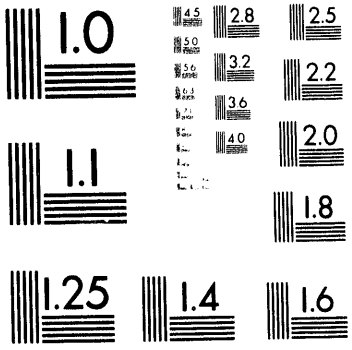
1.0
4.5
2.8
2.5
5.0
3.2
2.2
5.6
3.6
2.0
4.0
1.1
1.8
1.25
1.4
1.6

1 of 1

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GEODIM
Version 2.1

USERS MANUAL
(English Units Version)

by
Mats Larsson
Per-Gunnar Alm

Lund in January 1991

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GEODIM

Introduction

The development of the GEODIM computer program was initiated by Asea-Stal Geo Energy (ASEA), a daughter company of Asea-Stal (now Asea Brown Boveri). ASEA had originally become involved in geothermal development through its heat pump division, a pilot project to develop low temperature (<30°C) geothermal resource in the province of Skåne in southern-most Sweden, and specifically to meet a significant portion of the base load need of the city of Lund's district heating system.

In the late 1970s, the technical university located in Lund, Sweden, had become responsible for a major portion of Sweden's geothermal exploration and development program, the University focussed its efforts on defining the geothermal anomaly located just south of the city of Lund and crosses the entire southern portion of Sweden. The anomaly is associated with a major fault structure that provides the geothermal fluids access to aquifers located at economical drilling depths. Initial drilling succeeded in identifying a mid 20°C geothermal resource available in quantities attractive for development and with a temperature ideal for heat pump-assisted heating applications.

The University of Lund worked closely with Asea-Stal Geo Energy, which had been specifically organized to develop the Lund project as well as geothermal developments, both in Sweden and abroad, and aquifer thermal storage projects that depend upon basically the same technology.

The Lund system was completed in the mid 1980s with the successful drilling of four production wells and a like number of injections wells. Due to some geochemical problems, the system was designed and operated to keep the geothermal fluids under pressure from the production well through the evaporators of the heat pump and back to the injection wells.

The system initially served a 20 MW+ heat pump. The system boosts the temperature available from the geothermal to approximately 80°C for delivery to the Lund municipal district heat system.

With a strong desire to ensure optimum operations of the Lund system, and with an eye toward continued geothermal and aquifer thermal storage systems development in Sweden and abroad, ASEA commissioned the University of Lund Geotechnical Institute to develop a computer program (GEODIM) for use in the design and operational optimization purposes. The Washington State Energy Office (WSEO), because of its close working relationship with both ASEA and the Lund Geotechnical Institute, was asked to review and comment on the work in progress. The program was of extreme interest to WSEO because of its work in the design of low temperature geothermal systems in Washington State.

However, before the program could be completed, falling conventional fuel prices caused ASEA to be reorganized to focus its efforts on natural gas developments, and support for the completion of GEODIM was withdrawn.

In 1988, WSEO was offered the rights to the program in return for financial support required to complete program development. Since WSEO had been actively pursuing direct use as well as heat pump-assisted geothermal projects throughout south central and eastern Washington, and with support from the U. S. Department of Energy (USDOE), WSEO agreed to fund the completion of the program with certain modifications. The principal modification was to adapt the program to be equally useful for all geothermal non-electric projects and not only those dependent upon heat pumps.

In order to ensure the applicability of the program to as wide an array of geothermal projects as possible, WSEO, in turn, entered into contracts with the Idaho Department of Water Resources—Energy Division, and the Oregon Institute of Technology's Geo Heat Center for review of the work in progress and for assistance in testing the program once completed. Both organizations provided important input to the final design requirements for the program, but with their assistance it was quickly learned that testing of the program in a meaningful way in the United States would be impractical if not impossible.

The program is designed to optimize systems depending upon multiple wells for production and injection, and its use requires complete and accurate data on a number of parameters

concerning flow, temperature, geochemistry, pressure, draw down, etc. A majority if not all direct application geothermal resources developed in the United States consist of single production and injection wells and/or multiple production wells with no injection or are not instrumented to provide the data necessary for system optimization. Testing of the program in the U.S. was thus abandoned, but it was still felt that completion of the program would be desirable for the design and optimization of larger systems as they are developed and as more injection is required to maintain reservoir longevity.

It was also felt that when the program was completed it would be of significant benefit to those U.S. companies interested in entering the export market where, for example, in Europe, most systems do consist of multiple wells for both production and injection, and more detailed data acquisition is the rule rather than the exception.

Because of our inability to adequately test and calibrate the program in the U.S., it was decided that the Lund system, for which GEODIM was originally developed, would serve as the test system. The Lund system now has 5 years of operational data available and could thus serve as an ideal test of the design and optimization which had originally been completed there. The program was successfully completed and tested in 1991, and subsequently converted by WSEO from the original metric unit version to English units to be of maximum use world-wide.

The program is designed to allow geothermal project developers to design and optimize direct application heating systems from the production well through the piping system, to the central heat exchanger or heat pump evaporation, and then through the piping system to the injection wells. Although the program was originally designed for the design and optimization of geothermal systems, it may be used for any hydrothermal system. For example, a heat pump system that uses surface water, sewage effluent, or aquifer thermal storage, or a direct heat application that uses industrial waste heat or other thermal sources can also be modeled.

The use of the program is detailed in the user manual which is available in two separate versions to cover both English and metric units. In addition to covering the use of the program, the user manual contains several examples that were prepared by Lund's Geotechnical Institute to help the user better understand the capabilities of the program.

Soon after the release of GEODIM (June 1992), it is anticipated that the GEODIM program will become the basis for a new geothermal production module that will be added to the HEATMAP series of programs, also developed by WSEO and designed as tools for conducting feasibility and preliminary design studies relating to district heating and cooling systems. When available in HEATMAP in mid 1993, the GEODIM concept will significantly enhance HEATMAP's capability to deal with a wide range of thermal production units. Because HEATMAP is AUTOCAD-based, it will allow the user to physically locate wells and heat exchanger stations as well as any proposed piping systems, and should thus lead to more optimum system design and operation. As such, it should serve to promote much expanded use of geothermal energy for district heat and/or cooling purposes.

G E O D I M
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Lund in January 1991

Prepared by
The University of Lund
Lund, Sweden
and
The Washington State Energy Office
Olympia, U.S.A.

ACKNOWLEDGEMENTS

The program developer would like to thank the Oregon Institute of Technology and the Idaho Department of Water Resources for their input during the developement of the program.

The design and programming of the software GEODIM was completed by Mats Larsson of the University of Lund. He has also written the main part of this manual.

Chapter nine was written by Per-Gunnar Alm who has also been responsible for testing the program and editing the manual.

The English unit version of the program was prepared by Van Shafer of the Washington State Energy Office.

PREFACE

The GEODIM computer program has been developed as a joint project of the University of Lund, Lund, Sweden and the Washington State Energy Office (WSEO) and has been supported by the U.S. Department of Energy under Grant # DE-FG07-881D12739.

In addition to the University of Lund and WSEO, the Oregon Institute of Technology Geo Heat Center and the Idaho Department of Water Resources provided input into the development of the program.

The development of GEODIM was originally begun in response to the need to optimize the Lund, Sweden geothermal system. This system is the world's largest heat pump geothermal system having an output of 50MW thermal. The 50MW of output provides a significant percentage of the base load thermal demand of the Lund district heating system.

When approached by WSEO, the University of Lund agreed to expand the capability of the program and make it equally unstable for the optimization of direct use system's which do not employ heat pumps. In addition, the university prepared examples of how the program can be used.

WSEO has converted the program to English units thus making it available in either metric or English units. The two versions of the program are described in separate user manuals.

The program has been extensively tested against data from the Lund system which now has five years of operating data. The program has proved itself to be a valuable tool for optimizing piping systems and system operation.

Although the program was originally designed for the optimization of geothermal systems employing both production and injection wells, it can be just as successful used for my system using a water source be it surface water or waste water from industry or effluent from a sewage treatment plant.

Questions concerning the operation of the program should be addressed to the Washington State Energy Office, R. Gordon Bloomquist, 809 Legion Way SE, Olympia, WA 98504-3165.

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1. INTRODUCTION

GEODIM is a computer program for design and optimization of geothermal heat plants. Given environment and well specifications, GEODIM supports design and optimization of the interconnecting pipe system and the production pumps. Finally the available heat output is computed.

This program was originally designed for a geothermal project in Lund, Sweden. The Lund plant is a low temperature system with four production wells and five reinjection wells. The produced flow rate is about 700 liters per second (11100 gallons per minute), with a temperature of slightly above 20 degrees Celsius (70 degrees Fahrenheit). The central plant consists of two heat pumps with a total heat output of 50 thermal megawatts. The plant is connected to the district heating system of Lund.

In its present version, GEODIM is limited to configurations similar to that shown in figure 1.1. With the wells arranged in a sequentialbut not necessarily straight line connected to a central heat plant. The central plant is assumed to have no internal pressure loss, but since a booster pump may be inserted before the plant, this can be used to simulate pressure loss by inserting a negative value for the booster pump.

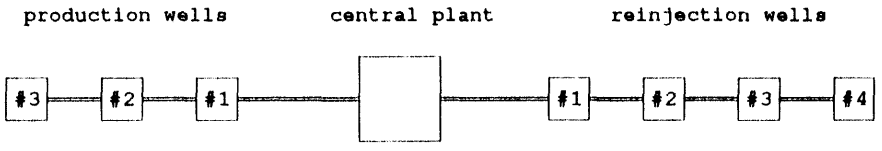

Figure 1.1 System configuration

GEODIM consists of four main input/output modules, each coupled to a calculations module. These modules are:

Environment specification

A work sheet is used for entering the chemical composition of the geothermal water, ground related parameters, and some default parameters.

Well design

A data base for source data is, implemented as card index files. This is the main input unit. It should be noted that the term "well" is not to be taken literally. It should be regarded as a node in the pipe system, which may or may not contain some sort of production/reinjection unit. For example, the "well" could be a body of surface water or a waste water treatment plant effluent line.

Pipe System design

This is the central unit of GEODIM, built around a work sheet with interactive calculation capability. The user can change the pipe dimensions and other parameters, and immediately see the effects on flow velocity, temperature losses, and friction losses.

Pump design

A work sheet for pump design, similar to the Pipe system work sheet. This unit also produces a pressure profile for the pipe system.

1.1 INPUT PARAMETERS

The environment specification is made up of the following parameters:

· **Salinity.** [% by weight]
The salinity parameter is used in the calculations of specific heat and density of the geothermal water. It is given as two numbers; the total content of monovalent compounds, and the total content of bivalent compounds. In the formulas used by GEODIM, monovalent compounds are represented by Sodium Chloride (NaCl), and bivalent compounds are represented by Calcium Chloride ($CaCl_2$). For practical purposes, the salinity factor may be disregarded unless the total contents is more than several percents.

· **Gas solubility point.** [psi]
The gas solubility point (or partial pressure) is used to determine the lowest allowable pressure in the pipe system. If the water does not contain any dissolved gas, this parameter should be zero. The salinity and gas solubility figures are obtained by chemical analysis of the geothermal water.

· **Reinjection temperature.** [°F]
The estimated (or desired) reinjection temperature can not be specified for each reinjection well. Instead, the output temperature from the heat plant should be used. Since temperature losses in the reinjection system is disregarded, this parameter affects the available heat output only. If the lowest possible temperature is used, then the maximum heat output will be calculated.

· **Burial depth.** [ft]
This is the average depth to the head of pipes, which affects the temperature losses. The value entered is used as a default value for each pipe section, it can be changed section for section in the Pipe System work sheet.

· **Absolute roughness.** [in]
This parameter describes the inner surface smoothness of a pipe. It is provided by the pipe manufacturer, and is used in the pressure loss calculations. A common standard value is 0.1 in.

· **Ground temperature.** [°F]
The average annual temperature at the actual burial depth, used in the temperature loss calculations.

· **Ground heat conductivity.** [Btu/ft/°F]
The average heat conductivity of the material surrounding the pipes is another parameter affecting temperature losses. For clay, a common material in southern Sweden, the heat conductivity is about 3 Btu/ft/°F. GEODIM can not, in its present version, properly calculate the temperature losses in sand bedded or insulated pipes. However, the user may substitute ground conductivity with sand or insulation conductivity without introducing unacceptable error. The thermal conductivity for sand is generally 0.5 Btu/ft/°F or less. The insulation data is provided by the pipe manufacturer.

· **Production pump efficiency.** [%]
The efficiency factor, provided by the pump manufacturer, is used to calculate the electrical power consumption of the pumps. A reasonable figure for a submersible pump is 75%. The efficiency of a shaft driven pump is approximate.

The Well data base is made up from the following parameters:

· **The number of production wells.** (1 - 6)

· **The number of reinjection wells.** (1 - 6)

For each production well:

· **Produced flow rate.** [g/m]
A flow rate of zero can be used to indicate either a closed well or a 'virtual well'. A virtual well is merely a node in the pipe system, which is used if some pipe parameter is to be changed between two wells. Another virtual well application is to determine the local pressure somewhere in the pipe system. If the flow rate is zero, the draw down and temperature parameters are of no importance.

· **Draw down** at the produced flow rate. [ft]
Throughout this manual, the term 'draw down' is used to indicate the steady state water level below wellhead at the produced flow rate. The draw down parameter is used to calculate the required pump capacity to produce a sufficient well head pressure. For artesian wells a negative value should be inserted.

· **Water temperature.** [°F]
The temperature measured at the wellhead at the produced flow rate should be used.

· **Distance** from the previous well. [ft]
The term 'distance' indicates the equivalent length of the pipe section that connects to the previous well (or, for well #1, the central plant).

· **Relative altitude** vs. the central plant. [ft]
The central plant is used as altitude reference. If the well head is located at a higher level than the plant, the relative altitude is positive, for a lower level it is negative.

For each reinjection well:

· **Reinjected flow rate.** [g/m]
A flow rate of zero can be used to indicate either a closed well or a 'virtual well'. A virtual well is merely a node in the pipe system, which is used if some pipe parameter is to be changed between two wells. Another virtual well application is to determine the local pressure somewhere in the pipe system. If the flow rate is zero, the reinjection parameter is of no importance.

· **Reinjection pressure** required for the reinjected flow rate. [ft]

· **Distance** from the previous well.[ft]
Total equivalent length should be used.

· **Relative altitude** vs. the heatplant.[ft]

1.2 OUTPUT PARAMETERS

The main output parameters are:

· **Total produced flow rate.** [g/m]

· **Available heat output.** [kW]

From the main menu it is possible to get an overview of data from the heatplant. See also figure 1.1.

```
G E O D I M  v2.11-e                Current Workfile: C:\GEODIM\LUND.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 4
                                                No.of Reinjection Wells : 5

                          RESULTS
Available power output at heatplant:    33.40 MW
Total produced flowrate:              1031.7 lb/sec
Water temperature at heatplant:         69.9 °F
Estimated reinjection temperature:      39.20 °F
Specific heat per lb at heatplant:       1.00 Btu/lb/°F
Salinity - monovalent compounds:          0.1 %
Salinity - bivalent compounds:            0.1 %
Gas solubility point:                     0.0 psi

Results Preview
```

Figure 1.1. Presentation of the results chosen from the main menu.

For each pipe section:

· **Mean velocity of flow.** [ft/s]

· **Temperature loss.** [°F]

· **Friction loss.** [ft]

Well parameters:

- **Pressure profile.** [psi]
  Water pressure at each well head.

- **Pump capacity.** [psi]
  Required capacity for each production pump.

- **Power consumption.** [kW]
  Electrical power consumption for each production pump.

1.3 PRINTED OUTPUT

To get a printed report of the results use the print screen utility on your computer. Connect a printer to your computer and press Prt Sc to get a hard copy of your current screen.

2. OVERVIEW

GEODIM is a menu driven, window orientated program. All menus are Lotus type, Eg. one line horizontal menus with selection bar. The submenus are pull down menus, Eg. vertical menus with selection bar. Selections are made either by moving the bar to the desired selection and then pressing <Enter>, or by pressing the key corresponding to the highlighted letter in the desired selection.

2.1. PROGRAM STRUCTURE

GEODIM is organized into ten units with associated menus, submenus and calculation routines. This layout emails two advantages; user friendliness and interactive operation. Thus the user can switch between the units and watch the effects of changes without having to run the program several times with different data sets.

The structure is shown in fig. 2.1. The different units are discussed later in this manual.

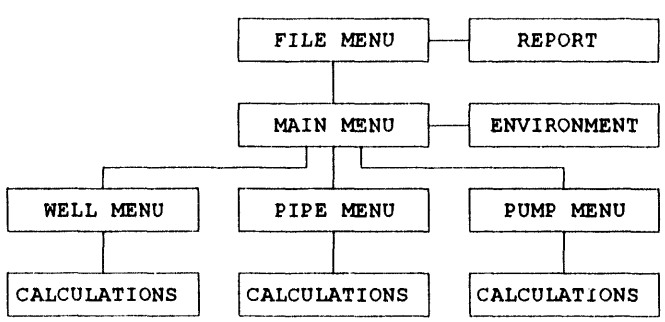

Figure 2.1. The program structure of GEODIM.

2.2 DATA STRUCTURE

The data is organized into three levels. The bottom level, the current workfile, is a disk file containing all data concerning the typical plant. The next level contains three temporary buffers for well, pipe, and pump data. These buffers are implemented as disk files in order to enable recovery from power failure etc. The top level is the active data used in calculations and screen presentations.

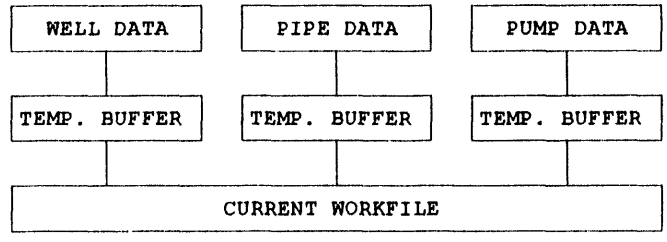

Figure 2.2. The data structure of GEODIM.

3. FILE MENU

The File Menu is the first screen that appears when GEODIM is run. All file operations are performed here. Selections are made from the menu line in the upper left corner. The bottom row contains a help/ status line. All selections are described in the next section, "File Menu Selections".

```
G E O D I M  v2.11-e                    No Workfile Selected.
New Open Save Options Main Quit
                 Rename
                 Erase
                 Report
                 EXT
                                  C:\GEODIM\*.GDF
                                 ..\            afile.gdf
                                 C\             bfile.gdf
                                 MANUAL\        lake.gdf
                                 OLD.TPU\       lund.gdf
                                 a.gdf          ml.gdf
                                 a1.gdf         qq.gdf
                                 aaa.gdf
Erase File
```

Figure 3.1. The Main Menu screen after the Options/Erase "GARBAGE.GDF" command.

Example:

To work with the file "LUND.GDF", perform the following steps:

1: Move the selection bar to "Open" and press <Return> (or press the <O> key). This will open the File Directory Window and place the selection bar at the first file.

2: Move the selection bar to "LUND.GDF" in the file directory window, and press <Return>. The file is now read in, and the window is closed.

3: Move the selection bar to "Main" and press <Return> (or press the <M> key). The screen should now look like fig. 5.1. on page 5-1.

3.1. FILE MENU SELECTIONS

- **New**
  Use this selection to create a new workfile. See next chapter (Create a new workfile) for details.

- **Open**
  A file directory window is opened, and a previously saved workfile can be selected.

- **Save**
  The active workfile may be saved under the same name (overwritten), under a different name, or discarded.

- **Options**
  This is a pull down submenu with following selections:

  - **Rename**
    Rename a workfile in the file directory.

  - **Erase**
    Erase a workfile in the file directory.

  - **EXT**
    Change the file name extension for the file directory window. Wildcards ("*" or "?") are accepted. The default extension is "GDF" (GEODIM Data File).

- **Main**
  Continue to the main menu.

- **Quit**
  Terminate program.

4. CREATING A NEW WORKFILE

To create a new workfile, select the "New" command in the File Menu. You will then be requested to enter a file name of maximum 8 characters, no extension. The extension is set using the 'EXT' option, see p.3-2. When a file name has been accepted, the environment specification work sheet is brought up.

```
G E O D I M  v2.11-e                Current Workfile: C:\GEODIM\LUND.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 4
                                                No.of Reinjection Wells : 5

                    DEFAULT SETTINGS
Geothermal Water
Salinity - Total Monovalent Compounds     0.10 [% /w]
Salinity - Total Bivalent Compounds       0.10 [% /w]
Gas Solubility Point                      0.00 [psi]
Reinjection Temperature                  39.20 [°F]
Pipe System
Burial Depth                              3.28 [ft]
Smoothness                               0.001 [in]
Ground Temperature                       50.00 [°F]
Ground Heat Conductivity                  3.12 [Btu/ft/°F]
Pump System
Production Pump Efficiency               75.00 [%]

| Move: arrow keys | Edit: <INS> | Save: <F2> | Restore: <F4> | Quit: <ESC> |
```

Figure 4.1 The Environment specification work sheet.

When the environment specification is completed, the next requests are the number of production and reinjection wells. Valid numbers are between 1 and 6.

Two index card files are used to enter well data, one file for production wells, and the other for reinjection wells. A separate card is used for each well.

Following parameters are required:

For each production well:

Produced flow rate
Draw down at produced flow rate (measured or calculated)
Water temperature
Distance from previous well (Eg. pipe length)
Relative altitude well-head - power plant

```
[PRODUCTION WELL #1]
[PRODUCTION WELL #2]
[PRODUCTION WELL #3]
 αp3                                Note 1 (max 25 chrs)
 Alpha Prod 3rd                     Note 2 (max 25 chrs)
Flow rate        111.70 g/m         Produced flow rate
Draw down         38.29 ft          Draw down at produced flow rate
Temperature       ______ °C         Water temperature
Distance                 ft         Distance from previous well
Rel. Altitude            ft         Relative altitude vs. heatplant
```

Figure 4.2 Entering water temperature for production well 3.

For each reinjection well:

Reinjected flow rate
Reinjection pressure at reinjected flow rate
Distance from previous well (Eg. pipe length)
Relative altitude well-head - powerplant

```
                                    [REINJECTION WELL #1]----
                                    [REINJECTION WELL #2]----
                                    [REINJECTION WELL #3]----
                                    [REINJECTION WELL #4]----
Note 1 (max 25 chrs)                 αr3
Note 2 (max 25 chrs)                 Alpha Rein 3rd
Reinjected flow rate                Flow rate        96.22 g/m
Reinjection pressure                Inj. Pressure   39.4__ ft

Distance from previous well         Distance               ft
Relative altitude vs. heatplant     Rel. Altitude          ft
```

Figure 4.3 Entering reinjection pressure for reinjection well 4.

5. MAIN MENU

This is the main screen from where the other screens are called. The name of the current workfile and the number of wells associated are found in the upper right corner.

```
G E O D I M  v2.11-e                Current Workfile: C:\GEODIM\LUND.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 4
                                                No.of Reinjection Wells : 5

Well Data
```

5.1 MAIN MENU SELECTIONS

- **Wells**
  Continue to the Well Menu and open the Well Data index card files.

- **Pipes**
  Continue to the Pipe Menu and open the Pipe System work sheet.

- **Pumps**
  Continue to the Pump Menu and open the Pump System work sheet.

- **Results**
  This brings up a preview of some parameters that are not shown in the other menus, eg. the available output power and the total produced flow rate.

- **Environment**
  Open the Environment Specification work sheet.

- **Quit**
  Return to the File Menu.

6. WELL MENU

The Well Screen is simply a view-and-edit function for Well data. The only calculation made is a check that the produced flow rate matches the reinjected flow rate. The same card index system as described in the "Create a new Workfile" is used.

```
G E O D I M  v2.11-e                Current Workfile: C:\GEODIM\LUND.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 4
                                                No.of Reinjection Wells : 5

                                                Overproduction 93 g/m

                                        REINJECTION WELL #5
                                        REINJECTION WELL #4
                                        REINJECTION WELL #3
                                        REINJECTION WELL #2
                                        REINJECTION WELL #1
                                        Vä 2

                                        Flowrate      1664.03 g/m
                                        Inj. Pressure 136.55 ft

                                        Distance      6561.60 ft
                                        Rel.Altitude   -32.81 ft

PRODUCTION WELL #4
PRODUCTION WELL #3
PRODUCTION WELL #2
PRODUCTION WELL #1
Sk 1

Flowrate      1843.11 g/m
Drawdown       128.94 ft
Temperature     68.81 °F
Distance      8802.39 ft
Rel.Altitude   -54.63 ft

| Move: arrow keys | Edit: <INS> | Save: <F2> | Restore: <F4> | Quit: <ESC> |
```

Figure 6.1 Well Menu - Changing the reinjection pressure at reinjection well no. 4.

The "Save" option means that the active data (as seen on the index cards) is stored in a temporary buffer.

The "Restore" option means that the temporary buffer is read back into the active data, i.e. the index cards are updated.

On entry, the temporary buffer holds the current workfile data, so "Restore" will do nothing unless the active data has been changed.

7. PIPE MENU

The Pipe Screen is a work sheet with five columns for input data, and three columns for calculated data. Each row denotes a pipe section between two wells.

Input parameters are:
1. d : Pipe dimension - inner diameter
2. H : Burial depth - surface to head
3. k : Smoothness
4. T_0 : Surrounding ground temperature
5. lambda : Thermal conduction factor

Calculated parameters are:
6. mv : Mean velocity of water
7. δT : Temperature loss
8. H_f : Friction loss

```
G E O D I M  v2.11-e                    Current Workfile: C:\GEODIM\LUND.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 4
                                                No.of Reinjection Wells : 5
```

PIPE SYSTEM DESIGN

	d [in]	H [ft]	k [in]	T0 [°F]	lambda [Btu/ft/°F]	mv [ft/s]	δT [°F]	Hf [ft]
P4-P3	12.41	6.56	0.010	41.00	3.12	4.92	0.00	0.00
P3-P2	17.35	6.56	0.010	41.00	3.12	4.92	0.08	5.99
P2-P1	21.52	6.56	0.010	41.00	3.12	4.92	0.05	3.83
P1-HP	24.82	6.56	0.010	41.00	3.12	4.92	0.30	26.37
HP-R1	24.82		0.010			4.92		20.05
R1-R2	21.87		0.010			4.92		3.31
R2-R3	18.76		0.010			4.92		10.28
R3-R4	15.63		0.010			4.92		0.00
R4-R5	10.85		0.010			4.92		0.00

```
| Move: arrow keys | Edit: <INS> | Save: <F2> | Restore: <F4> | Quit: <ESC> |
```

When a new workfile is created, default values are used for the H, k, T_0, and lambda columns. The pipe dimensions are calculated from the default mean velocity.

The "Save" and "Restore" commands are the same as described in the Well Menu section.

8. PUMP MENU

The Pump Screen is a work sheet with one column for input data, and three columns for calculated data. Each row denotes a node in the pipe system, Eg. a well head, the booster pump, or the heat plant.

Input parameter is:
1. PC : Pump Capacity

Calculated parameters are:
2. P : Electrical power consumption
3. WHP : Well Head Pressure
4: VR : Valve Rate

```
G E O D I M  v2.11-e                Current Workfile: C:\GEODIM\LUND.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 4
                                                No.of Reinjection Wells : 5

                    PUMP DESIGN
              PC        P     WHP      VR
            [psi]     [hp]   [psi]    [%]
        P4  97.42     6.00   43.89  100.00
        P3  97.95     5.76   43.89  100.00
        P2  91.30     5.93   37.92  100.00
        P1  90.53     5.55   34.93  100.00
        HP                    0.00
        BP  53.77    13.27   53.77
        R1                   59.30   99.79
        R2                   60.33  100.00
        R3                   63.51   97.95
        R4                   63.51   88.21
        R5                   63.51   88.21

| Move: arrow keys | Edit: <INS> | Save: <F2> | Restore: <F4> | Quit: <ESC>
```

The "Save" and "Restore" commands are the same as described in the Well Menu section.

9. EXAMPLES
9.1 CREATE DATA FILE

This examples will show you how to create a data file and use it for various applications. This section will also discuss the use of an already existing data file.

To start GEODIM, do the following:
For computers with a hard disk
it is assumed that the GEODIM software is copied onto the hard disk.
Change to the directory where the GEODIM files are located and **type GEODIM and press RETURN**

For computers with disk drives
Insert GEODIM diskette in drive, thereafter **type GEODIM and press RETURN**

The first thing GEODIM presents is the opening menu.

```
G E O D I M  v2.11-e          No Workfile Selected.
New Open Save Options Main Quit

Open Data File
```

To create a new data file either press **N** or move the highlighted area to NEW and press Return

You are then asked to give name of new data file.
Type TWOWELLS and press RETURN. No extension has to be given since GEODIM it self adds extension **.GDF**.

You are then asked to give the numbers of production wells and reinjection wells. In this first example, we are going to use one of each.
Thereafter GEODIM presents this screen:

```
G E O D I M  v2.11-e                          New Workfile: TWOWELLS.GDF
New Open Save Options Main Quit               No.of Production Wells  : 1
                                              No.of Reinjection Wells : 1
                        DEFAULT SETTINGS
                Geothermal Water
                Salinity - Total Monovalent Compounds  0.00   [% /w]
                Salinity - Total Bivalent Compounds           [% /w]
                Gas Solubility Point                          [psi]
                Reinjection Temperature                       [°F]
                Pipe System
                Burial Depth                                  [ft]
                Smoothness                                    [in]
                Ground Temperature                            [°F]
                Ground Heat Conductivity                      [Btu/ft/°F]
                Pump System
                Production Pump Efficiency                    [%]

Enter New Data
```

Enter the data below.
Note that there are certain parameters that have default values. If you accept them just press RETURN.

Salinity - Total Monovalent Compounds	**0.3**	**% /w**
Salinity - Total Bivalent Compounds	**0.2**	**% /w**
Gas Solubility Point	**87**	**psi**
Reinjection Temperature	**59**	**°F**
Burial Depth	**16**	**ft**
Smoothness	**0.01**	**in**
Ground Temperature	**46**	**°F**
Ground Heat Conductivity	**3.0**	**Btu/ft/°F**
Production Pump Efficiency	**75.0**	**%**

After the environmental parameters have been given to the program the specific data for each well has to be given according to the next two screens.

Enter the following values:

Production well:

Title:	ALPHA ONE	
Subtitle:	Production	
Flow rate:	1188	g/m
Draw down:	59.0	ft
Temperature:	113.0	°F
Distance:	3116	ft
Rel. Altitude:	17.75	ft

Reinjection well:

Title:	BETA ONE	
Subtitle:	Reinjection	
Flow rate:	1188	g/m
Inj.Pressure:	70.0	ft
Distance:	1722	ft
Rel. Altitude:	-7.0	ft

```
G E O D I M  v2.11-e                 No WorkfilNew Workfile: TWOWELLS.GDF
New Open Save Options Main Quit                 No.of Production Wells  : 1
                                                No.of Reinjection Wells : 1

            PRODUCTION WELL #1
                 ALPHA ONE
               PRODUCTION
        Flowrate       1188.00 g/m
        Drawdown         59.00 ft
        Temperature     113.00 °F
        Distance       3116.00 ft
        Rel.Altitude     17.75 ft

Enter New Data
```

```
G E O D I M  v2.11-e                 No WorkfilNew Workfile: TWOWELLS.GDF
New Open Save Options Main Quit                 No.of Production Wells  : 1
                                                No.of Reinjection Wells : 1

            PRODUCTION WELL #1                  REINJECTION WELL #1
                 ALPHA ONE                           BETA ONE
               PRODUCTION                         REINJECTION
        Flowrate       1188.00 g/m         Flowrate       1188.00 g/m
        Drawdown         59.00 ft          Inj. Pressure1722.00 ft
        Temperature     113.00 °F
        Distance       3116.00 ft          Distance       1722.00 ft
        Rel.Altitude     17.75 ft          Rel.Altitude -7        ft

Enter New Data
```

After the data input, you are back at the opening screen, but with **MAIN** highlighted.

```
G E O D I M  v2.11-e          Current Workfile: TWOWELLS.GDF
New Open Save Options Main Quit          No.of Production Wells  : 1
                                         No.of Reinjection Wells : 1

Main Menu
```

Here you can continue or quit. **To continue press RETURN.**
You will then reach the main screen where **WELLS** is highlighted. **Press RETURN**

```
G E O D I M  v2.11-e          No WorkfilNew Workfile: TWOWELLS.GDF
WELLS PIPES PUMPS Results Environ Quit   No.of Production Wells  : 1
                                         No.of Reinjection Wells : 1

      PRODUCTION WELL #1                 REINJECTION WELL #1
          ALPHA ONE                          BETA ONE
        PRODUCTION                         REINJECTION
Flowrate      1188.00 g/m          Flowrate      1188.00 g/m
Drawdown        59.00 ft           Inj. Pressure1722.00 ft
Temperature    113.00 °F
Distance      3116.00 ft           Distance      1722.00 ft
Rel.Altitude    17.75 ft           Rel.Altitude -7       ft

Enter New Data
```

Here it is possible to edit the input values for the different wells.
To leave this screen press ESC which will take you back to the main menu.
You can then go to the pipes screen as shown on the next page. **Choose PIPES and press RETURN**

```
G E O D I M  v2.11-e                    Current Workfile: TWOWELLS.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 1
                                                No.of Reinjection Wells : 1

                          PIPE SYSTEM DESIGN
                d       H       k      T0   lambda       mv      δT      Hf
              [in]    [ft]    [in]   [°F] [Btu/ft/°F] [ft/s]   [°F]    [ft]
| P1-HP |     9.93    6.56   0.010  41.00     3.12      4.92    1.18   28.43
| HP-R1 |     9.93           0.010                      4.92           16.26

| Move: arrow keys | Edit: <INS> | Save: <F2> | Restore: <F4> | Quit: <ESC> |
```

Since our data does not agree with the default values new data entries have to be made for H = 16.00 (burial depth) and T_0 = 46 (Surrounding ground temperature).
When these values have been corrected, the δT (temperature loss) will also change.
The screen will look like this.

```
G E O D I M  v2.11-e                    Current Workfile: TWOWELLS.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 1
                                                No.of Reinjection Wells : 1

                          PIPE SYSTEM DESIGN
                d       H       k      T0   lambda       mv      δT      Hf
              [in]    [ft]    [in]   [°F] [Btu/ft/°F] [ft/s]   [°F]    [ft]
| P1-HP |     9.93   16.00   0.010  46.00     3.12      4.92    0.88   28.43
| HP-R1 |     9.93           0.010                      4.92           16.26

| Move: arrow keys | Edit: <INS> | Save: <F2> | Restore: <F4> | Quit: <ESC> |
```

If you try to leave this screen by **Quit** without saving the new data first, you will be asked if you will save the pipe data. Press **Y**
You can then choose the pump screen. Choose **PUMPS** and press **RETURN**.

```
G E O D I M  v2.11-e                    Current Workfile: TWOWELLS.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 1
                                                No.of Reinjection Wells : 1

                    PUMP DESIGN
              PC        P     WHP      VR
            [psi]     [hp]   [psi]     [%]
     P1    116.53     4.60   91.35  100.00
     HP                       86.80
     BP    660.81    26.09  747.61
     R1                      743.61    4.07

| Move: arrow keys | Edit: <INS> | Save: <F2> | Restore: <F4> | Quit: <ESC> |
```

```
G E O D I M  v2.11-e                    Current Workfile: TWOWELLS.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 1
                                                No.of Reinjection Wells : 1

                              RESULTS
Available power output at heatplant:        9.20 MW
Total produced flowrate:                  165.1 lb/sec
Water temperature at heatplant:           112.1 °F
Estimated reinjection temperature:        59.00 °F
Specific heat per lb at heatplant:         0.99 Btu/lb/°F
Salinity - monovalent compounds:            0.3 %
Salinity - bivalent compounds:              0.2 %
Gas solubility point:                      86.8 psi

Results Preview
```

Before you leave the program don't forget to save the data file. Use the **SAVE** option in the **MAIN MENU**.

9.2 MODIFY DATA FILE

In the next example we are going to use an already existing file and modify some values. Start GEODIM and use the **OPEN** option. Choose file **TEST.GDF**. GEODIM then presents this screen:

```
G E O D I M  v2.11-e                Current Workfile: TEST.GDF
New Open Save Options Main Quit                 No.of Production Wells  : 1
                                                No.of Reinjection Wells : 1

Main Menu
```

Press RETURN and then chose Environment.

```
G E O D I M  v2.11-e                Current Workfile: C:\GEODIM\TEST.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 1
                                                No.of Reinjection Wells : 1

                    DEFAULT SETTINGS
Geothermal Water
Salinity - Total Monovalent Compounds     1.00 [% /w]
Salinity - Total Bivalent Compounds       0.10 [% /w]
Gas Solubility Point                      0.00 [psi]
Reinjection Temperature                  39.20 [°F]
Pipe System
Burial Depth                              3.28 [ft]
Smoothness                               0.010 [in]
Ground Temperature                       50.00 [°F]
Ground Heat Conductivity                  3.12 [Btu/ft/°F]
Pump System
Production Pump Efficiency               75.00 [%]

| Move: arrow keys | Edit: <INS> | Save: <F2> | Restore: <F4> | Quit: <ESC> |
```

Notice that Burial depth = 3.28 ft and Ground Temperature = 50 °F. After the environment has been studied let's look at the other screens. Choose **WELLS** to see the well data.

```
G E O D I M  v2.11-e                    Current Workfile: C:\GEODIM\TEST.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 1
                                                No.of Reinjection Wells : 1

            PRODUCTION WELL #1                      REINJECTION WELL #1

            Flowrate       1584.79 g/m              Flowrate       1584.79 g/m
            Drawdown         82.02 ft               Inj. Pressure 131.23 ft
            Temperature     122.00 °F
            Distance       3280.80 ft               Distance       3280.80 ft
            Rel.Altitude      0.00 ft               Rel.Altitude      0.00 ft

| Move: arrow keys | Edit: <INS> | Save: <F2> | Restore: <F4> | Quit: <ESC> |
```

Thereafter look at the **PIPES**.

```
G E O D I M  v2.11-e                    Current Workfile: C:\GEODIM\TEST.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 1
                                                No.of Reinjection Wells : 1

                              PIPE SYSTEM DESIGN
                d       H       k      T0   lambda       mv      δT      Hf
              [in]    [ft]    [in]   [°F] [Btu/ft/°F] [ft/s]   [°F]    [ft]
 P1-HP        11.47   6.56   0.010  41.00     3.12      4.92    1.10   24.98
 HP-R1        11.47          0.010                      4.92           25.90

| Move: arrow keys | Edit: <INS> | Save: <F2> | Restore: <F4> | Quit: <ESC> |
```

Our data does not agrees with the default values H = 3.00 (burial depth) and T_0 = 50 (Surrounding ground temperature).
When these values have been corrected, the screen will look like the one on the next side.

```
G E O D I M  v2.11-e                    Current Workfile: C:\GEODIM\TEST.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 1
                                                No.of Reinjection Wells : 1
```

PIPE SYSTEM DESIGN

	d [in]	H [ft]	k [in]	T0 [°F]	lambda [Btu/ft/°F]	mv [ft/s]	δT [°F]	Hf [ft]
P1-HP	11.47	3.00	0.010	50.00	3.12	4.92	1.29	24.98
HP-R1	11.47		0.010			4.92		25.90

```
| Move: arrow keys | Edit: <INS> | Save: <F2> | Restore: <F4> | Quit: <ESC> |
```

Next screen is **PUMPS** and thereafter the **RESULTS**.

```
G E O D I M  v2.11-e                    Current Workfile: C:\GEODIM\TEST.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 1
                                                No.of Reinjection Wells : 1
```

PUMP DESIGN

	PC [psi]	P [hp]	WHP [psi]	VR [%]
P1	45.51	2.40	10.62	100.00
HP			0.00	
BP	68.09	3.59	68.09	
R1			56.87	100.00

```
| Move: arrow keys | Edit: <INS> | Save: <F2> | Restore: <F4> | Quit: <ESC> |
```

```
G E O D I M  v2.11-e                Current Workfile: C:\GEODIM\TEST.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 1
                                                No.of Reinjection Wells : 1

                          RESULTS
Available power output at heatplant:     18.78 MW
Total produced flowrate:                 220.3 lb/sec
Water temperature at heatplant:          120.9 °F
Estimated reinjection temperature:       39.20 °F
Specific heat per lb at heatplant:        0.99 Btu/lb/°F
Salinity - monovalent compounds:           1.0 %
Salinity - bivalent compounds:             0.1 %
Gas solubility point:                      0.0 psi

Results Preview
```

Let us change some well data and study the result.

Assume:

```
Production well:
Flow rate:          2000    g/m
Draw down:            90.0 ft
Production well:
Flow rate:          2000    g/m
Inj. Pressure:       135.0 ft
```

After correction of well data the WELL MENU screen will look like this:

```
G E O D I M  v2.11-e                Current Workfile: C:\GEODIM\TEST.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 1
                                                No.of Reinjection Wells : 1

      PRODUCTION WELL #1                  REINJECTION WELL #1

Flowrate       2000.00 g/m          Flowrate       2000.00 g/m
Drawdown         90.00 ft           Inj. Pressure 135.00 ft
Temperature     122.00 °F
Distance       3280.80 ft           Distance       3280.80 ft
Rel.Altitude      0.00 ft           Rel.Altitude      0.00 ft

| Move: arrow keys | Edit: <INS> | Save: <F2> | Restore: <F4> | Quit: <ESC> |
```

A look at the PIPE MENU shows that the friction loss has changed due to the change of flow rate.

```
G E O D I M  v2.11-e                    Current Workfile: C:\GEODIM\TEST.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 1
                                                No.of Reinjection Wells : 1

                          PIPE SYSTEM DESIGN
                d      H      k      T0   lambda      mv     δT     Hf
              [in]   [ft]   [in]   [°F] [Btu/ft/°F] [ft/s]  [°F]   [ft]
 P1-HP        12.82  6.56  0.010  41.00    3.12      4.97   0.90  22.17
 HP-R1        12.82        0.010                     4.97         22.98

| Move: arrow keys | Edit: <INS> | Save: <F2> | Restore: <F4> | Quit: <ESC> |
```

The results screen shows changes in Available power output, Total produced flow rate and Water temperature.

```
G E O D I M  v2.11-e                    Current Workfile: C:\GEODIM\TEST.GDF
WELLS PIPES PUMPS Results Environ Quit          No.of Production Wells  : 1
                                                No.of Reinjection Wells : 1

                              RESULTS
Available power output at heatplant:      23.76 MW
Total produced flowrate:                  278.0 lb/sec
Water temperature at heatplant:           121.1 °F
Estimated reinjection temperature:        39.20 °F
Specific heat per lb at heatplant:         0.99 Btu/lb/°F
Salinity - monovalent compounds:            1.0 %
Salinity - bivalent compounds:              0.1 %
Gas solubility point:                       0.0 psi

Results Preview
```

APPENDIX A

Appendix A describes the formulas and algorithms used by GEODIM. For an explanation of terms and units, see appendix B.

The specific heat of the geothermal water depends mainly on the temperature and the salinity. The temperature dependence is described by the formula:

$$c_p(H_2O) = 4.223 - 3.64 \cdot 10^{-3} \cdot T + 9.076 \cdot 10^{-5} \cdot T^2 - 9.058 \cdot 10^{-7} \cdot T^3 + 3.494 \cdot 10^{-9} \cdot T^4$$

The salinity dependence is calculated by summing up the contributions from water, Sodium Chloride, and Calcium Chloride:

$$c_p = (1-S_1-S_2) \cdot c_p(H_2O) + S_1 \cdot c_p(NaCl) + S_2 \cdot c_p(CaCl_2)$$

Where $c_p(NaCl) = 0.863$ and $c_p(CaCl_2) = 0.677$

The density of the geothermal water is also depending on the temperature and salinity. The density is calculated as:

$$ro = \frac{S_1}{S_1+S_2} \cdot ro(NaCl) + \frac{S_2}{S_1+S_2} \cdot ro(CaCl_2)$$

Where

$$ro(NaCl) = 0.9999 + 7.55 \cdot 10^{-3} \cdot S_1 - 2.97 \cdot 10^{-4} \cdot T - 2.09 \cdot 10^{-6} \cdot T^2$$

and

$$ro(CaCl_2) = 0.9999 + 9.61 \cdot 10^{-3} \cdot S_2 - 1.95 \cdot 10^{-4} \cdot T - 2.66 \cdot 10^{-6} \cdot T^2$$

The temperature loss in each pipe section:

$$\delta T = \frac{2\pi \cdot \text{lambda} \cdot L \cdot (T - T_0)}{c_p \cdot Q \cdot \ln(2H/d + ((2H/d)^2 - 1)^{0.5})}$$

The temperature loss in each pipe section:

$$H_f = \frac{f \cdot L \cdot mv^2}{d \cdot 2g}$$

The mean velocity:

$$mv = \frac{4 \cdot Q}{\pi \cdot d^2}$$

The friction coefficient:

$$1/\sqrt{f} = -2 \cdot \log\left(\frac{k/d}{3.71} + \frac{2.51}{R_e \cdot \sqrt{f}}\right)$$

Reynold's number:

$$R_e = mv \cdot d / v_k$$

The kinematic viscosity:

$$v_k = (1.78/(1 + 0.033 \cdot T + 0.00022 \cdot T^2)) \cdot 10^{-6}$$

APPENDIX B

TERMS AND UNITS

c_p	[Btu/lb/°F]	Specific heat
ro	[lb/ft^3]	density
d	[in]	diameter
H	[ft]	burial depth
k	[in]	smoothness
T	[°F]	water temperature
T_0	[°F]	ground temperature
lambda	[Btu/ft/°F]	heat conductivity
mv	[ft/s]	mean velocity
δT	[°F]	temperature loss
H_f	[ft]	friction loss
PC	[psi]	production pump capacity
P	[kW]	electrical power
WHP	[psi]	well head pressure
VR	[%]	valve rate
S_1	[%]	salinity, monovalent compounds
S_2	[%]	salinity, bivalent compounds
L	[ft]	distance
Q	[g/m]	flow rate
v_k	[ft^2/s]	kinematic viscosity
R_e	[-]	Reynold's number
g	[ft/s^2]	gravity acceleration
f	[-]	friction coefficient

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END