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# An Update on the Geothermal Wells Drilled in Aluto Langano Geothermal Field

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## ABSTRACT

The Aluto Langano Geothermal field is located in the Lakes District, Ethiopian Rift Valley, about 220 Km South of the capital, Addis Ababa. Aluto Langano geothermal field has been prioritized with commercial interest since 1969 by conducting several surface geoscientific investigations resulting in drilling of eight (8) deep wells in early eighties and commissioning of a pilot binary power plant (7.3 MWe) in 1998. to 2010. Two (2) directional wells were also drilled in 2015. Six (6) wells (LA-3, LA-4, LA-6, LA-8, LA-9D and LA-10D) are found to be productive and one well (LA-7) is used as a reinjection well for the pilot power plant. The objective of this report is to study the current status of the productive wells (LA-3, LA-4, LA-6, LA-8, LA-9D and LA-10D) and the progress of the overall activities being conducting in the Aluto Langano geothermal field. Monitoring the wells through conducting a down hole measurement was the main task to evaluate the status of the reservoir in addition to taking a wellhead pressure reading during static and flowing conditions. As the pilot power plant has been none-operational since 2010 because of some defects in electro mechanical parts, the old wells (LA-3, LA-4, LA-6 and LA-8) has been under shut in condition. The down hole survey results at different time interval shows that the depth of the wells is getting reducing with depth and calliper size because of the scaling deposition. But one good promising of the wells shows that no temperature decline and pressure drop is being observed as the down hole surveys conducted in 2017 and 2018 revealed since the wells has been drilled in 1980s. No maintenance works to the power plant has been taken place since 2010, the plant stop working completely, though in 2006 a rehabilitation work to the wells and maintenance work to the power plant has been taken place. The recently drilled two directional wells (LA-9D and LA-10D) in 2015 do not start supplying a steam to a planned future power plant yet, however, a construction of wellhead power system is under tendering process using a grant finance from the Government of Japan. Furthermore, a contract agreement has been signed between Ethiopian Electric Power (EEP) and a drilling company to drill 22 wells in Aluto geothermal field to construct a 70 MWe power plant with the loan from World Bank. Out of them, approximately 4 wells are intended to be used as reinjection wells. A drilling consultancy service contract agreement has been signed in 2017 between EEP and Elctro Consultant (ELC S.p.A) of Italy. In order to develop the geothermal sector of the country, an establishment of an independent institution structure is being considered by the Ministry of Water, Irrigation and Electricity (MoWIE) as it is very necessary to follow, manage, explore, exploit and utilize the resource and achieving the energy mixing policy of the country in medium and long term development plan.

## 1.INTRODUCTION

The Aluto Langano Geothermal field is located in the Lakes District, Ethiopian main Rift Valley, about 220 km South of Addis Ababa and covers an area of about 100 km$^2$. It lies between lakes Langano and Ziway and rises to about 690 m above the surrounding Adami Tullu Plain which has an elevation of about 1600 m a.s.l. with a broad truncated base and a summit caldera 6 km by 9 km elongated in a WNW direction and has formed a basin of internal drainage. Volcanic activity at the Aluto Langano volcanic centre is entirely of Quaternary age and initiated with a rhyolite dome building phase intervened by explosive pyroclastic pumice eruptions. The youth nature of these volcanic products indicates a heat source which is still hot enough at depth. An extensive cap rock having large lateral coverage exists at Aluto Langano in the form of lake sediments and associated with overlying pyroclastic. These cap rocks serve to prevent the heat of the Aluto system from escaping to the surface, thus insuring a minimal cooling rate of the heating system, Ministry of Mines and Energy (2008).

A total of 10 deep exploratory wells have been drilled at the Aluto Langano geothermal field to a maximum depth of 2500 m. Information about the wells are shown in Table 1, 8 of the wells (LA-1 to LA-8) are vertical, drilled between 1983 and 1986, and two of them, LA-9D and LA-10D, are the first directional wells in Ethiopia, drilled to a depth of 1920 and 1950 m respectively, completed in 2016. Four productive wells among the earliest wells (LA-3, LA-4, LA-6 and LA-8) of the geothermal field have been supplying steam and brine to operate a binary pilot power plant commissioned in 1999, of approximately 7.3 MWe. At present, this power plant is non-functional, Teklemariam et al. (2000) as stated in Nigussie Gebru T., (2017).

## 2. OBJECTIVE

The objective of this report is to study the current status of the wells drilled and progress of over all activities being conducting in the Aluto Langano Geothermal field of Ethiopia.

## 3.CURRENT STATUS OF THE WELLS

There are 10 wells drilled in the 1980s and 2015 in Aluto Geothermal field. A total of 10 deep exploratory wells have been drilled at the Aluto Langano geothermal field to a maximum depth of 2500 m. Eight (8) of the wells (LA-1 to LA-8) are vertical, drilled between 1983 and 1986, and two of them, LA-9D and LA-10D, are the first directional wells in Ethiopia, drilled to a depth of 1920 and 1950 m respectively, completed in 2016. Four productive wells among the earliest wells (LA-3, LA-4, LA-6 and LA-8) of the geothermal field have been supplying steam and brine to operate a binary pilot power plant commissioned in 1999, of approximately 7.3 MWe. At present, this power plant is non-functional, Teklemariam et al., (2000). The first two wells (LA-1 and LA-2) drilled to a depth of 1317 m and 1602 m in the early 1980s does not show enough temperature (< 150 $^{O}$C) and permeability because they were drilled in the outside of the Aluto volcanic complex (southern and western escarpments). Whereas LA-5 also the coldest well and the temperature is highly inverted (< 167 °C) from 1000 m to down wards along the total depth 1866 m. This well is also considered as non-productive well. The remaining non-productive well is well LA-7 which is drilled to a depth of approximately 2450 m shows moderately good temperature (up to 220°C) and shows slight inversion as compared to wells LA-1, LA-2 and LA-5 but very poor permeability. So this well is proposed to be and used as a reinjection well for the brine from the pilot power plant. The remaining wells (LA-3, LA-4, LA-6, LA-8, LA-9D and LA-10D) are the productive wells and shows very high temperature and fairly good permeability which are located on the top of the Aluto volcanic complex. The status of the non-productive wells of the field are not part of this study as nothing activity is conducted since their drilling completion, 1980s. The current status of the remaining productive wells is described below one by one.

**TABLE 1: Information about the exploratory wells located in Aluto Langano geothermal field (ELC, 2016)**

| Well | WH Coordinates | | WH Elevation | Total Meas. Depth | Total Vertical Depth | Elevation of well bottom | Coordinates of well bottom | | 9 5/8" Casing Shoe | 7" slotted liner | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | North | East | m asl | m | m | m asl | North | East | MD (m) | MD (m) | |
| LA-1 | 853,308 | 474,047 | 1601 | 1317 | 1317 | 284 | *vertical well* | | 702 | 800-1317 | Sterile well |
| LA-2 | 861,501 | 469,489 | 1724 | 1602 | 1602 | 122 | *vertical well* | | 892 | 950-1602 | Sterile well |
| LA-3 | 860,723 | 477,401 | 1921 | 2144 | 2144 | -223 | *vertical well* | | 748 | 1035-2140 | |
| LA-4 | 860,839 | 478,359 | 1957 | 2062 | 2062 | -106 | *vertical well* | | 775 | 746-2035 | |
| LA-5 | 859,410 | 478,757 | 2038 | 1869 | 1869 | 169 | *vertical well* | | 752 | - | Unproductive well |
| LA-6 | 861,278 | 477,649 | 1963 | 2201 | 2201 | -239 | *vertical well* | | 754 | 1499-2201 | |
| LA-7 | 860,832 | 476,296 | 1891 | 2449 | 2449 | -558 | *vertical well* | | 956 | 1788-2449 | |
| LA-8 | 862,190 | 476,944 | 1895 | 2501 | 2501 | -606 | *vertical well* | | 721 | 1867-2464 | |
| | | | | | | | | | | | |
| LA-9D | 860,736 | 477,863 | 1956 | 1920 | 1784 | 172 | 860,849 | 477,422 | 605 | 599-1915 | |
| LA-10D | 860,846 | 477,807 | 1956 | 1951 | 1816 | 140 | 861,256 | 477,409 | 807 | 815-1951 | |

### 3.1 Status of well LA-3

This is the third exploratory well drilled to a maximum depth of 2144 m in 1983. This well is the first productive well and shows very high temperature (>300°C) and significant permeability drilled in Aluto volcanic complex. It was supplying steam to the binary power plant from 1998 to 2010 as the electromechanical part of the power plant get damaged and then finally stop working in 2010. After the completion and discharge test has been finished in the 1983, which is long time, on May 31, 2006 LA-3 was successfully and easily logged in a static condition with the Kuster K10 tool to a depth of 2125 m. The maximum temperature and pressure measured at this well was greater than 300°C and 160 bar. The wellhead component of the well at that time was good except for the master valve which is not completely shut or opened approximately greater than 80%. This could be because of the formation of calcite scaling in the master valve even outside the master valve in the pipe line as the well is flowing at a higher temperature of greater than 300°C. Another work mission was conducted in this well which was, monitoring of wellhead pressure and temperature at flowing condition in 2009. The Wellhead pressure fluctuates between 5.8 and 7.4 barg for a period of about one month due to boiling condensation cycle at wellhead temperature 130 °C. An attempt to conduct down hole measurement for this well was carried out in 2015 however because of the wellhead master valve unit in totally welded to the expansion spool part of the production casing by the calcite scaling which is not impossible to manage the wellhead unit at that time except monitoring the wellhead pressure at shut in condition. The wellhead pressure at static condition of the well has been monitoring at that time. The only option to solve this problem is killing the well by using cold fresh water then remove the wellhead equipment and finally install with new wellhead unit instantly. But at that time, this work worth significant cost both technically and economically to Ethiopian Electric Power (EEP). There was another urgent work which is drilling of two deep directional well have been carrying out at that time so that postponing the work of rehabilitating well LA-3 was good option. But there was an option to rehabilitate this well after the drilling and well testing of the two wells have been completed. Unfortunately, the EEP does not give good attention to follow the assignment properly so far because of the power plant is not yet maintained. The external pipe line of the well also get clogged and narrowed by greater than 60 % of the size of the pipe. As currently no information about the down hole condition of the well, it is very necessary maintaining the well head component of the well in order to know the down hole status of the well by conducting a down hole survey.

### 3.2 Status of well LA-4

This is the fourth deep exploration well of the field drilled in 1983 to a depth of 2062 m one kilo meter far in the east of well LA-3. The maximum temperature measured was greater than 200 °C and its permeability is greater than of the well LA-3 as briefly stated in Ethem Tan., 1986. Dick Benoit, 2006 as stated in Seifu A., (2006). The bottom hole of the LA-4 wellhead was free of scale until May 2006 as down hole logging using the sinker bar and Kuster10 tool has been conducted by an American company to rehabilitate the power plant and wells of the field at this time so that a clear depth of 2035 m found. A formation temperature of greater than 200 °C as well as formation pressure of greater than 140 barg has been confirmed at this depth. The wellhead equipment of this well also working properly at that time. A work mission to make survey the status of the wells in the field has been carried out in 2010 by the GSE and EEP team. Wellhead pressure monitoring was done at flowing condition sand fluctuates between 6 and 10 barg for about a period of one month Seifu A., (2010). In March 2016, a down hole logging to find the clear depth, the formation temperature and formation pressure of the well has been conducted beside the discharge testing of the two directional wells (LA-9D and LA-10D). This survey had also a significant role in knowing the interferences between this well and the newly drilled wells (LA-9D and LA-10D). A clear depth of 1048 m was found because of no rehabilitation and monitoring of the well has been conducted since 2006 and resulted in clogging of the well up to the mentioned depth by the carbonate scaling. A formation temperature of 230 °C and formation pressure of 72 barg has been confirmed at this depth. Furthermore, in September 2018 a down hole measurement has been conducted to a depth of 1000 m to know the status of the well. As a result, formation temperature and pressure of the well at this depth was 230 °C and 68 barg respectively. The down hole temperature and pressure profile of this well conducted at different time is shown in the figure below. The well head equipment of this well during the measurement was nor working properly as the master valve and side valves are corroded by the carbonate scaling. Even a carbonate scaling is observed outside of the well in the steam pipe line.

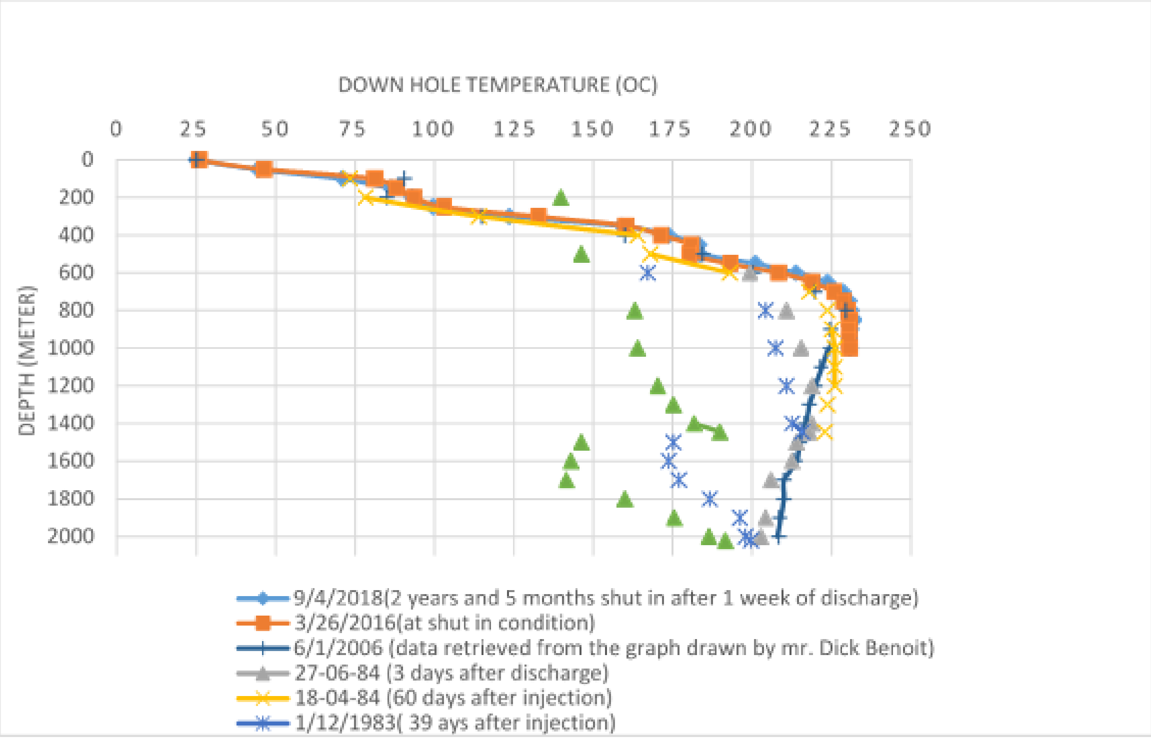


FIGURE 1: Down hole Temperature profile of well LA-4 at different time of surveys. You can imagine that even if the well was supplying steam to the binary power plant for approximately 10 years, from 1998 to 2010, the temperature of the formation shows no cooling because of the shallow cold ground water observed in the well as observed in the latest down hole measurements (March 2016 and September 2018).

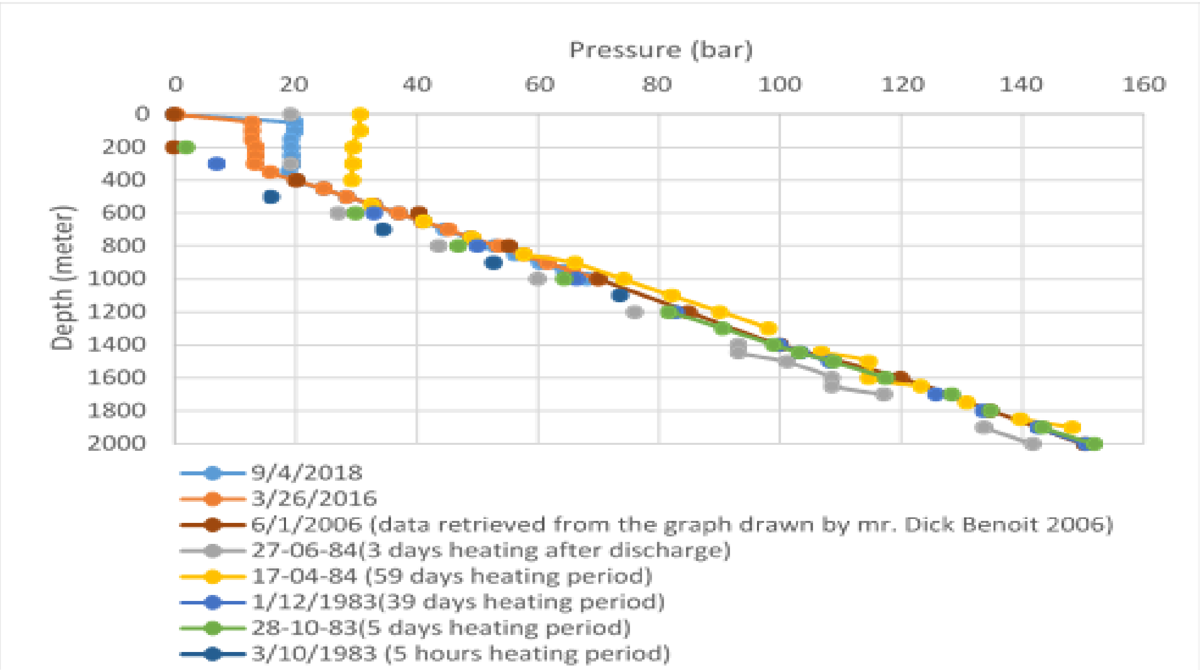


FIGURE 2: Down hole Pressure profile of well LA-4 at different time of surveys. The latest surveys show that the pressure of the reservoir does not reveal decline of pressure since completion test of the well conducted (1983). The graph shows that the ground water table can raise to a depth of 200 m.

### 3.3 Status of well LA-6

Ethem (1984) as cited in Nigussie Gebru T. (2017) well LA-6 is also part of the exploration wells of Aluto Langano geothermal field located at an elevation of 1962 m a.s.l. The well was drilled between March and July 1984 to a final depth of 2201 m and complete circulation loss was observed at 2094 m. The maximum temperature of the well after completion test carried out was 322 $^{O}$C at the bottom after 39 days of heating time and production. Currently the well head component of this well also does not work properly especially the master valve get corroded because of no rehabilitation work is except once (2006) was conducted. As the well is high temperature well, forming of a calcite scaling was the main problem even the size of outlet (discharge) pipes are found very narrow. The wellhead pressure of this well was fluctuates in the range 6.27 and 7.8 bar and the wellhead temperature fluctuates in the range of 173$^{o}$C to 180$^{o}$C at flowing conditions in 2010**.** The latest down hole survey of the well was conducted in the early January 2017, so that the clear depth of the well was found 2131 m that means only approximately 100 meter is clogged because of the scaling, which is deeper than of the depth in well LA-4. Figure 3 shows that the down hole condition of the well by taking in to consideration the data driven during completion period, during rehabilitation period and during interference test with the neighbourhood wells (LA-9D and LA-10D) drilled in the 2015. The latest down hole measurement was conducted in the early January of 2017. No maintenance work of wellhead equipment has been done after this survey. If down hole survey is anticipated,

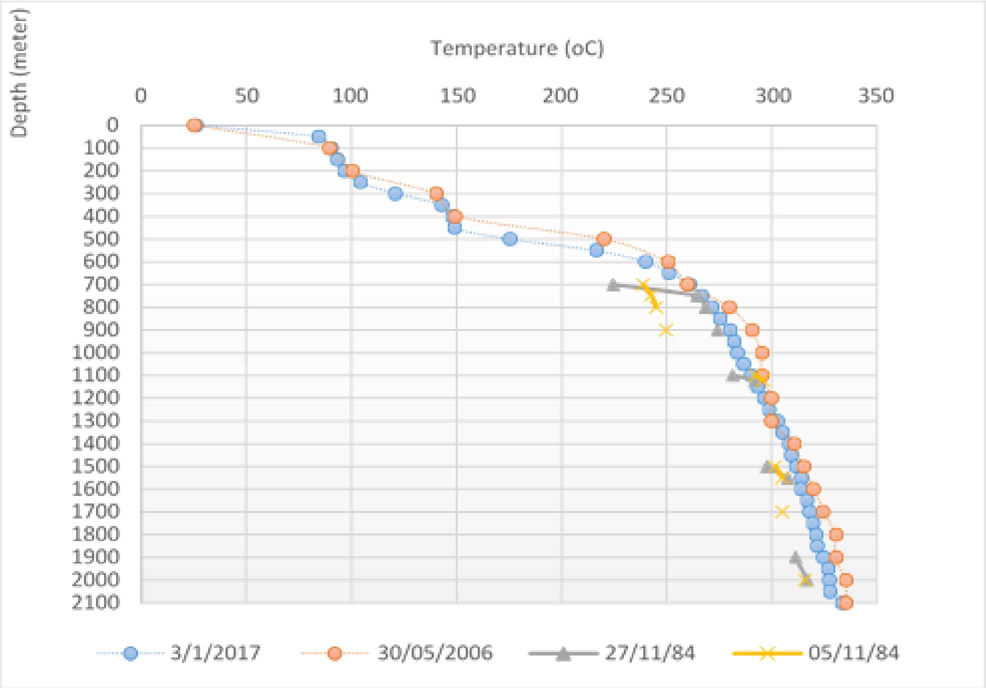


FIGURE 3: Down hole temperature profile of well LA-6. The surveys have been conducted during heat up periods at the completion test time, in 2006 and the latest measurement in Jan 3, 2017. The 2006 survey data is retrieved from a profile graph drawn by Dick Benoit in 2006.The temperature in this well also does not show any cooling effect even during the production period from 1998 to 2010.

the wellhead should have maintained first by killing the well and changing the old wellhead equipment by new equipment.

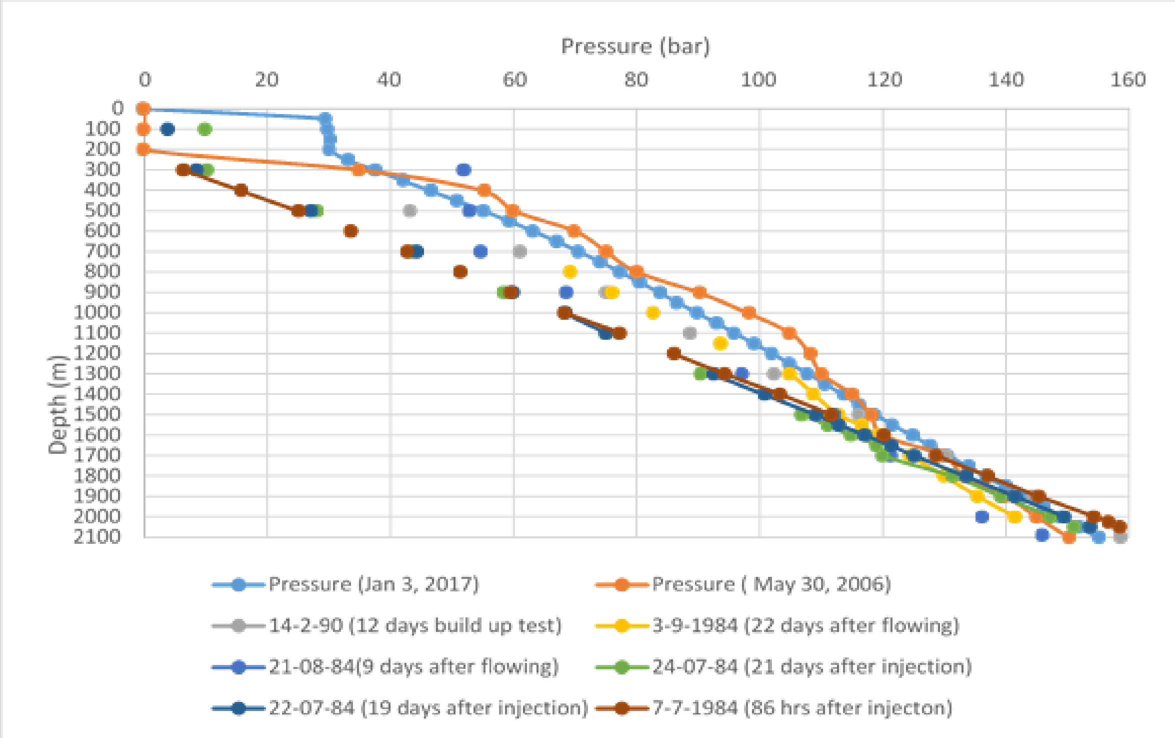


FIGURE 4: Down hole pressure profile of well LA-6. The well inferred that the pressure of the natural state formation can develop easily as proved by the latest down hole measurements (2017 and 2006 logs).

### 3.4 Status of well LA-8

This well is the deepest well drilled in the field to a depth of 2500 m to the North-West direction of well LA-6 and 1.5 km North of well LA-7. It is located in the North-East edge of the Aluto Volcanic Complex (Ethem Tan, 1985). This well has shown a similarity both in temperature profile and permeability with well LA-4. In May 2006 a downhole measurement has been attempted but the

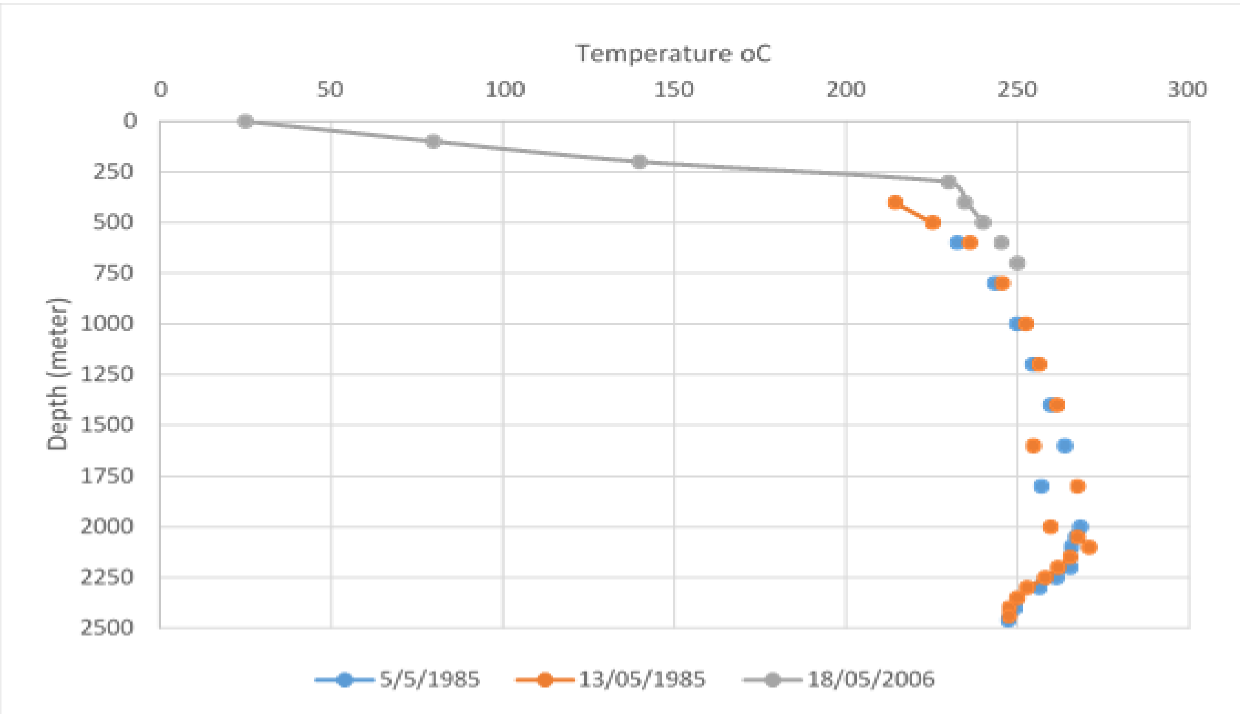


FIGURE 5: Down hole temperature profile of well LA-8. The last measurement was carried out in 2006 and the well at that time was clogged by the calcite and silica scaling reach up to depth of 700 m.

survey tools like Go-devil, Sinker bar and the KUSTER K10 cannot go beyond 700 m as in Dick Benoit 2006 stated clearly. The problem may be either a scaling is formed up to a depth of 700 m or a sediment deposited because of the collapsing the casing of the well as this well is highly supplying sediments to the power plant as mentioned in Asaye M., 2004. The wellhead pressure LA-8 at flowing condition fluctuates between 5.5 and 8.3 barg and the wellhead temperature was about 150 °C during the survey carried out in 2010.

### 3.5 Status of well LA-9D

This well is the first directional geothermal well in the history of the country drilled in 2015. The well is directed to N70°W and has a maximum inclination of 51°. The kick off point (KOP) is started at 700 m. The surface casing (20") is set to a depth of approximately 60 m then the anchor casing (13-3/8") is installed to 210 m depth then a production casing (9-5/8") is set to a depth of 605 m and finally the slotted liner (7") is installed to a depth of 1921 m. The stratigraphic sequence of LA-9D is similar with the wells LA-3, LA-4, LA-5 and LA-6. This well is a high temperature well as greater than 300 °C is observed at the bottom (1920 m depth) of the well. The injectivity index of this well is estimated as 29.2m3/h/MPa and the permeability thickness (kh) is estimated 2.0 Dm which reveal that the well is not very good permeable but it is a high enthalpy which is greater than 2000 kj/kg is estimated during the discharge test. It is under shut in condition since the discharge test has been conducted (from Nov 2015 to May 2016) except sometimes discharged for very short period of time for the purpose of showing the steam for honourable guest come from different governmental organizations and fund raisers. Also down hole measurements or monitoring are conducting every two years to see the status of the temperature, pressure and scaling condition of the well. Yet the down hole measurement shows that neither temperature nor pressure is change but a slight indication of scaling is observed.

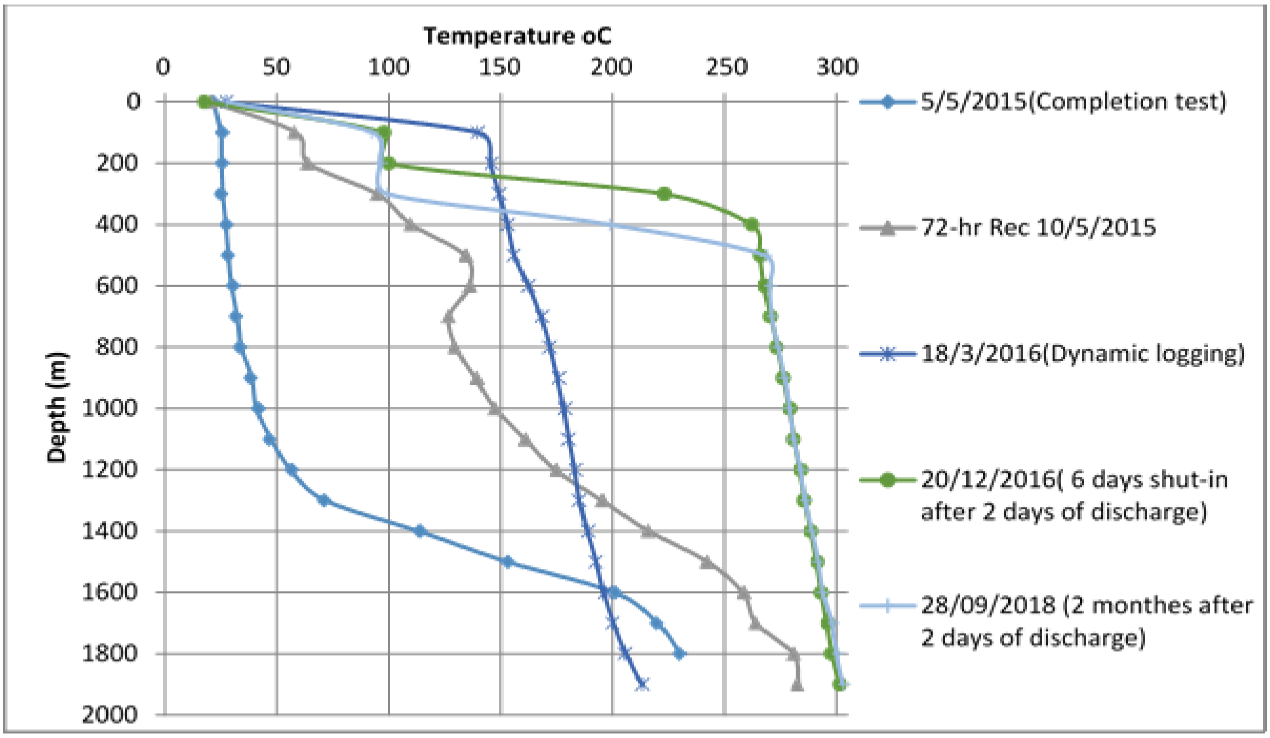


FIGURE 6: Down hole temperature profile of well LA-9D conducted at different times in static condition and dynamic condition. The last two measurement shows that the natural state formation temperature of the well. A down hole temperature of greater than 300 °C is recorded at the bottom of the well.

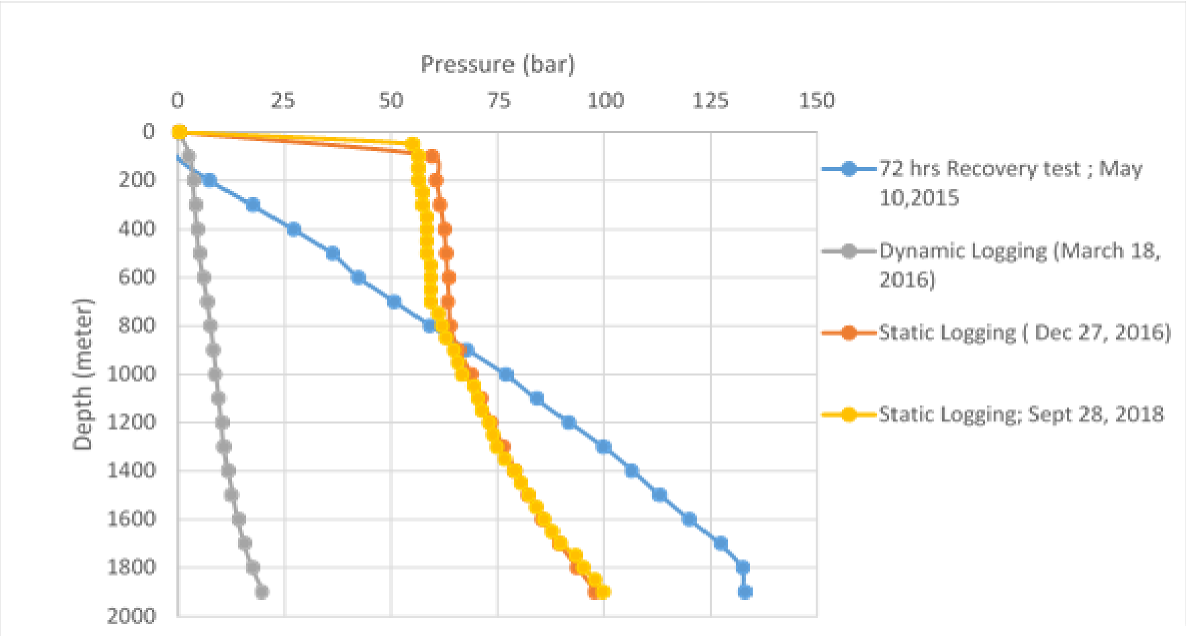


FIGURE 7: Down hole pressure profile of well LA-9D carried out at different times. The pressure falls when the well is at the dynamic condition. The last two profile starts overlap to each other from a depth of approximately 800 m to the final depth. These profile shows that the true reservoir pressure of the well at a natural state.

**3.6 Status of well LA-10D**

This well is the second directional well drilled following LA-9D. Drilling of well LA-10D takes approximately three months, which was started on June 25, 2015 and completed on October 2, 2015. The directional drilling kick off point (KOP) was at 450m to a direction of N43°W with a maximum inclination of 27.75°. The surface casing (20") is set to a depth of approximately 60 m then the anchor casing (13-3/8") is installed to 343 m depth then a production casing (9-5/8") is set to a depth of 807 m and finally the slotted liner (7") is installed to a depth of 1951 m. According to the report written by WestJEC (2016), the injectivity index of the well from the multi rate injection test is estimated as 53 m3/h/MPa which is almost twice that of well LA-9D. This reveals that this well is more productive than that of well LA-9D which is proven by the output as of for LA-10D is 2.7 MWe while for LA-9D is 2.4 MWe assuming a steam consumption rate of 8 t/h/MWe. The discharge test of the well is carried out using James lip pressure

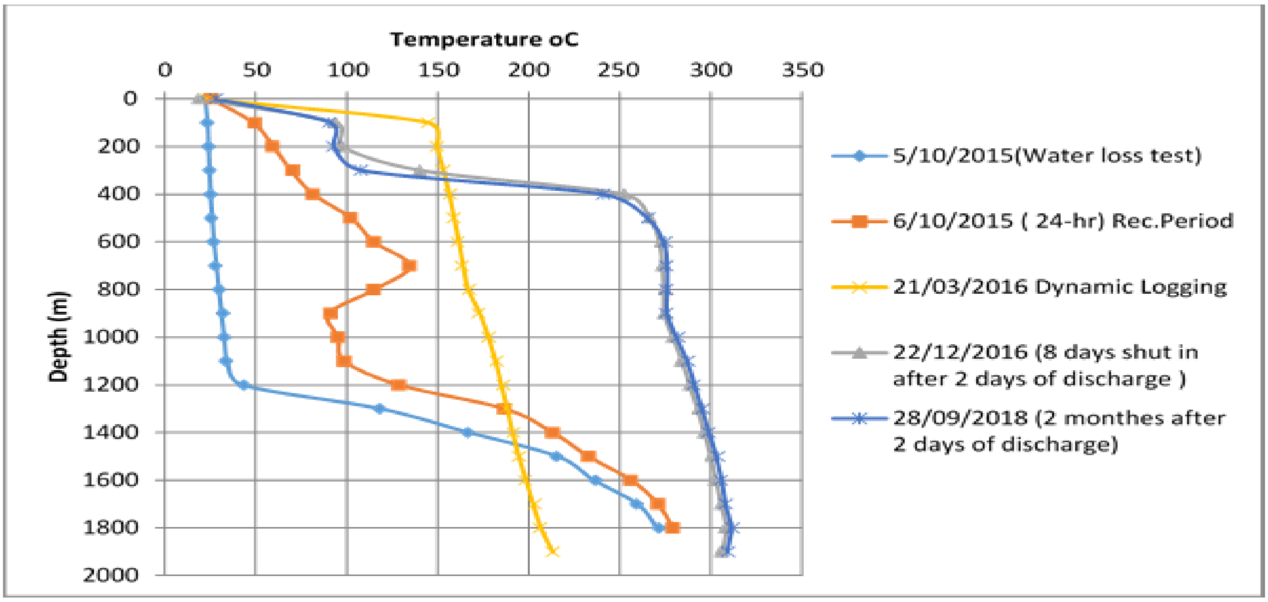


FIGURE 8: Down hole temperature profile of well LA-10D. The last measurements overlap to each other which shows that the natural state temperature of the reservoir does not show any difference with in one year and 9 months' time gap. The temperature of the well at a flowing condition is much less than at static condition.

method and enthalpy of the fluid out from well LA-10D is estimated as 1,666 kj/kg which is much smaller than of well LA-9D.

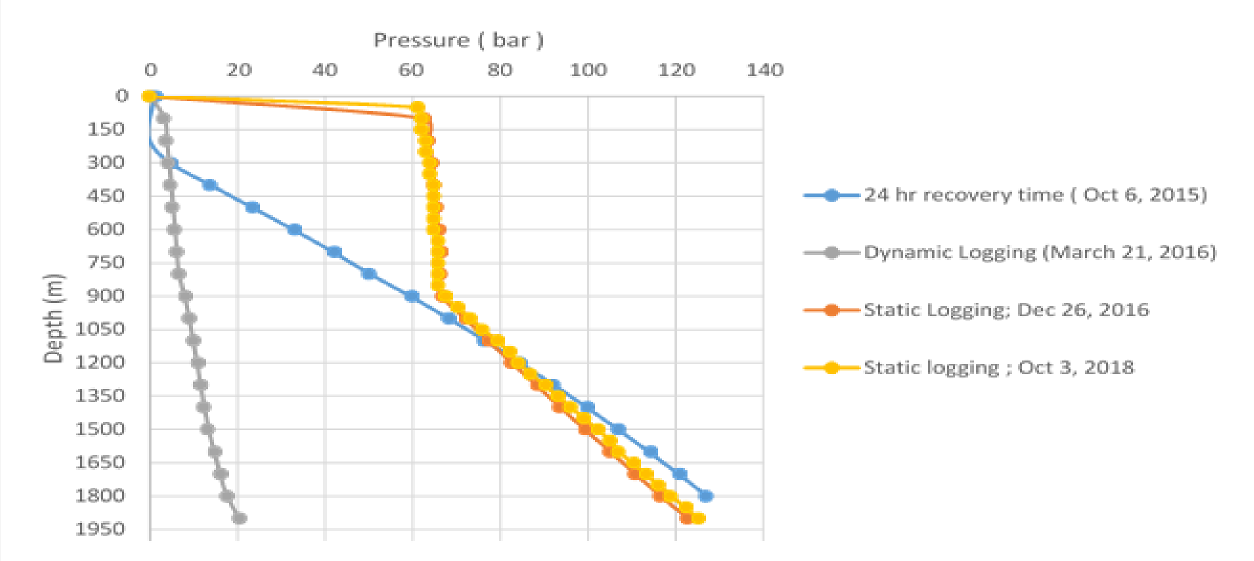


FIGURE 9: Down hole pressure profile of well LA-10D. The measurement has been carried out at static condition and flowing condition. The last two measurements are getting overlapping to each other at the whole depth of the well. This implies that there is a steam accumulation in the well up to a depth of 900 m as the gradient is very small while below this depth is accumulated cold water as the gradient is hydrostatic.

## 4. THE POWER PLANT

According to the report written by Geothermal Development Associates GDA in 2007, Aluto Langano Geothermal Power Plant is the first power plant in Ethiopia. It was established in 1998 as a pilot plant to test the geothermal resources and to identify any resources or issues that could affect the power plant as well as to provide power to interconnected grid system. Different studies have approved that up to 100MW electric can produced from the Aluto steam field. Aluto Langano steam field is known to be one of the high temperature prospected area in the country. The initial feasibility study was conducted in 1986, which concluded that the geothermal resource was sufficient to support power generation. Construction of the power plant began on January 1,1997. Ormat supplied and installed two units: The Geothermal Combined Cycle Unit (GCCU) and the Ormat Energy Converter (OEC), each rated at about 4 MW gross. The GCCU is composed of a conventional steam turbine and an organic turbine, each driving opposing ends of a single generator. High-pressure geothermal steam from two wells (LA-3 and LA-6) enters the steam turbine first and then passes to a shell-and-tube heat exchanger where the steam is condensed and a binary fluid is vaporized to drive the organic turbine. The OEC unit is driven by a binary fluid which is heated and vaporized in a shell-and-tube heat exchanger. The heat exchanger uses medium pressure geothermal steam from two wells (LA-4 and LA-8) and brine from all four productive wells.

The power plant was handed over to the Ethiopian Electric Power Corporation (EEPCo) on June 30, 1998. The OEC was in operation for barely 18 months, from July 1998, to December 1999, before shutting down when leaks developed in the heat exchanger tubes while the GCCU was in operation from July 1998 to June 2002, when it had to be shut down due to failure of the steam turbine bearings. After extensive repairs and upgrades, the plant has been successfully re-commissioned the GCCU in June 2007. Repairs included de-staging the steam turbine, replacement of steam turbine bearings and steam seals, complete overhaul of air-cooled condenser fans, drive components (motor bearings, shaft bearings, belts and pulleys) and upgrades to the plant and unit PLC-based control systems.

The power plant again stops working as many electromechanical parts gets failed in 2009.Comparing the energy generated before and after rehabilitation, it is found that after rehabilitation about 10 % more energy is being generated than the previously generated energy, Seifu A., (2010). Which means, the total generated energy before rehabilitation during August 1998 to June 2002 was about 44.15 GWh and the total generated energy after rehabilitation from June 2007 to June 2009 was about 25.76 GWh. No maintenance work has been attempted to repair the damaged part of the power plant since 2009.The main reason could probably no skilled man power in geothermal science who manages and monitors the steam field is attached to the power plant and the higher management body of Ethiopian Electric Power does not give attention to geothermal development because they give more focus to hydro as well as wind development activities.

## 5. CONCLUSION:

Though there is fairly good Geothermal department in the Geological Survey of Ethiopia (GSE), but it does not carry out steam field monitoring and power plant operation rather it conducts only exploration studies. As there is no well-established geothermal department both in man power and office facility which monitors the steam field and power plant with in the EEP company, the focus on the geothermal well rehabilitation and power plant overhauling to maintain the electro mechanical part is very poor since 2009. Even though there are other Geothermal fields being implemented by EEP, they are being managed by different department managers at different offices which reveals that the higher officials of the company do not give priority or encourage to the sector to achieve the energy mix policy of the country. Because of the power plant stop functioning, the wells get shut in for long period of time since 2009 so that right now they reach to a stage of not supplying steam. Calcite and Silica scaling is formed inside the well in the different casing types even in the liner casing and outside the well in the well heads and discharge pipe lines. The well head equipment's like the expansion spool, master valve, side valve and bleeding valve are also does not operated as the they get welded to each other by the scaling. The scaling problem is very critical in the field which reveals that even the two wells recently drilled in 2015 are also certainly exposed to this problem if they would not connect to a power plant because at this moment these wells are under shut in condition but down hole measurement is still fairly conducted every year to monitor and know the status of the wells.

## 6. RECOMMENDATIONS:

It is certainly very important especially the two recently drilled wells are should be given a priority. Because a new mobile well head generator working by the steam coming from the two wells is under preparation to construct within a couple of years. The two recently drilled wells (LA-9D and LA-10D) should be monitored every month and should be discharged every couple of months in order to prevent from calcite and silica scaling in the well.

In order to maintain the steam field and the power plant, first the electro mechanical part of the power plant should be inspected by well experienced expatriate staffs and should suggest the solution how to maintain it. As the old wells are already stop supplying steam for approximately 10 years, a calcite and silica scaling is formed inside the wells and outside in the discharge pipes and master valves, the possible option to rehabilitate the wells is, by killing the wells and dismantling the wellhead equipment's parallely during the killing or immediately after the killing process taken place. Either a newly wellhead equipment's are fixed in the wellhead and washing the wells by chemicals that are able to melt the scaling in the wells or reaming the wells by a rig. Maintaining and replacing with new discharge pipes that conveys the steam to the power plant is another work which should have emphasis on it.

Even though the cost of constructing new power plant is high but as alternative option should be considered as the steam from the old four wells to give 7.3 MWe and recently drilled two wells able to produce 2.5 MWe can operate together new power plant to get approximately 10 MWe. Else there should be need totally newly discharge pipes used to gather the steam from the wells and convey it to the power plant. Daily wellhead and down hole monitoring every six month or every one year for the wells and timely maintenance plan for the power plant is very important. Effective reservoir management and monitoring plan is also another remaining work in order to see the condition of the reservoir both whether a temperature decline because of a hydrological connection to cold water or pressure draw down due to over exploitation is observed in the field. Of course this is a long term activity and if many wells are drilled in the field.

In order to facilitate the monitoring of the wells and power plant effectively, a skilled man power as well as good and separate geothermal department that has its own procurement specialist not under the umbrella of generation construction executive officer but the umbrella of the Chief Executive Officer (CEO) should be established. Because currently, it is observed that many activities in line to geothermal development is carried out but their progress is extremely slow. Many steps should pass especially the procurement process is pretty slow, before reaching the CEO and during these steps, things get delayed finally the development becomes very poor progress.

As Ethiopia is endowed by huge potential of geothermal energy (up to 10,000MW) which is the big opportunity for the country as located in the main rift valley, as like as hydro reaches, this resource should be utilized for filling the gap of the electricity access of the country. The important and main solution to develop the geothermal sector in the country is there should be well established geothermal institute in the country. One very good and special feature of this sector is, it gives a constant base load power because it is not affected by the global climate change.

Currently there are many Geothermal development offices in the country which are not wel established and do not have good connection to each other. For instance, a Geothermal directorate under the umbrella of Geological Survey of Ethiopia (GSE) which only has a responsibility of surface exploration only. Another Geothermal project office (Aluto Geothermal project, Alalobeda Geothermal project and Tendaho Geothermal projects) are under the umbrella of EEP which their responsibility is steam field development and power plant construction as well as reservoir management and monitoring. Furthermore, the Geothermal energy regulatory body is established under the umbrella of Ethiopian Energy Authority (EEA). Therefore, if all of these offices are merged in to one independent institute or company, the development of the sector will be boost rapidly in addition to the hydro, wind and solar energy and lastly energy mix policy of the country will be achieved soon.

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