

APPLICATION OF DATABASE IN MONITORING THE PERFORMANCE OF GEOTHERMAL STEAM FIELDS AND POWER PLANTS IN THE PHILIPPINES

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ABSTRACT

Database is vital for the efficient development and management of geothermal resources. The Philippines with an installed geothermal energy capacity of 1930.89 MWe and still with a great potential for geothermal exploration and development is generating an increasing volume of geothermal data. A computerized geothermal database was designed and developed for storage, retrieval and manipulation of data collected from geothermal fields. 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 of the resource, 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 softwares were also utilized to provide fast, simple and easy data input, editing, viewing, reporting and graphing.

1.0 INTRODUCTION

The Philippine Department of Energy (DOE) is a government agency mandated to administer programs for exploration, development, transportation, marketing and appropriate management of energy resources in all forms including 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

(GRCDD) of the DOE is specifically mandated to oversee, monitor and regulate geothermal operations undertaken by both private and government entities to ensure strict compliance to government policies and standards (Requejo, 1996; Sylvania, 1995).

The Philippines remains to be the world's second largest producer of geothermal energy for electricity generation. As of December 2002, an installed capacity of 1930.89 MWe in six geothermal production fields (Fig. 1) has been reached in 30 years of geothermal exploration, development and utilization. This is only 43% of the 4,537.02 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 GRCDD 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 plant performance should be closely monitored to avoid over-exploitation of the geothermal resource.

2.0 DATABASE DEVELOPMENT

2.1 Data Collection

To fully accomplish its mandated function, the DOE requires submission of report and

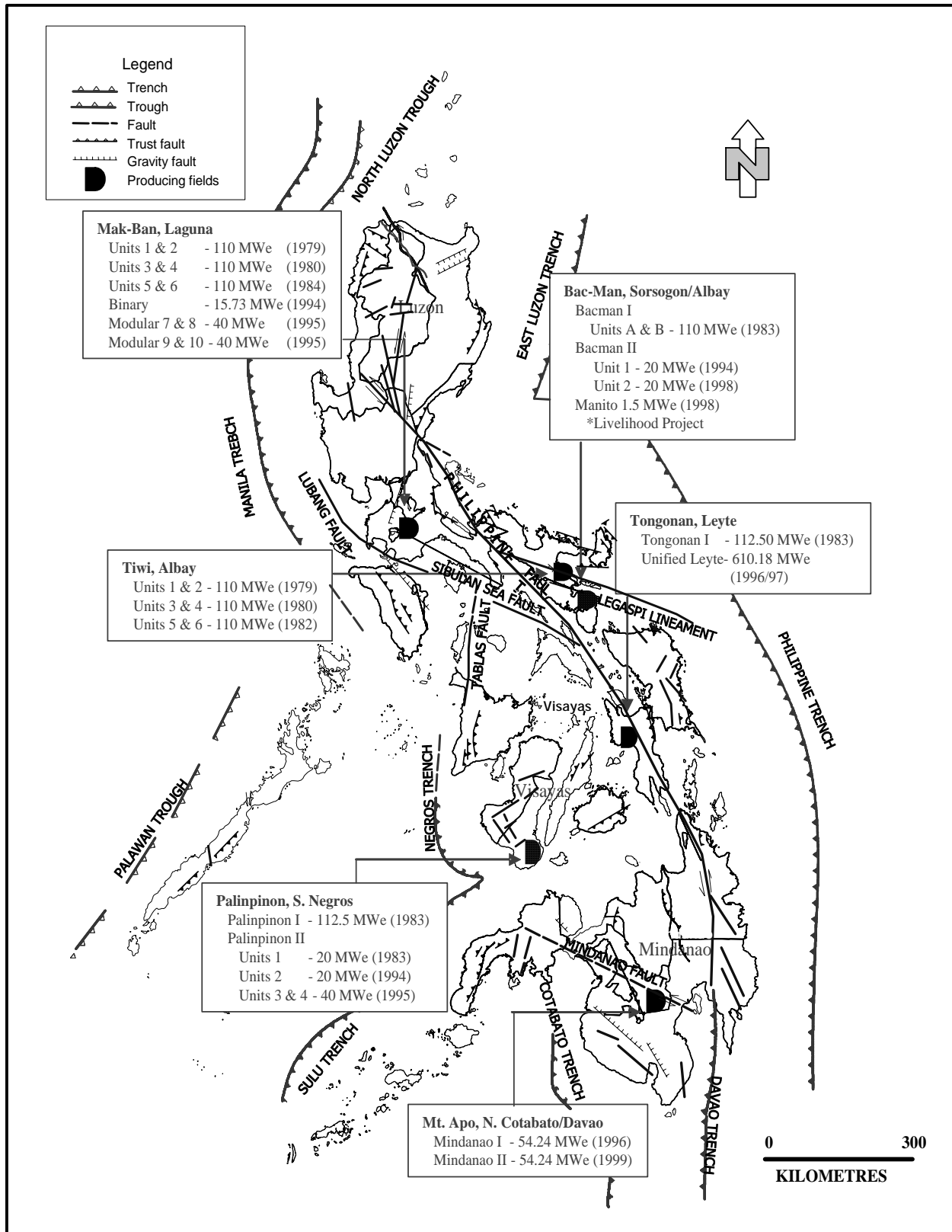


Figure 1. Map of the Philippines with the location of the six geothermal production fields.

PHILIPPINE GEOTHERMAL, INC.
PGI Monthly Production and Injection Report
For BULALO - December, 2002
Monthly Report by Field

MONTHLY OPERATION					LAST ENTHALPHY TEST					AVERAGE PRODUCTION RATE					CUMULATIVE PRODUCTION				LAST ACTIVITY		
Well Name	Well Type	WS/SS	Prod Hrs	Inj Hrs	Date	WHP (psig)	Steam (kwh)	Brine (kwh)	Mass (kwh)	Enth (Btu/lb)	Flow (gpm)	Temp (F)	Brine (kwh)	Mass (kwh)	Inj (kwh)	Steam (Mlb)	Brine (Mlb)	Mass (Mlb)	Inert (Mlb)	Last Activity	Date
BUL53	PROD	SS03	720		10-05-02	145	74	83	143	778	101		70	74	103	10804	17028	36102		FLOW START	11-15-02
BUL54	IDLE				09-02-01	195	88	533	627	471											
BUL55	PROD	SS03			09-17-02	143	52	54	118	723						8805	10848	19712		SHUT-IN	11-04-02
BUL56	ABDN	NESP			04-19-88	182	118	183	281	808						4286	8828	15204		SHUT-IN	08-15-89
BUL57	INJ																				
BUL58	INJ				11-09-02	44	18	143	158	304						120	820	1948	4624	SHUT-IN	11-07-02
BUL59	PROD	SS05			08-17-02	145	55	8	81	1708						13139	9894	22723		SHUT-IN	11-08-02
BUL60	PROD	SS02	720		12-17-02	179	128		128	1169	155		131		131	32580	12803	44589		FLOW START	04-28-02
BUL61	ABDN	NESP			11-23-85	142	71	78	148	741						281	352	803	20	SHUT-IN	08-22-88
BUL62	PROD	SS06			04-15-80	153	5	5	5	1195						8582	6907	13290		SHUT-IN	07-07-00
BUL63	ABDN																				
BUL64	PROD	SS02			08-15-02	131	31		31	1195						17085	740	58412		SHUT-IN	10-09-02
BUL65	PROD	SS02			10-23-02	168	104	82	236	900						22338	13276	33482		SHUT-IN	11-18-02
BUL66	PROD	SS07			03-04-02	130	120	453	573	595						9535	37045	48581		SHUT-IN	11-04-02
BUL67	PROD	SS07			09-18-02	128	131	87	218	840						13343	9648	23181		SHUT-IN	11-04-02
BUL68	ABDN																				
BUL69	INJ																				
BUL70	PROD	SS04	720		07-05-02	168	100	111	219	785	348		15	14	29	13004	12294	25798		18 FLOW START	03-19-02
BUL71	PROD	SS02			09-06-02	160	88	176	284	819						17836	13180	30820		SHUT-IN	11-19-02
BUL72	PROD	SS06	720		10-21-02	174	113	46	181	948	165		102	120	228	14407	13468	27875		FLOW START	05-09-02
BUL73	INJ		720									85									
BUL74	PROD	SS06			07-20-02	154	58	51	109	794						8871	8300	18171		SHUT-IN	10-23-02
BUL75	INJ		720									113									
BUL76	PROD	SS01	720		10-25-02	176	155	120	275	825	185		136	112	248	9478	25165	33845		38 FLOW START	06-04-01
BUL77	INJ		70									88									
BUL78	INJ		720									95									
BUL79	PROD	SS06			08-14-02	149	22		22	1186						8696	3226	11820		SHUT-IN	10-29-02
BUL80	PROD	SS06	720		10-24-02	182	87	183	257	805	172		80	181	241	13282	9425	22712		FLOW START	10-04-01
BUL81	INJ		720									63									

Figure 2. Production and injection report.

information in paper from geothermal steam field developers and power plant operators such as:

- Production and injection report containing mass flow rate, steam flow rate, and water flow rate of production wells; and injection rate of injection wells (Fig. 2)
- Report on well test activities and downhole measurements (pressure and temperature) (Fig. 3)
- Report on mass and heat extraction and injection (Fig. 4)
- Report on power output generation of geothermal power plants

Data in these reports are evaluated, analyzed and used by the DOE in preparing a monitoring report. The submitted reports are presently compiled in a manual filing system.

PNOC-EDC
 Name of Project: **Southern Negros Geothermal Project**
 For the month of: **November 2002**

A. Downhole Measurements

1. *KT/KP Survey (Refer to attached Field Sheet)*

14Nov02	N8RD	KT 70, KP 79	Shut
14Nov02	N2	KT 61, KP 45	Shut
18Nov02	N1	KT 83, KP 68	Shut
20Nov02	OK3R	KT 84, KP 87	Shut
22Nov02	PN8RD	KT 99	Shut
28Nov02	PN8RD	KP 100	Shut

2. *Go-Direct/Slotted Survey*

Well Name	Survey Type	Date Conducted	Penetrated Depth (ft/ft)	Total Depth (m/d)	REMARKS
N8RD	32x60 mm SB	17Nov02	2660	2992.1	MCD
N11RD	125/105 mm GD	15Nov02	2490	2515.9	MCD
OK3R	60 mm SB	20Nov02	1590	1521.8	MCD
PN8RD	60 mm SB	22Nov02	3090	3124.4	MCD

B. Well Testing

1. *Water Flow Measurements*

Well Name	Date Conducted	Current		Previous	
		Valve Opening	Capacity/Flow (kg/s)	Valve Opening	Capacity/Flow (kg/s)
SG3RD	12Nov02	FO	22.7	FO	26.2
TC3RD	05Nov02	FO	26.8	FO	26.0
TC3RD	-do-	11T	117.6*	11T	150.6*
TC4RD	-do-	FO	52.8	FO	49.0
ML12RD	-do-	FO	35.8	FO	55.8
OK3R	-do-	Shut	-	Shut	-
PN8RD	-do-	4T	79.0*	4T	38.0*

Note: 1. Values in BOLD figures indicate min. capacity while those in ITALICS are flow measurements.
 2* Measurements taken from in situ flowmeter indicators.
 3. Full flow measurements conducted in simultaneous with TPT measurements.
 Higher load of PN8RD due to steam flow measurements across the arifice plate.

Figure 3. Well test activities and downhole measurements.

PNO-C Energy Development Corporation Leyte Geothermal Production Field for the month of November 2002								
Well Name	Extracted this month		Extracted to date		Injected this month		Injected to date	
	Mass (tons)	Energy (GJ)	Mass (tons)	Energy (GJ)	Mass (tons)	Energy (GJ)	Mass (tons)	Energy (GJ)
MALITBOG								
501	128,823	148.86	11,617,923	18700.13	99,533	67.02		
503	116,122	152.58	11,077,603	15217.99	80,869	54.48		
508D	115,749	140.83	11,883,601	11838.07	85,874	57.83		
509	112,536	146.99	6,265,625	8363.73	78,821	53.08		
510D	117,417	159.57	9,012,257	12711.84	79,316	53.40		
511D	136,285	259.23	9,004,669	18109.55	57,007	38.39		
513D	176,428	270.15	13,440,612	19839.99	104,561	70.41		
514D	102,313	149.78	8,459,732	11987.62	64,048	43.12		
515D	119,933	196.81	8,699,632	14782.07	65,007	43.77		
TOTAL	1,126,616	1,624.40	89,804,020	131,950.99	715,036	481.48	47,515,599	28,170.60
SOUTH SAMBALORAN								
301D	94,455	283.05	4,873,628	12085.1	--	--		
302	207,232	258.42	12,452,706	16166.8	150,988	101.68		
303	139,113	272.04	9,442,493	18277.83	54,578	36.74		
304D	58,475	146.42	4,156,269	9437.8	7,777	5.24		
305D	129,781	299.92	6,738,662	15660.18	29,073	19.57		
306D	118,213	329.22	7,454,019	20379.26	--	--		
307D	34,215	95.15	2,170,985	5943.98	--	--		
308D	38,113	99.66	6,437,784	14085.93	3,040	2.05		
309D	173,663	282.2	9,939,629	19001.94	95,281	64.15		
310D	184,351	423.09	13,874,111	27729.58	42,646	28.72		
311D	57,329	159.49	2,448,737	6606.11	0	0		
TOTAL	1,234,940	2,626.66	79,991,023	165,374.5	363,363	256.13	25,664,279	17,589.63

Figure 4. Mass heat and extraction and injection report.

2.2 Database Design

A database is a structured collection of data. Data in this design refer to information gathered from paper reports submitted to the DOE. An Oracle Relational Database Management System (RDBMS) provides 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 users for an intended application (Ensor and Stevenson, 1997).

The database is made up of tables. Information that describes or illustrates a certain subject are 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 are created for various sets of information. Grouping of information to form a

table is a basic requirement for RDBMS; hence, user needs familiarity with geothermal operations.

2.2.1 Data Modelling

Based on the DOE's requirements in performing its functions, grouping of information to form tables was identified. Below is brief description of tables that were created.

Well table describes the characteristics of each geothermal well. It contains information about 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 location, coverage area installed capacity; and date when service contract was awarded for field development.

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

Prod_Inj table stores data being monitored by the 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 logging operations in a well. Type of log and tool used in the logging operation found this table.

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

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

Drilling table provides information about a drilling activity and the drilling rig used. It has dates when drilling started and ended, as well as total drilled depths.

Drillact table stores 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 progress of a drilling activity according to the schedule of the well's drilling program.

Comptest table refers to results of a completion test conducted in a well after drilling. These are important data used in reservoir modeling such as injectivity index, maximum wellhead pressure, permeability-thickness and measured depth of circulation losses.

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

Rig table gives the specifications of rigs used in drilling a geothermal well.

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

Plantspecs table provides information about

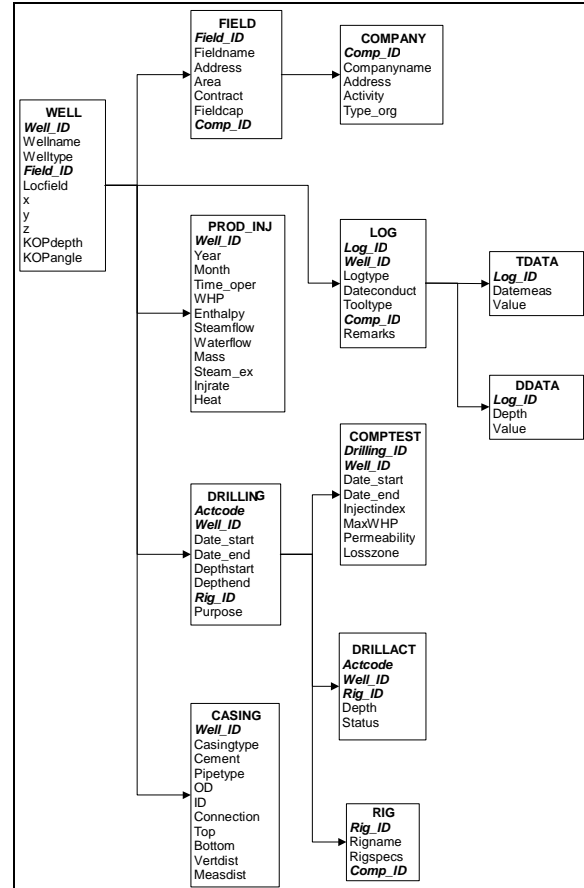


Figure 5. Steam field data model

technical specifications of facilities of the power plant such as turbine, generator, condenser, cooling tower and pumps.

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

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

These tables were used in 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 steam field performance which is composed of the WELL, FIELD, COMPANY, PROD_INJ, LOG, TDATA, DDATA, DRILLING, COMPTST, CASING, and RIG tables (Fig. 5); while the second data model

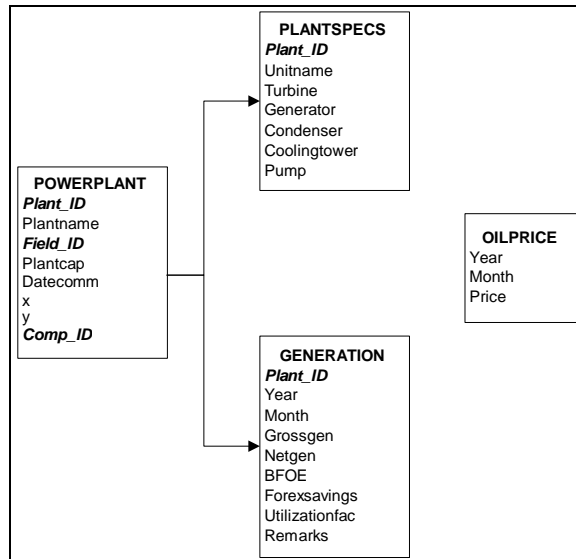


Figure 6. Power plant data model

comprises the POWERPLANT, PLANTSPECS, GENERATION and OILPRICE tables (Fig. 6). Making two data models is necessary because geothermal energy development in the Philippines is divided into two entities, steam field developers and power plant operators. The name given to each table is the main subject that it pertains. The column names given are specific categories of information that the table contains and records are the data relating to the column.

In Figures 5 and 6, table names are in bold capital letters, while primary key(s) are in bold italics. Primary key(s) are selected to uniquely define the occurrence of each record. Choosing a primary key (s) is important because 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

Structured Query Language (SQL*Plus) was used in the creation of tables. 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). An example is the production and injection report submitted to the DOE which contains mass flow rate, steam flow rate and water flow rate of each production well, and 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 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 the DOE currently monitors six geothermal production fields in the Philippines.

3.0 DATABASE APPLICATION

The primary purpose of developing this geothermal database is for the DOE to use it in monitoring the management and operation of 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, it can also be used in various applications to give meaning to data contained in the database. The Oracle Developer softwares are powerful tools that provide appropriate database applications that users require.

3.1 Data Forms

The Forms Builder is an Oracle Developer tool that enables 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 to show how this tool can be applied for monitoring geothermal steam fields and power plant operations. All data forms were created through the Form Builder Data Block Wizard. This

The screenshot shows a database application window titled 'WINDOW1'. It contains three main data blocks:

GEOHERMAL FIELD

Field id	Field Name	Capacity	Camp id
1	Tanapuan	722.68	18
2	Pak-San	425.73	28

COMPANY

Comp id:
 Company:
 Activity:

WELL

Well id	Wellname	Welltype	Field id	Larfield	X	Y	Z
9768	PHL02	PROD	2	S001	1523542	1559568	987
9768	PHL02	INJE	2	N001	1524802	1568268	986
9808	PHL03A	PROD	2	S001	1523258	1559968	1832
9808	PHL04	PROD	2	S003	1528568	1558678	786
9848	PHL05	INJE	2	S001	1522596	1568518	1281
9868	PHL06	PROD	2	S002	1523036	1559508	863
9888	PHL07	PROD	2	S001	1523728	1568008	992
9908	PHL08	PROD	2	S003	1523012	1559008	825
9928	PHL09	PROD	2	S001	1523196	1568468	1341
9948	PHL18	PROD	2	S003	1523448	1558768	832

Record: 2/7

Figure 7. Form for the inventory of wells in a specific geothermal field

wizard allows 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 shows the on-screen view of the design form,
- Object Navigator describes the content of the design form such as data blocks, items and triggers, etc., and
- Property Palette makes 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 (Fig. 7) 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 (Figs. 5 and 6) 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 8. 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 for monitoring the steam field performance by comparing sudden changes or large differences in the well's production or injection rates. Input of new record for 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 (Fig. 9). Data blocks are composed 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.

WFDOWN1

Action Edit Query Block Record Field Help

GOOTHERMAL FIELD

Field Id	Fieldname	Fieldcap	Comp Id
1	Tangass	722.68	19
2	Maik-San	425.73	20

WELL

Well Id	Wellname	Welltype	Field Id	Locfield
9940	BUL30	PROD	2	5583
9928	BUL39	PROD	2	5581
9946	BUL10	PROD	2	5583

PRODUCTION + INJECTION

Well Id	Year	Month	Who	Enthalpy	Steamflow	Waterflow	Mass	Intrate
9940	2002	1	140	815	109	87	196	0
9940	2002	2	140	815	109	80	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	238	0
9940	2002	6	160	773	125	120	245	0
9940	2002	7	160	773	137	132	268	0
9940	2002	8	160	773	140	140	280	0
9940	2002	9	155	844	140	141	288	0
9940	2002	10	155	844	152	117	268	0
9940	2002	11	155	844	154	107	267	0
9940	2002	12	155	844	154	107	267	0

Record: 107

start Stop Object Navigator WFDOWN1

Figure 8. Form for the production and injection rate of each well

WFDOWN1

Action Edit Query Block Record Field Help

GOOTHERMAL FIELD

Field Id	Fieldname	Fieldcap	Comp Id
2	Maik-San	425.73	20

WELL

Well Id	Wellname	Welltype	Field Id	Locfield
9768	BUL01	PROD	2	5901

LOG INFORMATION

Log Id	Well Id	Logtype	Daterecord	Tooltype	Comp Id	Remarks
67	9768	TEMPERATURE	1989-11-06	KUSTER TEMPERATURE	20	Scheduled for logging
68	9768	TEMPERATURE	1989-11-06	KUSTER TEMPERATURE	20	Scheduled for logging

TEMPERATURE WITH TIME

Log Id	Between	Value
67	1989-11-06	48
67	1989-11-06	279
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	48
68	192	279
68	385	280
68	467	280
68	649	281
68	762	281
68	904	284
68	1067	287
68	1219	289
68	1372	291
68	1524	293
68	1677	293

Record: 1292

start Project ... Values ... Stop Object ... WFDOWN1

Figure 9. Form for the log information and log result conducted in a well

The screenshot shows a database application window titled "WIDROW1" with a menu bar (Action, Edit, Query, Block, Record, Field) and a toolbar. The main content area is divided into four sections:

- GEOTHERMAL FIELD:** A table with columns: Field Id, Fieldname, Fieldmap, Comp Id. Data row: 2, Max. Run, 405.73, 78.
- WELL:** A table with columns: Well Id, Wellname, Welltype, field Id, Locfield, X, Y, Z. Data row: ST68, BSL01, PPHO, 2, SC01, 523642, 1009568, 987.
- DRILLING INFORMATION:** A table with columns: Actcode, Well Id, Date Start, Date End, Depthstart, Depthend, Rig Id, Remarks. Data row: 1, ST68, 2003-07-01, 2003-08-30, 0, 2631, 19, Drilling of new well.
- STATUS OF DRILLING ACTIVITY:** A table with columns: Actcode, Well Id, Rig Id, Statdate, Depth, Status. Data rows:

Actcode	Well Id	Rig Id	Statdate	Depth	Status
1	ST68	10	2003-07-01	0	Rig mobilization
1	ST68	10	2003-07-18	0	Start of drilling 24" hole
1	ST68	10	2003-07-28	300	Set 10 5/8" casing
1	ST68	10	2003-07-30	600	Set 13 3/8" casing
1	ST68	10	2003-08-18	900	Drilling of 32 1/4" hole
1	ST68	10	2003-08-28	1500	Set 3 5/8" surface liner
1	ST68	10	2003-08-30	2631	Drilling completed

At the bottom, it shows "Record: 2/7" and a toolbar with icons for Start, Stop, Refresh, and other functions.

Figure 10. Form for drilling information and status of drilling activity in a well

Figure 10 shows a data form for drilling information and status of drilling activity in a well. The design of this form which includes the FIELD, WELL, DRILLING and DRILLACT tables will be used for monitoring the progress of a drilling activity as compared with the drilling program.

Data on power generation of geothermal power plants is shown on the data form Figure 11. Comprising the form are data blocks from POWERPLANT, COMPANY and GENERATION tables. The design of the form provides a clear picture of each power plant's output generation every month, for easy monitoring of the power plant performance. A large decrease in power generation in a certain month can be easily noted by the DOE who should determine causes for such power output changes.

The capability of utilizing the form for simple computations is also illustrated in Figure 11. 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 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 power plants can therefore be quickly assessed by the DOE.

The data forms presented are only some of the illustrations on how this tool can be applied in monitoring performance of geothermal steam fields and power plants in the Philippines. These forms still need to be further evaluated for necessary improvements.

3.2 Report Layout

Organizing reports on situation of the Philippine geothermal sector is one of the main tasks of the DOE. 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

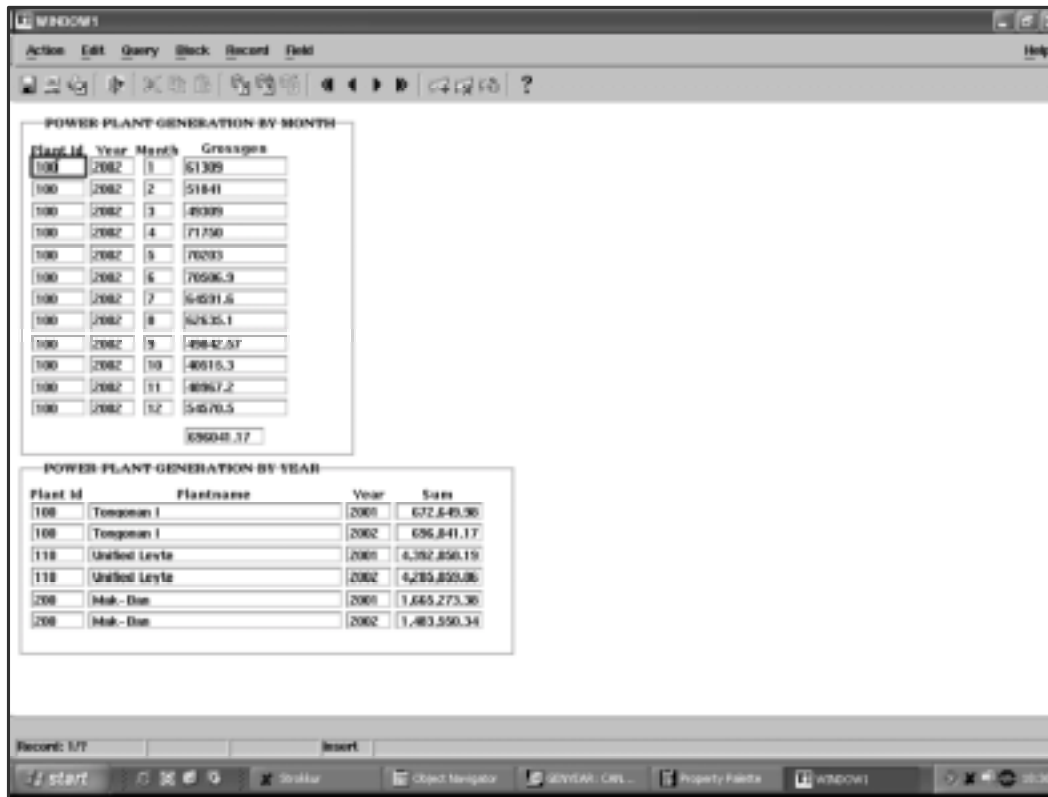


Figure 11. Form for power generation of geothermal power plants

readily accessible for a better view as compared with the forms.

The report “Philippine geothermal power plants highlights” presented in Figure 12 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 power plants with their corresponding computed utilization factor as compared with previous year’s performance. Low generation which is equal to low utilization factor usually indicates problems in power plant facilities.

3.3 Graphical Output

Graphical output is the third application of the geothermal database. For monitoring steam fields, wellhead pressure, enthalpy and mass flow rate of individual wells are some of the parameters being determined. Graphing will

provide information on well performance such as decline in steam production which may require improving the well. The graphs are created in two command files, SQL commands and Gnuplot commands. The SQL commands import data from the database, and Gnuplot commands draw data into X-Y graph (Williams and Kelley, 1993).

The graph of mass flow rate with time (Fig. 13) 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 (Fig. 14) is also used to accompany evaluation of well performance. A drop in wellhead pressure at the same wellhead opening may be due to well blockages. To remove well blockages, work-over of wells are conducted which may include mechanical drilling out of blockages and/or acidizing operations.

In Figure 15, a graph of enthalpy with time is another method of monitoring a well’s production. Increase in discharge enthalpy with a decrease in mass flow but without change in steam flow (Fig. 16) is possibly caused by reservoir pressure drawdown. On the

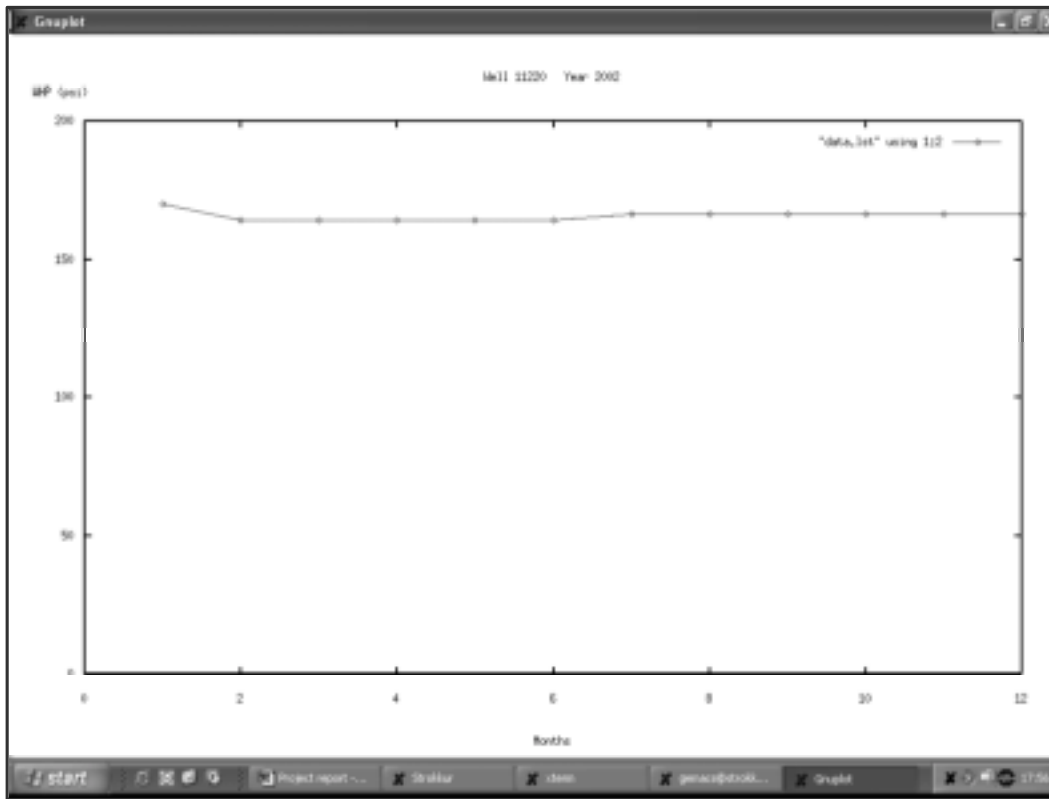


Figure 14. Graph of wellhead pressure with time

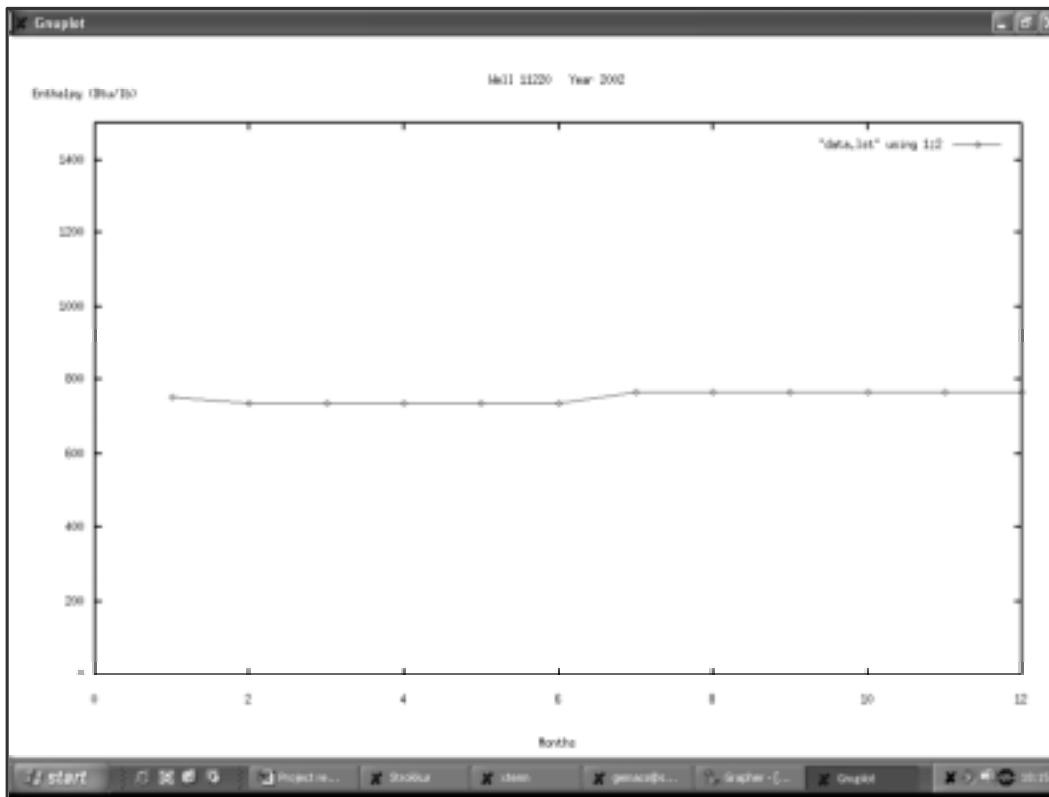


Figure 15. Graph of enthalpy with time

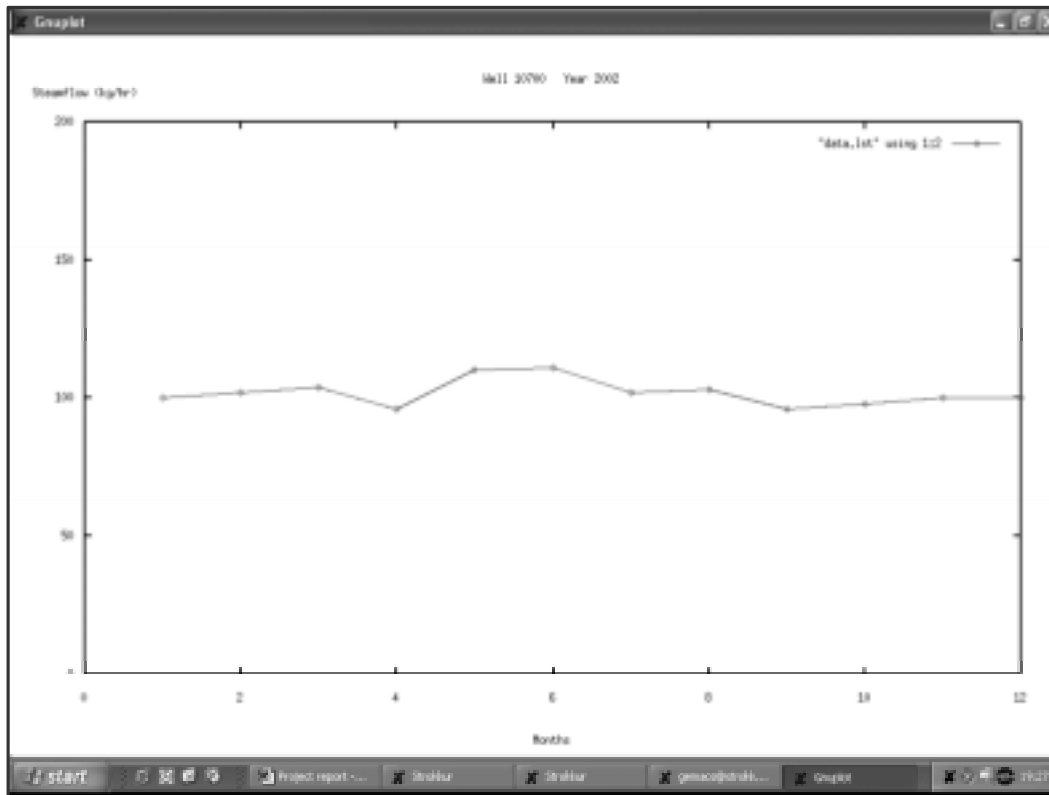


Figure 16. Graph of steam flow rate with time

other hand, decline in enthalpy is likely associated with reservoir cooling induced by inflow of natural recharge or injection returns (Sarmiento, 2000). Assessment of production and injection strategies should be done to address these reservoir changes. Steam field developers need to inform the DOE about the results of these geothermal resource assessments.

4.0 SUMMARY

For 30 years, geothermal energy development in the Philippines has grown. 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 management strategies of geothermal steam fields and power plants in the country.

A 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

is composed of tables that store and provide data about physical characteristics of wells, drilling information and reservoir monitoring parameters. The power plant data model, on the other hand, consists of tables that handle and provide information about specifications and power generation of power plants. Data from paper reports were entered into tables of the database using the SQL*Loader software. Test runs were conducted to check design of the database according to the objectives. The capability of the database was integrated to create data forms, report layouts and graphical outputs using Oracle Developer Forms, Reports Builder and Gnuplot softwares. As a result, the database developed can be readily implemented and applied by the DOE as a tool for monitoring the performance of steam fields and power plants in the Philippines.

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