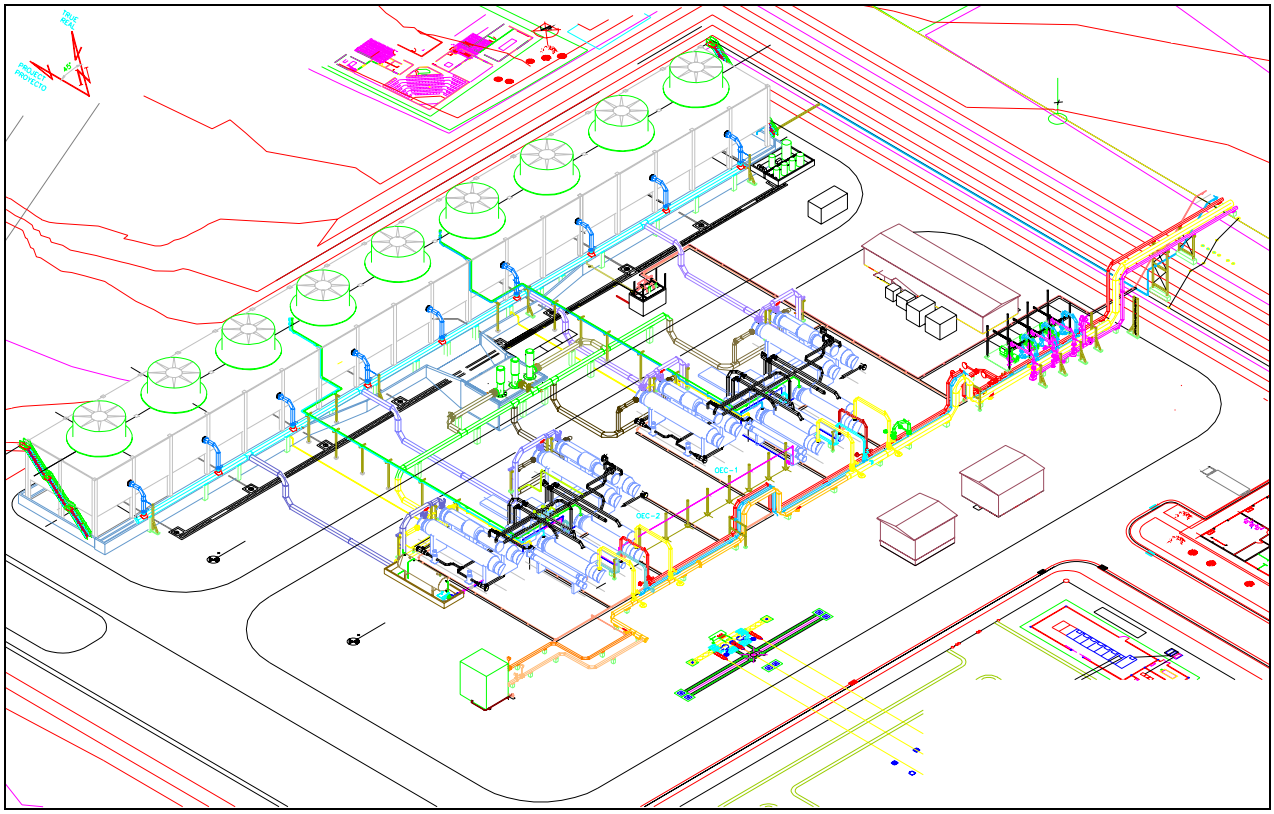

Figure 6: Binary plant at Las Pailas geothermal field.

Id	Item	Days	Start	End
1	**Construction program at Las Pailas**	**1040**	**10/18/2007**	**10/12/2011**
2	Signature of agreement between ICE-BCIE	1	10/18/2007	10/18/2007
3	Acquisitions	600	10/18/2007	02/03/2010
4	New infrastructure	300	01/02/2008	02/24/2009
5	Well drilling	900	01/02/2008	06/14/2011
6	**Power House**	**507**	**04/30/2009**	**04/08/2011**
7	Civil works	400	04/30/2009	11/10/2010
8	Installation of electromechanical equipment	330	01/04/2010	04/08/2011
9	Substation & transmission lines	330	01/05/2010	04/11/2011
10	Separation station & gathering system	330	01/04/2010	04/08/2011
11	Tests & plant commissioning	120	06/14/2011	10/12/2011

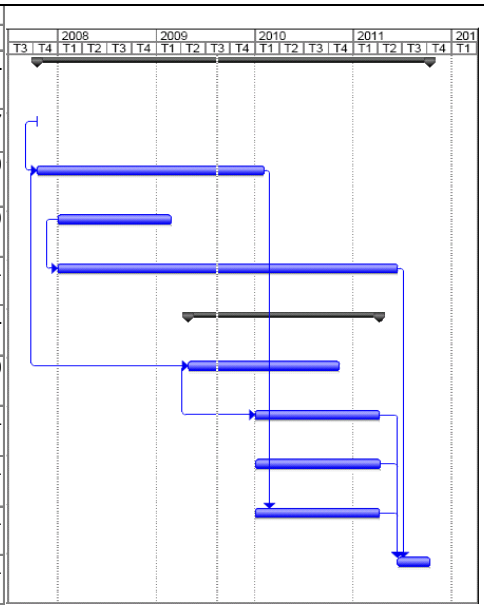

Figure 7: Gantt Diagram for Las Pailas Project.

6. CURRENT STATUS OF THE PROJECT

ICE should finish the construction of the power plant after 48 months from the contract signature between ICE and BCIE; this date will be October 18, 2011. The actual construction program is 44% complete (Figure 7) while in the theoretical construction program it should have been 46% complete. Currently, two deviated wells (PGP-12 and PGP-24) are being drilled, the new infrastructure is being built (access roads, work camp, electricity lines and all that is required to begin the various constructions) as well as the foundation of the power house.

Figure 8: Location of the power plant at Las Pailas project. Photo by I. Rojas.

The majority of the main acquisitions already have been defined such as: design and electromechanical equipment, directional drilling, materials and equipment for the substation and transmission lines, as well as materials for the separation station and the gathering system.

Unfortunately, the acquisition of the service for directional drilling experienced a delay (it began in July 2009) and therefore this is categorized as the critical activity of the project (See Figure 7). This may change if good results are obtained in the geothermal wells that are being drilled and which will be drilled in the future. Once the required amounts for steam and brine are found, the tests involved in the commissioning of the plant can take place.

7. FINAL REMARKS

Two different geothermal consulting companies GeothermEx Inc. (USA) and West JEC (Japan) indicated in their respective studies that the Las Pailas geothermal zone was capable of supporting a 35 MW plant.

The funding to build this plant was obtained by the Banco Centroamericano de Integración Económica and the commissioning of the plant should take place in October 2011.

Only one company participated in the bidding process. The other invited companies did not participate because they were too overloaded to consider the construction of a new 35 MW power plant.

Once the results of the final cost of electricity were completed, ICE recommended Alternative 1, taking into account the experience and the technical aspects for this development.

ICE has drilled 9 vertical geothermal wells looking for production and injections areas. These wells have allowed ICE to define only the southern boundary of the reservoir. The eastern boundary is more or less established since ICE is not yet planning to drill more wells to the east of well PGP-02. New deviated wells are being drilled to find the northern and western boundaries of the field as well as the production and injection required for the 35 MW plant.

ICE still needs to drill more wells to reach the amount of fluids (steam and brine) that are required by the 35 MW plant. Currently, there are between 16 and 19 MW confirmed for production; the missing megawatts will be sought towards the northern and western zones of the current production area.

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8. ACKNOWLEDGEMENTS

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