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Geothermal data management at the Ministry of Energy and Mines, Nicaragua

Needs assessment and legal merit for official geothermal monitoring information system.

Gunnlaugur M. Einarsson – ÍSOR
Jónas Ketilsson - NEA

Prepared for ICEIDA

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Orkustofnun
Orkugarður ● Grensásvegur 9 ● 108 Reykjavík ● Iceland ● Tel. +354 569 6000 ● Fax: +354 568 8896
os@os.is ● www.os.is

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Abstract:

The aim of this report is to analyse the current status of geothermal data and information management at MEM and propose improvements within the context of ICEIDA's Geothermal Capacity Building Project in Nicaragua. The objective is to facilitate MEM in collecting, storing and analyzing information gathered on the geothermal resources. Currently no formal management system is in place and some software needs updating. For long term data collection and management it is recommended that in the exploitation concessions a list of information deemed necessary by MEM should be attached to concession contracts and a Nicaraguan Code for Reporting should be created and secondly that a computer network should be purchased with a high level of security and backup capacity. The approach suggested to facilitate MEM in being able to collect and manage this data involves collaboration between ÍSOR's information technology department, the geothermal directorate and internal information technology department at MEM. It is recommended that relevant hardware and software should be purchased and MEM personnel be trained with on site cooperation. A preliminary budget and timetable for this task in year 2010-2011 is introduced.

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1 INTRODUCTION

This report is part of a capacity building project titled "Iceland - Nicaragua: Geothermal Capacity Building Project". The original a proposal for this project was put forth by the Government of Nicaragua to the Government of Iceland, through the Ministry of Energy and Mines (MEM) as the main counterpart, and the Ministry of the Environment and Natural Resources (MARENA). The project is financed by the Icelandic Agency for International Development (ICEIDA). It consists of three components: short and medium-term technical assistance; instruction and training; and endowment of equipment. These three components are closely linked to the overall objective which is to enhance geothermal utilization in Nicaragua.

The aim of this report is to analyse the current status of geothermal data and information management at MEM and propose improvements. The objective is to facilitate MEM in collecting, storing and analyzing information gathered on the geothermal resources and reserves of the country. The report analyses the following fundamental questions regarding data management at MEM. Those are:

1. What is the objective and legal framework for data collection?
2. What is the current status of MEM´s data?
3. How should data be collected and managed in the long term?
4. How can data collection procedures and data management facilities at MEM be improved?
5. How much do improvements cost?

With these objectives in mind a two person team visited Nicaragua in October 2009 on behalf of ICEIDA, to try to answer these questions. The team consisted of Jónas Ketilsson, a geothermal specialist from the Icelandic National Energy Authority (NEA) and Gunnlaugur M. Einarsson a geographic information specialist from Iceland GeoSurvey (ÍSOR). Þráinn Friðriksson, the project manager on behalf of ÍSOR, was in Managua at the same time and took part in the discussions.

Data and information management is a crucial part of geothermal development as decisions need to be based on valid measurements and accurate data. Geothermal information has been defined by ISOR (Einarsson and Hauksdóttir, in press) as information describing a geothermal resource, its natural state, exploration and utilization. Geothermal information is mostly geographical, as geothermal resources, drilling operations, geothermal heat and electricity production occur at some geographic location. Geographical Information Systems (GIS) have been developed to manage, analyse and visualize such information.

What follows is a report documenting the results of this work. In chapter 2 legal merit of data gathering is discussed, in chapter 3 geothermal information is briefly described, in chapter 4 the current status of MEM's geothermal data is discussed and in chapter 5 improvements are proposed and a time plan is outlined.

2 LEGAL MERIT FOR OFFICIAL GEOTHERMAL DATA COLLECTION

The objective of official resource monitoring is to ensure that the most efficient exploitation of the resource is practiced in the long run and that extraction of geothermal fluid does not exceed levels deemed necessary. Therefore MEM needs to collect and manage geothermal information that enables MEM to evaluate geothermal resources in Nicaragua. Before any monitoring is determined, there must be a recognized need for the monitoring and the objectives have to be clear. In Steinsdóttir et al. (2009) an overview is given of the public monitoring framework in Iceland and Nicaragua and comparison made to other relevant countries, e.g. New Zealand and the United States of America. For official geothermal data collection to be successfull, legal merit of the execution is of great importance.

Shortly after the publication of the Master Plan for Geothermal Development in Nicaragua a new legal framework came into effect by the passing of Act no. 443/2002, the Geothermal Resources Act and relevant Regulation no. 003/2003. This legislation was then reformed by passing Act no. 290/2007 when MEM was created and all of INE´s (the previous monitoring body) obligations mentioned in the Geothermal Resources Act where transferred to MEM. According to the Act the MEM and MARENA are jointly responsible for regulating and monitoring geothermal resources exploration and exploitation concessions.

2.1 Issued Exploitation Concessions

In Nicaragua two developers have been issued a geothermal resource exploitation concessions, ENEL has concession in the geothermal resource area of Momotombo, issued in 1983 and GeoNica has the concession for San Jacinto Tizate, issued in 2001. Since the two exploitation concessions where issued prior to the Geothermal Resources Act, the concession holders are regulated by Act No. 316/1958, the General Law for the Exploitation of Natural Resources. In the current legislation, the Geothermal Resources Act (Art. 78 of Act No. 443/2002), it is stipulated that geothermal resource exploration or exploitation concessions that were granted or awarded prior to the Act may be adjusted or conformed to it at the request of the concession holder. According to verbal communication with MEM, the concession holder for San Jacinto Tizate has agreed to fall under the scope of the Act. The concession holder for the Momotombo geothermal resource area is currently not willing to do so even though the concession holder is a publicly owned power company.

2.2 Issued Exploration Concessions

Since the Geothermal Resources Act was passed three geothermal resource exploration concessions have been issued for the exploration of geothermal resource areas. Those are for the geothermal areas Casita-San Cristobal (2009), Monte-Galan (2006) and Chiltepe (2006). These exploration concessions are regulated by the Geothermal Resources Act (443/2002).

2.3 Obligations of Concession Holders

The Geothermal Resources Act (443/2002) is the legal framework that authorities in Nicaragua and concession holders have to work within. In Section D of Art. 36 of the Geothermal Resources Act it is stipulated that MEM is to be provided with technical reports relevant to works and purposes covered by the concession, as well as any other reporting requirement defined in the Act, its regulations there under and the concession agreement thereof.

In the geothermal resource exploration concession, official monitoring is further stipulated. The concession holder is to provide MEM with technical reports every three months where work relevant to the concession is covered. These reports are to detail; work accomplished, approximate costs incurred and any modification planned on the work programs and budget as a result of concession operations. An annual progress report is also required, summarizing the four quarterly reports. In addition to what is outlined in the Geothermal Resource Act the MEM can specify in the concession any further information which is to be provided in the reports.

In the issued geothermal resource exploration concessions the concession holder is obliged to supply results of investigations of geological, geochemical, geophysical, hydrogeological studies, results of drilling and reservoir tests conducted. Prior to drilling the concession holder is obliged to provide a committee, formed by MEM, technical specifications of the well, design of casings and valves etc. In the concession it is stipulated that all fluids extracted have to be injected back into the resource.

As stipulated in Article 67, in Act 443/2002 geothermal resource exploration or exploitation concession holders shall pay annually a severance tax per ton of vapor produced in the geothermal resource area, based upon payment assessments and mechanisms defined. The concession holder is liable for and shall pay taxes as of the 5^{th} year following the geothermal-electric power plant start-up date or the year when the concession holder’s financial statements reflect positive income figures, in compliance with tax legislation in force.

2.4 Nicaraguan Code for Geothermal Reporting

The official monitoring of the concession holders has to be within the legal framework of Art. 36 of the Geothermal Resources Act as well as obligations and liabilities defined in other articles of the Geothermal Resources Act, regulations there under and obligations stipulated in the concession. Obligations of the concession holder to regularly report to MEM could be stipulated in a Nicaraguan code for geothermal reporting as an appendix in the exploitation concession or by implementing a national technical obligatory standard (es. *norma tecnica obligatoria Nicaraguense*) for geothermal development as outlined further in Steinsdóttir et al. (2009). If not, then the MEM is not explicitly given the authority to structure the reporting of the concession holders after exploitation concessions have been issued. Standardized reporting would be very beneficial both for MEM and for concession holders as then there would be no question as to what is required. This would ensure that all relevant data is collected in a standardized and consistent manner. Then the MEM has the data needed to assess the resources and reserves of the country, operation efficiency and recommend further exploitation of a particular geothermal resource area.

If such a code for reporting is created it should provide clear instructions for the concession holder as to the keeping of a logbook for all his activities, drilling and exploitation and what information is to be presented to MEM. The following is a list of the major information categories that would be beneficial to MEM to incorporate in the geothermal resource exploitation concession which will be issued in the near future:

- i. The amount of geothermal fluid extracted from the geothermal reservoir each month (kg).
- ii. The amount of geothermal fluid extracted from each well in the geothermal area each month (kg).
- iii. The amount of fluid re-injected into the geothermal reservoir each month (kg).
- iv. The amount of fluid re-injected into each well in the geothermal area each month (kg).
- v. The temperature of the water re-injected into the geothermal reservoir each month (°C).
- vi. Results of water level measurements in wells in which the water level can be measured and are within the geothermal area (m).
- vii. The pressure changes or drawdown determined in the geothermal reservoir (bar)
- viii. The results of measurements of the enthalpy of the fluid from every production well in the geothermal area (kJ/kg).
- ix. Chemical analysis of the geothermal water (and steam, if appropriate).
- x. Greenhouse-Gas-Emissions (GGE) from the geothermal power plant each month (kg)
- xi. Results from simulations of the geothermal reservoir.
- xii. Results of measurements made to monitor changes in the geothermal reservoir.
- xiii. Information on drilling in the industrial area.
- xiv. A resume of improved understanding of the physical characteristics of the geothermal reservoir based on the results of the latest drilling

The data that should be turned in are on one hand information regarding wells as a construction and on the other hand information regarding wells as an indicator for the physical characteristics of the resource.

Constructional information for example:

- i. Location of the well (coordinate, place, area) and well track.
- ii. Depth of well and casing program.
- iii. Drilling year.

Resource information, for example:

- i. Flow from the hole.
- ii. Temperature of the well fluid.
- iii. Locations of productive aquifers in the well.
- iv. Chemical combination of the well fluid.
- v. Temperature and pressure in the geothermal reservoir.

3 GEOTHERMAL INFORMATION

Geothermal information is a broad concept that covers many different types of data. They are of various sources and of various stages of interpretation. There are several approaches to classify geothermal information for example scale, dimension, level of interpretation and origin. In this report the conceptual classification shown on figure 1 is used.

Geothermal Information		Master plan / Baseline	*Concession*	
			Exploration phase	**Utilization phase**
		>>>>>> Time >>>>>>>		
investment	**Resource information**	x	x	x
	Environmental information	x	x	x
	Constructional information		x	x
	Operational information			x

Figure 1*. Conceptual classification of geothermal information.*

This model of geothermal information is linked to major phases of geothermal development versus a thematic classification of the information. After trying out various other methods available to classify geothermal information this conceptual classification is the one that is most suitable for classification for Nicaraguan geothermal information. In the next the following sections the focus will be on all of these classes.

3.1 Master Plan information

Master Plan information is on a national level, focusing on the big picture, and estimates the theoretical capability of various geothermal fields and prioritizes them for further exploration and development. This stage requires information about major volcanic systems, tectonic setting, extent of geothermal manifestations, indicator chemical analysis, hydrological setting, environmental considerations, environmentally protected areas, boundaries of areas, access to the area and other infrastructure. Production capacity is often estimated using a simple volumetric method with Monte Carlo simulations with estimated minimum and maximum values for a set of parameters. Master Plan information is usually compiled into reports with maps and tables. The reports are then made available for possible exploration companies and developers.

3.2 Resource information

The data relevant to this category is mostly collected during the exploration phase. This data is generally geoscientific and spatial in nature and can therefore be visualized on a map. This information can be in all dimensions, as some geophysical and geochemical methods can provide an indication as to the physical conditions at depth in the geothermal reservoir. In addition some subsurface data obtained from boreholes during drilling would fall into this category. This would include the information such as the mud log, and wireline measurements obtained for the purpose of getting information about the geology and geophysics of the reservoir.

Resource information is used to estimate physical characteristics of the resource, both the physical properties and the initial physical conditions of the system.

3.3 Environmental information

Environmental information is for the most part beyond the scope of this report as monitoring the environment is the responsibility of MARENA. This part will not be discussed in detail but environmental is none the less an important component of geothermal information. Information in this category shows for example the locations of environmentally important areas, environmentally protected areas and input and output information from environmental evaluation as well as environmental impact assessment.

3.4 Constructional information

Constructional information focuses on the technical aspects of how a geothermal reservoir is utilized. This data is therefore in most respects only relevant to the developer. However some constructional information is important for monitoring. This information consists of general data about geothermal boreholes such as design, location, absolute/relative depth of boreholes and directional information, width of the pipes in the boreholes, casing program and casing depth as well as well head design.

Constructional information also includes the design parameters of power plants. Generally information about the design of geothermal power plant is not relevant to the official monitoring body. Few parameters are however relevant. Those include the type and purpose of the geothermal power plant and installed capacity as to estimate the efficiency of exploitation and exergy use.

3.5 Operational information

Operational information focuses on data that is collected during the production stages of a geothermal resource. This data focuses on describing how physical conditions in a geothermal reservoir changes with utilization. Important parameters include temperature, pressure and enthalpy changes. Geochemical analysis can also indicate changes of the physical conditions due to for example inflow of colder fluids into the reservoir. Geochemical information is therefore a vital part of geothermal operational information.

4 CURRENT STATUS OF MEM'S GEOTHERMAL DATA

In this chapter the current status of data facilities and information management at MEM are outlined. The description here does not follow strictly the conceptual classification that is outlined in chapter 3 but instead on the status of the geothermal data at MEM. This chapter is divided into seven sections, the first five focus on data, the sixth focuses on computer facilities and the seventh summarises the chapter.

4.1 Master Plan information

The compilation of a Master Plan for geothermal development in Nicaragua was carried out by GeothermEx Inc, in 1999 and 2000. It consists of 12 large volumes. Overview articles are available, for example Sanyal et. al. (2000).

The Master Plan is mostly a desk study on previously published work. However some geoscientific research was conducted as electromagnetic data was collected in four fields and fluid and rock samples were collected and analysed.

The Master Plan consists of the following for each of the study areas.

- Thematic maps in a regional scale (1:250.000) that are based on the INETER topographic maps of Nicaragua in the scale of 1:50.000. The themes are:
    - Geology
    - Tectonic setting and faults
    - Geophysics
    - Hydrogeology
    - Infrastructure
    - Environmentally protected areas
- Geochemical database dating back to 1955. As well new data that was collected for the Master Plan study.
- Production capacity of geothermal systems using the volumetric method with Monte Carlo simulation.

Some of the data that GeothermEx used in this project does not exist in the country. Negotiations with GeothermEx to get electronic copies of this data have not been successful and MEM has been putting effort into digitizing some of the Master Plan maps. One person has worked on digitizing the project but she has spent the last 6 months in Reykjavík at UNU Geothermal Training Program.

In discussion with MEM it was mentioned that the National cartographic institute INETER might have some more detailed geologic data available. An evaluation of that data is needed to see if this data is more detailed or at least comparable to the data that MEM is digitizing. Magdalena Perez is of the opinion that digitizing these maps is valuable, as this enables people to get to know the areas. The original Master Plan delivered by GeothermEx is in Spanish. This has all been typed up and translated into

English. Tabular data has also been typed up, and is therefore available electronically. Since the data already has been typed up, it needs to be structured into a searchable format.

GIS facilities

As stated in the previous section a functional and operational geographic information system is available to MEM, in the form of ESRI´s ArcGIS suite, at the ArcEditor licence level. This is currently being used to digitize map data. The maps are at large scale and the spatial accuracy of the digitization is acceptable at this scale of work. Some attributes have been attached (typed up) as the work progressed, mostly for the purpose of displaying the information on the map. Other geographic objects do not have any attributes attached. The format for this data is ESRI's shapefile, which is widely used but has many limitations. There are two coordinate systems currently being used, the WGS 84 geographic coordinate system and the NAD27 projected coordinate system. The software used is capable of converting the data between these two coordinate systems.

Geothermal potential estimates

MEM is interested in being able to redo and re-evaluate some of the volumetric assessment using Monte Carlo method. MEM therefore needs access to software that is capable of performing such analysis. As part of the Iceland-Nicaragua: Geothermal Capacity Building Project a short course on volumetric modeling will be held in the next months. The software that is available is @Risk a proprietary Excel add-in, and software developed by ÍSOR for NEA. Both options should be available to MEM.

Identified needs for Master Plan information:

- Import of tabular data into a searchable format.
- Organization of GIS database.
- Volumetric model software (for example ÍSOR software if possible otherwise buy @RISK).
- Look in INETER´s geological data in detail.

4.2 Exploration information

The concession holder hands in to MEM reports according to obligations in the concession (see chapter 2.3). Accumulation of specific information given in the reports could be useful for MEM to update for example the resource assessment of the country using resistivity surveys.

These data are the foundation of MEM's independent evaluation of exploration results. Should further exploration data be made available in other formats than reports, they would be easy to integrate into the GIS system.

Information that falls into this category is therefore mostly based on observations of MEM in their inspection of the geothermal fields and of results of work that the concession holder has submitted in a digital format.

Identified needs for exploration information:

- Structure to organize reports and other documents that is submitted by the concession holders.
- System to store data that is collected during field inspections.

4.3 Constructional information

This category of information is important but might not seem relevant for an official monitoring body. However, technical information about how geothermal resources are used is important. This information is currently not being managed in an organized manner at MEM, although examples of all the relevant information are available and collected.

Boreholes

Great interest has been shown in setting up a borehole database that is capable of reporting basic information on individual wells. The idea from MEM is to be able to use ArcGIS to do this. Then the user would be to retrieve relevant information about the borehole on a map. This is a good concept that has to be developed further. To our knowledge no standardized dataset exists about boreholes in Nicaragua like the one that exists in Iceland. It will be required to develop a geothermal borehole dataset for use at MEM. This dataset is then the basis of further work as other data, e.g. exploitation data is in many instances related to boreholes. The GIS dataset needs therefore to be related to tabular data, such as what is described in the next section.

Technical drawings

It is foreseeable that MEM needs to have access to some technical drawings of boreholes, power plants and other structures. This would be available in their native format, as pdf's or as jpg files. There needs to exist a structure to store these drawings.

Identified needs for constructional information:

- Development of a geothermal borehole dataset.
- Structure for storing technical drawings.

4.4 Production information

For the monitoring purposes of the geothermal directorate of the Nicaraguan Ministry of Energy and Mines, production information is the most important data collected from concession holders. As established in chapter 2 production data is now being collected at geothermal fields where concessions fall under the Geothermal Resources Act (San Jacinto Tizate). The relationship between MEM and the concession holder is good, and information is sent promptly to MEM at request. The information that is sent by email consists of information on steam and water flow, amount of re-injected fluid, well head pressure and chemical composition. Some of this data is collected daily and MEM gets all the data, although the concession holder is only obligated to send this data quarterly.

In the case of the Momotombo geothermal area the concession does not fall under the Geothermal Resources Act. The concession holder is therefore not legally obligated by that Act to submit data to the MEM. However some production data from Momotombo exists at MEM.

The production information that is obtained when a geothermal reservoir is being exploited varies from one area to the next. However there are some basic parameters that are always relevant. The information system will therefore have to be able to track this data with emphasis on what is stipulated in the concession.

Boreholes

MEM receives quite complete production information from concession holders of San Jacinto Tizate under the Geothermal Resources Act. For production wells those are: fluid extracted (steam/water), enthalpy, temperature and pressure logs, water level drawdown, pressure changes, locations of production zones, well head pressure, separator pressure, separator temperature, opening of the well, depth of injector head (when applicable), formation temperature (down hole temperature) and well track. For injection wells similar information is collected: fluid injected (water), well head pressure, temperature and well track.

Geothermal reservoir and power plant

Data that is collected by MEM's geothermal directorate and describes the geothermal reservoir is the following: Total mass flow extracted from the resource (monthly), total mass injected into the resource (monthly), temperature into the power plant, water level in monitoring wells (when possible), drawdown (when possible) and total geothermal water produced. In addition, results of reservoir simulations and reports on changes in the physical characteristics are submitted. Drilling reports are also submitted.

Relevant power plant parameters are also collected. Those are: design drawings, inlet pressure, inlet temperature, parasitic load, outlet pressure, outlet temperature condensing pressure and total flow of steam into the turbine.

Meta information, data that describes what the data is saying, is being collected up to certain degree, although the proper definitions and standards are not being applied. Units are clearly defined; flow (steam, water, re-injection) is measured in tn/hour, Output in MW_e, and chemical data in their relevant units.

Identified needs for production information:

- Development of a structured relational database that relates to the other data such as the borehole dataset.
- Define and structure the units used.
- Clearly define and stipulate in concession agreement what data should be turned in to MEM.

4.5 Geochemical information

Geochemical data is important to the geothermal directorate at MEM, for two reasons. Firstly geochemistry is important to characterize the potential of the geothermal reservoir as well as playing a significant role monitoring the production and physical conditions of geothermal reservoirs. Secondly the results of analysis carried out at MEM's geochemical lab.

External geochemical data

Geochemical data that would fall into this category is from all phases of geothermal development, the master plan, exploration and production phases. The variables that are being looked at here are more or less the same and the values are comparable. Sampling sites are comparable; they are either a borehole or a geothermal manifestation, manmade or natural. Similar methods are also used to analyse the data and the same variables are being looked at. Therefore both the data describing the sampling site and describing the chemical conditions of the sample need to be collected.

For the Master Plan coordinates have been obtained during the digitization of maps. However this relationship needs to be further defined. Production geochemical data is mostly obtained from locations such as boreholes, within the power plant or buildings. Locations of these should therefore be easy to obtain. For the analysis of this geochemical data, many of the parameters needs to plot against each other and against time. Currently Excel is used to store and plot this data, as well as Grapher is used to make graphs and plots from this data.

Identified needs for geochemical information:

- Structure for internal and external geochemical data.
- Geochemical database that contains the sample sites as well as results of the chemical analysis of the sample as well as methods used for sampling and analysis.
- Define and structure the units used, preferably to the SI system.

4.6 Information Systems

Computer System

In the previous sections the focus has been on what the MEM's geothermal information system includes and should include. In this section the focus is on the computer facilities that holds all this data.

Computers at MEM are not locally networked, and data is stored on individual user workstations and not on a central network. As a result the data is not secure. Backup procedures are not in place and the loss of valuable data is very likely. This also means that data is only accessible to the staff member that works on the individual workstation.

In some instances software that is being used for data analysis is outdated. Other software needs upgrading, or a new licence needs to be acquired. This is the case for the graphics software, Grapher and Surfer.

The volume of data that the geothermal directorate at MEM is working with is not excessive. The GIS data is likely to take up most hard disk space but tabular data such as the production and chemical data the volume is minimal and is counted in 10-100 MB. However this is likely to increase over the next years and an information system needs to take this into account.

Some of the data that the geothermal directorate of MEM has do deal with is confidential. Therefore it strengthens MEM's position to geothermal concession holders that are hesitant to supply MEM with data to say that the information system is secure and backed up. This is currently not the case.

Responsibility of data is sometimes in question while overall responsibility lies with the director of the geothermal department. There are tasks that can easily be delegated to other personnel at MEM. It would then be required to associate responsibility of the data management to various members of the team so that one is responsible for the Master Plan data, someone else for the production data and so on. But it is also necessary to have more than one person that can access and update all the data, so people can go on holidays or leave their positions at MEM.

Code for Geothermal Reporting

Geothermal development is in underway Nicaragua with two production concession holders currently in generation. As geothermal development progresses monitoring and storing information from the concession holder can become tedious if a structured reporting is not in place. MEM should stipulate further what information is required of the concession holder to submit in the exploitation concession as has been previously mentioned in chapter 2.4.

The code for reporting can be created using Microsoft Excel as has been conceptually visualized in Figure 2. The information reported is then imported into the database using a semiautomatic export function. With a set of functions built in the database the information can then be interpreted by for monitoring purposes and to estimate reserves and resources of the country and the basis for enlargement of an existing geothermal power plant. When it is time for the concession holder to update the information, an automatic function exports the information that exists in the database back into Excel. The concession holder can then review if the information is correct, make corrections if values have been reassessed from last submission. Other information the concession holder offers to send to MEM can of course be imported into the database but the objective of the software is to structure the reporting by the concession holder so that MEM has a set of parameters in all cases for comparison purposes.

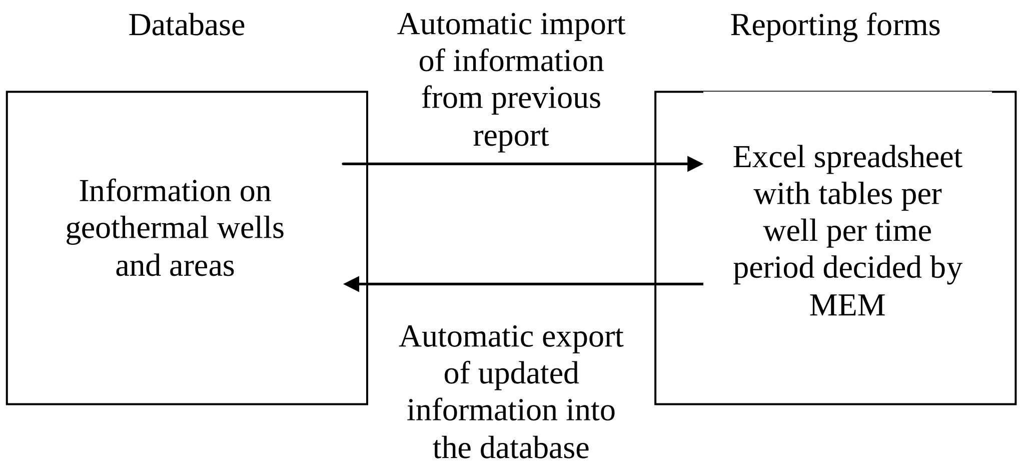

Figure *2. Conceptual visualization of the Geothermal Energy Reporting Software*

Information system needs

- Set up a central server for the geothermal directorate what can run a modern relational database system and that is backed up regularly
- Get licensed copies of data analysis software (Grapher, Surfer)
- Training of staff to be able to use the information system
- Define the software for geothermal energy reporting and develop a prototype
- Document everything in detail

4.7 Overview of the identified needs

In the previous sections each of the identified categories of geothermal data that is available has been discussed and needs for improvements identified. In this section an overview is given of the identified needs.

Master Plan information needs

- Import of tabular data into a searchable format.
- Organization of GIS database.
- Volumetric model software (i.e. ÍSOR software if possible otherwise buy @RISK).
- Look in INETER´s geological data in detail.

Exploration information needs

- Structure to organize reports and other documents that is submitted by the concession holders.
- System to store data that is collected during field inspections.

Constructional information needs

- Development of a geothermal borehole dataset.
- Structure for storing technical drawings.

Production information needs

- Development of a structured database that relates to the other data such as the borehole dataset.
- Define and structure the units used.
- Clearly define and stipulate in concession agreement what data should be turned in to MEM.

Geochemical information needs

- Separate structure for internal and external geochemical data.
- Geochemical database that contains the sample sites as well as results of the chemical analysis of the sample.
- Define and structure the units used, preferably to the SI system.

Information system needs

- Set up a central server for the geothermal directorate what can run a modern relational database system and that is backed up regularly.
- Get licensed copies of data analysis software (Grapher, Surfer).
- Training of staff to be able to use the information system.
- Define the software for geothermal energy reporting and develop a prototype.
- Detailed documentation.

5 CONCLUSION AND RECOMMENDATIONS

The aim of this report is to analyse the current status of geothermal data and information management at Ministry of Energy and Mines (MEM) and propose improvements. In this report the current information environment at the geothermal directorate of the MEM is described and the relevant needs for improvements outlined. One of the objectives of the needs-assessment was to answer five fundamental questions concerning information systems. The following are answers to these questions:

1. **What is the objective and legal framework for data collection?**

   The objective of official geothermal data collection is to enable MEM to evaluate geothermal resources in Nicaragua, based on relevant available data. The objective of official resource monitoring is to ensure that the most efficient exploitation of the resource is withheld in the long run and that extraction of geothermal fluid does not exceed levels deemed necessary. The MEM is obligated by law to collect data on the natural state of geothermal resources of the country and monitor the response to exploitation and the efficiency of the production. MEM is also required in exploration concessions and law to monitor how geothermal resources are explored and utilized. Therefore the Ministry needs to collect data from the field, request data from concession holders and make independent assessment as to fulfil its official monitoring role in Nicaragua.

2. **What is the current status of MEM´s data?**

   Currently no formal information gathering and management system is in place. This means that data is currently stored on individual workstations where data is not properly backed up and security of information is not acceptable. The analysis carried out by MEM personnel is carried out using software that is not up-to-date and the status of licences can be questioned. Therefore improvements are needed.

3. **How should data be collected and managed in the long term?**

   In the long term the current status of data is not acceptable, for various reasons including security. Development of an information management system is therefore important, before data will get lost for example because of termination of employment of some key personnel or computer malfunction. The following are a few examples of how the data could be collected and managed in the long term:

   1. In the exploitation concession, include a list of information required by the concession holder to hand in to MEM. Create a reporting software that is interactive with the database and incorporates the above list of information.
   2. Install network computers to a local network with a high level of security and backup.
   3. Develop a relational database system for secure storing of e.g. geochemical data and production data.
   4. Organize GIS data and link GIS to database.
   5. Analysis and interpretation of information carried out by the use of relevant software like Grapher and Surfer and volumetric model software like ÍSOR has developed or equivalent.

4. **How can data collection procedures and data management facilities at MEM be improved?**

The approach suggested involves collaboration between ISOR's information technology department, the geothermal directorate at MEM and MEM's internal information technology department. This is because the technical staff at MEM needs to understand the structure and organization of the information system, and understand what data is stored within it. The information system also needs to be flexible. If people have taken part in developing the system they are more likely to make the changes that they feel needed. The objective of development of the information system is firstly to store geothermal information in an oraganized manner, and secondly to provide training for MEM personnel in the use of databases, information management and GIS. The following tasks have been identified as to facilitate MEM in being able to collect and manage the data:

Task 1 - *Purchase of hardware*

This task would include purchase of a server that will then be used to hold central data storage on a file system, as well as a relational database. Install of the software would be the responsibility of MEM's IT department.

Task 2 - *Purchase of software*

This task would include the purchase of the needed software for the server as well as getting licences for the software that is currently in use.

Task 3 - *Training and development of database*

In this task the database would be developed in cooperation between IT specialists from ÍSOR and MEM's people. This would serve two purposes, both the development of the database training of staff so that they will be able to expand the system without external assistance.

5. **How much do improvements cost?**

The improvements suggested in this report are twofold. Firstly it is the cost of obtaining a central computer, a server and the acquirement of software licences. Secondly it is the work to be carried out in collaboration between ÍSOR and the MEM´s geothermal directorate. A preliminary budget and a timetable for this work are shown in tables 1 and 2 respectively (next page).

***Table 1**. Budget for the proposed work*

Tasks	units	Costs (ikr)	Other costs (USD)	Comments
1. Server and installation				
1.1 Decision on hardware (hrs)	8	66.763	534	
1.2 Purches of hardware			7.200	
1.3 Install				MEM IT
Total for task 1	**8**		**7.734**	
2. Software				
2.1 Operating system for server (Windows Server 2009)	1		1.345	
2.2 Relational database system	1		4.000	
2.3 @Risk software	1		1.400	
2.4 Grapher	1		350	
2.5 Surfer	1		699	
2.6 ÍSOR volumetric software	1		0	
Total for task 2			**7.794**	
3. Training and development of database				
3.1 Remote technical assistance	80	667.632	5.341	
3.2 Preliminary database development and training preparation	80	667.632	5.341	
3.3. Database development (onsite 2 persons 1 weeks)				
3.3.1 Table and relationship development (work)	40	333.816	2.671	objective: production data, chemical data & well information
3.3.2 Data input/output formats	40	333.816	2.671	
3.5 Technical assitance with ArcGIS (onsite 1 person 1 week)				
3.5.1 Organizing GIS data	20	166.908	1.335	
3.5.2 Relationship between GIS and database	20	166.908	1.335	
3.3 and 3.5 on site work travel cost				
3.3 and 3.5 per diem 1 week (days)	8	363.200	2.906	
3.3 and 3.5 per diem 2 weeks (days)	15	654.400	5.235	
3.3 and 3.5 airfare (two round trips)	2	300.000	2.400	
Total for task 3		**3.654.312**	**29.234**	
Total cost			**44.763**	

***Table 2**. Work schedule in year 2010.*

	2010														
Tasks	Jan				feb				March				April		
	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3
1. Server and installation															
1.1 Decision on hardware															
1.2 Purches of hardware															
1.3 Install															
3. Training and development of database															
3.1 Remote technical assistance															
3.2 Preliminary database development and training preparation															
3.3. Database development (onsite 2 persons 1 week)															
3.3.1 Table and relationship development															
3.3.2 Data input/output formats															
3.4 Data entry															
3.5 Technical assitance with ArcGIS (onsite)															
3.5.1 Organizing GIS data															
3.5.2 Relationship between GIS and database															

REFERENCES

Einarsson G.M. and Hauksdóttir S. (in press) GeoInformation in Geothermal Development, Submitted to WGC 2010.

Geothermal Master Plan for Nicaragua. English pdf version.

Sanyal, S.K, Granados E.E., Henneberger R.C., Klein C.W., Velásquez L. and Zúñiga A, (2000). Development of a geothermal masterplan for Nicaragua Proceedings World Geothermal Congress 2000, Kyushu - Tohoku, Japan, May 28 - June 10, 2000

Steinsdóttir, G., Kristjánsson, S. and Ketilsson J. (2009) Public monitoring of geothermal utilization: lessons learned in Iceland considered for geothermal development in Nicaragua. Orkustofnun. Rep. no. OS-2009/006. Reykjavik.