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GEOTHERMAL REINJECTION SYSTEMS IN EL SALVADOR

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ABSTRACT

Reinjection systems for disposing wastewater in Berlín and Ahuachapán geothermal fields, El Salvador, began operating in the 1990s. Currently, twenty-seven reinjection wells are used for disposing 4559 tons/ hour of the separated water (100% reinjection of residual water) from the operation of the power plants in both geothermal fields. In addition, pumping systems using in-line centrifugal pumps have been installed to improve the absorption capacity of both fields and ensure the plants' operation with ongoing maximum extraction. Other activities have also been implemented, including chemical inhibition of scaling due to mineral deposition in the reinjection lines; periodic maintenance work on wells; and mechanical and chemical cleaning to remove mineral deposits inside the pipes and near permeable zones of the wells. Plans to investigate TZIM stimulation process and the hydraulic stimulation in the wells, and implementation of multilateral drilling design in existing and future wells will be carried out, with the aim of improving/maintaining the absorption capacities of each field, and complying with the generation plan of the power plants, as well as the commitment to the regulatory board in charge of the concessions in both fields.

1. INTRODUCTION

Generating electricity with geothermal energy in El Salvador requires the extraction of fluids from the geothermal reservoir. In the country, the geothermal fields are located in Ahuachapán and Berlín, both with liquid-dominated reservoir allowing mixture of two-phase fluids (steam and water) on the surface. The steam is used to run the geothermal power plant and the water is reinjected into the reservoir using wells for this purpose.

In its early years (1975-1999), the separated (residual) water in the Ahuachapán geothermal field was managed through surface disposal at atmospheric pressure, using a concrete channel (71 km in length) that led out to the Pacific Ocean, however, this process was terminated in 1999 (Herrera et al., 2010).

In the Berlin geothermal field, the power plant began its operation in 1992. From the start, the separated water has been reinjected into one of the existing wells in the field's production area (Well TR-9). Subsequently, the first reinjection wells were incorporated, which were drilled in the field's current reinjection area, located to the north of the production zone.

2. EXISTING REINJECTION SYSTEM

2.1 The Ahuachapán geothermal system

The reinjection system in the Ahuachapán geothermal field has been operating at full capacity since 1999, reinjecting 100% of the separated water. The system began with three wells in the Chipilapa area (located to the northeast of the field), one well in Ahuachapán, and a reinjection line of 24"diameter and 5 km in length, shown in Figure 1. A total of 5 reinjection wells are currently used.

Because the reinjection system initially operated only at atmospheric pressure (from the flashers towards the disposal channel) and that the pressure in the reinjection line is very low, periodic operational problems of reinjection towards the Chipilapa area were encountered, mainly due to the limitation in reinjecting all available water. For this reason, an in-line pumping system was installed using especially designed centrifugal pumps to increase the reinjection pressure, where the absorption capacity of the wells would be the same as the total water mass required for reinjection. The pumping system (called Total Reinjection Ahuachapán or RTA in Spanish) began its operation in 2004, and it comprises a total of six centrifugal pumps. Due to the increased mass and generation of the power plant (85 MWe at present), a second reinjection line and an additional pump were installed in 2008. Thus, 100% reinjection of the wastewater produced by the power plant operation is achieved.

The average reinjected massflow in 2011 was 2,329.0 ton/hr (LaGeo, 2011). The steam fraction of the fluid from the wells in the Ahuachapán field was 19% of the total mass extracted from the reservoir. Approximately 76% of the total mass was reinjected during that same year. The steam is used in the power plant through the electricity generation process; however, there exists a small amount that is lost along the surface equipment.

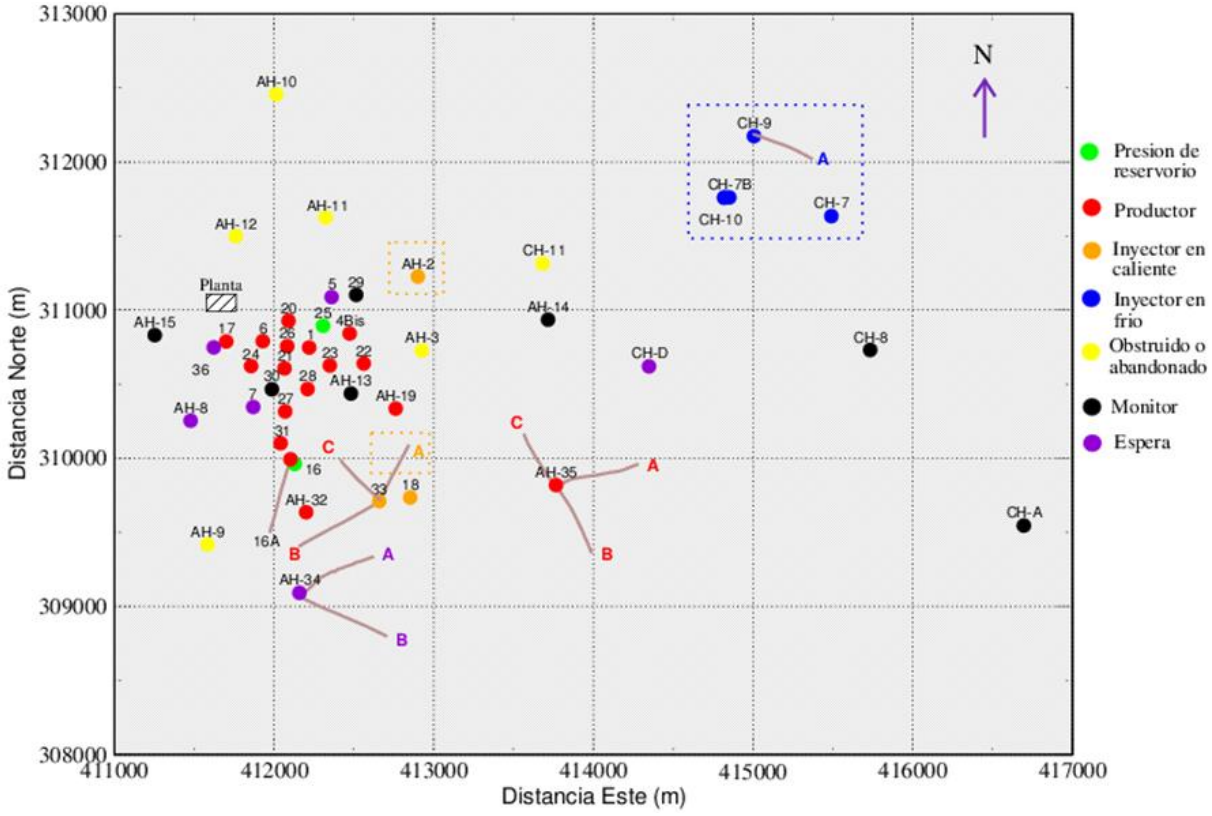

FIGURE 1: Location map of wells in the Ahuachapán Geothermal Field

2.2 The Berlín Geothermal Field system

The reinjection system at the Berlin geothermal field has been operating since the commissioning of the power plant in 1992 (Barrios, 2001). Reinjection started in TR-9 well, located at the central part of the field. The first wells in the reinjection area, on the northern part of the field, were drilled in 1994. With the increase of the plant's capacity from 10 MWe to its current 109 MWe, additional reinjection wells have been incorporated.

At present, there are 15 wells drilled within the two aquifers of the reservoir (intermediate and deep aquifers), as shown in Figure 2. The number of wells needed to completely reinject all the water extracted from the geothermal process is greater than that of Ahuachapán, because of the low to medium permeability in the Berlín reservoir. Since reinjection has been a recurring constraint for the Berlín power plant's operation at full capacity, various actions have been taken. For example, a pumping station (called Total Reinjection Berlín or RTB in Spanish), composed of three centrifugal pumps, was installed in 2008 at the facilities of the wellpad of the TR-1 wells in order to increase the reinjection capacity. For the past two years, only one of the three pumps is operating periodically, in order to maintain the reinjection capacity that the power plant requires for operating at maximum extraction.

With the construction of the Binary Cycle Unit (Unit 4) in 2008, residual heat is being extracted from the separated water available from the operation of Units 1 and 2 to operate Unit 4. The water's temperature is reduced by 40ºC (from 180 to 140ºC); with the decrease in temperature, the scaling potential by deposition of minerals such as silica increases. To address this problem, periodic monitoring is carried out, as well as the injection of a silica scaling inhibitor to reduce scaling problem.

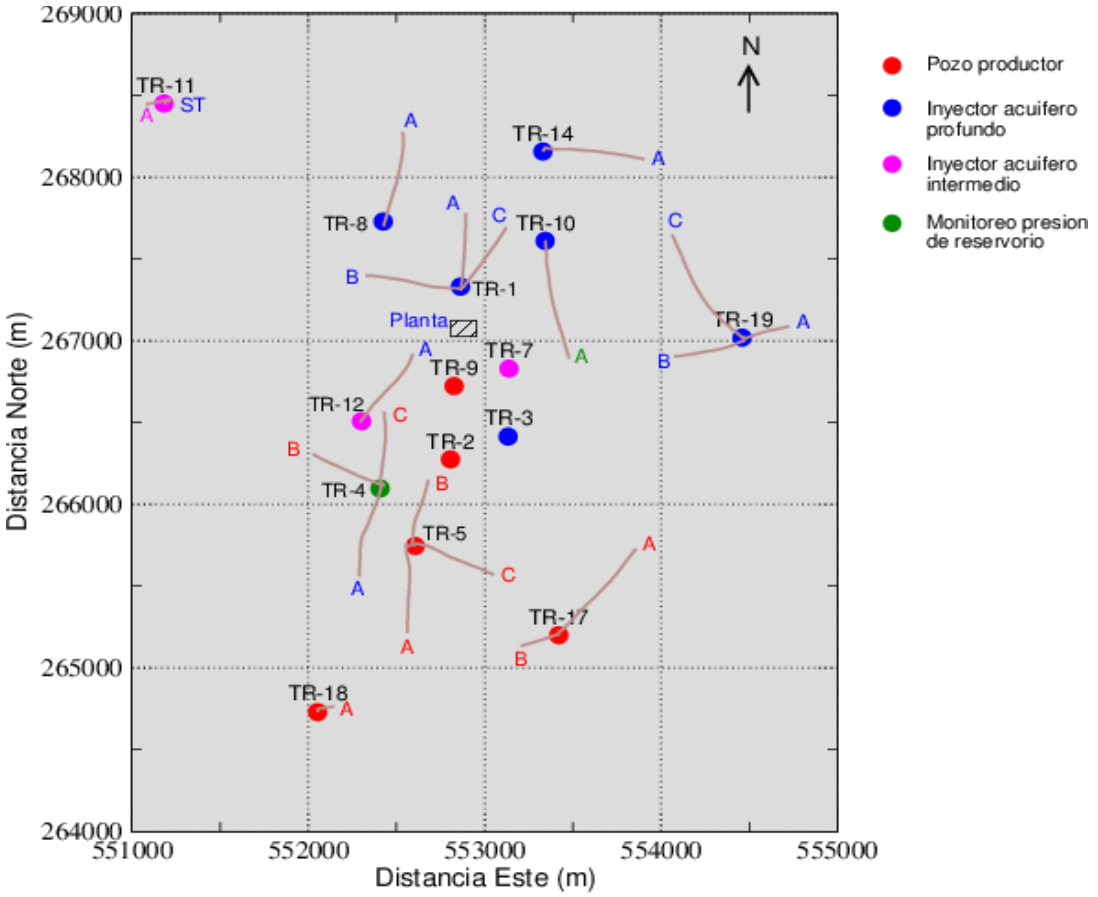

FIGURE 2: Location Map of Wells in the Berlín Geothermal field

The average reinjected massflow in 2011 was 2,230.0 ton/hr (LaGeo, 2011). The steam quality of the wells in the Berlín geothermal field is 25% of the total mass extracted from the reservoir. Approximately 78.5% is reinjected and the rest of the mass is utilized during power generation and some are lost along the surface equipment.

2.3 Existing reinjection wells in the fields

a) Wells in the Ahuachapán Geothermal Field.

The reinjection wells in the Ahuachapán geothermal field are mostly located at the Chipilapa area. The first wells were drilled in the 1990s, and the most recent in 2011. Initially, the wells were constructed with an 8.5" open hole completion along the permeable reservoir zone and subsequently, with 12.25" diameter at depths between 700 and 1500 m. Because they intersect fractures with primary permeability, the wells drilled in more recent years have 12.25" diameter and have absorption capacities of up to 250 kg/s (900 tons/hr), as in the case of the CH-9A well. Directional wells have been designed to intersect the identified faults, where the last stage is a 9.625" slotted liner that hangs in the production casing, or lies within the rock formation of the reservoir.

Because the permeability of the wells in Ahuachapán is high, only six wells are used, with an average absorption capacity of 125kg/s (450 ton/hr).

For the reinjection of the power station's condensate water, a shallow well is used to reinject most of this fluid into a shallow aquifer.

The typical design of a reinjection well in Ahuachapán is shown in Figure 3.

b) Wells in the Berlín Geothermal Field.

Reinjection in the Berlín geothermal field is carried out at different depths within the two geothermal aquifers, the deep reservoir with a depth of more than 2000 m and the intermediate aquifer, which is located between 600 to 800 m depths. Accordingly, there are two types of reinjection wells: shallow wells drilled along the intermediate aquifer and wells for the deep aquifer (more than 2,000 m depth).

A total of 15 reinjection wells are used, most are located to the northwest of the production area, while some are in the central part of the field. The first reinjection wells were drilled in 1994 and the most recent ones were drilled for the operation of Unit 3 in 2006. Due to the existing permeability condition and steep topography, the Berlín geothermal field has multiple-wellpads (up to 4) with directional and vertical wells. The deep wells are completed with 8.5" diameter in the reservoir zone and 12.25" diameter wells in the intermediate aquifer zone. The depths range from 733 to 3450 m. The average absorption capacity of the reinjection wells is 40 kg/s (144 ton/hr). The well completion is designed with the production casing of the deep wells partially placed and is hung on the anchor casing. The 7" to 9.625" diameter slotted liners are used along the permeable section of the reservoir.

To comply with the reinjection plan, shallow wells located around the perimeter of the reinjection are used to reinject the condensate water coming from the power station. Three wells have been drilled, but only one is used to reinject this water.

The typical design of a deep reinjection well is shown in Figures 3 and 4.

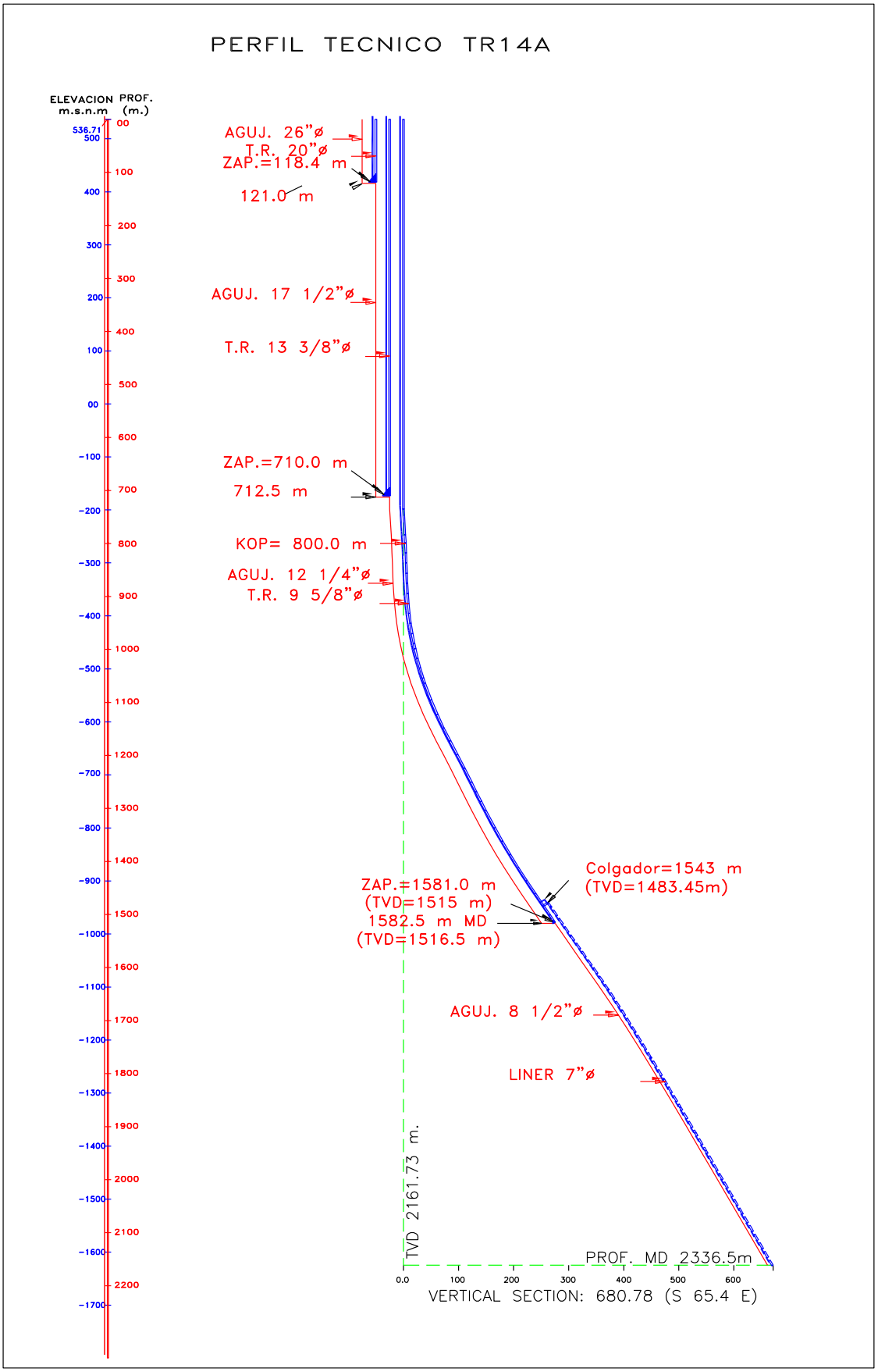

FIGURE 3: Completed reinjection well in the Berlín Geothermal Field

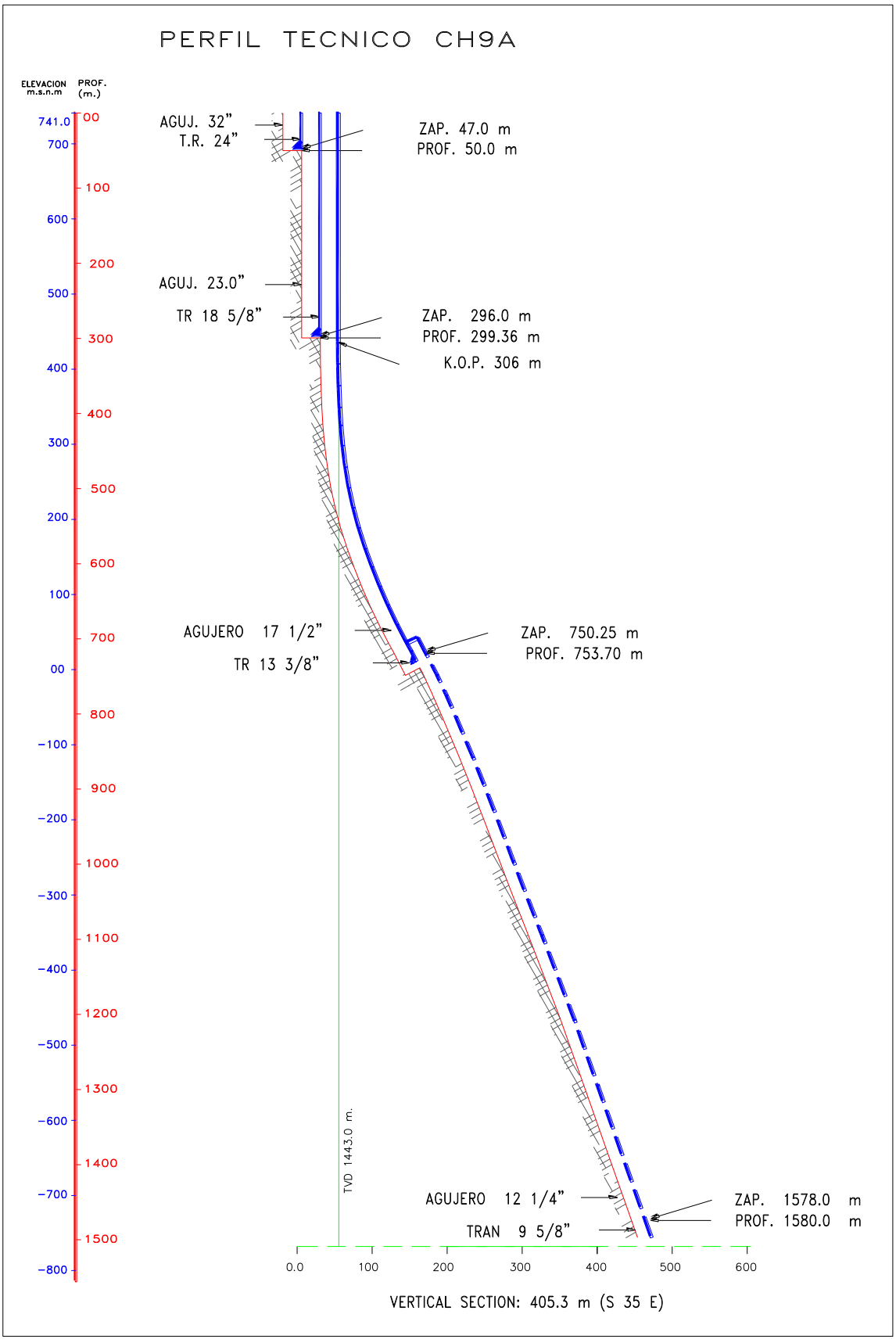

FIGURE 4: Completed reinjection well in the Ahuachapán Geothermal Field

2.4 Reinjection pumping system in the fields

Due to the existing absorption capacity limitations that have been encountered in operating the power stations in both fields, which led to constraints in power generation, the installation of in-line pumping systems have been set up in each field, with the aim of supporting the reinjection operation and making it more efficient, as well as improving water management strategy.

a) Pumping system in the Ahuachapán Field

The pumping system in Ahuachapán has been operating since 1994. It is comprised of six Torishima electric centrifugal pumps and four hot water pumps that can handle a flow rate of 3,800 GPM, pressure up to 11 bars and a capacity of 400 HP per unit. Additionally, there are two pumps for cooling water (at room temperature) with 4,400 GPM, 10 bars and 700 HP. The system is installed close to the power station and its operation is automatized from the power station control room. The pumping system operates continuously with three hot water pumps.

Figure 5 shows photographs of the system's pumps.

b) Pumping system in the Berlín Field

The pumping system in Berlín, operating since 2008, is installed at the TR-1 wellpad and works by increasing the reinjection pressure of the water being transported towards the three wells located in the same wellpad. Its design was adapted on the operating conditions of the wells with the desired flow rate and pressure conditions as well as the permeability of the wells. It is comprised of three Sultzer electric centrifugal pumps, which can handle 1,980 GPM, 75 bars of pressure and a capacity of 11,150 HP per pump. The maximum water temperature reinjected is 170ºC. One of the pumps has been operating almost continuously in the reinjection system since 2011.

Pumps in Ahuachapán

Pumps in Berlín

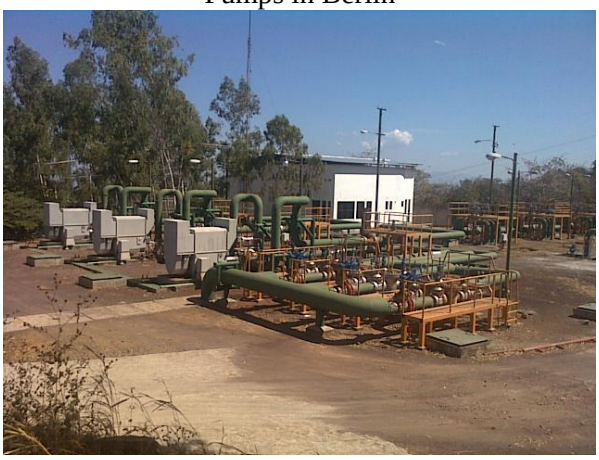

FIGURE 5: Reinjection pumping system at the Ahuachapán and the Berlín Geothermal Fields

2.5 Other elements of the system and routine maintenance

Another component of the reinjection system in the Berlín geothermal field is a solid filtration system on TR-14 wellpad, which retains solid materials coming from the mineral scaling deposits along the reinjection lines, as well as rock fragments and other solid deposits from the reservoir not captured by the separation system.

Another activity undertaken in the Berlín geothermal field is the chemical inhibition of silica scaling, which is observed in the Binary Cycle Power Station due to the drop in temperature.

Experimental tests are being carried out in the Ahuachapán field regarding scaling in the reinjection line towards the wells in the Chipilapa area, with the aim of identifying the type of inhibitor to minimize this phenomenon.

Mechanical cleaning (using drill strings inside the wells) and chemical cleaning (injecting acid mixtures to dissolve/remove mineral scaling inside the well and on the permeable formation close to the wells) are both carried out either periodically or as needed. Through these activities, the absorption capacities of the wells can be recovered to at least its average value.

3. PROPOSED ACTIONS FOR THE FUTURE

For the purpose of maintaining/improving existing reinjection capacity, the following points can be utilized in the proposed plan of action for medium and long terms:

- Continue with the chemical cleaning process inside the wells; assess the effectiveness of the additives/processes used, as well as evaluate a more periodic use of the drill string for injecting fluids, which can achieve better results in the improvement of well absorption capacity.
- Install more solid control filters in other wellpads of reinjection wells in the Berlín geothermal field (TR-8, TR-10), with the objective of avoiding the clogging of the wells due to the entry of solids during the reinjection process. At present, the use of these filters has changed the timeframe for chemical cleaning from 2 to 5 years.
- Investigate the enhancement of permeability of the wells by the hydrofracturing or using the TZIM diverter system.
- Intervention/drilling of wells using multiple section (multilateral) drilling in existing wells will be evaluated/carried out for both existing and new wellpads.

4. CONCLUSIONS

All proposed maintenance and prevention programs must be carried out with the purpose of avoiding any negative effects on the generation capacity of the power plants due to constraints/decreases in injection capacity. It has to be taken into account that one of the principal objectives of LaGeo's operational plans is complying with the power station generation plan.

All necessary measures should be taken to make the scaling inhibition and well chemical cleaning processes more efficient.

Follow up activities for the monitoring plans of fluid chemical properties and of inhibition of line/well depositions should be undertaken, so as to not affect the systems' injection capacity.

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