PRELIMINARY ENVIRONMENTAL IMPACT ASSESSMENT FOR THE DEVELOPMENT OF TENDAHO GEOTHERMAL FIELD, ETHIOPIA

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ABSTRACT

The Tendaho geothermal field is one of the geothermal fields in the Ethiopian rift valley that has been explored by deep drilling. Six geothermal wells have been drilled to date, four of which are productive. There is a plan to progress the resource to development in three phases, which includes small scale power plant, deep drilling and medium scale plant. In this report, analysis of the current status of the environment, environmental effects which the proposed development activity may entail and mitigation measures to be taken to reduce impacts to the level of insignificance are discussed The characteristics of the existing environment at Tendaho includes: a flat topography, scarce wildlife, scarce vegetation, arid climate, limited surface water body, un polluted air, natural thermal features, sparse population and poor socio economic condition. Impacts on the environment from deep drilling are predicted to be minimal and short term. Potential impacts of utilization of the resource on the environment are physical, chemical and socio economic. The physical impacts on the geology and the landscape relate to construction activities and abstraction of water from the reservoir. Given the chemical concentration of the geothermal fluids, the risk of contaminating the ground water by waste water disposal is considered low. Air emission during operation will cause no significant contamination of the air, since the gas content of the resource is low. The impacts on the socio economic condition are mainly positive, including a rise in employment opportunities and an indirect stimulation of rural development. All the impacts are mitigatable with careful management of the resource and implementation of appropriate environmental protection measures.

1. INTRODUCTION

The Tendaho geothermal field is located in Afar regional state in the NE part of Ethiopia, some 600 kms from the capital city, Addis Ababa (Figure 1). It is situated in the north western part of Tendaho graben, a 4,000 km^2 structural feature with high-standing fault scarps bounding a flat plain dotted by young volcanic edifices and local structural highs. The graben hosts the world famous "Afar Triple Junction" where the Red Sea, Gulf of Aden and Main Ethiopian rifts come together giving rise to a prime region of geothermal potential. The geothermal field is one of the several geothermal fields in the Ethopian rift valley which has been identified as high temperature geothermal area (UNDP,1973). Long term geothermal exploration work has been conducted in Tendaho area since the early 1980s

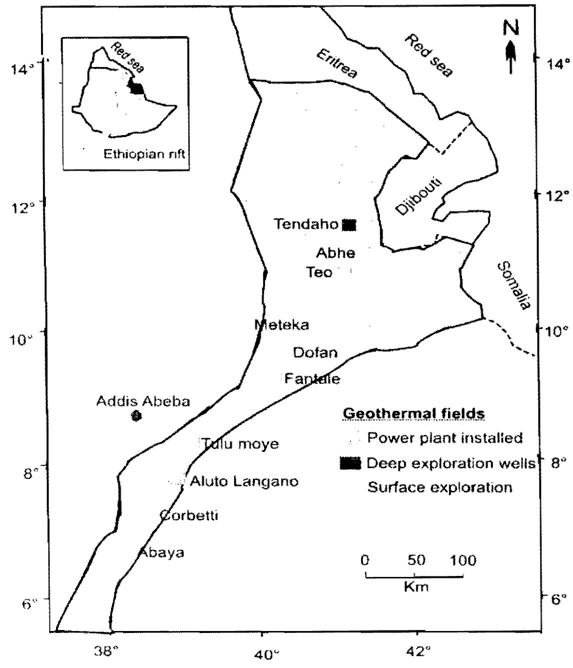

Figure 1. Location map of Tendaho

Based on the on exploration results, six geothermal wells have been drilled to date, four of which are productive. Three of the productive wells tap geothermal fluid from relatively shallow depth (about 500m depth) and one from deeper depth (about 1800m). As a result the exisistence of both shallow and deep resource suitable for electricity production has been confirmed. There is a plan to progress the field to development in three phases which include small scale plant (< 5 MW) using the exisisting productive wells in the first phase, further deep drilling in the second phase and medium scale plant (20-30 MW) in the third phase.

At present electrical power in Ethiopia is generated at hydro, thermal and geothermal power stations. About 800 Mw electricity is installed, out of which, 90% is from large scale hydropower plants and the rest from thermal, mini hydro and geothermal. All the thermal power plants are generating from diesel oil. The Tendaho area is located remote from the national hydropower grid. There are no rivers in the vicinity with potential head suitable for small scale hydro plants. The current alternatives for power generation are diesel generation and geothermal power.

This report is a modified version of the work of the author at United Nations Geothermal training programme in Iceland in 2005. The report briefly states characteristics of the geothermal resource and the nature of the proposed geothermal development at Tendaho. It also describes the exisisting environment and assesses the impacts of the development on the environment. The significance of impacts, are investigated and mitigation measures are suggested.

In the past the environment was not given particular attention in the development endeavours of Ethiopia, since project evaluation and decision-making mechanisms were unwarrantedly made to focus on short-term technical feasibility and economic benefits. For this reason, past development practices fell short of anticipating, eliminating or mitigating potential environmental problems early in the planning process. Since recent years the concept of sustainable development and environmental rights are entrenched in the rights of the people of Ethiopia through environmental regulations and laws. The environmental impact assessment (EIA) and procedural guidelines of Ethiopia was used as guideline during this study. In the EIA guideline, developments such as geothermal, are designated as projects whose type, scale or other relevant characteristics have potential to cause some significant environmental impacts but not necessarily to warrant an environmental impact study. During this assessment stake holder opinion, an environmental interaction matrix, impact significance rating criteria and national and international standards were used.

2. CHARACTERSTICS OF THE GEOTHERMAL RESOURCE

The quality of the geothermal resource is high (high temperature, good permeability, two phase reservoir, low gas content and benign chemistry).

Temperature as high as 250 ° C and 270 ° C has been recorded within the shallow and deep resource respectively. The chemistry of the geothermal fluids indicated low concentration of contaminants, such as As, B, H_2S, NH_3 and Li, even compared to that of most other geothermal resources of the world. The non condensable gas (NCG) content of the resource is also low ranging from 0.1 to 1 % in weight of separated steam (Aquater, 1996). Release of NCG's such as CO2 and SO2 from the proposed development were estimated to be 5.4 kg/ MWh and 0.3 kg/MWh respectively (Kebede, 2005).

TABLE 1: Trace constituents in selected geothermal fields (mg/l)

Geothermal field	As	B	H_2S	NH_3	Li	Source
Tendaho (TD-4) (separated water)	0.4	4.6	< 0.1	1.49	1.06	Aquater, 1996
Wairaki (NZl) (deep water)	4.7	30	1.7	0.2	14	Brown, 1995
Salton Sea (USA) (deep water)	12	390	16	386	215	Brown, 1995
Cerro Prieto (Mexico) (deep water)	4.7	19	0.6	127		Brown, 1995
Nesjavellir (Iceland) (separated water)	0.05	2.1				Wetangula, 2004
Threshold value	0.3	0.5	*0.05	*1.5		EPA, 2000 and *Brown, 1995

The chemical composition of geothermal fluids is extremely variable. The chemistry of the fluids discharged is largely dependent on the geochemistry of the reservoir, and the operations conditions used for power generation and vary from one geothermal field to other. The chemical composition of the Tendaho geothermal water at surface is tabulated in Table 2. The concentration of most of the chemical constituents is below threshold value for drinking water. Chloride is the major anion in significant concentration compared to that of the surrounding cold surface and ground water and threshold value.

With regards to potential safety risk during exploitation hydrothermal eruption occurred at Tendaho in 2000 while testing the shallow reservoir (Amdeberhan, 2005), evidencing a potential safety risk in future exploitation activities.

TABLE 2: Analytical data of geothermal and other water in Tendaho
And drinking water threshold value (mg/l)

Location	pH	Mg	Na	Cl	SO_4	NO_3	F	Source
TD-6	9.5	1	635	1000	156	1.68	1.7	Ali and Gizaw, 2000
TD-5	9.4	0.2	620	905	142	1.77	1.3	Ali and Gizaw, 2003
TD-4	8.4	0.04	708	977	129	0.5	7.2	Aquater, 1996
Awash river	7.8	10	430	60	58	2.2	1.5	Teclu and Gizaw, 2004
Doubti g/w wells	8	12-35	337-635	251-483	207-584	1.33-11	1.67-2	Teclu and Gizaw, 2004
Threshold value	5.5-9.5	100	400	600	600	10	1.5	EPA, 2000

3. CHARACTERSTICS OF THE PROPOSED DEVELOPMENT

The proposed geothermal power generation entails the extraction of raw heat of the earth and its conversion in to electricity. A techno economical study taht has been conducted after the completion of the productive wells suggested that the best alternative for geothermal power plant development at Tendaho. On the bases of the available power, base demand, risk and exisisting electric connection system a low investment and low efficiencey alternative (steam cycle with about 3 MW back prssure unit) was recommended for the first project phase (Aquater,1996). A proposed development strategy of the resource by deep exploratory and production drilling in phase II envisage power expansion by 20-30 MW condensing units in phase III (Aquater, 1996).

The main activities of the proposed development that will have significant interaction with the environment are considered to be construction, waste disposal, abstraction of underground water, and utilization of the resource.

The construction activities will involve excavation of material for drill pads, roads and power houses, construction of roads, pipe lines, power houses and transmission lines.

Waste disposal involves: (i) the disposal of the excess drilling fluid in to evaporation ponds, (ii) waste geothermal water disposal during exploitation and (iii) the release of non condensable gases in to the atmosphere.The alternatives for ways of waste water disposal were considered to be, reinjection, disposal into evaporation ponds and disposal in to the near by river (Awash). Drilling and power production may also create noise pollution on the local enviroment.

4. DESCRIPTION OF THE EXISITING ENVIROMENT

4.1 Environmental geology, landscape and land use

The area of potential interest is predominantly a flat terrain at an elevation of 370 to 380 m a.s.l., locally interrupted by scattered isolated volcanic hills, rising few hundred meters above the flat plain, forming a rugged topography (Figure 2). The Tendaho geothermal field is located in geologically active zone with history of natural occurrences of earthquakes (Gresta et al, 1997).

Hydrothermal activity, both active and extinct, can be observed in the Tendaho graben. The active manifestations occur in various parts of the graben. High temperature fumaroles (>90°C) and associated extensively altered land occurs at Ayrobera. Hot springs at Begaloma form salty Crater Lake. Several mud pots and fumaroles are emerging from sediments near Doubti geothermal wells. Erupting hot springs (near or at boiling point), silica sinter depositions and fumaroles occur at Alalobeda, in the SW part of the area (Figure 2).

The potential prospect, where exploration work is planned to be conducted, covers an area of be about 300 km^2. The initial development area is located in the NE part of Doubti cotton plantation

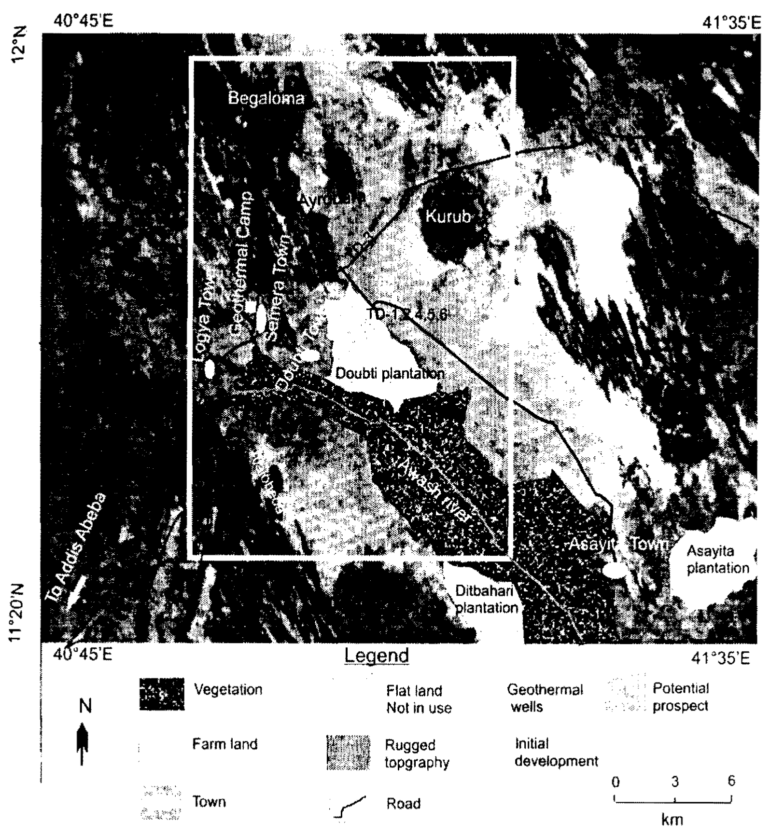

Figure 2, Project Area, Land use and Vegetation cover map

and covers few thousand square meters (Figure2). The main land uses around the project area are for grazing and irrigated farming. The irrigated farms are mainly, mechanised farms of the Doubti, Assayita and Ditbahari. Permanent settlement areas are limited; and include small towns such as Logia, Semera, Doubti and Assayita (Figure 2).

4.2 Water and air quality

The waters at depth in Tendaho geothermal system are sodium chloride type. The deep recharge to the system originates in the western escarpment and plateau at elevations above 2000 m a.s.l. The shallow reservoir is characterised by a TDS value of about 2500 ppm and 2000 ppm at well head and reservoir condition respectively (Aquater, 1996).

The only surface water body close to the intended development area is Awash River (Figure 2). The Awash water has a sodium carbonate type of composition with a TDS content of about 600ppm. It is suitable for irrigation. The ground water potential of the area is generally high, however in large part, the water is of poor quality (high salinity, high iron and high temperature) (MoWR and UNICEF, 2003). The TDS values tend to rise in the ground water than in Awash River. Natural thermal water circulation at shallow levels is also affecting the quality of the ground water.

The state of the atmosphere at Tendaho and its surrounding is generally good. The area has not been exposed to major anthropogenic interference that had significant impact on the environment. However pollutions that originate from exhaust smoke of heavy duty trucks crossing the area, air emissions from fossil fuel generators for electricity production and flaring of gas and fire wood in residential houses may have minor cumulative impact on the quality of the local air.

4.3 Climate, flora and fauna

The Tendaho Geothermal area is designated as a hot climatic zone. Daytime conditions are torrid. Although the hot zone's average annual daytime temperature is about 27°C, mid year readings in the Tendaho area often soar to more than 40°C. The moisture content of the air through most of the year is very dry. Rainfall in Tendaho area is always meagre. The total rainfall from March 2004 to July 2005 was143.9mm (NMSA, 2005).

Vegetation is mostly confined to drought-resistant plants such as acacia. Most of the existing vegetation has been destroyed by the local people to produce charcoal and for fire wood. Broader leafed vegetation is restricted along Awash river course and areas irrigated by the river. The narrow green belt along the course of Awash River covers about 10 % of the potential prospect area (Figure 2). Wildlife is rare in the project area.

4.4 Socio economic conditions

The economic livelihood of the region's population is mostly based on pastoralism, mainly camel and goat herding. Because of the existence of fertile alluvial soils and Awash River, the most important sedentary economic activity of the past 4-5 decades has been growing cotton at plantations at Doubti, Det Bahri, and Asayita (Figure 2). Since recent years, irrigated farming for food crops has been growing in importance.

Tendaho graben is traversed by an excellent tarmac highway that serves as the main transport route for Ethiopia's foreign trade through Djibouti. Thus another economic basis for the towns in the area is service provision to the truck traffic on that highway. The town of Logiya is a product of the road traffic. Doubti, the wereda seat of government and Det Bahri started as satellite towns to the farms that bear their names. The population of Doubti wereda in July 2004 was estimated at 83,987(60% male) of which 25% or 21,095 people lived in small towns.

In Doubti woreda of Tendaho area for domestic and livestock consumption, the main sources of water include: Water supply schemes from ground water, Awash River, traditional wells, ponds and water tinkering. As regards social services, there exist one high school, 17 low level schools, one hospital and 8 health centers. (MoWR and UNICEF, 2003). The available social services are far below the local demand.

According to Ethiopian Electric Power Cooperation data files, currently all electric power generated in the Tendaho area is from diesel generators. Diesel fuel is imported, and transported from the port of Djibouti at high cost. Thus the electricity generation cost is very high (about US 21 cents/kwh). Nearly US 12 cents/kwh of this amount is the cost of diesel fuel.

The high cost of electricity in reference to the low income leads to the rural poor inability to maximize on the use of electricity and therefore resorts to other alternative affordable energy resources. As a result the energy consumption of the rural population is mainly based on biomass fuel use: wood from acacia trees, crop residue and camel and goat droppings. However all the major towns in the vicinity of Tendaho have electricity supply, used primarily in household lighting and the commercial sector. The total current generation is about 3MW. The peak load demand is projected to be 4.5 Mw in 2010. Household and commercial consumption is now severely limited due to the relatively high cost of power.

The level of generation and use per capita of electrical energy is one of the indications of development levels of a society. In Doubti district of the Tendaho area the current annual production of electricity is about 23 .6 GWh for a population of 83,987 and hence the yearly use per capita of electricity is about 282 KW/hr. This value is one of the lowest in Africa, indicating the high poverty levels of the society. Most of the population is nomadic, moving from place to place in search of water and grazing land for their stock. Main root causes for the low level of sedentary life are the scarcity of social services, including water supply, health canter, education canter, energy supply and the scarcity of job opportunities.

5. ENVIRONMENTAL IMPACT ASSESSMENT

The environmental issues considered in this assessment include: the geology, landscape, land use, climate, flora, fauna, water quality, air quality, occupational and public safety and socio economic conditions. Initial screening of potential impacts due to the development indicated that impacts on the land use, climate, flora, fauna and air quality would be too low to entail noticeable environmental disturbances. The small portion of land required for the development will not alter the exisisting land use. The estimated air emissions of green house gases from the atmosphere discharge systems are considered to be too low to affect the climate and air quality. Potential impact on the flora and fauna is not considered due to rarity of wild life and vegetation.

Therefore, only potential impacts on the geology, landscape, water quality, occupational and public safety and socio economic conditions are further addressed in more detail.

5.1 Impacts on the geology and landscape

The intended construction activities and excavations of materials for constriction will have a physical impact on the geology and landscape. Excavated loose soil will be easily prone to erosion. Piles of excavated material would affect the aesthetic value of the landscape. High pressure re injections may trigger micro earthquakes and impact the geology. Abstraction of water from underground during production will have a negative effect on the performance of natural hydrothermal manifestations, which are part of the scenery of the landscape. Power houses, steam gathering and disposal pipe lines, and electric transmission lines will have negative impact on the aesthetic value of the natural landscape.

5.2 Impact on water quality

One of the alternatives of waste water disposal, disposing it in to Awash River, if implemented will have a thermal and chemical effect in the water quality of the river negatively impacting the biota of the river and the local community at downstream.

Disposal of the waste water into surface evaporation ponds will have a chemical impact on the shallow ground water due to infiltration. Chloride is the major anion in Tendaho geothermal water that may affect the taste and odour of the shallow ground water, if infiltrated (Table 2).

5.3 Impact on occupational and public safety

Occupational and public safety is necessary to protect the human population and the host community from accidental hazards. Besides the possible occurrence of safety hazards, such as burn and noise, the potential occurrence of hydrothermal eruptions due to exploitation constitute a potential hazard.

5.4 Impact on socio economic conditions

Utilization of the geothermal resource for electricity generation instead of the diesel generated power results in the supply of sustainable modern energy. The geothermal electricity to be generated during the initial phase of the project (3MW) would be consumed locally replacing the diesel generators. The anticipated power generation of 20 –30 MW during the final phase of the development would partially serve to meet the rising local demand and the rest of it could be connected to the national grid to serve as a back up for hydro power.

The typical unit cost of power from geothermal plants in areas of high quality resource such as Tendaho, based upon a discount rate of 10 % and assuming a capacity factor of 90% is 5.0 – 7.0 US c / kwh for small plants (<5 MW) and 4.0-6.0 US c / kwh for medium plants (5-30 MW) (The World Bank Group,2004). With the unit cost of diesel generation in Tendaho at about 21 USc/kwh, geothermal generation is economically a very attractive option.

The excess power from the local demand will be connected to the national grid to serve as a back up of hydropower. This will introduce a new type of energy, geothermal energy, in the energy mix of the country. Replacement of imported fuels by the indigenous resource, geothermal energy, will save foreign currency. Investment in the area will be attracted by the availability of sustainable and sufficient electricity. Therefore the geothermal development will have positive impact on the socio economy both at local and national level.

Geothermal energy development can be classified as a primary industry (Tsvi and Jack, 1994). Development of the Tendaho geothermal resource could have secondary impacts on job generations in other industries. These include the expansion of agriculture and agro industries that will be stimulated by availability of sufficient and sustainable power. A tertiary positive impact on on job creation would be also generated by improvement of social services that are required to support the would be enhanced economic activities.

Improved social services including water supply, health centres, education centers and telecommunications would create favourable conditions of life which the society enjoys . Improved economy, creation of sufficient jobs and social services will ultimately positively change the way of life of the community.

6. ASSESSMENT OF IMPACT SIGNIFICANCE

6.1 Criteria of assessment

The magnitude and significance of impact is measured using various criteria's. Most commonly it is measured using scientific standards or clearly described criteria. Here the criteria by Munn, 1979 are referred, which uses the extent, intensity, duration, mitigation potential, acceptability and degree of certainty of the impact. Accordingly the criterion for categorizing these impacts into low, medium and high is given in Table 3.

TABLE 3: Categories used for rating of impact magnitude and significance

Criteria	High	Medium	Low
Extent of impact	National/ International	Regional	Site specific/local
Intensity of impact	Affects endangered species and / or protected areas	Affects areas of potential conservation value	Affects areas of little conservation value
Duration of impact	More than 15 yrs	5-15yrs	0-5 yrs
Mitigation potential	Little or no mechanism exists	Partially mitigatable	Mitigatable to the level of insignificance
Acceptability	Unacceptable or requires redesigning	Manageable with regulatory controls	No risk to public health
Degree of certainty	Over 70% certain	40-70% certain	Less than 40% certain

6.2 Impact significance of the proposed development

The impacts of the proposed development on the existing environment with and without mitigation on are rated according to the criteria set on Table 3. The results of assessment are shown on (Table 4).Assessment of the significance of impacts with out mitigation indicated that:

(i) The extent, intensity and degree of certainty of impact on the geology and landscape and are rated medium. Given that the life span of geothermal plants is more tan 15 years the duration of impacts is rated high,

(ii) The impact on water quality in terms of acceptability and degree of certainty is rated medium. The duration of impact is rated high. In all the remaining other activities the impacts are considered low,

(iii) The potential impacts on occupational and public safety are partially mitigatable, manageable with regulatory controls and 40%-70% certain and hence are rated medium. The extent and intensity of impact is considered low and

(iv) The positive impacts on the socio economic condition have a national extent, duration of more than 15 years and over 70% certain, hence are rated high.

Almost all the impacts are mitigatable to the level of insignificance. Generally the significance of impacts of the proposed geothermal power utilizations would be directly proportional to the magnitude of the development. Hence, the initial phase of the development would have relatively lower impacts than the final phase.

TABLE 4: Impact significance rating of the proposed development

A: CRITERIA		B: Charecterstic of the existing enviroment → Geology and landscape	Water quality	Occupational and public safety	Socio economic condition
Without mitigation	Extent of the impact	M	L	L	H
	Intensity of the impact	M	L	L	
	Duration of the impact	H	H	H	H
	Mitigation potential	L	L	M	
	Acceptability	L	M	M	
	Degree of certainty	M	M	M	H
With mitigation	Extent of the impact	L	L	L	
	Intensity of the impact	L	L	L	
	Duration of the impact	M	M	M	
	Acceptability	L	L	L	
	Degree of certainty	L	M	L	

NOTE:

H: High
M: Medium
L : Low

7. IMPACT MITIGATION AND ENVIRONMENTAL MANAGEMENT MEASURES

The physical impacts on the geology and landscape could be remedied by restoring the integrity of the surrounding. Soil erosion due to excavation of the top soil could be mitigated by planting trees. Measure to mitigate the negative impact of steam gathering and disposal pipe lines on the aesthetic value of the landscape is by painting and camouflaging the pipes with the landscape. To minimize the effects of exploitation on the performance of the surrounding thermal manifestation appropriate measures shall be taken to avoid over exploitation and re inject the waste fluid to maintain the reservoir pressure. The micro earthquake triggering effect of high pressure deep re injection could be avoided by pumping the water at lower pressures.

Potential thermal water infiltration in to the shallow ground water from waste water evaporation ponds could be minimized by sitting the ponds on relatively impermeable soil. Waste water disposal in to Awash River should be avoided. The best environmentally friendly alternative for waste water disposal, deep re injection, shall be adopted.

The management of potential impacts on public and occupational safety includes allowing access to hazardous area only to people with appropriate training and safety equipment, training of employees and the host community to raise their awareness of the harms and the use of appropriate silencers and hearing protection to control hearing hazards due to noise. To minimize the risk of hydrothermal eruption, environmental management measures, such as: not overexploiting of the reservoir, sitting evaporation ponds as far as possible from the productive wells and in a relatively stable area, construction of the plant at least 200m away from the location that evidenced hydrothermal eruption and monitoring of the surface thermal activities, to help predict any future eruption will be essential. Maintaining reservoir pressure to minimize steam formation and the concomitant increase in heat flow is recommendable. Excavation of the overburden in thermaly active sites for drilling and building would lower the lithostatic presuure, that would stimulate hydrothermal eruptions. Therefore thermally active locations should be avoided as drilling and building sites.

To enhance the benefits of the host community from the positive socio economic impacts preferential employment should be given to the host communities. Support from the host community should be secured by way of consultation, information, education and evidence that the lives of the rural poor are to be improved as a result of the geothermal development

8. CONCLUSIONS AND RECOMMENDATIONS

Preliminary assessment of potential negative environmental impacts due to the proposed development identified, physical impacts on the geology and landscape, chemical and thermal impacts on the water quality and impacts on occupational and public safety. Assessment of the significance of the impacts showed that the impacts in most of the evaluation criteria are of medium to low rate. All the negative impacts are mitigatable with appropriate mitigation and environmental management measures.

Assessment of impacts on the socio economic condition indicates that the proposed development would have positive local and national impacts of high significance. The use of geothermal power instead of the diesel generated power would lower generation costs in the long term, would save the foreign currency being spent on the purchase of oil for power production and secure availability of cheaper and sustainable electivity to meet the rising future demands

These would encourage investors to invest in the region, ultimately creating more job opportunities. As a result it will effectively enhance the income of the society, reduce production costs and increase the purchasing power of the consumer and by extension contributes to poverty reduction efforts at local and national level. Improved economy and availability of sufficient social services due to the development will rapidly change the way of life of the community.

Chemical and air emission monitoring work should be conducted during exploitation to know temporal charges. Study of wind pattern would be valuable to predict the dominant wind direction and the possible effect. Noise level studies are necessary to manage potential hearing hazards. A detailed EIA is recommended before the final phase of development, based on evaluation of additional data and stake holder analysis.

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