

GeTools – Geothermal Engineering Tools

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ABSTRACT

GeTools is a user-friendly software package which consists of four tool boxes, namely (1) drilling toolbox, (2) reservoir engineering toolbox, (3) production engineering toolbox and (4) fluid properties and geochemistry toolbox. It was developed to help the engineers involved in geothermal field development to conduct various calculations and analyses, to answer questions about the wells, the reservoir and the steam field such as well trajectory, reservoir electricity potential, reservoir characteristic as estimated using geostatistical methods, well output, decline curves, future production and saturation index.

1. INTRODUCTION

Various geothermal software has been developed to provide tools for engineers to answer questions about the wells, the reservoir and the steam field. They are, among others GDManger (Barnett et al., 1987; Anderson et al., 1992), WELLSIM (GENZL and Univ. of Auckland, 1991), MULKOM and TOUGH2 (Pruess 1983, 1987, 1988 and 1991), GEOTRANS (Garcia et al., 2000), the BDGEO Software Package (Iglesias et al, 2000).

In 1988-1989, the first author of this paper developed a software, namely GPE (Geothermal Production Engineering), to provide tools for (i) the calculation of output from geothermal wells, using data obtained from lip pressure (vertical and horizontal discharge), calorimeter and separator tests, (ii) the calculation of pressure drop in geothermal wells, water-steam lines and steam transmission lines, (iii) the prediction of the behaviour of geothermal wells, and (iv) the prediction of temperature distribution in soil heated by geothermal fluid (soil heating). In 1997 we modified this software in order to make it more user friendly and to upgrade its capability. The modified software is called GES, which stands for Geothermal Engineering Software. Additional modules facilitate the calculation of geothermal reserve potential, the analysis of data resulting from transient tests (pressure build-up, pressure draw down) and the calculation of power output and steam consumption.

In early 2000 we developed an Integrated Reservoir Information System (IRIS) for the Kamojang geothermal field (PERTAMINA), under a contract between Institut Teknologi Bandung (ITB) and PERTAMINA. To help the engineers work more effectively and efficiently in conducting various analyses, a number of independent application modules were installed and called GeTools, which stands for Geothermal Engineering Tools. It consists of four tool boxes: (1) drilling toolbox, (2) reservoir engineering toolbox, (3) production engineering toolbox and (4) fluid properties and geochemistry toolbox. The drilling toolbox allows the user to calculate and visualize

well trajectory based on drilling survey data. The Reservoir Engineering toolbox allows the user to compute reservoir reserves and reservoir characteristics using geostatistics tools. The Production Engineering toolbox can be used to calculate choke diameter, to calculate flow rate from measurements through orifice plate, to design orifice diameter, to calculate production test using lip pressure method, to simulate well output with different bore diameter, to construct well output curve based on production test using back pressure method, to analyze production decline and to forecast future production using interactive decline curve analysis. The Fluid Properties and Geochemistry toolbox allows the user to calculate fluid thermodynamic properties and saturation index.

GeTools was developed using Delphi 5, with Interbase 6 as database engine; in the operational system of Microsoft Windows.

2. PROGRAM DESCRIPTION

2.1. Drilling Toolbox

Information obtained during drilling should be analyzed to extract valuable information about the subsurface system. The main virtues of the drilling toolbox at present allow the user to calculate and visualize well trajectory based on drilling survey data. Drilling surveys are normally run to monitor the well progress while drilling. Survey data provide a pictorial image of the path of the well and the data are normally plotted on the same graph as that of the planned course. If the well is found to deviate from its planned direction, correction measures can be taken to bring the well back to the required direction.

There are various methods for determining the well geometry from the measured survey data. They are (1) tangential method; (2) balanced tangential method; (3) angle averaging method; (4) radius of curvature method; (5) minimum curvature method. The minimum curvature method is one of the most accurate calculation methods. All these methods were reviewed by Rabia (1985).

Relevant data required include: inclination angle, I , azimuth, A , and measured hole Depth, MD . The intention is to calculate the hole True Vertical Depth (TVD), the horizontal displacement or departures of the new hole position.

The Well Trajectory toolbox in GeTools was developed using the minimum curvature method. It relies on the principle of minimising the total curvature within the physical constraints of the well bore. The equations are similar to those of the balanced tangential method, except that the survey data are multiplied by a ratio factor, RF , to produce the required smoothing effect.

The Well Trajectory toolbox in GeTools offers visualisation of well trajectory in 2D and 3D (Fig. 1 and 2).

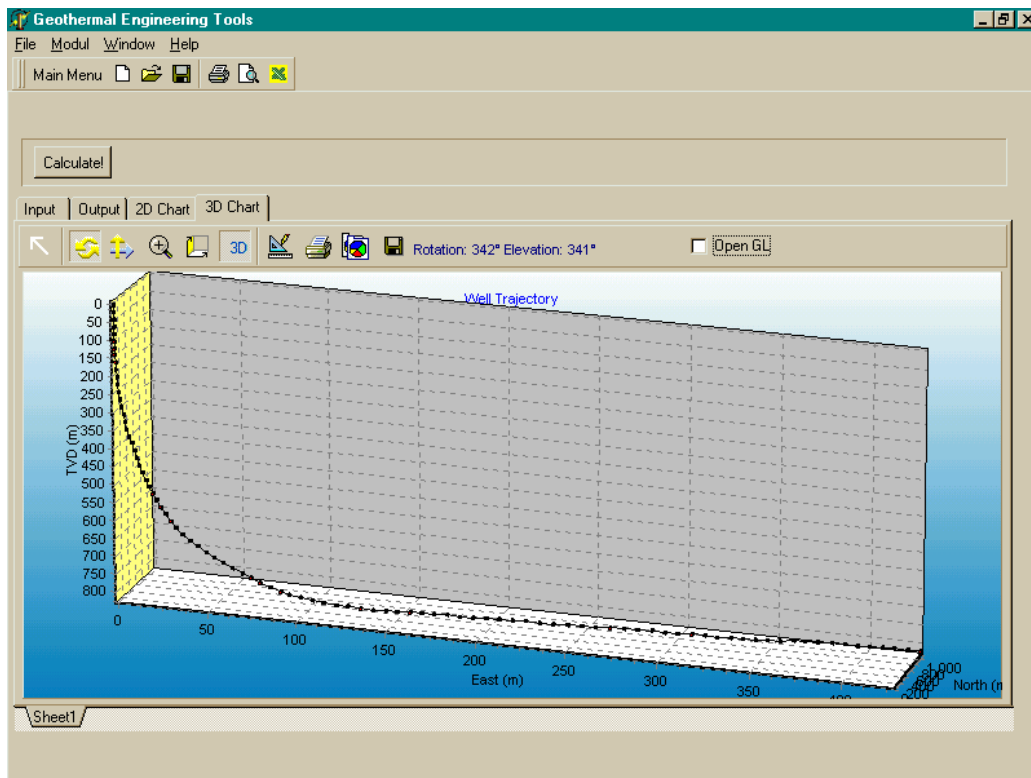


Figure 1: Figure 1: 3D Visualisation of Well Trajectory.

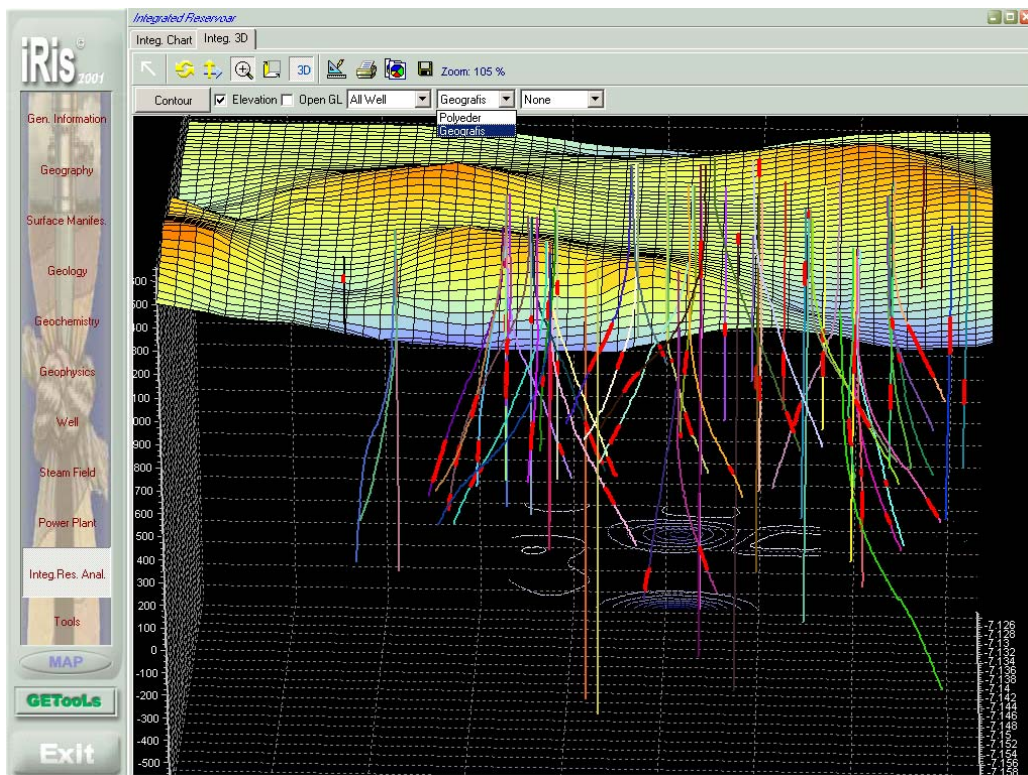


Figure 2: All Well Trajectories in the Field.

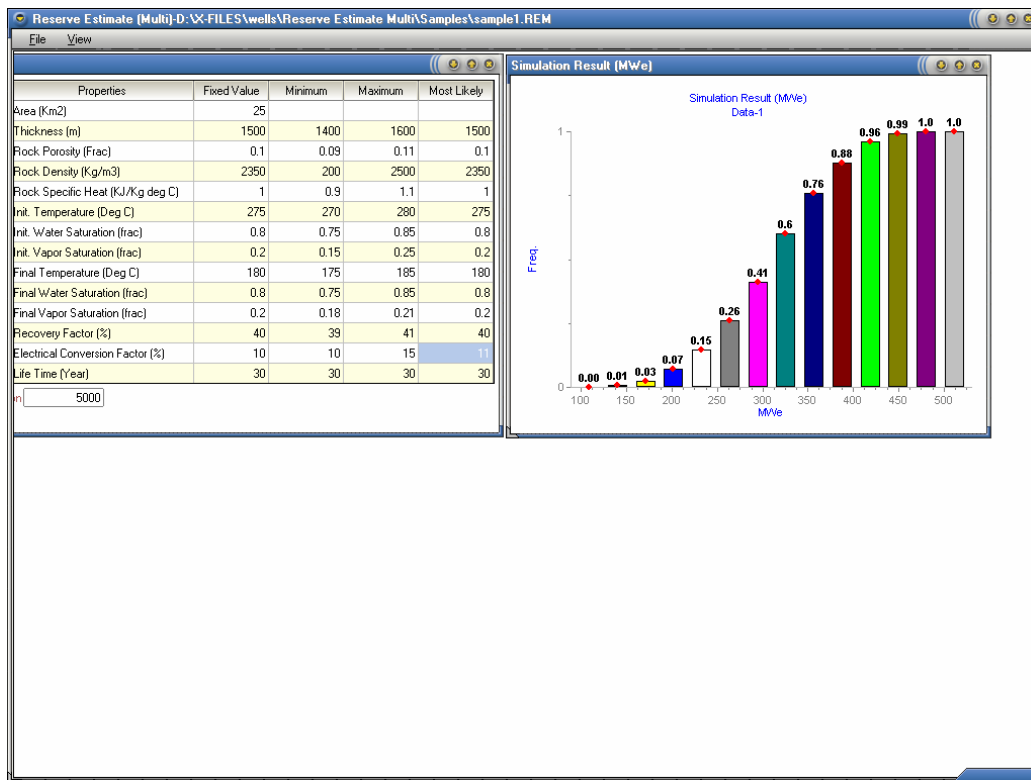


Figure 3: Reserve Estimation using Volumetric Method and Monte Carlo Simulation.

2.2 Reservoir Engineering Toolbox

The Reservoir Engineering Toolbox allows the user to compute reservoir reserves and reservoir characteristics using geostatistical tools.

2.2.1 Reserve Module

The reserve module allows the user to determine reserve and electricity potential of the reservoir using (1) volumetric method as outlined by O'Sullivan (1986) and (2) material and energy balance method as outlined by Brigham and Morrow (1977).

2.2.1.1 Volumetric Method

Based upon the values of reservoir area, reservoir temperature, thickness, porosity, water saturation, rock properties and some other parameters, such as recovery factor and electrical conversion factor, resource data program will calculate the resources and the reserve size and also its capacity to generate electricity using a method outlined by O'Sullivan and Mc Kibbin (1986).

For reserve calculation using the volumetric method, the user can enter a fixed value for each reservoir parameter, which is accepted by all parties, or if there is considerable debate regarding their values, the user can use Monte Carlo Simulation to find the most probable value of the reserves. If the latter option is chosen, the user should enter minimum and maximum values for each variable, and also

the most likely value (optional). Based on the distribution curves, the program will generate random numbers to determine a distribution curve of the reserves and the most probable value of the reserves (Fig. 3).

2.2.1.2 Material And Energy Balance Method

For steam-dominated reservoirs, reserves may be calculated using the method of Brigham and Morrow (1977) who looked at three systems:

1. A system completely filled with steam but no water present,
2. A system where there is water on the bottom and steam at the top. As steam is produced, some of the water will boil and the liquid level will drop with production (Falling Liquid Level),
3. A system where there is also water on the bottom and steam at the top, but it is assumed that the liquid boils throughout the liquid system and that the liquid level will not drop (Constant Liquid Level).

The results of calculation are presented in a graphical format showing the pressure decline with production, together with an estimation of the remaining steam in the reservoir at abandonment pressure and the remaining production time (Figs. 4 and 5).

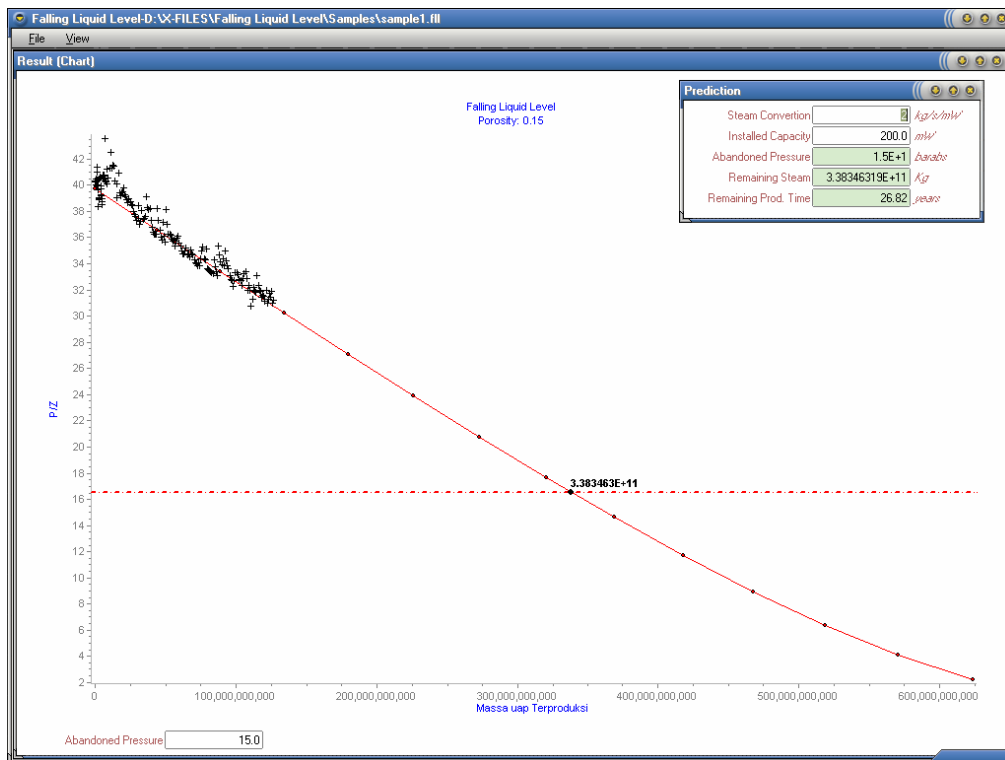


Figure 4: Reserve Estimation using Brigham and Morrow Method for Falling Liquid Level.

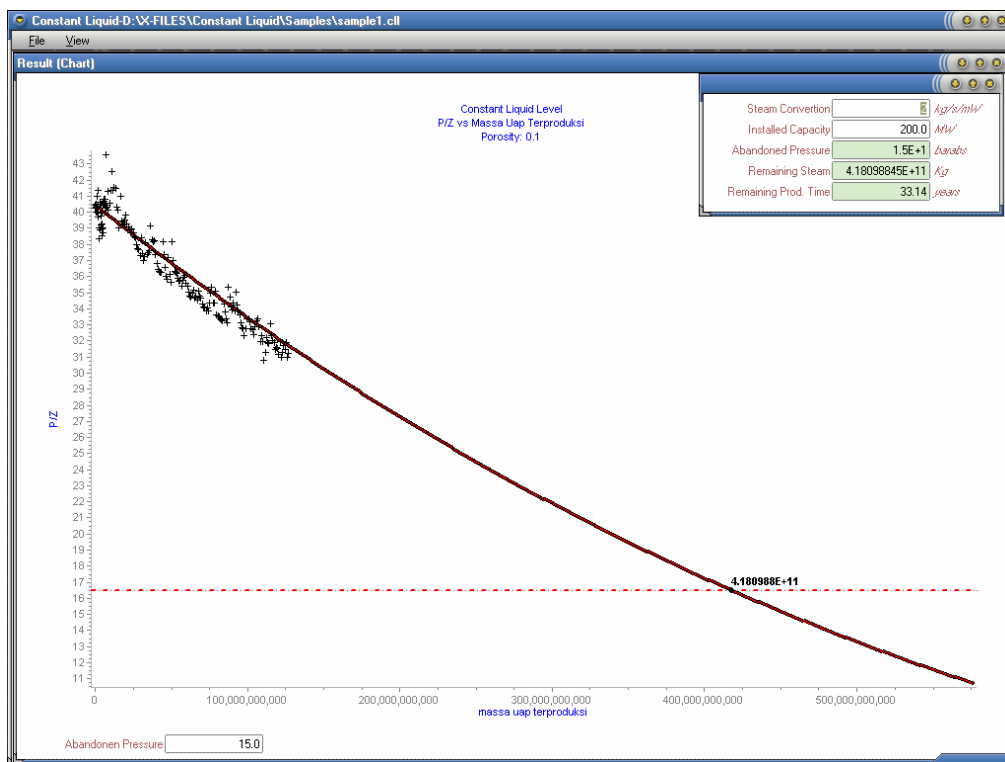


Figure 5: Reserve Estimation using Brigham and Morrow Method for Constant Liquid Level.

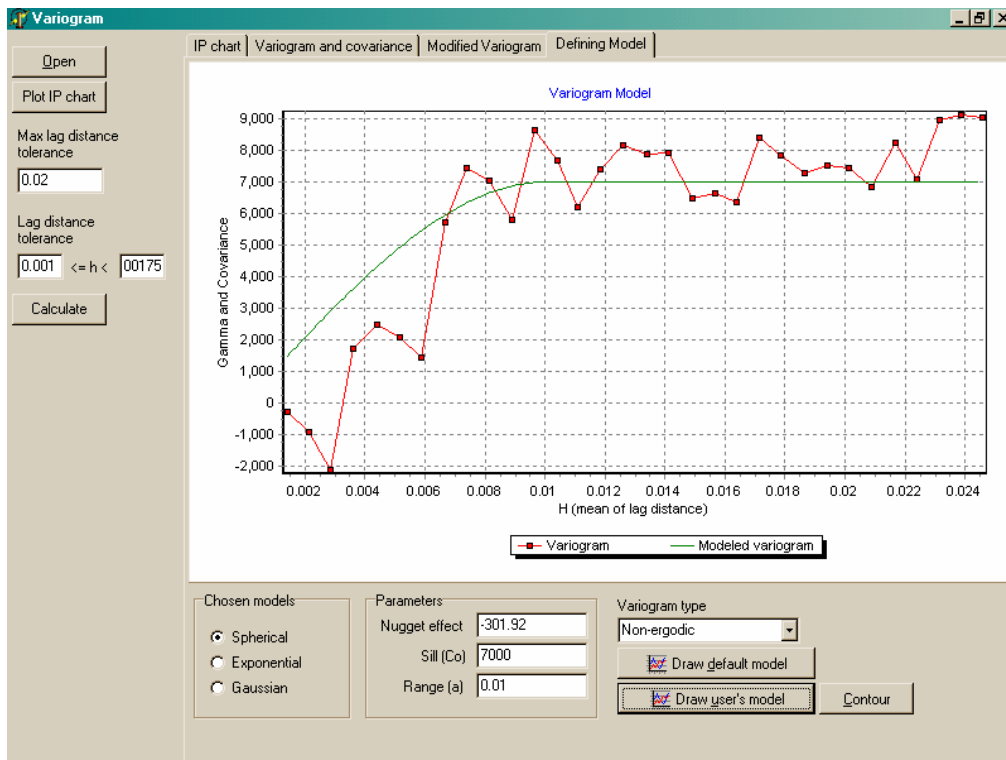


Figure 6: Spherical Variogram Geostatistical Modeling.

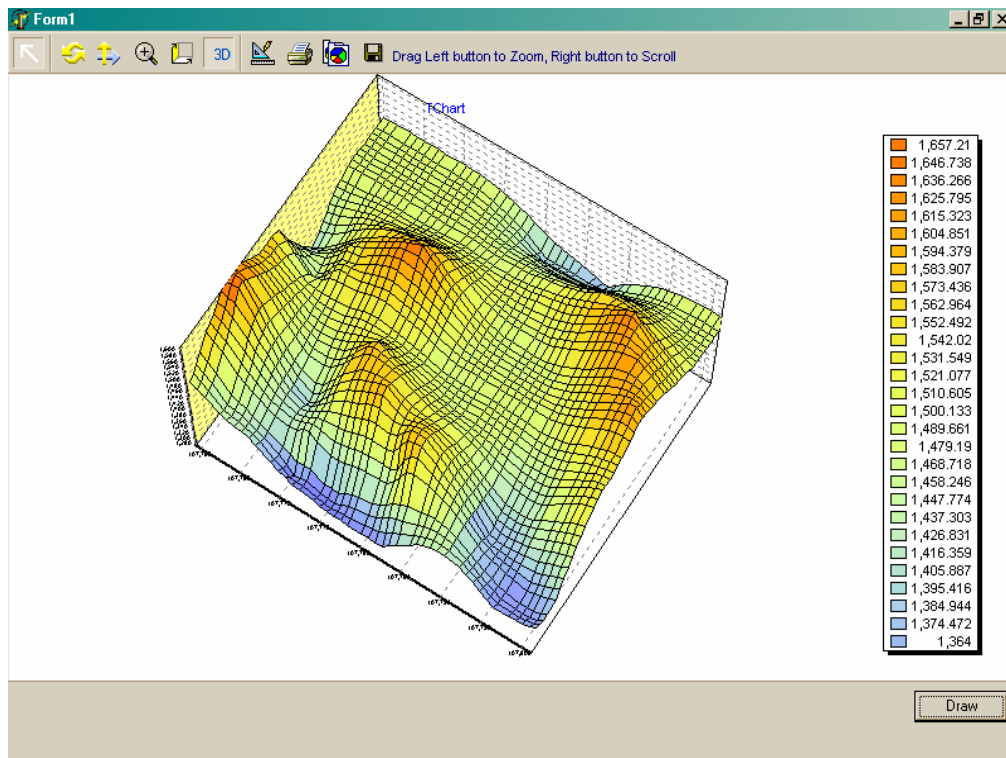


Figure 7: Output from Geostatistics Tool.

2.2.2 Reservoir Characterization using *Geostatistics Tool*

Reservoir characteristics such as porosity, permeability, thickness, water saturation, pressure and temperature are available only in well locations. For a proper reservoir description, we need to predict the variation in these reservoir properties as a function of spatial locations. The

more data that are available, the better will be the reservoir description.

Many methods are available to estimate the correlation for unsampled locations. GeTools uses geostatistical methods where the relation between parameters is not only a function of distance but also entails modelling the relation

between parameters and among parameters with distance. Application of geostatistics requires a three step procedure. These steps are the assumption of stationarity, the spatial modeling of sample data and the estimation of a variable value at the unsampled location.

Figs. 6 and 7 show the output from the Geostatistics Toolbox.

2.3 Production Engineering Toolbox

Production Engineering Toolbox consists of four modules:

1. Orifice Plate and Venturi Tubes Module
2. Lip Pressure and Choke Diameter Module
3. Wellbore Simulation Module
4. Decline Curve Analysis

2.3.1 Orifice Plate and Venturi Tubes Module

Orifice Plate Module allow user to determine water and steam flowrate from the result of measurements using an orifice plate. The mass flow rate through the orifice plate is calculated from measurements of the difference between the pressure on the wall of the pipe at specified distance upstream and downstream of the obstruction.

This module was developed using methods for the measurement of fluid flow in pipes through orifice plates, nozzles and venturi tubes outlined by British Standards Institution (B.S. 1042: Part 1, 1964). At present this module offers calculations for orifice plate with radius tappings, flange tappings, corner tappings and for venturi tubes.

Relevant data required include:

1. Date and time of measurements
2. Well Head Pressure (WHP)
3. Upstream Pressure (Pu)
4. Pressure difference (ΔP) at upstream and downstream
5. Upstream Temperature (Tu)
6. Diameter of Orifice Plates (d)
7. Pipe diameter at upstream (D)
8. Type of tappings
9. Type of material

Figs. 8 and 9 show output from the orifice plate module in tabular and graphic formats.

The screenshot shows the 'Geothermal Engineering Tools' application window. The 'Production Test > Orifice' module is active. The 'Method' is set to 'Radius'. The 'Input' tab is selected, showing a table with 5 rows of data. The table columns are: Date, Time, PU (ksc), TKS (ksc), DP (ksc), TU (°C), m (kg/s), and Q (MW/Th). The data is as follows:

Date	Time	PU (ksc)	TKS (ksc)	DP (ksc)	TU (°C)	m (kg/s)	Q (MW/Th)
9/1/98	12:00:00 PM	14.85	15	0.323	200	18.404	51.384
9/14/98	12:00:00 PM	17.38	17.5	0.23	207	16.769	46.873
9/23/98	12:00:00 PM	17.38	17.5	0.226	207	16.624	46.469
9/28/98	12:00:00 PM	19.92	20	0.154	213	14.783	41.341
10/13/98	12:00:00 PM	24.89	25	0.049	226	9.310	26.122

On the right side of the interface, there are input fields for 'Elevasi' (1500 m), 'Pipe' (Type: 18-8 Stainless Steel, Diameter: 242.93 mm), and 'Orifice' (Type: 18-8 Stainless Steel, Diameter: 200 mm). At the bottom, there is a 'Description' field with the text 'Edit1' and a file path 'radius example / flange example /'.

Figure 8: Output from Orifice Plate Module in Tabular Format.

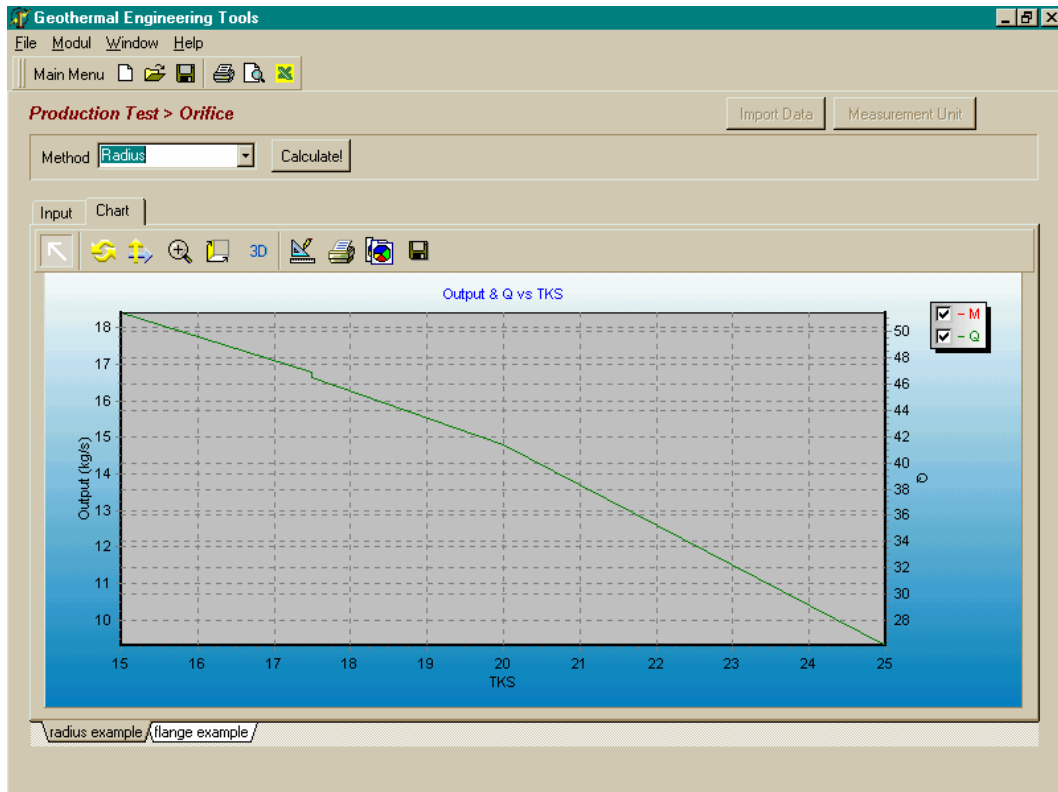


Figure 9: Output from Orifice Plate Module in Graphic Format.

For design purposes, this module provides a program to determine the diameter of orifice plates.

2.3.2 Lip Pressure and Choke Diameter Module

The Lip Pressure module allows users to calculate mass flow rates of water and steam from measurements using lip pressure method outlined by James (1986). It offers a graph of output/production curve that shows relationship between wellhead pressure and mass flow rate, enthalpy and dryness.

The Choke diameter module allows user to calculate choke diameter from data obtained during a production test (Fig. 10). Relevant data required include mass flow rate, fluid enthalpy, cross section area of lip pipe, lip pressure and upstream pressure.

Figure 10: Output from Choke Diameter Module.

2.3.3 Wellbore Simulation Module

The inflow performance of a well represents the ability of the well to produce the fluids. Because of high temperatures encountered in geothermal wells, pressures are usually measured at the wellhead. It is possible to measure the temperature and pressure in the well, but measurements are usually carried out when the well is shut in. Measurements are difficult when the fluid is flowing at high rates. The ability of a well to produce fluids depends, among other parameters, on the reservoir pressure and the rock permeability.

The Wellbore simulation module is designed to provide tools for predicting the performance of geothermal wells. The concept of simulation is the same as that outlined in Hadgu (1989), Gunn and Freeston (1991) and Soendaroe (1997). If the wellhead condition or the bottom hole condition is given, users can predict changes in condition with depth and if a series of runs are made for different wellhead conditions or bottomhole conditions (different production rates) an output/production curve, showing mass flow rate at various well head pressure, can be produced.

Figs. 11 and 12 show the input data and output of the Wellbore Simulation Module.

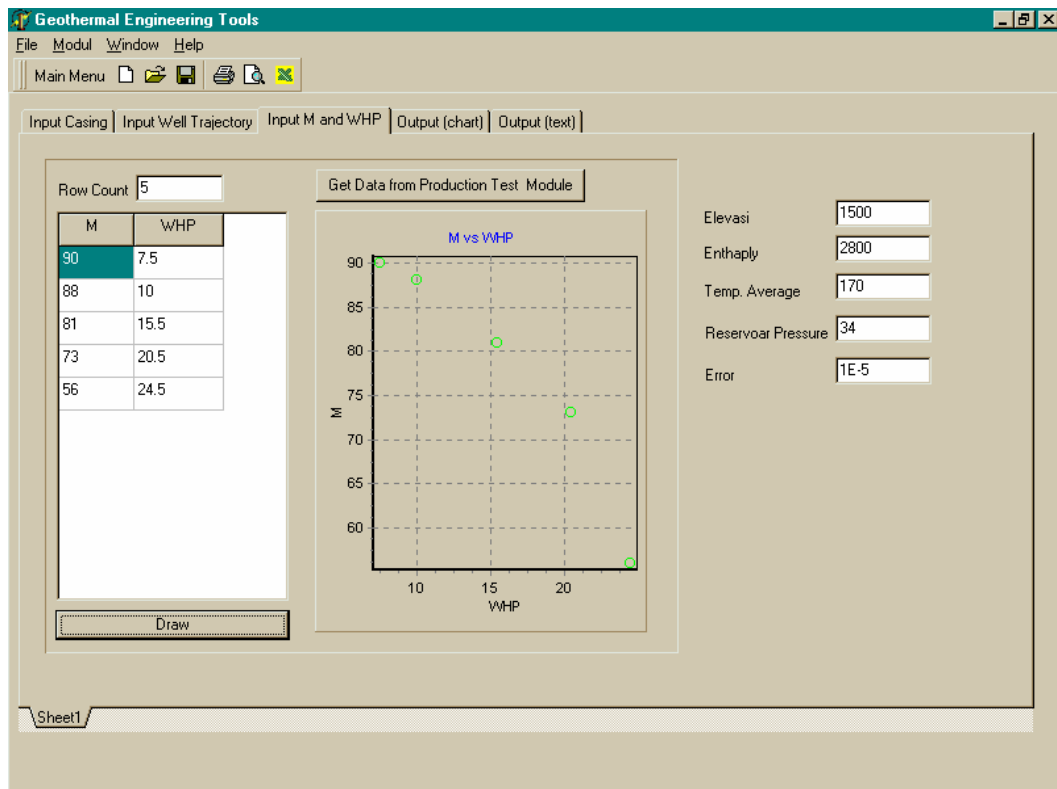


Figure 11: Input Data for Wellbore Simulation.

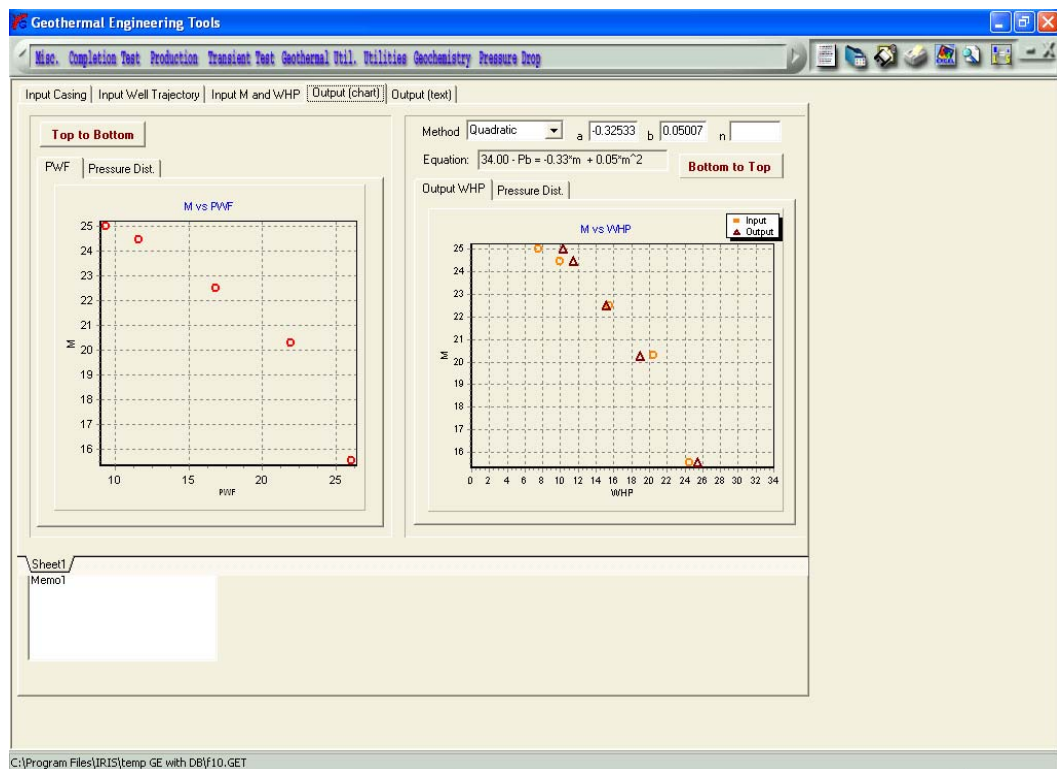


Figure 12: The Results of Wellbore Simulation.

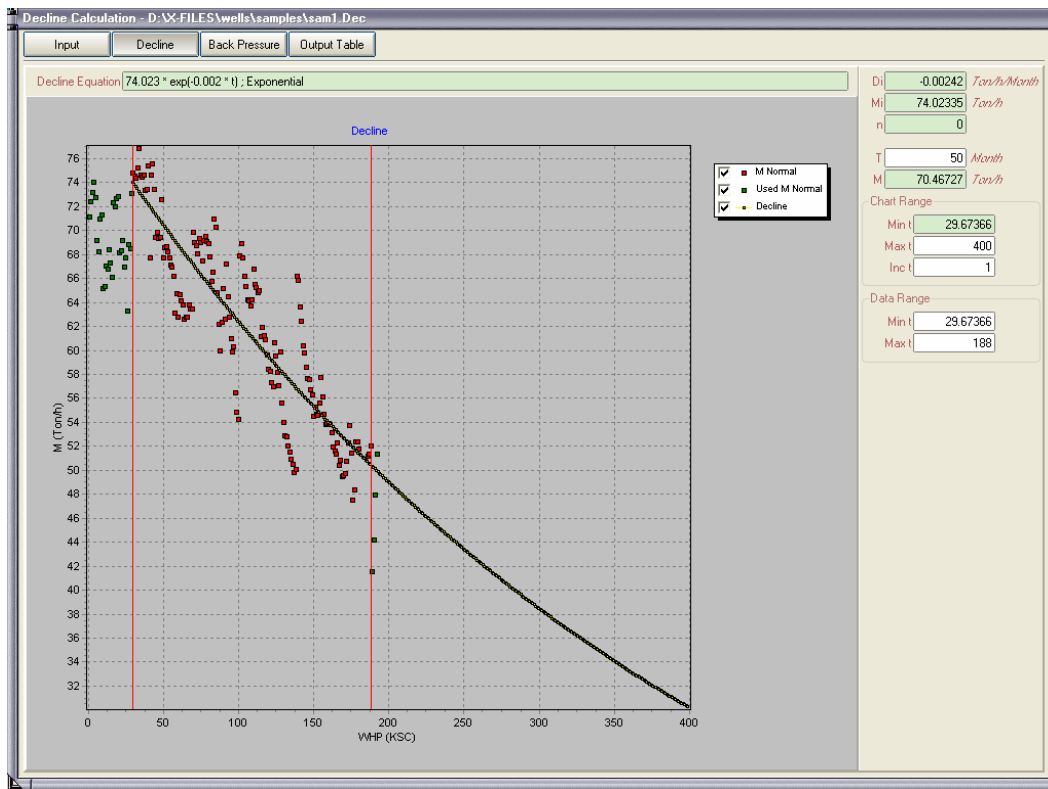


Figure 13: Output from Decline Curve Analysis Module.

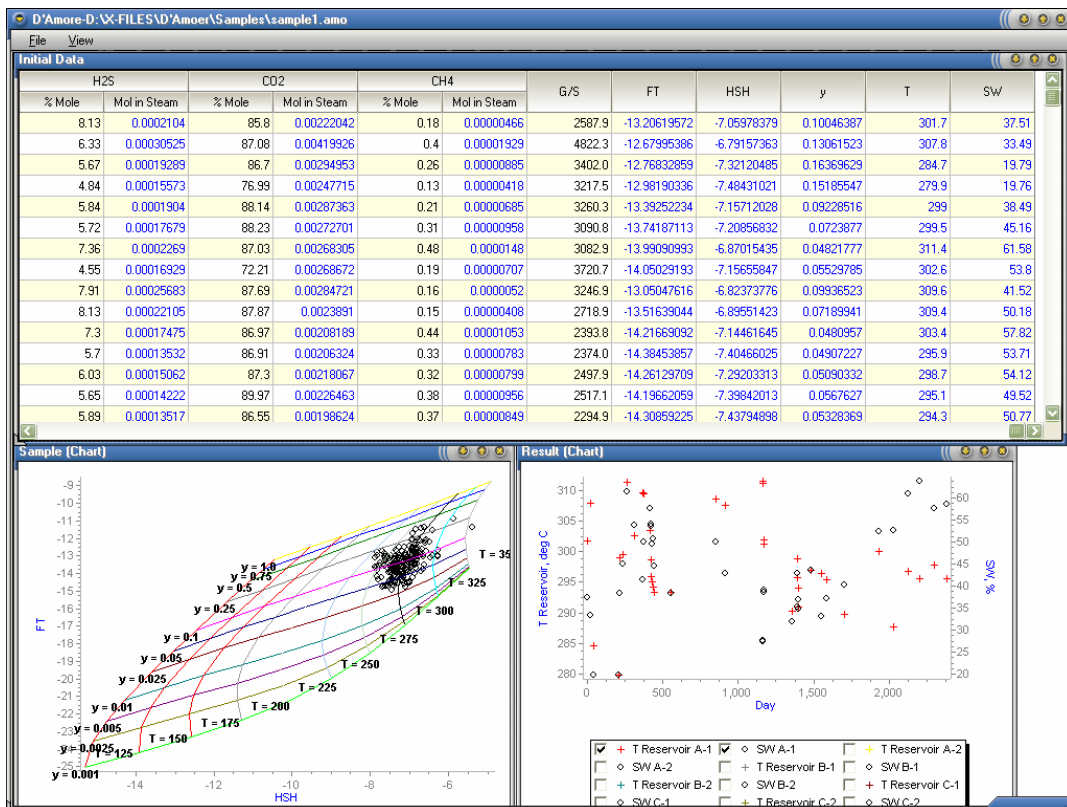


Figure 14: Prediction of Steam Fraction and Reservoir Temperature from Gas Composition.

2.3.4 Decline Curve Analysis Module

Decline curve analysis has been used for many years to predict future well performance from production data. Many different methods have been developed to determine the decline curve parameters. GeTools use the algorithm for hyperbolic decline curve fitting proposed by Spivey (1986).

The algorithm is self starting and converges very rapidly. This program allows an automatic decline curve analysis, either for individual wells or for large groups of wells. The result of analysis is shown in Fig. 13.

2.4 Fluid Properties and Geochemistry Module

The Fluid Properties and Geochemistry Module allows the user to calculate (1) fluid thermodynamic properties and (2) geothermal reservoir temperatures and steam fraction from gas composition.

The Fluid properties module allows users to evaluate water and steam properties at various conditions. The water and steam properties calculated include specific volume, density, viscosity, internal energy, enthalpy, entropy and specific heat. The module can be used stand alone to calculate fluid properties, but it can also provide services to other modules with appropriate properties as functions of pressure and temperature. The correlations currently exists are those derived from the steam table of Rogers and Mayhew (1980) and those deduced by Tortike and Ali (1989).

The Geochemistry module allows users to calculate reservoir temperatures and steam fraction from gas composition using the method proposed by D'Amore and Truesdell (1985). Fig. 14 shows the output from this module in graphic and tabular formats.

3. CONCLUSIONS

GeTools is a userfriendly software packages. Data entry is easy, simple and self-explanatory. The highly graphical nature of the software is extremely helpful. It may help users to work more effectively and efficiently in conducting various analyses.

REFERENCES

- Anderson, E.B., Usher, G.N.H. (1992): GDManager – An Integrated Geothermal Data Management System, Proc. of 13th NZ Geothermal Workshop, Univ. of Auckland, pp. 121-126.
- Barnett, P.R. Farrel, R.B., Paterson, A.R. and Ussher, G.N. (1987): GDManager – A Development in the Management, Interpretation and Representation of Geothermal Field Data, Proc. Of 9th NZ Geothermal Workshop, Univ. of Auckland, pp. 9-15.
- D'Amore, F. and Truesdell A.H. (1986): Calculation of Geothermal Reservoir Temperatures and Steam Fractions from Gas Compositions, Geothermal Resources Council Transactions, Vol 9 – Part 1, pp 305-310.
- Geothermal Energy New Zealand Ltd. and Univ. of Auckland (1991): WELLSIM, Tutorial Manual.
- Geothermal Energy New Zealand Ltd. (1994): Geothermal Data Management and Wellbore Simulation Software: Computer Programs for Geothermal Developers, Part 1, Proc. Geothermal Resources Council, pp. 123-127.
- Gunn, C. and Freeston D.H. (1991): An Integrated Steady-State Wellbore Simulation and Analysis Package, Proc. of 13th NZ Geothermal Workshop, Univ. of Auckland, pp. 161-166.
- Garcia et al. (2000): GEOTRANS: A Computer Code for Estimating Transient Temperature in the Completion of Geothermal Wells with Drilling Fluid Losses, Proc. World Geothermal Conference, Kyushu – Tohoku, Japan, pp. 4023 – 4028.
- Hadgu T. (1989): Vertical Two-Phase Flow Studies and Modelling of Flow in Geothermal Wells. University of Auckland, Department of Mechanical Engineering, Ph.D. Thesis.
- Iglasias et al. (2000): The BDGEO Software Package: A Multi-Toolbox system for Storage, Visualization and Analysis of Geothermal Data, Proc. World Geothermal Conference, Kyushu – Tohoku, Japan, pp. 4043 – 4048.
- Journel, A. (1987): Use of Geostatistics for Reservoir Characterization, Notes from a course, Stanford University.
- Kelkar, M.: “Applied Geostatistics for Reservoir Characterization”, The University of Tulsa, Tulsa-Oklahoma.
- Methods for the Measurement of Fluid Flow in Pipes. Part 1: Orifices Plates, Nozzles and Venturi Tubes, B.S. 1042: Part 1: 1964, British Standards Institution, 221 pp.
- O'Sullivan, M.J. and Mc.Kibbin R. (1987): Geothermal Reservoir Engineering, Course Material, Geothermal Institute - University of Auckland.
- O'Sullivan, M.J. and McKibbin R. (1988): Geothermal Reservoir Engineering, A Manual for Geothermal Reservoir Engineering Course at the Geothermal Institute, University of Auckland, 174 pp.