ONE SHEET PROGRAM FOR INTEGRATED PROJECT SERVICES AT LAGUNA COLORADA GEOTHERMAL FIELD

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ABSTRACT

ENDE, the national electricity company of Bolivia is planning to build a 100 MW power plant in the Sol de Mañana geothermal field. There already are 5 drilled wells (they will make up) and nowadays ENDE is planning to drill 25 new wells (16 production wells and 9 reinjection wells) to extract geothermal energy in two units (50 MW each one). In order to achieve this ambitious goal, it will be required to hire a company that is supposed to manage all the drilling operations on the field (Building and design of the access roads, pads, drilling, well-testing, etc.), this service is known as Integrated Drilling Services. In order to help find the best and more suitable company for this project, a one sheet program has been developed to show and illustrate to companies the key points of the services they must carry out. It is divided into two pages, the front face shows all the operations for the drilling service such as general information of the field, depth of the geological structures, well diameter, BHA, cement program, casing configuration, drilling fluids, and risks. This part gives an understandable summary of the drilling sequence and basic considerations. The back face shows all the well-testing procedures and equipment, wellheads, triaxial stresses for the casing, and a detailed scheme of all the services that will be required to perform this enormous project. This program is just a brief compilation of the main operations required for ENDE. Besides, this illustrative piece of paper is needed for a quick understanding of the necessities and as an advantage it could be carried everywhere.

1. INTRODUCTION

From 1988 to 1992, five exploratory wells were drilled in the Laguna Colorada Geothermal field through Ente Nazionale per L'energia Elettrica (ENEL) with technical cooperation of Bolivian Oil Company (YPFB).

The depth of the wells drilled is as follows:

- SDM-1: 1178.5 m
- SDM-2: 1486.5 m
- SDM-3: 1406.0 m
- SDM-4: 1726.2 m
- SDM-5: 1705.0 m

These wells presented good characteristics, temperatures around 240 to 250 °C and pressures, at the bottom, from 45 to 55 bars. It was projected that this field could produce 100 MW for the connection with the National Interconnected System (SIN).

The scope of the work for the Integrated Services includes the drilling of an estimated 25 wells, of which 16 well are for the production of two-phase fluid (brine/steam) and 9 for reinjection of brine. It is also contemplated to complete the workover of 5 existing wells. For this it is necessary to supply 2 rigs with all auxiliary and complementary services, including the necessary materials, as well as other equipment for the workovers. The drilling is scheduled to begin in 2023 for an estimated period of 36 months.

1.1 Study area

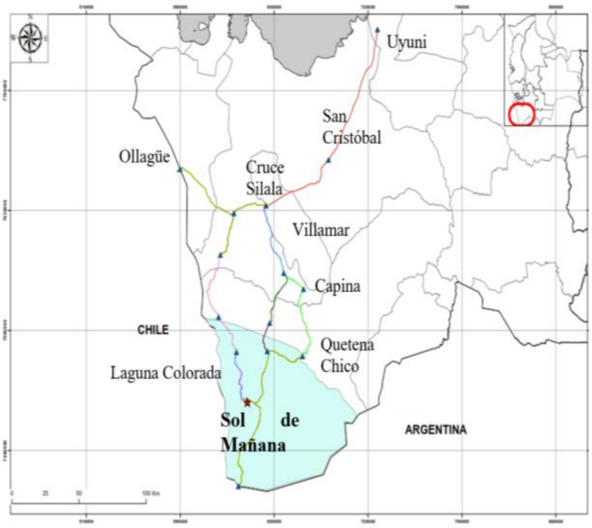

Figure 1: Location Map of the Study Area (ENDE, 2018).

Geographically, the study area is located in the extreme southwest of the Bolivian high plateau, in the Potosi department near the border of Chile and Argentina, at an altitude of 4900 - 5000 m above sea level. The Sol de Mañana field is located 20 km to the south of Laguna Colorada with the coordinates 67° 45´10" W, 22° 25´ 50" (Figure 1).

2. ONE SHEET PROGRAM

The one sheet program (OSP) is a summary of the basic information, equipment, and operations, which are presented in a simple and illustrative way, in order to have a clear notion of the work to be carried out in the Integrated Drilling Services. This program has two faces (front face and back face) that are part of the same laminated sheet that is easily transportable and that can be reviewed and used by all employees before and during drilling operations both in the field and in the headquarters. This program must be prepared for each producing and reinjection wells. In this sense, a preliminary OSP was developed in order to have a clear example with the minimum requirements requested by ENDE. It should be noted that this program is only demonstrative.

2.1 FRONT FACE

A detailed and completed figure of the front face is shown in the Annex A.

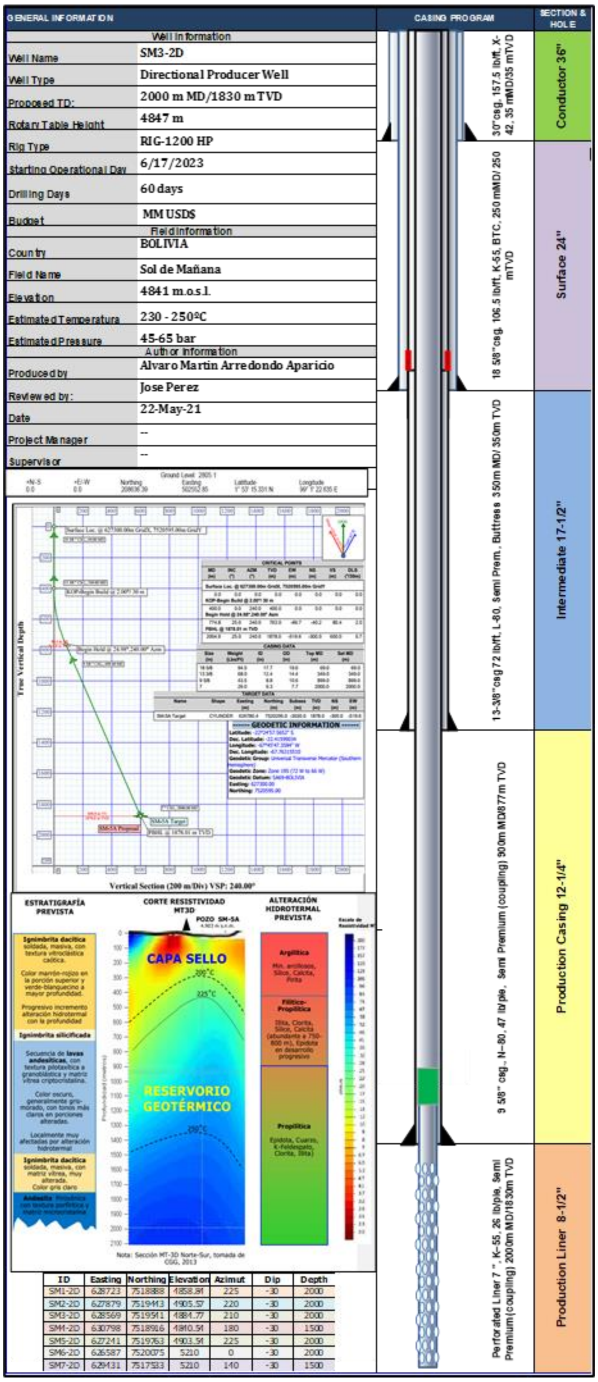

Figure 2: Front face One Sheet Program (left side).

On the left side of the front face (Figure 2) we have the following structure:

2.1.1 General Information

In this section, it is possible to find the general data of the well to be drilled and tested, such as the name of the well, type of well, measured depth (MD), true vertical depth (TVD), the height of the rotary drilling table, power required by the drilling tower, estimated day of the start of the operation, estimated drilling days, and the estimated budget. This is followed by the information of the territory, such as the country in which the Integrated Drilling Service is carried out, the name of the field, the elevation of the ground, and the estimated temperature and pressure at the final drilling depth. This part also specifies the responsible for the development of this program. In this section, there is also a graph of True Vertical Depth (TVD) vs Vertical Section which indicates the depth point at which the well will start with its deviation, kick of point (KOP). For the producing well, the KOP starts at 400 MD at a rate of 2° for every 30 meters drilled. This figure also presents the depths at which the casings will settle and the final target of the well at the estimated depth, this information is explained in more detail in the casing program section. Below this graphic is the lithological and stratigraphic profile of the geothermal reservoir obtained from the geophysical studies carried out previously, which were corroborated and associated with the geological data from the drilling of the 5 existing wells in this area. This stratigraphic sequence is that expected for the area and must be corroborated and corrected as the wells are drilled. Finally, this section has the satellite coordinates of the well to be drilled and the neighboring wells.

2.1.2 Casing Program

This section is of greatest importance since it specifies the settlement depths and the characteristics of the casing to be used in each drilling section. The production wells have the following characteristics:

- Conductor section; 30" casing, 157.5 lb/ft, X-42, 6m MD / 6m TVD.
- Surface section; 18 5/8" casing, 106.5 lb/ft, K-55, BTC, 70m MD / 70m TVD.
- Intermediate section; 13 3/8" casing 72 lb/ft, L-80, Semi Prem., Buttress, 350m MD / 350m TVD.
- Producing section; 9 5/8" casing., N–80, 47 lb/ft, Semi Premium (coupling), 900m MD / 877m TVD.
- Producing Liner section; Perforated Liner 7 ", K–55, 26 lb/ft, Semi Premium (coupling) 2000m MD / 1830m TVD.

2.1.3 Section & hole

This part specifies the section and diameter of the open hole/bit diameter. Both the producing wells and reinjection wells will have the same diameter in their different sections.

On the right side of the front face (Figure 3) we have the following structure:

2.1.4 Blowout Preventer (BOP) stack

In this section there is a basic illustration of the Blowout Preventer (BOP) for each section, this equipment is used in the case of surges where the well must be closed and controlled. This equipment must be periodically tested, and its design is of extreme importance during drilling. The main and most basic components for each section (except for the conductor section) are the following:

- Coating pipe.
- API 2000 flange.
- Spool.
- 2 1/16” API 2000 valve.
- API 2000 double damper preventer.
- API 2000 Annular Preventer.
- Overflow tube.
- Waterline.

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2.1.5 Bottom Hole Assembly (BHA)

In this part of the program you will find, for each section, a detailed proposed BHA to be used and a basic illustration of it. The BHA, as the name suggests, is located at the bottom of the drill string, which consists (from the bottom to the surface of a hole) of the bit, stabilizers, drill collars, heavy drill pipes, jars and the crossover subs for the diverse forms of strings. The downhole arrangement must provide the force for the bit to fracture the rock (weight on the bit), survive a hostile mechanical environment, and provide the driller with directional control of the wellbore. Often the arrangement includes a mud motor, directional drilling, and measurement equipment, drilling measurement acquisition tools, drilling logging tools, and other special devices.

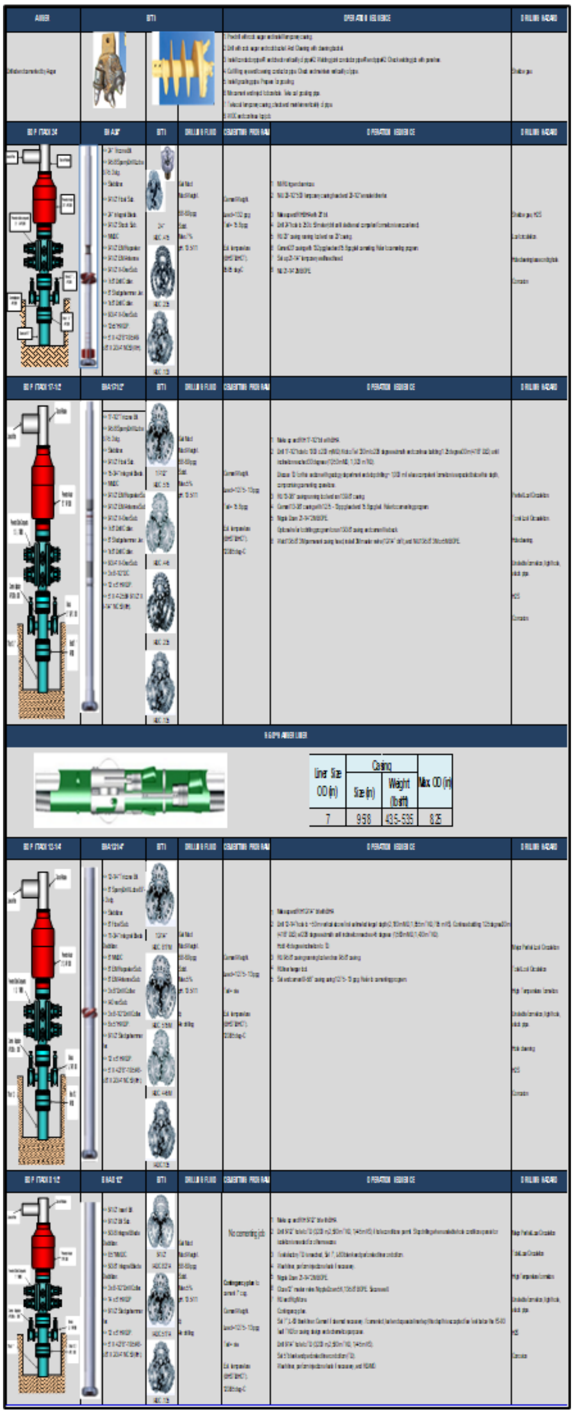

Figure 3: Front face One Sheet Program (right side).

2.1.6 Bits

Bits are the main components in drilling since it is the tool in charge of crushing and cutting the rock to reach the desired depth in an optimal time. Choosing the type of bit and its characteristics is of vital importance for drilling since the penetration rate can be affected by their selection. Each bit has a special design in its jets and teeth which are designed for the type of rock to be drilled. In this section, there is an illustration and specification of the bits to be used for each section, both for producing wells and for reinjection wells. Table 1 describes the types of bits considered for each section.

Diameter (plg)	Section	Bit
36	Conductor	Auger
24	Surface	IADC: 415
		IADC: 235
		IADC: 133
17 ½	Intermediate	IADC: 515
		IADC: 445
		IADC: 235
		IADC: 135
12 ¼	Production	IADC: 617M
		IADC: 515M
		IADC: 445M
		IADC: 135
8 ½	Producing Liner	IADC: 627A
		IADC: 517A
		IADC: 135

Table 1: Proposed bits.

2.1.7 Drilling Fluid

This segment indicates a basic composition of the drilling fluids to be used in each section. These drilling fluids are water-based with certain additives that are applied to maintain hydrostatic pressure in the fluid column. The formulation was also considered when the loss of total circulation occurs, which is foreseen when dealing with the drilling of geothermal wells where this generally occurs in their last sections. It is in this sense that for the last two sections, both in producing wells and injector wells, the use of air at high pressures as drilling fluid and the use of blind batches to clean the well are planned.

2.1.8 Cementing program

In this section, we have the basic components of the cement grout that will be used considering the particularities that each section presents, and the percentage of excess required. It should be noted that the last section will not be cemented and only the liner will be installed in the open hole. In the following table, you can see certain basic criteria of each compound that will be used in the different sections of the well.

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Component	Features
Accelerators	Fast setting cement.
Extenders	Light cement slurry for large volumes of cement.
Defoamers	It prevents gelling, prevent cavitation in pumps and pump the actual cement density.
Retarders	It helps increase setting time so that large volumes of cement can be pumped longer.
Filtering Loss Agents	It reduces the loss of the aqueous phase in the formation.
Dispersants	Disperse cement grains reducing permeability, reduce viscosity, improve slurry mixing and improve additive efficiency for loss of filtration.
Weight agents	They increase the density of the cement
Retrogression Agents	Above 230 ° F, cement destabilizes, increasing permeability and decreasing compressive strength. This agent helps combat this effect.
Anti-sedimentation additives	It reduces free water, sedimentation, and unstable slurries.

Table 2: Cementing additives.

2.1.9 Operation sequence

This segment presents a summary and a systematic description of the activities to be carried out in each drilling section. The consultant must adhere to this operational sequence to ensure success in each segment. This operational sequence will be agreed upon and defined by the contractor and subcontractors who participate in the Integrated Drilling Services.

2.1.10 Drilling Hazard

This is the last section of the front face of the one-sheet program. The risks detected are the most common for each section, however, the contractor will have to carry out more detailed risk analysis in order to create preventive actions and contingency plans in case of their occurrence.

2.2 BACK FACE

A detailed and completed figure of the back face is shown in the Annex B.

2.2.1 Depth v Cost vs Time curve

The figure presented in this section gives a perfect representation of the cost per meter drilled as a function of the time foreseen for each stage or section. In producing wells, it is estimated to drill for about 60 continuous days to a measured depth (MD) of 2000 m at an estimated cost which will be defined in the future, while for reinjection wells it is expected to drill for 45 continuous days to the depth of measure (MD) of 1500 m. During drilling, a real diagram will be generated which can be compared with this in the future.

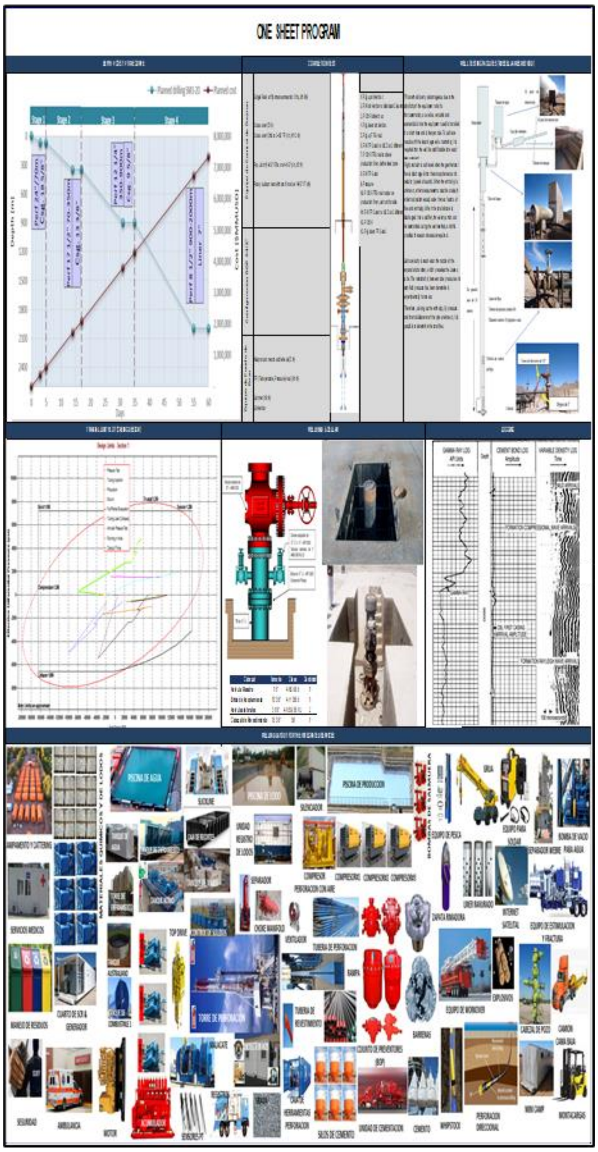

Figure 4: Back face One Sheet Program.

On the back face (Figure 4) we have the following structure:

2.2.2 Completion test

This segment, first, lists the basic equipment to be used during completion tests (Pressure Control Equipment, BOP Configuration, and Downhole Equipment) which are also illustrated for easy recognition. Following a scheme of the equipment used is the description of the operational sequence for the well tests.

2.2.3 Well testing facilities (Russel James Method)

There are several production test methods such as the Russel James method or the tracer's method, among others, that are well accepted by the geothermal industry. It will depend on the analysis and perspective of the contractor to define the method or methods for the production tests to be carried out in the wells of the Sol de Mañana field. As an example and based on previous studies carried out in this field, it was decided to choose the Russel James Method for this section. First, a basic description of the advantages and considerations to be taken into account to develop this method was made. Subsequently to this, the necessary equipment to carry out the production tests were illustrated, including:

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- Wellhead.
- Discharge line.
- Flow control valve.
- Flowline.
- James tube.
- Silencer.
- Water tank.
- Weir box.
- Drainpipe.

With the data collected from this test, the total flow of the geothermal fluid can be determined.

2.2.4 Triaxial Limit Plot (Casing Design)

The figure in this section is intended to explain and demonstrate that the chosen casing will withstand the different stresses that the well will be subjected to during its operational life. The forces considered are tension, compression, and collapse which are delimited by the characteristics of the grade of the casing. This pipe must be able to withstand these stresses, thus ensuring the integrity and stability of the well.

2.2.5 Wellhead and Cellar

The wellhead is an equipment installed after drilling is completed. This equipment is in charge of regulating the pressure and production flow, among other tasks, during the operational life of the well. That is why the design and proper choice of this equipment are of the utmost importance. The wellhead is installed in the cellar and attached to the casing, there are 2 types of cellars, as shown in the figure 3, and the contractor must define the type of cellar to be applied to each well.

2.2.6 Logging

During drilling the contractor must run logs to verify the integrity of the well. Among the most common registers are Gamma Ray, Sonic, SP, VDL, CBL, etc. This section illustrates the gamma-ray, CBL, and VDL logs which basically serve to infer the type of lithology being crossed and the integrity and quality of the cementation job between the casing and the formation. These records are very important since they can detect poor cementation which must be corrected before proceeding with the drilling of the next section.

2.2.7 Wellpad Layout for Integrated Service Equipment

This section can be considered the most visually attractive since it will give a clear and illustrative idea to anyone to be able to recognize the equipment in a single view before and during visits to the platform. In addition, this will facilitate communication between the workers of the operator, supervision, and contractor, among others. Possible equipment to be used by each drilling and intervention drill was placed, which includes auxiliary components such as fishing tools, water storage tanks and key equipment such as drill bits, drilling, and casing pipes, and the set of preventers, among others. In this section, the most relevant facilities and equipment for the integrated service will be present and any person who consults it will easily identify the scope of the services and operations present in the execution of this stage of the project.

3. CONCLUSION

The development of a one sheet program for Integrated Drilling Services should be standardised among the geothermal discipline because it can explain all the services required in a clear and illustrative manner.

By defining the framework of the required services, a better control of the project can be executed, and a well-developed One Sheet Program is essential for this objective.

The sections arranged in the one sheet program were exhaustibly analysed to show all the possible condensed information in a friendly and comprehensible manner for the good understanding of the reader. Besides, the combination of figures and theory in each section give a more didactical way to understand it.

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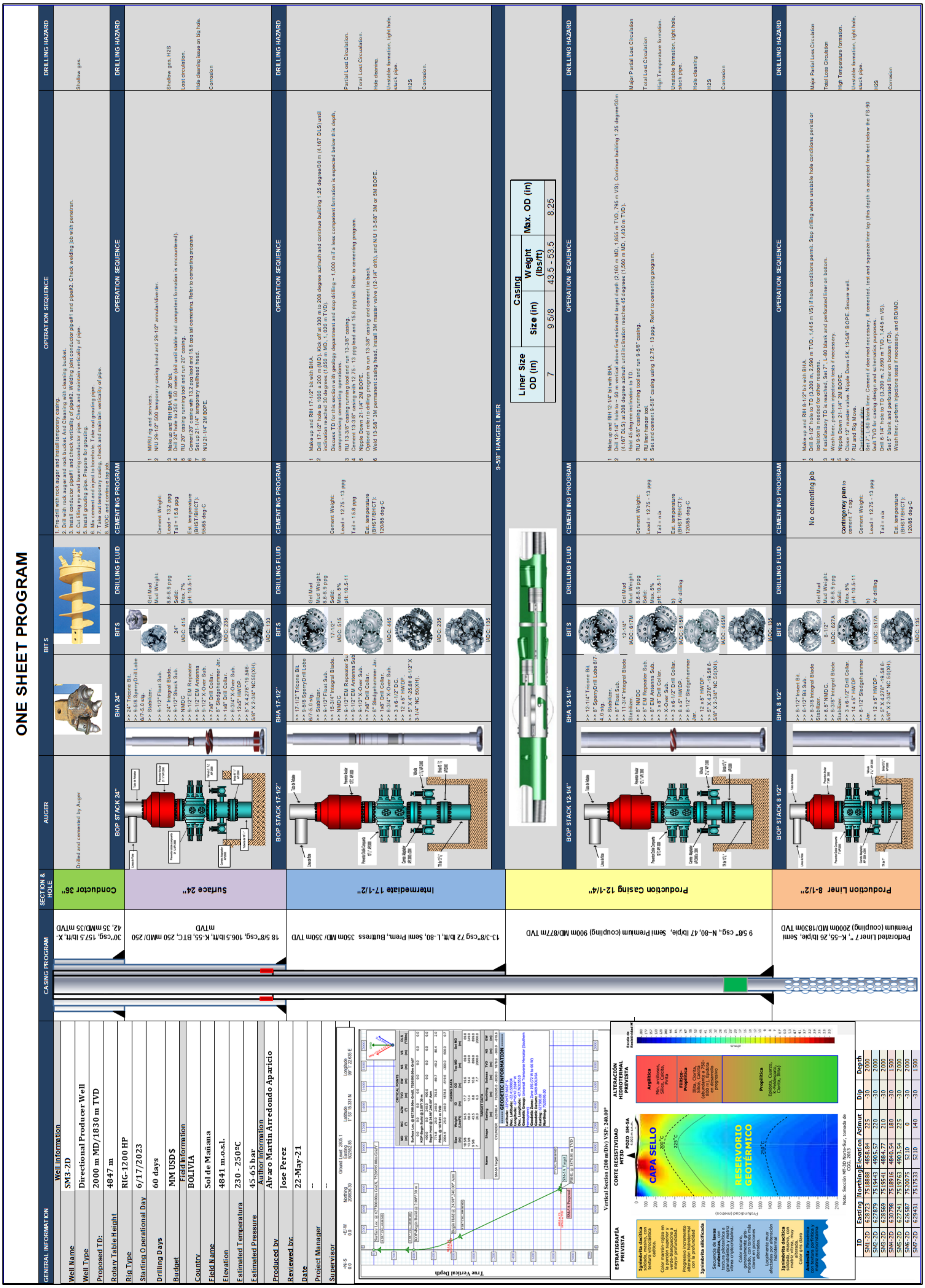
Annex A

Front face OSP



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Annex B

Back face OSP