

Application of Database in Monitoring the Performance of Geothermal Steam Fields and Power Plants in the Philippines

Ariel D. Fronda

Geothermal and Coal Resources Development Division, Energy Resource Development Bureau

Department of Energy, Energy Center, Merritt Road, Fort Bonifacio, Taguig, Metro Manila, Philippines

adfronda@yahoo.com

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ABSTRACT

Data is vital for the efficient development and management of geothermal resources. The Philippines with an installed capacity of 1,930.89 MWe and still with a great potential for geothermal exploration and development will generate an increasing volume of data. A computerized geothermal database was designed and developed for the storage, retrieval and manipulation of the collected data. The database will be used and applied by the Philippine Department of Energy (DOE) in monitoring the performance of geothermal steam fields and power plants to avoid over exploitation and assure sustainable geothermal resource management.

Well information, reservoir monitoring parameters, drilling information and power plant generation are the essential data considered for the database development using the Oracle Relational Database Management System (RDBMS). Oracle Developer tools and other related computer software were also utilized to provide the fast, simple and easy data input, editing, viewing, reporting and graphing.

1. INTRODUCTION

The Philippine Department of Energy (DOE) is a government agency mandated among others, to administer the programs for exploration, development, transportation, marketing and appropriate management of energy resources in all forms, which includes geothermal energy. It regulates and exercises full supervision and control over all government and private energy-related projects to ensure proper exploitation, utilization and sustainable development of the country's indigenous resources.

The Geothermal and Coal Resources Development Division (GCRDD), which is under the Energy Resource Development Bureau of DOE, is mandated among others, to oversee, monitor and regulate geothermal operations undertaken by both private and government entities to ensure strict compliance to the policies and standards of the government (Requejo, 1996; Salvania, 1995).

The Philippines remains to be the second largest producer of geothermal energy for electricity generation. As of December 2003, an installed capacity of 1,930.89 MWe in six geothermal production fields (Figure 1) has been reached in 30 years of geothermal exploration, development and utilization. This is only 43% of the 4,537 MWe total geothermal resource potential of the country.

Along with development and continuous exploitation of geothermal resources to attain energy self-reliance, large

volume of data on geothermal energy is being produced and accumulated. Hence, the GCRDD of the DOE should develop a computerized database that will efficiently store, retrieve and manipulate geothermal information.

This paper discusses the development of a geothermal database as a project for the UNU Geothermal Training Program in Iceland. This database can be used as a tool by the DOE in monitoring and supervising the exploration and development of geothermal energy resources. Geothermal steam fields and power plants performance should be closely monitored to avoid over-exploitation of the geothermal resource.

2. DATABASE DEVELOPMENT

2.1 Data Collection

For DOE to fully accomplish its mandated function, it requires submission of report and information in paper from the geothermal steam field developers and power plant operators regarding their operations. These includes the following:

- Production and injection report that contain data from wells in production or injection which give information on mass flow rate, steam flow rate, water (brine) flow rate and injection rate of each well (Figure 2)
- Report on well test activities and downhole measurements (pressure and temperature) conducted
- Mass and heat extraction and injection report
- Report on power generation of the power plants

These data are evaluated, analyzed and used for a separate report that DOE is preparing for monitoring. Eventually, the submitted reports are compiled in a manual filing system.

This is the procedure on how DOE handles data. However, based from the experience, if these data are not properly kept or managed, misplacement or even lost of these paper reports may happen because of natural human mistakes. This inefficiency is inherent from a manual filing system. This is basically the reason why the author recognizes the importance of developing a computerized database and avoids the effects of the manual filing system.

2.2 Database design

The concentration of the database design is on the aspects of geothermal reservoir and resource management. In order to design a reliable and accurate computerized database on this specialized subject, it is an advantage for the designer to have an ample knowledge on geothermal reservoir

engineering and a very good experience on designing databases. Although the author has little exposure on geothermal reservoir engineering and database designing, the experts of Orkustofnun, the National Energy Authority of Iceland through this geothermal training programme, imparted the required knowledge and experience.

To start with, a database is a structured collection of data. Data in this design refers to the information gathered from paper reports submitted to DOE. Then, an Oracle Relational Database Management System (RDBMS) was considered in this project to provide the structure and mechanism to process the available data. This RDBMS allows access to the stored data to be retrieved and

manipulated according to the specific need of the users for an intended application (Ensor and Stevenson, 1997).

The database developed in this project is made up of tables. Information that describe or illustrate a certain subject were combined and stored in a table. Each table is composed of rows (horizontal) and columns (vertical). Rows are made up of records (Ellison, 1989). Each record contains a data value at the intersection of a row and a column. Different tables were created for the various sets of information. Grouping of information to form a table is considered as a basic requirement for RDBMS but needs careful study, analysis and know how of the business process, in this case, this refers to familiarity with geothermal operations.

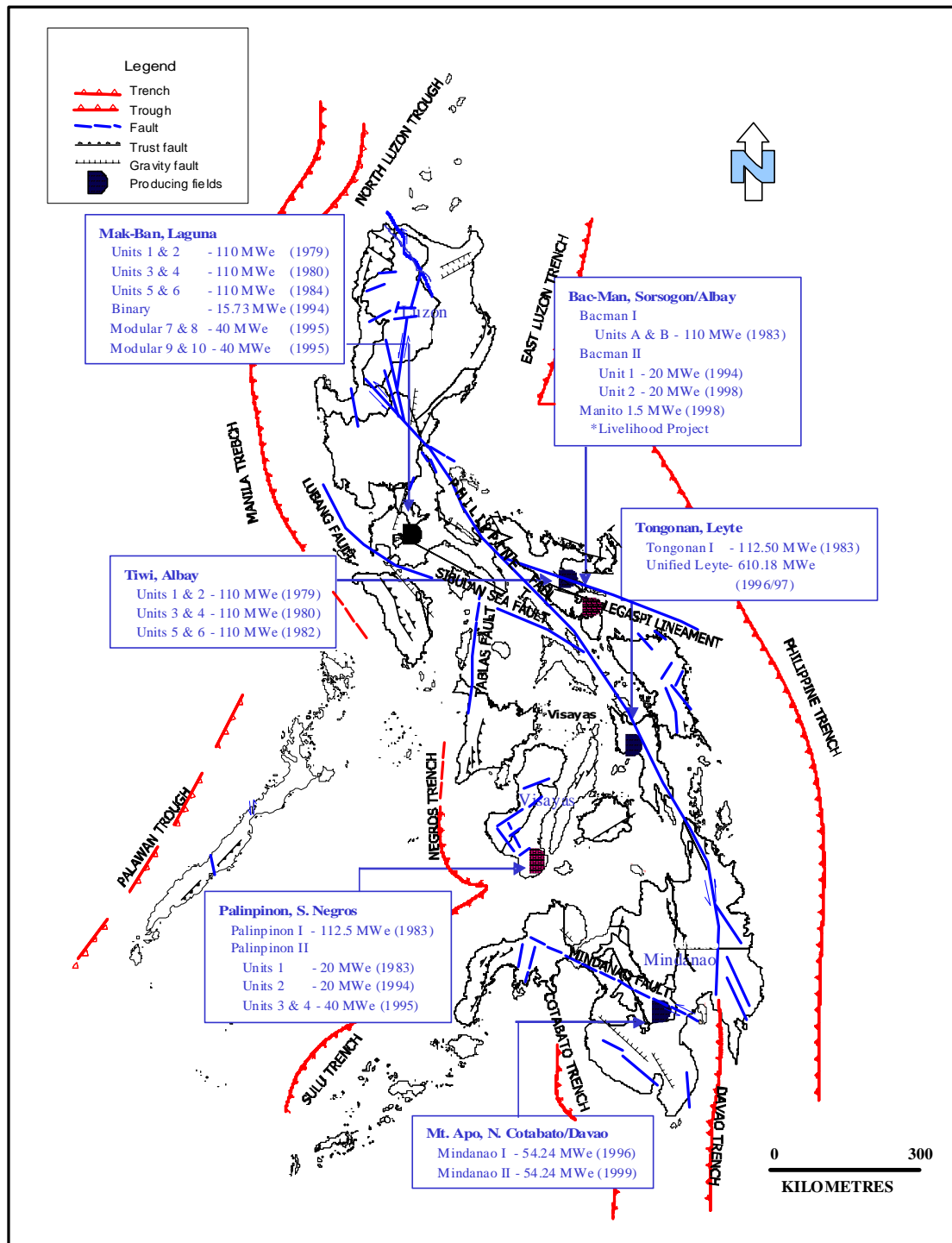


Figure 1: Map of the Philippines with the located of the six geothermal production fields

MONTHLY OPERATION					LAST ENTHALPY TEST					AVERAGE PROD/INJ RATE					CUMULATIVE PROD/INJ					LAST ACTIVITY		
Well Name	Well Type	WS/ SS	Prod Hrs	Inj Hrs	Date	WHP psig	Steam kph	Brine kph	Mass kph	Enth Btu/lb	FWHP	IWHP	Steam kph	Brine kph	Mass kph	Inj kph	Steam Mlb	Brine Mlb	Mass Mlb	Inject Mlb	Last Activity	Date
BUL53	PROD	SS03	720		10-08-02	145	74	69	143	778	151		79	74	153		18654	17528	36182		FLOW START	11-15-02
BUL54	IDLE				09-02-81	195	98	539	637	471										53849		
BUL55	PROD	SS03			09-17-02	143	52	64	116	720							8863	10849	19712		SHUT-IN	11-04-02
BUL56	ABDN	NBSP			04-16-88	192	118	163	281	699							6366	8838	15204		SHUT-IN	09-15-89
BUL57	INJ																			12425		
BUL58	IDLE				11-06-92	44	19	140	159	364							128	920	1048	49524	SHUT-IN	11-27-92
BUL59	PROD	SS05			09-17-02	145	55	6	61	1109							13139	9584	22723		SHUT-IN	11-05-02
BUL60	PROD	SS02	720		12-17-02	179	128		128	1199	155		131		131		32566	12003	44569		FLOW START	04-26-02
BUL61	ABDN	NBSP			11-25-85	142	71	78	149	741							251	352	603	20	SHUT-IN	08-22-88
BUL62	PROD	SS06			04-15-00	153	5		5	1195							6392	6907	13299		SHUT-IN	07-07-00
BUL63	ABDN																					
BUL64	PROD	SS02			08-15-02	131	31		31	1196							17666	746	18412		SHUT-IN	10-09-02
BUL65	PROD	SS02			10-23-02	165	154	82	236	900							22236	12216	34452		SHUT-IN	11-18-02
BUL66	PROD	SS07			09-04-02	130	120	453	573	506							9535	37046	46581		SHUT-IN	11-04-02
BUL67	PROD	SS07			09-19-02	129	131	87	218	846							13343	9848	23191		SHUT-IN	11-04-02
BUL68	ABDN																			13722		
BUL69	INJ																			44198		
BUL70	PROD	SS04	720		07-05-02	166	108	111	219	765	345		15	14	29		13594	12204	25798	16	FLOW START	03-19-02
BUL71	PROD	SS02			08-06-02	160	86	178	264	619							17630	13190	30820		SHUT-IN	11-19-02
BUL72	PROD	SS06	720		10-21-02	174	113	48	161	946	165		102	126	228		14407	13468	27875		FLOW START	05-08-02
BUL73	INJ			720								65								347		
BUL74	PROD	SS05			07-22-02	154	58	51	109	794							8871	6300	15171		SHUT-IN	10-29-02
BUL75	INJ			720								113								355		
BUL76	PROD	SS01	720		10-25-02	178	155	120	275	826	185		136	112	248		8478	25165	33643	30	FLOW START	08-24-01
BUL77	INJ			78								88								323		
BUL78	INJ			720								95								676		
BUL79	PROD	SS05			05-14-02	143	22		22	1188							8606	3226	11832		SHUT-IN	10-29-02
BUL80	PROD	SS06	720		10-24-02	182	87	150	237	665	172		90	151	241		13292	9420	22712		FLOW START	10-04-01
BUL81	INJ			720								63								106		

Figure 2: Production and injection report

2.2.1 Data modelling

Analyzing DOE's requirements in performing its functions was the first thing that was done in the database design. From this, grouping of information that formed the tables were identified. Below is the brief description of the tables that were created:

Well table describes the characteristics of each geothermal well. It contains information about the type of the well drilled in a specific location of a geothermal steam field.

Field table gives information about a producing geothermal steam field in the Philippines. It indicates the location, coverage area of the steam field, field's installed capacity and the date when the service contract was awarded for the development of the field.

Company table gives information about the company that manages the development of a steam field or the operation of a power plant.

Prod_Inj table stores data that are being monitored by DOE. These are the wellhead pressure, enthalpy, steam flow rate, water flow rate, mass flow rate, injection rate, heat extraction and heat injection of production and injection wells.

Log table describes the log conducted to a well. Hence, the type of log and the tool used in the log are the information in this table.

Tdata table stores the values obtained from the log according to the date and time that the log was performed.

Ddata table stores the values gathered from the log according to the measured depths that a log was performed.

Drilling table provides information about a drilling activity and the drilling rig used. It has the dates when drilling was started and ended as well as the starting and ending depth.

Drillact table stores the information about the status of a drilling activity such as drilling of a new well or work-over on a well in a certain period and the drilling rig used. This will be used for monitoring the progress of a drilling activity according to the schedule of the well's drilling programme.

Comptest test refers to the result of a completion test conducted to a well after drilling. These are important data used in reservoir modelling. Injectivity index, maximum wellhead pressure, permeability-thickness and the measured depth of circulation losses are the available information.

Casing table holds the description of the casing installed in a well. The type of casing, cement, type of pipe with its diameter, connection and the length of casing are the information in this table.

Rig table gives the specifications of the rigs used to drill wells.

Powerplant table gives the names of the geothermal power plants in the Philippines with the installed capacity and their corresponding turbine-generator unit capacity.

Plantspecs table provides the information about the technical specifications of the facilities of the power plant such as the turbine, generator, condenser, cooling tower and pumps.

Generation table keeps and stores the electricity generation data of the each power plant. This table is used for the geothermal sector reports of DOE that is open for public information.

Oilprice table has the average fuel oil price per month that is needed in the computation of the saving derived from utilizing geothermal energy instead of fuel oil.

These tables were used for the construction of the data models. The purpose of data modelling is to develop graphical representation of the structure of the database design. Two data models were organized, first is the structure of a database for monitoring the steam field performance which is composed of the WELL, FIELD, COMPANY, PROD_INJ, LOG, TDATA, DDATA, DRILLING, COMPTTEST, CASING, and RIG tables (Figure 5), while the second data model comprises POWERPLANT, PLANTSPECS, GENERATION and OILPRICE tables (Figure 6). The idea of making two data models is that, DOE at present, receives and gives information in two separate ways because geothermal energy development in the Philippines is divided and managed also into two entities, the steam field developers and the power plant operators. The name given to each tables is the main subject that the fields pertains. The column names given are the specific categories of information that the table contains and the records are the data relating to the column.

In Figures 3 and 4, table names are in bold capital letters while the primary key(s) are in bold italics. Primary key(s) were selected to uniquely define the occurrence of each record. Choosing a primary key (s) is important because the relationships in the database rely on it. Information from related tables can be retrieved through the primary key(s). It allows the user and the database system to identify, locate and refer to one particular record in the table. Tables that show relationship between each other are connected by arrows.

2.2.2 Creation of tables

In the creation of the tables, Structured Query Language (SQL*Plus) was used. It is a standard relational language for database access and manipulation. The language consists of statements or commands to insert, update, delete, query and protect data (Van Der Lans, 1988).

2.2.3 Data input, loading and manipulation

Entering rows of data for the tables created were done in several ways. First is using the insert command. The second way is using the SQL* Loader. This is advisable for entering large volumes of data from external files in a variety of formats such as data in spreadsheets. The SQL* Loader performs filtering by selectively loading records based on the data values and can load multiple tables simultaneously (Moran and Dimmick, 1987). The production and injection report submitted to DOE is an example of this, because the information here are the mass flow rate, steam flow rate and water flow rate of each production well, and the injection flow rate of each injection well of a geothermal steam field. Likewise, the Awk programming language in the Unix system was also used to make the loading of data fast and easy. Awk makes data manipulation simple by scanning the input files and splits each input file into columns automatically with very short programs (Aho et al., 1988). This is a convenient way of data input and manipulation considering that DOE monitors six geothermal production fields in the Philippines.

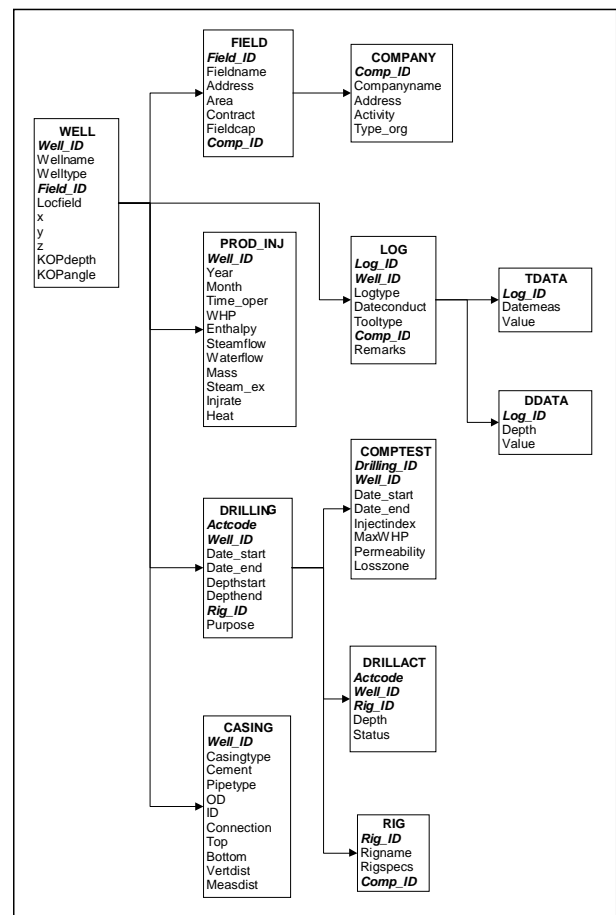


Figure 3: Steam field data model

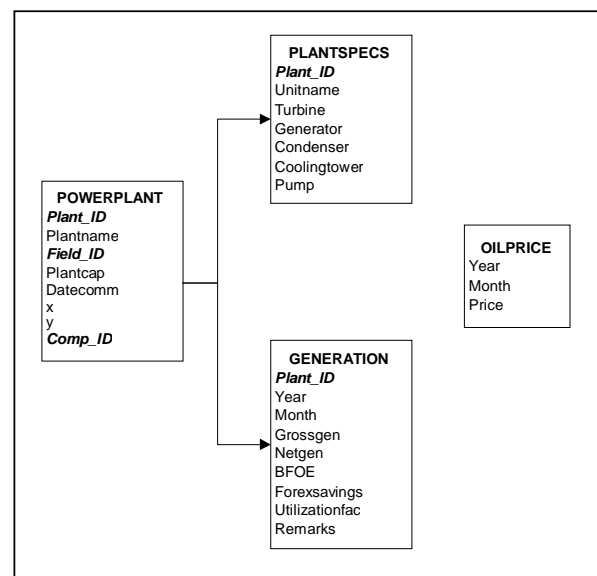


Figure 4: Power plant data model

3. APPLICATION OF DATABASE IN MONITORING GEOTHERMAL STEAM FIELD AND POWER PLANT PERFORMANCE

The database developed in this project is not only in fulfillment of the requirement to complete the UNU Geothermal Training Programme, but the foremost purpose is the application of this database in DOE's function to monitor the management and operation of the geothermal fields and power plants in the Philippines.

The importance of database can only be felt and realized, if besides from storage and retrieval of valuable information, can also be used in various applications to give meaning to the data inside the database. The Oracle Developer softwares are powerful tools that provide the appropriate database applications that the users require. The author tries to present how the Oracle Developer Forms, Reports and the Graphical output with the aid of the Gnuplot software are used in the monitoring responsibility of DOE.

3.1 Data forms

The Forms Builder is an Oracle Developer tool that enables the end users to retrieve, view, enter, modify and save information in the database directly into the created on-screen forms. Several data forms were designed in this project to show how this tool can be applied for monitoring geothermal steam fields and power plants operations. All data forms were created through the Form Builder Data Block Wizard. This wizard allows the quick and easy creation of data blocks based on tables, views or a set of stored procedures (Chu and Lim, 1994). The three essential parts of the Forms Builder are the following:

- Layout Editor that shows the on-screen view of the design form

Object Navigator that describes the content of the design form such as the data blocks, items and triggers, etc. and

- Property Palette for making the adjustments or changes in the physical properties of the design form.

A data form for the inventory of wells in a specific geothermal steam field as shown in Figure 5 is composed of

three data blocks from FIELD, COMPANY and WELL tables. Relationships among these data blocks were created based on join conditions. Similar columns from different tables satisfy the join condition. Usually, the primary key(s) of the tables (Figures 3 and 4) are chosen for the join condition. The form for the inventory of wells can be used to view all the wells drilled in a selected geothermal steam field with their corresponding location in the field. Additional wells that will be drilled can be entered into the form directly simply by typing the necessary information on the empty box after the last record.

A data form for the production and injection rate of each well in a specific geothermal field is shown in Figure 6. The design of this form is composed of FIELD, WELL and PROD_INJ tables that enable the user or viewer to easily compare the performance of a well in each month. This is a good application of the database to monitor the steam field performance through the sudden change or big difference of all the well's production or injection rates. Input of new record for the succeeding months can be done on the next empty record.

A log information and log result conducted in a well is shown in data form Figure 7. Data blocks are consisted of the FIELD, WELL, LOG, TDATA and DDATA tables. Data from this form will be used in plotting temperature and pressure profiles of wells with respect to time or depth.

Figure 8 shows a data form for that gives the drilling information and the status of a drilling activity in a well. The design of this form, which include the FIELD, WELL, DRILLING and DRILLACT tables, will be used for monitoring the progress of a drilling activity as compared with the drilling programme.

The screenshot shows an Oracle Developer Form window titled 'WINDOW1'. It contains three data blocks:

- GEOTHERMAL FIELD**: A table with 2 records.

Field Id	Field Name	Capacity	Comp Id
1	Tongonan	722.68	10
2	Mak-Ban	425.73	20
- COMPANY**: A form with three fields:
 - Comp Id: 20
 - Company: Philippine Geothermal, Inc.
 - Activity: Steam field developer
- WELL**: A table with 10 records.

Well Id	Wellname	Welltype	Field Id	Locfield	X	Y	Z
9760	BUL01	PROD	2	SS01	523562	1559560	987
9780	BUL02	IDLE	2	NBSP	524082	1560350	926
9800	BUL03A	PROD	2	SS01	523228	1559950	1032
9820	BUL04	PROD	2	SS03	522668	1558670	786
9840	BUL05	IDLE	2	SS01	522696	1560510	1291
9860	BUL06	PROD	2	SS02	523036	1559520	863
9880	BUL07	PROD	2	SS01	523720	1560000	997
9900	BUL08	PROD	2	SS03	523012	1559000	825
9920	BUL09	PROD	2	SS01	523198	1560460	1141
9940	BUL10	PROD	2	SS03	523440	1558780	832

At the bottom, there is a status bar showing 'Record: 2/?' and an 'Insert' button. The Windows taskbar at the very bottom shows the 'start' button, several icons, and the system clock '18:05'.

Figure 5: Form for the inventory of wells

WINDOW1

Action Edit Query Block Record Field Help

GEOTHERMAL FIELD

Field Id	Fieldname	Fieldcap	Comp Id
1	Tongonan	722.68	10
2	Mak-Ban	425.73	20

WELL

Well Id	Wellname	Welltype	Field Id	Locfield
9900	BUL08	PROD	2	SS03
9920	BUL09	PROD	2	SS01
9940	BUL10	PROD	2	SS03

PRODUCTION + INJECTION

Well Id	Year	Month	Whp	Enthalpy	Steamflow	Waterflow	Mass	Injrate
9940	2002	1	140	815	109	87	196	0
9940	2002	2	140	815	109	88	197	0
9940	2002	3	140	815	108	87	195	0
9940	2002	4	160	773	118	94	212	0
9940	2002	5	160	773	122	113	235	0
9940	2002	6	160	773	125	120	245	0
9940	2002	7	160	773	137	132	269	0
9940	2002	8	160	773	145	140	285	0
9940	2002	9	159	844	145	141	286	0
9940	2002	10	159	844	152	117	269	0
9940	2002	11	159	844	154	107	261	0
9940	2002	12	159	844	154	107	261	0

Record: 10/? Insert

start Stokkur Object Navigator IWellPROD: CANVAS... WINDOW1 18:11

Figure 6: Form for the production and injection rate of each well

WINDOW1

Action Edit Query Block Record Field Help

GEOTHERMAL FIELD

Field Id	Fieldname	Fieldcap	Comp Id
2	Mak-Ban	425.73	20

WELL

Well Id	Wellname	Welltype	Field Id	Locfield	X	Y	Z
9760	BUL01	PROD	2	SS01	523562	1559560	987

DRILLING INFORMATION

Actcode	Well Id	Date Start	Date End	Depthstart	Depthend	Rig Id	Remarks
1	9760	2003-07-01	2003-08-30	0	2631	10	Drilling of new well

STATUS OF DRILLING ACTIVITY

Actcode	Well Id	Rig Id	Statdate	Depth	Status
1	9760	10	2003-07-01	0	Rig mobilization
1	9760	10	2003-07-10	0	Start of drilling 24" hole
1	9760	10	2003-07-20	300	Set 18 5/8" casing
1	9760	10	2003-07-30	600	Set 13 3/8" casing
1	9760	10	2003-08-10	900	Drilling of 12 1/4" hole
1	9760	10	2003-08-20	1500	Set 9 5/8" slotted liner
1	9760	10	2003-08-30	2631	Drilling completed

Record: 2/? Insert

start Stokkur Object Navigator Property Palette DRILLING: CAN... WINDOW1 17:48

Figure 7: Form for the log information and log result conducted in a well

WINDOW1

Action Edit Query Block Record Field Help

POWER PLANT GENERATION BY MONTH

Plant Id	Year	Month	Grossgen
100	2002	1	61309
100	2002	2	51841
100	2002	3	49309
100	2002	4	71750
100	2002	5	70203
100	2002	6	70506.9
100	2002	7	64591.6
100	2002	8	62635.1
100	2002	9	49842.57
100	2002	10	40515.3
100	2002	11	48967.2
100	2002	12	54570.5
			696041.17

POWER PLANT GENERATION BY YEAR

Plant Id	Plantname	Year	Sum
100	Tongonan I	2001	672,649.98
100	Tongonan I	2002	696,041.17
110	Unified Leyte	2001	4,392,050.19
110	Unified Leyte	2002	4,285,059.86
200	Mak-Ban	2001	1,665,273.38
200	Mak-Ban	2002	1,483,550.34

Record: 1/?

start | Strokkur | Object Navigator | GENYEAR: CAN... | Property Palette | WINDOW1 | 18:36

Figure 8: Form for the drilling information and status of drilling activity

WINDOW1

Action Edit Query Block Record Field Help

GEOHERMAL FIELD

Field Id	Fieldname	Fieldcap	Comp Id
2	Mak-Ban	425.73	20

WELL

Well Id	Wellname	Welltype	Field Id	Locfield
9760	BUL01	PROD	2	SS01

LOG INFORMATION

Log Id	Well Id	Logtype	Dateconduct	Tooltype	Comp Id	Remarks
67	9760	TEMPERATURE	1989-11-06	KUSTER TEMPERATURE	20	Scheduled for logging
68	9760	TEMEPERATURE	1989-11-06	KUSTER TEMPERATURE	20	Scheduled for logging

TEMPERATURE WITH TIME

Log Id	Datemeas	Value
67	1989-11-06	40
67	1989-11-06	278
67	1989-11-06	280
67	1989-11-06	280
67	1989-11-06	281
67	1989-11-06	281
67	1989-11-06	284
67	1989-11-06	287
67	1989-11-06	289
67	1989-11-06	291
67	1989-11-06	293
67	1989-11-06	293

TEMPERATURE WITH DEPTH

Log Id	Depth	Value
68	0	40
68	152	278
68	305	280
68	457	280
68	609	281
68	762	281
68	914	284
68	1067	287
68	1219	289
68	1372	291
68	1524	293
68	1677	293

Record: 12/12

start | Project ... | Yahoo! ... | Strokkur | Strokkur | Object ... | LOG: C... | WINDO... | 14:42

Figure 9: Form for the geothermal power plants generation with computation

**PHILIPPINE GEOTHERMAL
POWER PLANTS HIGHLIGHTS**

POWER PLANT	INSTALLED CAPACITY (MWe)	GENERATION for 2002 (MWh)	GENERATION for 2001 (MWh)	UTILIZATION FACTOR for 2002 (%)	UTILIZATION FACTOR for 2001 (%)
Bacman I	110.00	28,910.88	0.00	36.50	0.00
Bacman II	40.00	13,340.48	26,659.80	46.32	92.57
Mak- Ban	330.00	81,250.35	142,674.87	34.20	60.05
Mak- Ban Binary	15.73	1,710.00	3,741.12	15.10	33.03
Mak- Ban Modular	80.00	30,492.00	40,538.90	52.94	70.38
Manito Lowland	1.50	0.00	0.00	0.00	0.00
Mindanao I	54.24	34,687.86	22,850.53	88.82	58.51
Mindanao II	54.24	34,490.33	36,992.18	88.32	94.72
Palinpinon I	112.50	63,948.80	63,640.80	78.95	78.57
Palinpinon II	80.00	49,062.17	54,196.90	85.18	94.09
Tiwi	330.00	64,854.20	19,218.60	27.30	8.09
Tongonan I	112.50	54,570.50	56,722.00	67.37	70.03
Unified Leyte	610.18	361,258.64	377,857.92	82.23	86.01
TOTAL	1930.89	818,576.21	845,093.62		
AVERAGE:				54.09	57.39

Figure 10: Report on the Philippine geothermal power plants highlights

Data on power generation of the geothermal power plants is shown on the data form Figure 9. Comprising the form are data blocks from POWERPLANT, COMPANY and GENERATION tables. The design of the form provides a clear picture of the each power plant's generation every month, which is a good application of monitoring the performance of the power plant. A big decrease in generation in a certain month can easily be noticed in which DOE should know the reason for such change.

The capability of utilizing the form for simple computations is illustrated in Figure 9. The first data block that comes from the GENERATION table shows the monthly generation of a selected power plant. Then, a new data block was created for the computation of the sum of the generation through a post-query trigger using a PL/SQL command. On the other hand, the third data block shows the sum of the generation of certain power plants in chosen years. It was created from ALL_GENERATION view having the columns Plant_ID, Plantname, Year and Sum. This form is designed to easily view and compare the generation of a power plant in two succeeding years. Performance of the power plants can therefore be quickly assessed.

3.2 Report Layout

Organizing reports about the situation of the Philippine geothermal sector is one of the main tasks of DOE. These reports are usually provided for public information. A sample report layout was constructed using the Oracle Developer Report Builder software. This is a database application tool for building standard and customized reports from a simple tabular to complex matrix report styles readily accessible for a better view as compared with the forms.

The report "Philippine geothermal power plants highlights" presented in Figure 10 was created using the Report Wizard of the Report Builder. The wizard follows a systematic procedure but requires knowledge of the SQL commands.

Adjustments or changes of the design report are also done in the Report Editor, Object Navigator and Property Palette of the Report Builder. The columns of the said report are chosen from ALL_GENERATION view. The format of the report gives the electricity generation of the power plants with their corresponding computed utilization factor as compared with the previous year's performance. Usually, low generation, which is equal to low utilization factor, indicates problems in the facilities of the power plant.

3.3 Graphical Output

Graphical output is the third application of the database undertaken in this project. For the purpose of monitoring the steam fields, graphing the wellhead pressure, enthalpy and mass flow rate of individual wells are some of the parameters being determined. This will provide information on the well performance such as decline in production which may require decision of improving the well. The graphs are created in two command files, the SQL commands and the Gnuplot commands. The SQL commands import the data from the database and the Gnuplot commands draw the data into X-Y graph (Williams, 1993).

The graph of mass flow rate with time (Figure 11) of a well has a constant production rate but might demonstrate decline in the future due to mineral deposition. Graph of wellhead pressure with time (Figure 12) is also used to accompany an evaluation of well performance. A drop of the wellhead pressure at the same wellhead opening is also a result of well blockages. Work-over of wells are usually

the solution to this problem that includes mechanical drilling out of blockages and/or acid treatment.

Figure 13 shows a graph of enthalpy with time, which is another requirement for sound judgments in improving a well's production. Increase in discharge enthalpy with a decrease in mass flow but without change in steam flow (Figure 14) is possibly caused by reservoir pressure drawdown. On the other hand, decline in enthalpy perhaps is associated with reservoir cooling induced by inflow of natural recharge or injection returns (Sarmiento, 2000). Assessment of the production and injection strategies is mostly suggested in making the necessary resource

management changes. Whatever actions and decisions the steam field developers will carry out, it is an obligatory that DOE has to be informed.

Temperature decline normally accompanies decline in enthalpy. Shifting in production or injection strategies is usually adopted to address the declines in temperature and enthalpy. Typically, increasing enthalpies would indicate drawdown resulting in expanding two-phase horizons and declining water levels in the well. This increase could result in higher steam flow, which could meet or even surpass the steam requirement for the power plant (Malate, 2003).

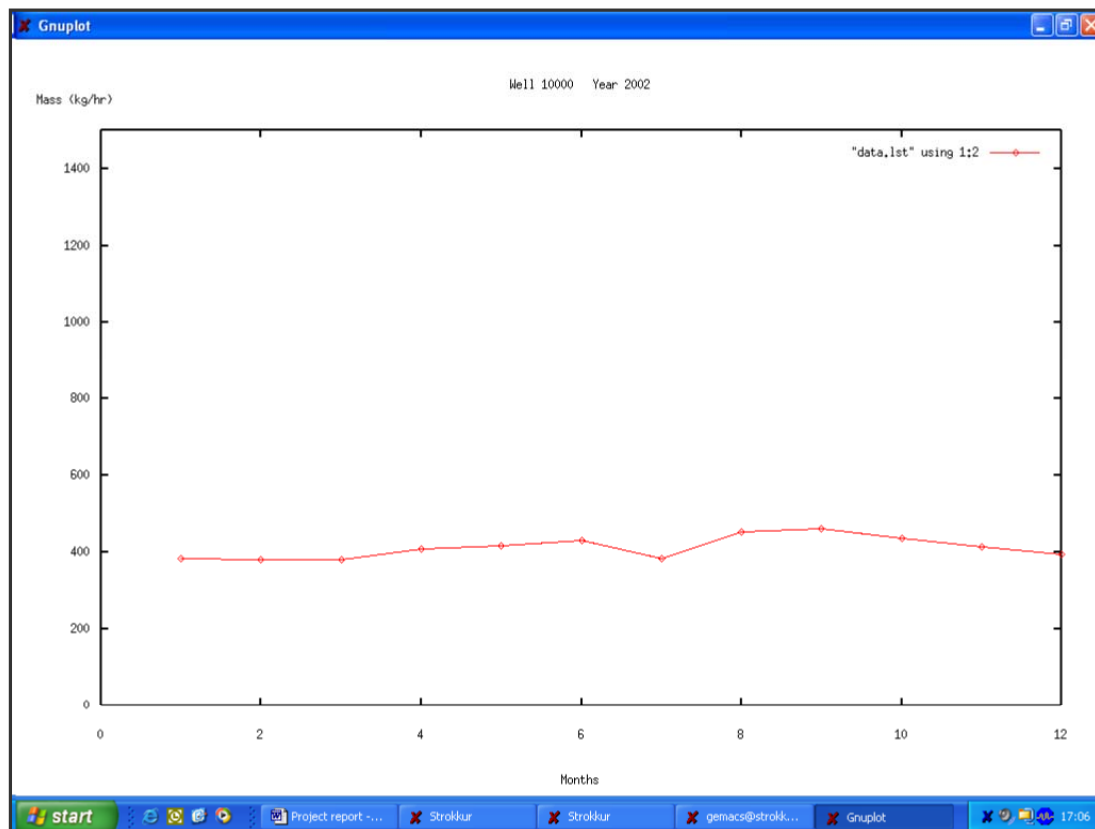


Figure 11: Graph of mass flow rate with time

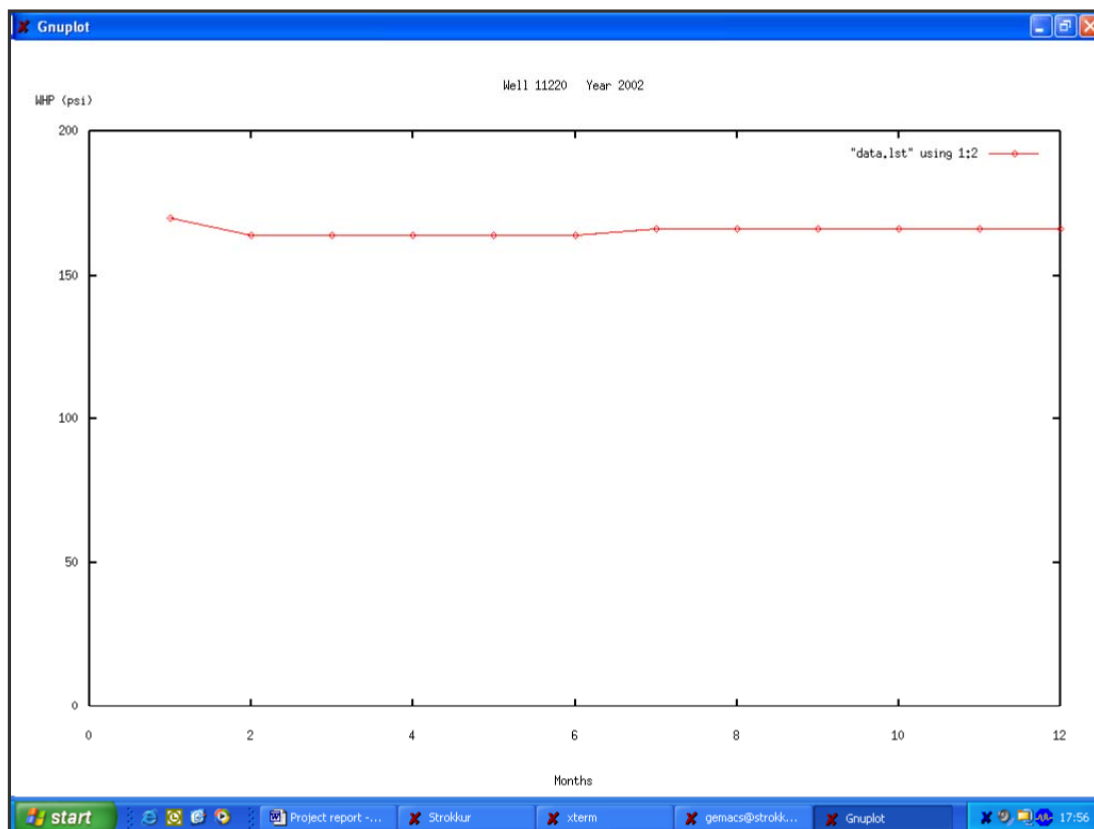


Figure 12: Graph of wellhead pressure with time

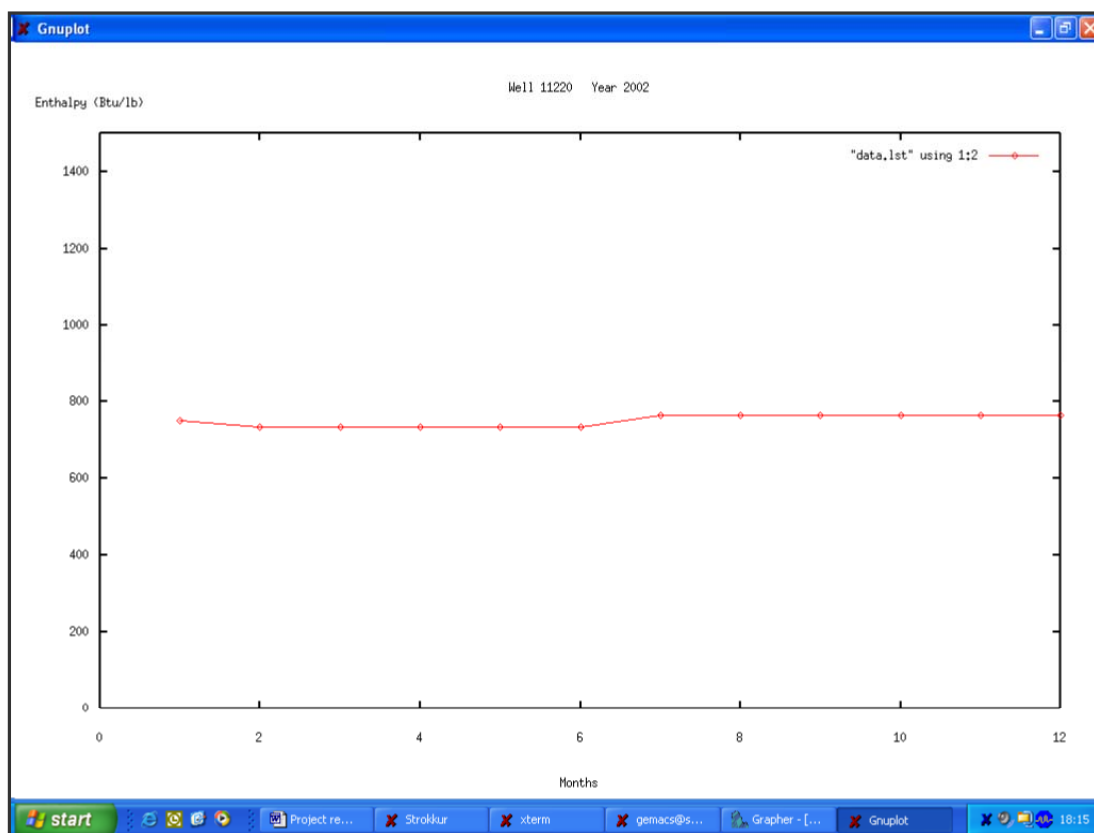


Figure 13: Graph of enthalpy with time

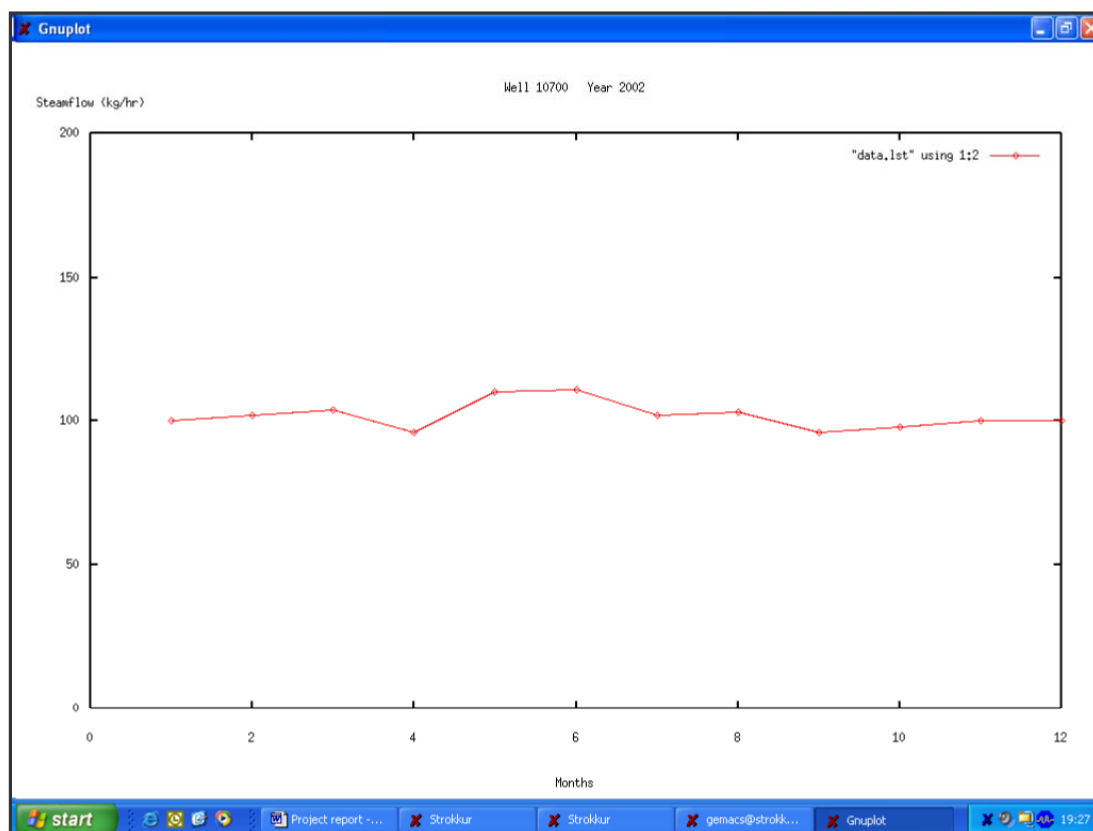


Figure 14: Graph of steam flow rate with time

4. CONCLUSIONS AND RECOMMENDATIONS

Geothermal energy development in the Philippines for about 30 years has grown up through its own experiences and of course with the knowledge and skills shared by other countries such as Iceland. These experiences were gained from the volume of data gathered and studied aiming for the sustainable management of the geothermal resource.

Accordingly, the Philippine Department of Energy (DOE) being the government agency mandated to supervise and regulate geothermal operations recognizes that development and application of a computerized database is an important tool for monitoring the management strategies of geothermal steam fields and power plants in the country.

The database structure was developed and processed using the Oracle Relational Database Management System (RDBMS). Two data models designed are the steam field and the power plant data models. The steam field model composes tables that stores and provides data about the physical characteristics of the wells, drilling information and reservoir monitoring parameters. While, the power plant data model consists of tables that handles and provides information about the specifications and power generation of the power plants. Data from the paper reports were entered into the tables of the database using the SQL*Loader software. Test runs were conducted to check the design of the database according to the objectives. The capability of the database was integrated to create data forms, report layout and graphical outputs that can be used in monitoring the performance of the steam fields and power plants in the Philippines. Oracle Developer Forms, Reports Builder and Gnuplot software were utilized in the said procedure.

As a result, the database developed here can be readily implemented and applied as a tool for monitoring the performance of steam fields and power plants in the Philippines as well as a good beginning for DOE to improve from its existing manual filing system.

However, it is recommended that an additional and continuous study on database is still needed. In addition, as part of monitoring, more exposure in geothermal operations is required to DOE in verifying data integrity submitted by the steam field developers and power plant operators. DOE should also go along with the advancement of database and geothermal technology.

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