# Western Sterea Hellas DSS 1.0
# User Manual

Developed by

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Developed for

The Greek Ministry of Environment,
Regional Planning, & Public Works
(ΥΠΕΧΩΔΕ)

December 1998

## Acknowledgments

The work described herein was sponsored by the Greek Ministry of Environment, Regional Planning, and Public Works (ΥΠΕΧΩΔΕ) through a subcontract with the National Technical University of Athens (NTUA). Additional support was provided by the Georgia Water Resources Institute in U.S.A.

We would like to thank Dr. Demetris Koutsoyiannis of NTUA for providing the data used in this study, and for his insightful comments on the formulation of the alternative configurations of the Western Sterea Hellas Water Resources System. It is our sincere hope that this prototype collaboration (among ΥΠΕΧΩΔΕ, NTUA, and GWRI) will continue in the form of other mutually beneficial technical and research exchanges and projects.

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# Western Sterea Hellas

# Decision Support System

## 1. Introduction

**Western Sterea Hellas Decision Support System (WSHDSS)** is a decision support software for the management of the Western Sterea Hellas Reservoir System in Greece. **WSHDSS** includes a database, a Forecast-Control Model, a Forecast-Control-Simulation Model, and a graphical user interface. This manual describes the usage of the software package, while the model theory is the subject of a separate technical report.

## 2. System Requirements and Installation

**WSHDSS** is a user friendly software running on IBM-compatible personal computers under the Microsoft Windows environment. Its graphical user interface (GUI) is written in Microsoft Visual Basic Language, while its mathematical models are programmed in standard Fortran Language 90 and compiled by the Microsoft Fortran Power Station 4.0. To run **WSHDSS**, the following hardware and software are needed:

- ❑ An IBM-compatible PC with a Pentium Processor
- ❑ A hard disk with 10 Megabyte free space
- ❑ A 3 ½" floppy drive or a CD Drive
- ❑ 32 Megabyte of RAM
- ❑ A mouse
- ❑ MS Windows 95 / NT 4.0 or higher Operating System

**WSHDSS** can be installed using the program **SETUP.EXE**. To copy the software to your hard disk from the setup floppy disks, follow the steps outlined below:

1. Insert Disk 1 in Drive **A.**

**2**. Use Windows Explorer to run the setup program in **A.**

**3**. Follow the setup instructions shown on the screen.

To install the software from a CD disc, run the **SETUP.EXE** program on the CD and then follow the instructions on the screen.

The **SETUP** program copies all **WSHDSS** files into the specified directory, and generates a group file named **Western Sterea Hellas DSS 1.0** containing one item with the same name.

# 3. Models' Overview

The Western Sterea Hellas Reservoir System include three existing reservoirs (Kremasta, Kastraki, and Stratos) and four proposed reservoirs (Mesohora Sykia, Pyli, and Mouzaki). The Mesohora, Sykia, Kremasta, Kastraki, and Stratos reservoirs are in the Acheloos Basin while Pyli and Mouzaki reservoirs are in the Thessalia Valley.

Thessalia Valley is in central Greece and is a key agricultural region for the national economy. However, in recent years, the impacts of population growth and agricultural expansion have resulted in frequent droughts, diminishing water supplies, and ecosystem degradation. To reverse this trend and to maintain the sustainability of the land resources, a water diversion has been proposed from Acheloos River Basin. The diversion is planned to take place from Sykia. Figure 1 schematically depicts the layout of the hydraulic works that would enable this inter-basin water transfer.

The control model included in this software incorporates all major elements of the system configuration. The model includes a forecast-control (i.e., optimization) and a forecast-control-simulation component. The purpose of the forecast-control model is to develop optimal reservoir operation policies, while that of the forecast-control-simulation model is to evaluate the performance of these policies over the historical inflow record.

To make a control or control-simulation run, inflow forecasting traces for all reservoirs must first be provided. In both applications, a Corridor-based inflow forecasting model has been developed and is coupled with the control and control-simulation models. The control model determines the optimal operation of the reservoirs. Namely, it uses the forecasted inflows to determine reservoir release sequences which meet certain systemwide objectives. The simulation model simulates the response of the system under the guidance of the control model over the historical inflow record. This model can be used to assess the benefits of the reservoir regulation and of the various system configurations.

In general, Windows-based applications consist of a set of windows (or screens). In **WSHDSS**, each model has one input window and one or more output windows associated with it. The input window defines the data necessary to run the model, while the output windows display the results of each run. In the remainder of this manual, the windows associated with the control and simulation models are described through a step-by-step sample run. The current version of **WSHDSS** supports a single run at a time.

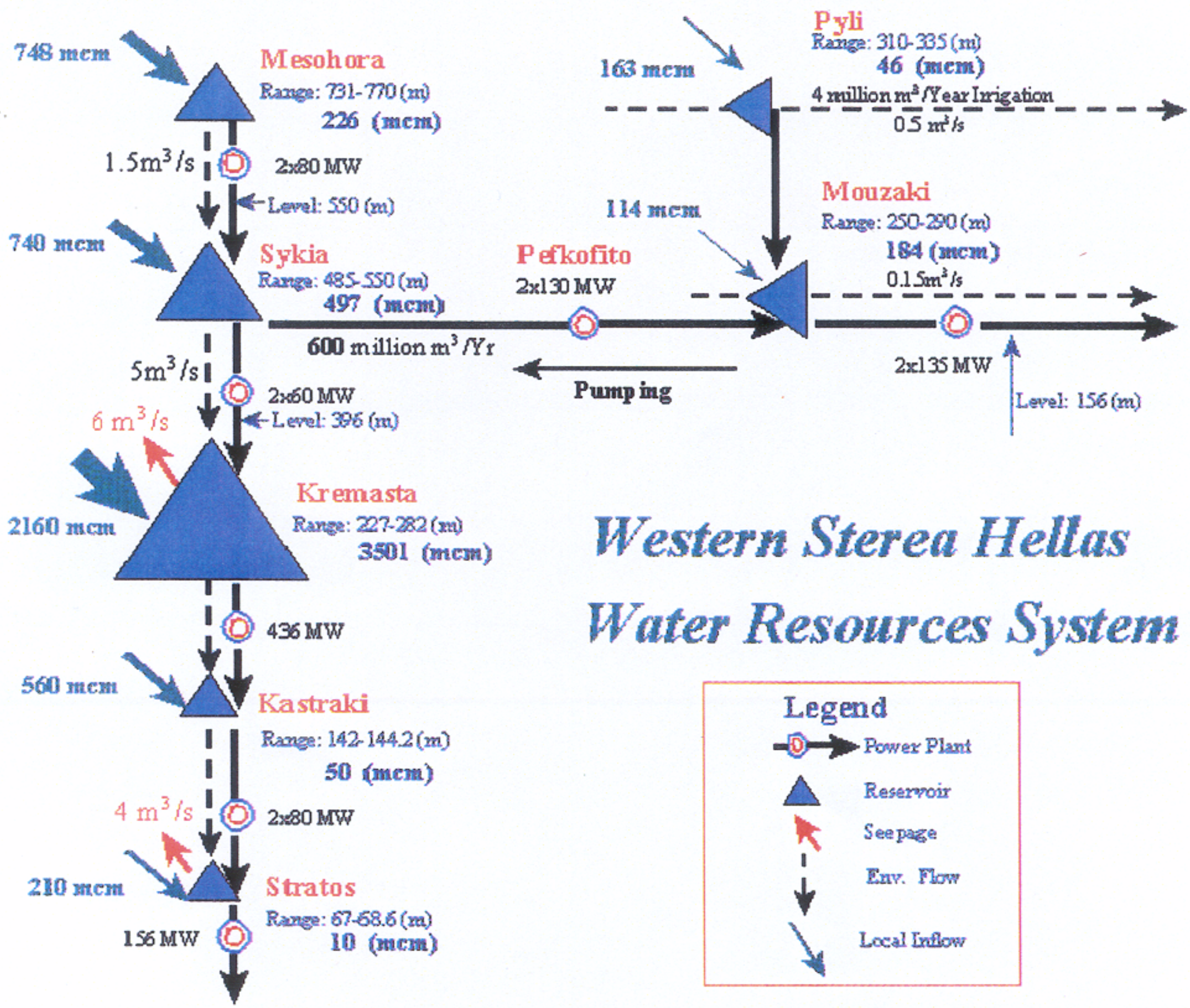


**Figure 1**: West Sterea Hellas Water Resources System

# 4. Starting WSHDSS

**WSHDSS** is launched by double clicking its icon. The software title (first) window of **WSHDSS** will appear as shown on Figure 2. The starting window contains the software title and information about the developers. This window will automatically disappear after about 5 seconds, and the second window, Model Selection, showing a schematic of the system (Figure 3), will appear on the screen. If you do not care to wait, you can double-click the mouse on the title window, and the Model Selection Window will show-up right away.

The Model Selection Window is the starting place for **WSHDSS** models. Three items are provided on the menu bar: **Forecast-Control**, **Forecast-Control-Simulation**, and **Exit**. The first two launches a run of the two respective model and **Exit** terminates this run.

You can either run the control model or the simulation model by just clicking the corresponding menu item. In what follows, the features of the control and simulation model interface are discussed through sample runs.

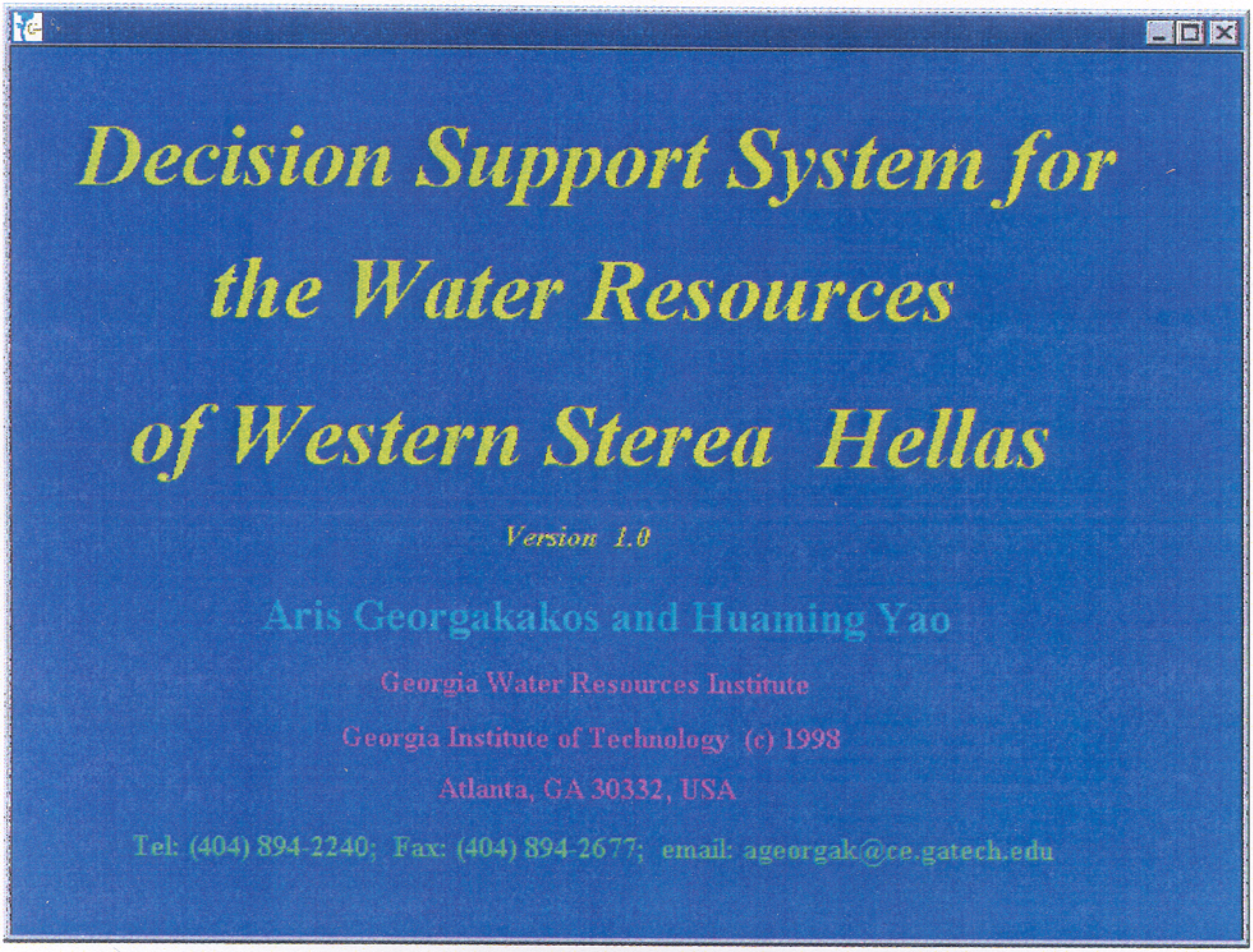


**Figure 2**: WSHDSS Starting Window

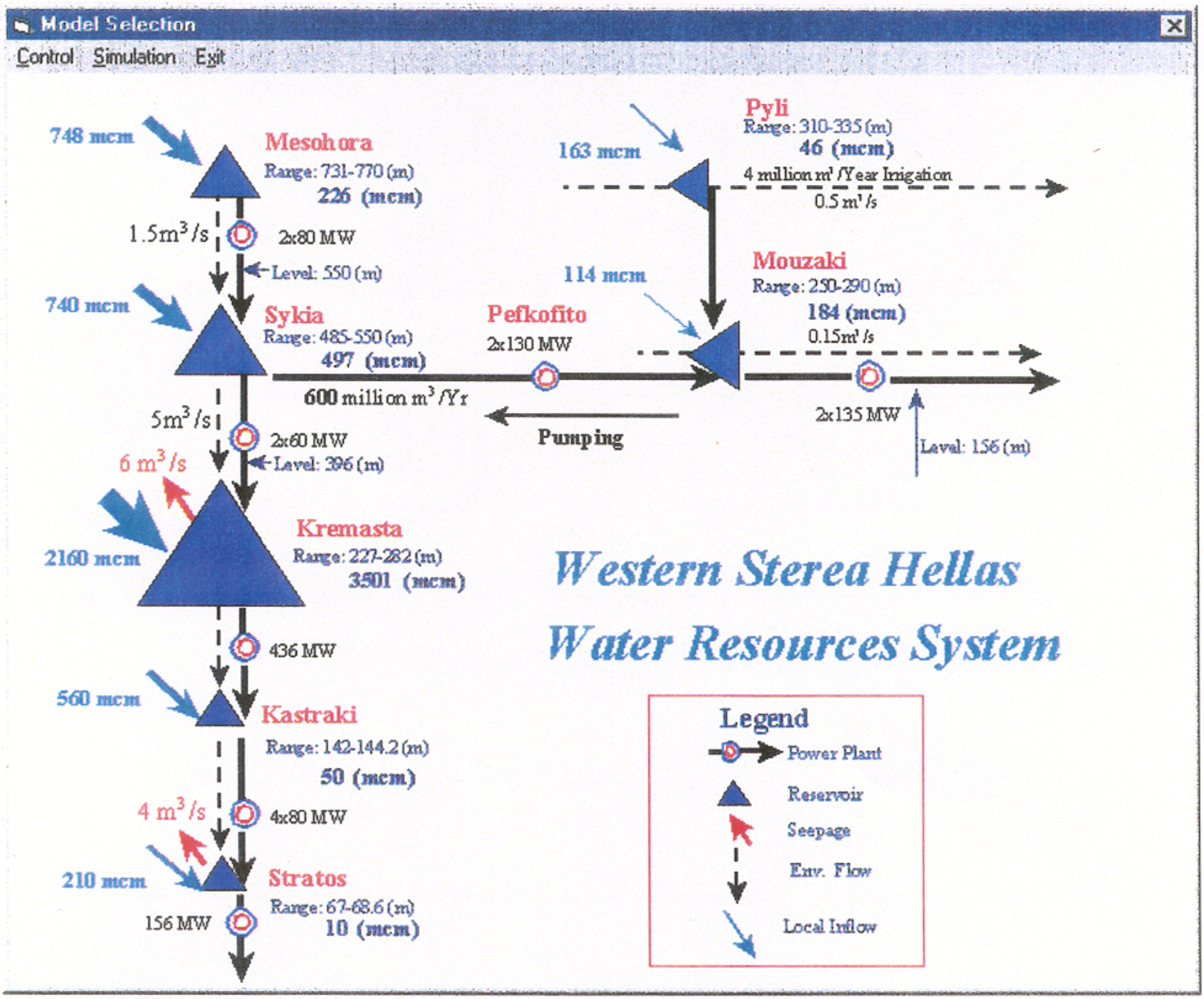


**Figure 3**: Model Selection Window

# 5. Control Model

## 5.1 Control Model Input

If you select **Forecast-Control** in the Model Selection window, the input window for the control model appears on the screen (Figure 4). The input data are grouped into three folders: **Data Files, Control Parameters,** and **Reservoir Parameters**.

**Data Files** are grouped into two panels: Input Files and Output Files. The three input data files should be prepared first outside this interface using any ASCII editor. The first file is the **Historical Inflows**. In this file, you prepare the historical inflow data for all reservoirs. This file is used as the database by the inflow forecasting model to make predictions. A sample file, **grkhisfl.dat,** is provided. If you would like to use a custom file of historical flows, the custom file needs to follow the same format as in **grkhisfl1.dat**. A partial listing of this sample file is shown below:

```
Monthly Inflows (m^3/s) Used as Database for the corridor forecasting model
Starting yyyy mm; Ending yyyy mm
1960 10
1994  9
       Mesohora Sykia Kremasta Kastraki Stratos Pyli Mouzaki
196010 6.712   4.385  31.504  11.500 2.705   0.000  0.068
196011 15.874  16.980 32.146  12.100 3.855   1.383  0.000
196012 58.682  55.089 175.429 35.300 16.225  9.024  6.541
196101 29.377  22.868 90.855  22.400 8.275   5.743  4.116
196102 22.267  25.029 86.304  24.000 7.880   6.316  4.400
196103 26.257  19.550 67.894  13.800 6.375   7.316  4.609
196104 19.635  23.984 62.682  10.400 5.835   3.550  1.193
196105 17.583  18.142 41.775  11.600 4.455   2.169  1.339
196106 8.132   8.022  26.645  10.100 2.645   1.061  0.510
196107 3.852   4.344  21.803  10.100 2.005   0.456  0.866
196108 3.049   0.000  17.051  8.200  1.415   0.211  0.221
196109 0.122   0.187  18.191  9.400  1.395   0.193  0.385
196110 10.375  7.140  15.585  10.900 2.200   2.337  0.929
196111 31.113  30.032 86.956  22.800 8.545   8.339  3.596
196112 35.450  33.709 82.941  21.200 8.665   10.430 5.076
196201 22.050  19.992 62.258  18.600 6.145   5.565  3.533
196202 37.077  37.120 89.003  27.000 9.510   8.414  3.720
196203 70.782  72.084 187.134 41.700 18.585  17.766 8.840
```

```
.........
199308 1.536   2.534   12.230 6.500   1.140   0.235   0.053
199309 2.027   2.390   15.583 5.000   1.250   0.253   0.000
199310 2.269   2.152   9.279  6.400   1.005   0.518   0.000
199311 17.437  14.070  29.293 15.200  3.800   5.424   2.365
199312 42.729  38.355  130.116 23.800 11.750  13.520  8.215
199401 40.390  42.498  109.112 19.200 10.560  12.296  9.480
199402 48.066  47.096  67.338 20.000  9.125   13.794  13.402
199403 23.941  31.295  92.364 7.500   7.755   12.930  10.137
199404 31.137  30.551  101.112 14.600 8.870   9.355   6.439
199405 23.539  22.888  44.873 13.200  5.225   3.536   2.950
199406 6.105   8.895   20.800 10.200  2.300   0.952   0.608
199407 4.467   4.002   18.731 6.800   1.700   0.518   0.173
199408 2.434   2.574   16.591 7.900   1.475   0.350   0.163
199409 1.294   1.642   13.464 7.700   1.205   0.134   0.060
```

All data files are in ASCII format and can be created with any word processor. The first line of this file is a comment describing the data file. The second line is also a comment which describes the data on the third and fourth lines. The two numbers on the third line specify the starting time of the monthly historical flow. The first number represents the starting year, and the second represents the starting month index over the year. For example, October 1961 will be entered as 1961 10. Similar to the starting time, the ending time is specified on the fourth line with the same format. The fifth line is a comment line for the remainder of the data. The actual inflow data starts on the sixth line. There are eight numbers on each line. The first number is the time index, which tells the year, and the month index for the data on that line. The second to eighth numbers are the monthly historical flows for respectively Mesohora, Sykia, Kremasta, Kastraki, Stratos, Pyli, and Mouzaki, respectively. The data lines continue to the ending time specified on the fourth line. The program reads the flow data in a free-style format. It is, thus, not important how many spaces are placed between each number as long as they are in the right order and on the same line.

The second file contains **Other Hydrologic and Demand Data.** In this file, you prepare monthly data such as, minimum releases from each reservoir, evaporation, rainfall, etc. A sample file, **grktimepara.dat,** is provided. This file may be modified to run different cases, however, it must follow the same format. A complete listing of this sample file is shown and discussed below:

Monthly Data File

Minimum Release Umin0(10^6 m^3)

| Month | S1 | S2 | S3 | S4 | S5 | S6 | S7 |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 56.246 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 50.803 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 56.246 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 54.432 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 149.99 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 145.15 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 149.99 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 149.99 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 145.15 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 56.246 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 54.432 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 56.246 | 0 | 0 |

Monthly Upstream Water Demand DMD(10^6 m^3)

| Month | S1 | S2 | S3 | S4 | S5 | S6 | S7 |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0.44 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0.944 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 1.208 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 1.056 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0.152 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Monthly Evaporation Rate (mm)

| Mon | Mosohora | Sykia | Kremasta | Kastraki | Stratos | Pyli | Mouzaki |
|---|---|---|---|---|---|---|---|
| 1 | 35.2 | 37.5 | 33.37 | 33.37 | 33.37 | 40.8 | 41 |
| 2 | 34.8 | 40.8 | 52.86 | 52.86 | 52.86 | 40.3 | 44.6 |
| 3 | 53.3 | 56.5 | 79.38 | 79.38 | 79.38 | 61.5 | 61.6 |
| 4 | 68.3 | 74.7 | 119.99 | 119.99 | 119.99 | 78.5 | 81.3 |
| 5 | 115.3 | 122.3 | 162.94 | 162.94 | 162.94 | 131.9 | 132.7 |
| 6 | 169.1 | 185.5 | 206.24 | 206.24 | 206.24 | 192.6 | 200.7 |
| 7 | 222.7 | 236.5 | 237.79 | 237.79 | 237.79 | 252.9 | 255.4 |
| 8 | 176.9 | 187.8 | 212.18 | 212.18 | 212.18 | 201 | 202.9 |
| 9 | 123.3 | 135.3 | 147.19 | 147.19 | 147.19 | 140.4 | 146.4 |
| 10 | 57.8 | 61.2 | 76.01 | 76.01 | 76.01 | 66.2 | 66.4 |
| 11 | 32.2 | 35.2 | 38.50 | 38.50 | 38.50 | 37.1 | 38.3 |
| 12 | 32.4 | 34.4 | 25.57 | 25.57 | 25.57 | 37.4 | 37.6 |

Monthly Rainfall Rate (mm)

| Mon | Mosohora | Sykia | Kremasta | Kastraki | Stratos | Pyli | Mouzaki |
|---|---|---|---|---|---|---|---|
| 1 | 223.04 | 266.65 | 149.18 | 134.45 | 134.45 | 207.49 | 194.09 |
| 2 | 212.66 | 251.06 | 144.55 | 136.78 | 136.78 | 200.61 | 175.27 |
| 3 | 159.56 | 184.66 | 115.17 | 104.32 | 104.32 | 161.85 | 143.27 |
| 4 | 133.80 | 158.36 | 95.88 | 78.79 | 78.79 | 144.87 | 125.73 |
| 5 | 101.20 | 109.24 | 72.31 | 51.17 | 51.17 | 104.88 | 86.61 |
| 6 | 48.06 | 53.46 | 37.62 | 33.73 | 33.73 | 43.52 | 40.54 |
| 7 | 36.75 | 39.06 | 23.30 | 18.60 | 18.60 | 28.04 | 25.53 |
| 8 | 34.20 | 45.06 | 20.10 | 22.86 | 22.86 | 33.90 | 29.77 |
| 9 | 64.79 | 75.44 | 50.03 | 42.79 | 42.79 | 60.35 | 57.36 |
| 10 | 165.00 | 174.91 | 108.29 | 103.88 | 103.88 | 181.36 | 154.15 |
| 11 | 255.52 | 293.29 | 216.31 | 206.34 | 206.34 | 225.85 | 197.54 |
| 12 | 295.99 | 340.50 | 210.69 | 187.13 | 187.13 | 287.74 | 245.11 |

Irrigation Requirement Percentage Monthly Distribution

| Mon | Percent |
|---|---|
| 1 | 0. |
| 2 | 0. |
| 3 | 0. |
| 4 | 5. |
| 5 | 11. |
| 6 | 23.6 |
| 7 | 30.2 |
| 8 | 26.4 |
| 9 | 3.8 |
| 10 | 0. |
| 11 | 0. |
| 12 | 0. |

This file contains the monthly sequences over one year of Minimum Discharge Constraints, Upstream Water Demand, Average Evaporation Rate, Average Rainfall Rate, and the Irrigation Requirement Monthly Distribution in percent form. The data format follows the same format as the historical inflow file. The Minimum Discharge is the minimum reservoir discharge constraint, specified in million cubic meters per month. In this file, only Stratos has a non-zero minimum constraint. The Upstream Water Demand is the water withdrawn from the reservoir. The irrigation of 4 million cubic meters per year from Pyli is considered as upstream water withdrawal from the reservoir and distributed according to the irrigation distribution discussed later. The evaporation and rainfall rates are in millimeters per month. The difference of these two are used in the model as the net evaporation rate to compute the actual reservoir evaporation loss (or gain). If more recent information becomes available, these data files should be updated. The last item in this file is the irrigation demand percentage distribution. This distribution is used to compute the Pyli upstream water demand discussed earlier and also used inside the control model to generate the release minimum constraint for Mouzaki if a diversion occurs. The monthly minimum release constrain for Mouzaki is equal to the annual planned diversion volume multiplied by the corresponding distribution coefficient.

The third file, **Control Model Parameters**, contains the parameters used in the ELQG control model. To fully understand the meaning of each parameter in this file, you need to consult the corresponding technical report. This file contains the penalty coefficients in the objective function. By changing the relative magnitude among the penalty coefficients, you can conduct runs for different scenarios. However, to achieve the desired results, you must be experienced in calibrating the penalty coefficients. The full listing of a sample file, **grkdppara.dat,** is given below:

```
This file contains optimal algorithm related parameters
BETA,SIGMA,EIMIN (ELQG PARAMETERS)
0.05 .01E-10 0.001
Penalty for Energy Value PENA(i)
1.E-4   1.E-4   1.E-4   1.E-4   1.E-4   1.E-4   1.E-4   1.E-4   0.
Penalty for Target State  PENB(I)
1.E2    1.E2    1.E2    1.E2    1.E2    1.E2    1.E2    0.E2    0.
Penalty for Target Control  PENC(I)
1.E3    1.E3    1.E3    1.E3    1.E3    1.E3    1.E3    1.E3    1.E3
Penalty for State Constraint  PEND(I)
1.E6    1.E6    1.E6    1.E6    1.E6    1.E6    1.E6    0.E6    0.
Penalty for Level Proportional Terms PENE(I)
0.E6    0.E6    0.E6    0.E6    0.E6    0.E6    0.E6    0.E6    0.
Penalty for Target State  PENEB(I)
1.E4    1.E4    1.E4    1.E4    1.E4    1.E4    1.E4    1.E5    0.E-7
Penalty for State Constraint  PENED(I)
1.E6    1.E6    1.E6    1.E6    1.E6    1.E6    1.E6    0.E6    0.
```

Again, this data file follows the same general comment-data rule as before. The first three numbers BETA, SIGMA, and EIMIN are ELQG related internal parameters. Ordinarily, you should not change these values. The remaining values are the penalty coefficients for each penalty term in the objective function associated with each reservoir or state variable. PENA is the penalty coefficient for energy generation, PENB for target elevation, PENC for Target Control, PEND for Elevation Constraints, PENE for Uniform Fluctuation (not used in the control model). PENEB and PENED are the penalty coefficients for the corresponding terminal terms. Three points about the values in the sample file need to be mentioned: (1) there are nine state variables in this file whereas we described only eight state variables in the technical report. The ninth variable is not used in the current version and will be reserved for future development; (2) there is no state constraint penalty for the augmented state variable; and (3) the high terminal penalty for the eighth state variable is used to meet the planned annual diversion value.

As pointed earlier, the input files should be prepared outside the interface. However, you can open these files and make quick changes in the interface. In all places where input data file names appear, you can double-click the text box and the Windows program **Wordpad** will open with the specified file in it. In this way, you can directly access the ASCII file and make a quick change.

In the **Output Files** panel, you need to type any valid file names for the model outputs from the current run. The control model will generate traces for various quantities such as reservoir elevation, inflow, release, primary energy, secondary energy, total energy, primary energy value, secondary energy value, total energy value, spillage, deficit, net evaporation loss, and control statistics. You should use file names with extension ".out" to avoid the confusion with the system input data files, which have the ".dat" extension.

The second folder, **Control Parameters** (Figure 5), contains the information you will change almost every time you run the control model. The input data in this folder are grouped into four panels. In the **Forecasting Model**, you specify the inflow forecasting model related inputs. The **Inflow File** contains the most recent inflows for all reservoirs. The recent inflows are used by the Corridor Inflow Forecasting Model. This file is prepared outside of this interface. The length of this file depends on the **Corridor Length**, expressed in months. **Number of Traces** is the number of forecasting traces generated by the inflow model. Usually, 15-20 traces are at least recommended. A sample file, **grkfl0.dat,** is listed below:

```
Recent Monthly Inflows Record(m^3/s)
Starting yyyy/mm; Ending yyyy/mm
1961 7
1961 9
       Mesohora Sykia Kremasta Kastraki Stratos Pyli Mouzaki
196107 3.852    4.344   21.803  10.100  2.005   0.456   0.866
196108 3.049    0.000   17.051  8.200   1.415   0.211   0.221
196109 0.122    0.187   18.191  9.400   1.395   0.193   0.385
```

This file should be prepared before launching the WSHDSS run. It has the same format as the **Historical Inflows.** Note that the starting time and the ending time, which determine the length of this file, should be consistent with the starting time and the **Corridor length** specified in the interface. The current version of this software does not check the time consistency. A later version will make this more automatic and remove the redundant information.

In the **Energy and Price Data,** you specify the following input data: **Primary Energy Price (dr/KWH), Secondary Energy, Price(dr/ KWH), Pumping Energy Price (dr/KWH), Irrigation Price (dr/m$^3$ ), Maximum Daily Peaking Hours, and Maximum Daily Pumping Hours**. The pumping price usually is the same as the secondary energy price, but can be different. The **Maximum Daily Peaking Hours** and the **Maximum Daily Pumping Hours** are assumed to be 6 and 8 hours every day.

In the **System Configuration Options**, one can select one of the four predefined options to run the control model. Depending on the selected system configuration, some other input parameters may not apply. For example, if the first option is selected, then, the diversion should be zero, and the pumping operation of Pefkofito should be unchecked. The control model internally does the data validation. However, you should also understand the input data consistency. The A future software version could include the data validation from the interface as well. The control model can be run either with or without the Pefkofito pump-storage mode. Check the associated box if pump-storage mode is active. In the **Diversion** box, type the annual planned diversion number in million cubic meters, for example, 600.

The last panel is **Control Intervals**, where you specify the **Control Horizon** and the **Starting Date. Control Horizon** is the number of months into the future considered by the control model. Usually, one year (12) or less will suffice. The **Starting Time** represents the initial time of the control horizon. The time is specified by two parameters: Year and Month. The month is selected from the drop-down lists.

The third folder, **Reservoir Parameters** (Figure 6), contains reservoir-related information such as Initial Elevation ($H_0$), Target Elevation (Htrg), Maximum Elevation (Hmx), Minimum Elevation (Hmn), Environmental Flow (Env.), Seepage Loss (Seepg), and Reliability. The elevation related items are in meters, the flow related items (Environmental Flow and Seepage) are in $m^3/s$, and the reliability is in percentage. The **Maximum and Minimum Elevation** are the reservoir elevation bounds. The **Initial Elevation** is the elevation at the beginning of the control run. The Target Elevation is the target level for which the reservoir should be in normal operation. A good choice will be the maximum bound. In this case, the control model will try to maintain the reservoir elevation high, which is beneficial for the energy generation in long term operation. This term is not a dominant term in the objective function. The Seepage is the reservoir loss. The environmental flows are the minimum required flows for downstream natural channels. These flows do not pass through the power facilities but will flow into the downstream reservoir (except for Pyli) as shown in the system schematic (Figure 1). The **Reliability** is the probability of reservoir elevations staying within the bounds. It depends on the active reservoir storage. The **Reliability** for Kremasta can be high (90%) while for the other (small) reservoirs should be low (50-60%). For a **Reliability** value of 50%, the control model only controls the mean trajectory, and ignores variability.

The above concludes the input data requirements of the **Forecast-Control Model.** We are now ready to run the model. This can be done by pressing the **Run** button. The execution of the control model takes about 20 to 30 seconds on a Pentium 300 MHz PC. When it finishes, **WSHDSS** brings the control output window up on the screen. If you do not want to run the control model at this point, press the **Cancel** button. If the results from the previous runs are saved, you can simply display the results by pressing the **Display** button.

Before we proceed to the output window, let us describe a way to run the control model without the interface. Running the program without the interface may be of interest for a long simulation execution. The input window does two things when you press the **Run** button: (1) collect all the input data on the screen and write them out into a file called "grkreg.in"; (2) launch the run of the control program "grkreg.exe". File grkreg.in is an ASCII file. You can open and modify it with any text editor.

A sample is listed below:

```
This file contains input data generated by the interface for the control program
Historical Inflow Database file
grkhisfl.dat
Simulation Inflow file
grkfl0.dat
Time Dependant Parameter File
grktimepara.dat
DP Parameter File
grkdppara.dat
Elevation Output File
htrc.out
Inflow Output File
wtrc.out
Release output File
utrc.out
Primary Energy File
eptrc.out
Secondary Energy File
estcr.out
Total Energy File
etrc.out
Primary Energy Value File
epvtrc.out
Secondary Energy Value File
esvtrc.out
Total Energy Value File
evtrc.out
Annual Stats File
statstrc.out
Spill Output File
spltrc.out
Deficit File
dfcttrc.out
Evaporation Loss File
evplstrc.out
Irrigation Value File
irrigvtrc.out
Control Horizon in Month LT:
 12
Starting Year and Month:
 1961          10
Number of Forecasting Traces NTRC
 20
Lag-Time of Previous Flow Used for Corridor Model NCOR (Months)
 3
Elevation Reliability Level (%)        PCT
 50             50             50             50             50             50             50
Price for Primary Energy RATEENP,Secondary Energy, PUMPING RATEENS (dr/kwh)
 12             6              6
Price for Irrigation RATEIRRIG(dr/m^3)
 20
Number of Peak Hours Per working day NPKHR0(Max. 24)
 6
Max. Pumping Hours Per working day NPMPHR0(Max. 24)
 8
Initial Elevations (m)
 768            540            275            143            68             335            285
Max. Elevations (m)
 770            550            282            144.2          68.6           335            290
Min. Elevations (m)
 731            485            227            142            67             310            250
Running Target Elevation (m)
 770            550            282            144.2          68.6           335            290
Environmental Flow (m^3/s)
 1.5            5              0              0              0              0.5            0.15
```

```
Seepage Loss  Flow (m^3/s)
 0              0             6             0             4             0             0
Annual Water Transferred from Sykia to Mouzaki (million m^3/Yr, Max 600)
 600
System Configuration Option 1: Orirginal; 2: Left 5 Reservoir; 3: Full System ; 4: Pyli is out
 3
State Existance Option (0: not; 1: yes)
 1              1             1             1             1             1             1
Pumping Operation Option (0: not; 1: yes)
 1
Forecasting Model Option (0: Perfect; 1: Corridor)
 1
```

Basically, grkreg.in contains all information specified in the interface. You can open this file and make necessary modifications. Then, you run the control program "grkreg.exe". When the run finishes, the results are saved in the corresponding output files in ASCII format. You can view them and plot them using any spreadsheet software.

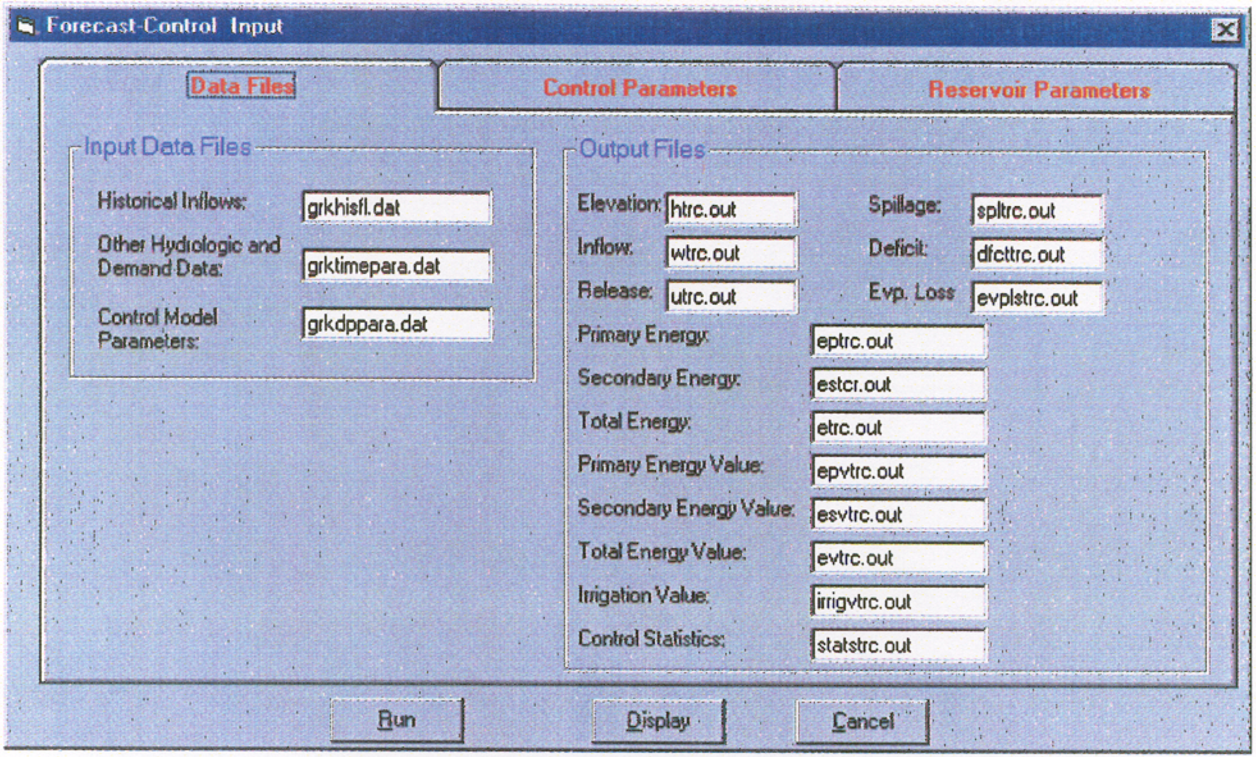


**Figure 4**: Control Model Input; Data Files

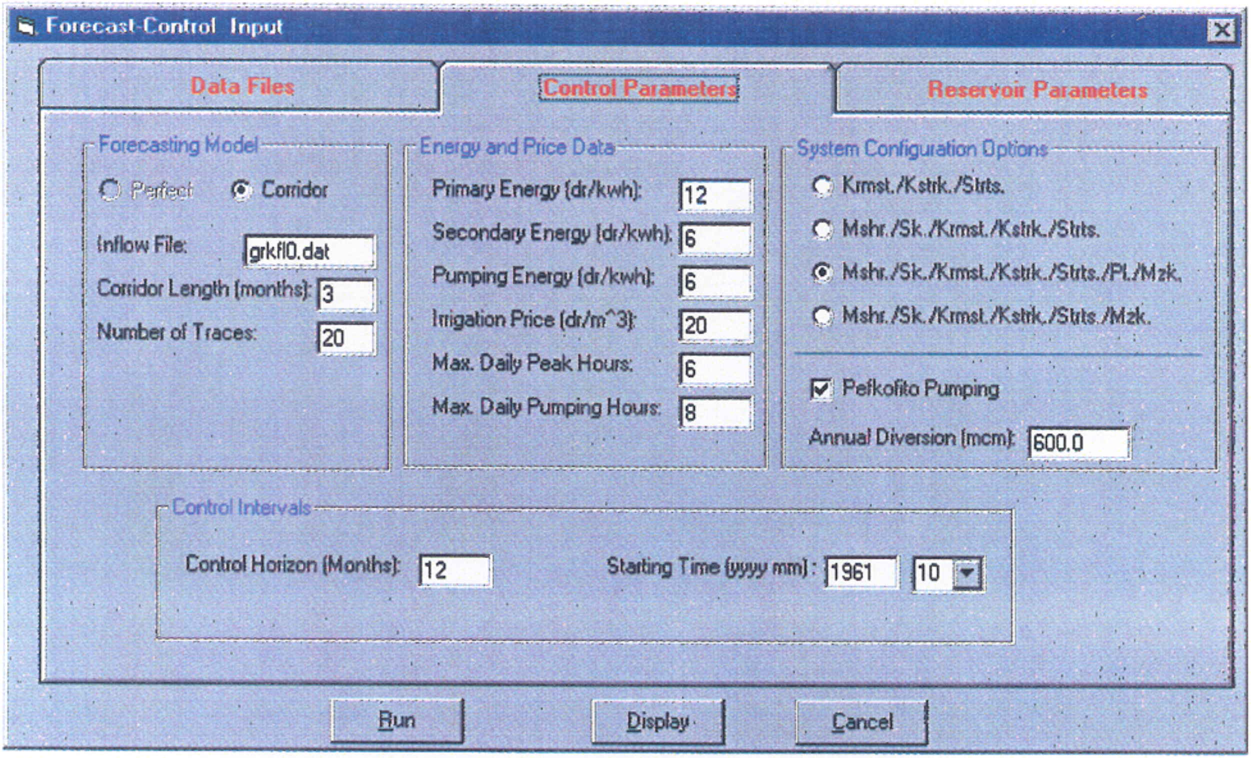


**Figure 5**: Control Model Input; Control Parameters

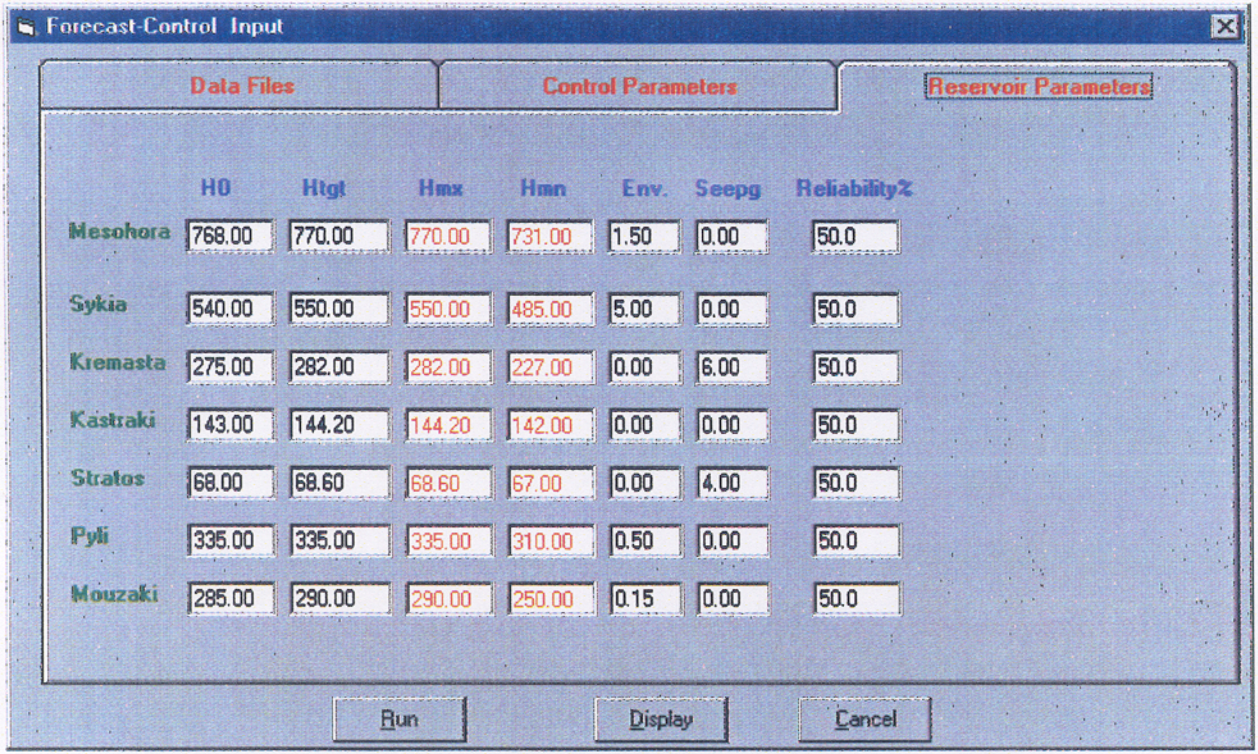

**Figure 6**: Control Model Input; Reservoir Parameters

## 5.2 Control Model Output

Figure 7 shows a picture of the control model output window. The model generates sequences of elevations, releases, inflows, spillage, deficit, evaporation loss, irrigation value, primary energy, secondary energy, total energy, primary energy value, secondary energy value, total energy value, and associated statistics. In the interface, the sequences are displayed by reservoir, as shown on the menu bar. For each reservoir, **WSHDSS** displays sequences by four screens: Flow/Level/Release, Energy, Energy Value, and Irrigation Value. You can switch the screens by pressing the corresponding buttons. You can display either the entire traces or just the ranges for all the quantities by selecting the associated option buttons located in the middle left of the screen. For each reservoir, the annual statistics of mean, maximum, and minimum values of energy, energy value, inflow, release, and irrigation value are shown in the table located at the left bottom. If you select Pefkofito under the **Reservoir Plots** menu, the sequences of diversion (release from Pefkofito), energy generation, and pumping energy consumption will be shown on the screen. To see the sequences of system quantities such as system energy, energy value, and irrigation value, select the menu item **System** under the **Reservoir Plots**.

After each run, the control model results are saved in 14 files specified in the input window. You can review the results outside **WSHDSS** or directly from the interface. By selecting the menu item under **Tables**, you can open the corresponding output files with the Windows program **Wordpad**. The output files for the traces are saved in a tabular format and are self-explanatory. You should not make any changes while viewing the output files during the current run because **WSHDSS** reads the same files for the display. If the file format is changed, the display of the various sequences may malfunction. However, you can save these files under different names for other purposes such as technical reports. The annual statistics of some important quantities are saved in a separated file. A sample is listed below:

```
Control Model Statistics

 Annual Inflows Max. Min. Mean (mcm)
    1   1316.58    366.25    706.78
```

| | | | |
|---|---|---|---|
| 2 | 1375.57 | 379.21 | 688.15 |
| 3 | 4722.01 | 904.66 | 1998.66 |
| 4 | 947.60 | 302.52 | 511.16 |
| 5 | 418.09 | 99.90 | 195.24 |
| 6 | 270.37 | 69.00 | 152.03 |
| 7 | 226.16 | 33.10 | 106.50 |

Annual Release Max. Min. Mean (mcm)

| | | | |
|---|---|---|---|
| 1 | 1307.03 | 537.13 | 769.17 |
| 2 | 2070.09 | 816.76 | 981.98 |
| 3 | 6480.20 | 2842.09 | 3195.10 |
| 4 | 7391.69 | 3159.29 | 3695.25 |
| 5 | 7677.14 | 3167.11 | 3763.75 |
| 6 | 256.07 | 102.67 | 156.24 |
| 7 | 1168.49 | 869.48 | 989.24 |
| 8 | 600.00 | 600.00 | 600.00 |

Annual Net Evaporation Loss Max. Min. Mean (mcm)

| | | | |
|---|---|---|---|
| 1 | -3.63 | -5.90 | -4.78 |
| 2 | -8.50 | -13.06 | -10.05 |
| 3 | 13.88 | 5.83 | 11.18 |
| 4 | 6.88 | 5.66 | 6.30 |
| 5 | 2.17 | 1.64 | 1.91 |
| 6 | -.73 | -1.71 | -1.17 |
| 7 | -1.47 | -2.57 | -1.75 |

Annual Spillage Max. Min. Mean (mcm)

| | | | |
|---|---|---|---|
| 1 | 33.46 | .00 | 1.67 |
| 2 | 543.76 | .00 | 38.63 |
| 3 | 828.25 | .00 | 47.06 |
| 4 | 127.02 | .00 | 6.35 |
| 5 | 240.69 | .00 | 12.03 |
| 6 | .00 | .00 | .00 |
| 7 | .00 | .00 | .00 |

Annual Deficit Max. Min. Mean (mcm)

| | | | |
|---|---|---|---|
| 1 | 3.02 | .00 | .25 |
| 2 | 205.32 | .00 | 20.15 |
| 3 | .00 | .00 | .00 |
| 4 | .00 | .00 | .00 |
| 5 | 10.28 | .00 | .89 |
| 6 | 43.78 | .00 | 4.60 |
| 7 | 96.23 | .00 | 12.76 |

Storage Change Max. Min. Mean (mcm)

| | | | |
|---|---|---|---|
| 1 | -15.78 | -210.38 | -104.67 |
| 2 | -82.53 | -385.39 | -204.84 |
| 3 | 268.14 | -1158.02 | -257.17 |
| 4 | 29.50 | -20.59 | 4.72 |
| 5 | 4.49 | -7.18 | -1.32 |
| 6 | -2.58 | -45.34 | -21.90 |
| 7 | -89.43 | -136.15 | -129.48 |

Annual Irrigation Value (Bdr.)

| | | | |
|---|---|---|---|
| 1 | .00 | .00 | .00 |
| 2 | .00 | .00 | .00 |
| 3 | .00 | .00 | .00 |
| 4 | .00 | .00 | .00 |
| 5 | 9.25 | 9.05 | 9.24 |
| 6 | .08 | .00 | .07 |
| 7 | 15.24 | 11.94 | 13.87 |
| 8 | 24.57 | 21.18 | 23.18 |

Primary (Max.Min.Mean), Secondary,Total Energy(GWH)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 273.27 | 183.81 | 248.56 | 369.10 | 62.10 | 124.69 | 638.44 | 245.90 | 373.25 |
| 2 | 176.25 | 159.73 | 168.69 | 385.33 | 104.92 | 169.80 | 561.58 | 264.65 | 338.49 |
| 3 | 817.65 | 731.00 | 771.29 | 1288.07 | 184.53 | 345.94 | 2105.72 | 915.92 | 1117.22 |
| 4 | 555.80 | 497.73 | 517.36 | 739.47 | 39.63 | 126.57 | 1295.27 | 537.36 | 643.93 |
| 5 | 272.26 | 244.69 | 252.70 | 390.65 | 27.21 | 76.09 | 662.90 | 272.22 | 328.79 |
| 6 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| 7 | 346.93 | 231.21 | 284.67 | 3.61 | .00 | 2.98 | 350.00 | 231.21 | 287.65 |
| 8 | 510.78 | 452.51 | 498.32 | 47.92 | 44.04 | 46.64 | 558.69 | 496.55 | 544.96 |
| 9 | .00 | .00 | .00 | -307.75 | -301.10 | -307.16 | -307.75 | -301.10 | -307.16 |
| 10 | 2947.77 | 2524.50 | 2741.57 | 2915.80 | 168.54 | 585.56 | 5863.57 | 2693.04 | 3327.13 |

Primary, Secondary, Total Energy Value (BDr)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.28 | 2.21 | 2.98 | 2.21 | .37 | .75 | 5.49 | 2.58 | 3.73 |
| 2 | 2.12 | 1.92 | 2.02 | 2.31 | .63 | 1.02 | 4.43 | 2.55 | 3.04 |
| 3 | 9.81 | 8.77 | 9.26 | 7.73 | 1.11 | 2.08 | 17.54 | 9.88 | 11.33 |
| 4 | 6.67 | 5.97 | 6.21 | 4.44 | .24 | .76 | 11.11 | 6.21 | 6.97 |
| 5 | 3.27 | 2.94 | 3.03 | 2.34 | .16 | .46 | 5.61 | 3.10 | 3.49 |
| 6 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| 7 | 4.16 | 2.77 | 3.42 | .02 | .00 | .02 | 4.18 | 2.77 | 3.43 |
| 8 | 6.13 | 5.43 | 5.98 | .29 | .26 | .28 | 6.42 | 5.69 | 6.26 |
| 9 | .00 | .00 | .00 | -1.85 | -1.81 | -1.84 | -1.85 | -1.81 | -1.84 |
| 10 | 35.37 | 30.29 | 32.90 | 17.49 | 1.01 | 3.51 | 52.87 | 31.31 | 36.41 |

This file contains the maximum, minimum, and the mean values computed based on the traces for different quantities. For each quantity, the statistics are listed by reservoir index 1 to 7 corresponding to reservoirs Mesohora, Skyia, Kremasta, Kastraki, Stratos, Pyli, and Mouzaki.
In the release statistics, index 8 corresponds to the net release from Pefkofito, which represents the planned water transfer from Sykia to Mouzaki. In the irrigation statistics, index 8 corresponds to the total system values. In the energy and energy value statistics, index 8 corresponds to Pefkofito generation mode operation, 9 corresponds to Pefkofito pumping mode operation, and 10 corresponds to the system statistics. When at pumping mode, Pefkofito consumes secondary energy. Therefore, both energy and energy values are negative.

You can print the sequences currently displayed by selecting **Print**.
Select **Return** to go back to the previous window, and **Exit** to end the current run.

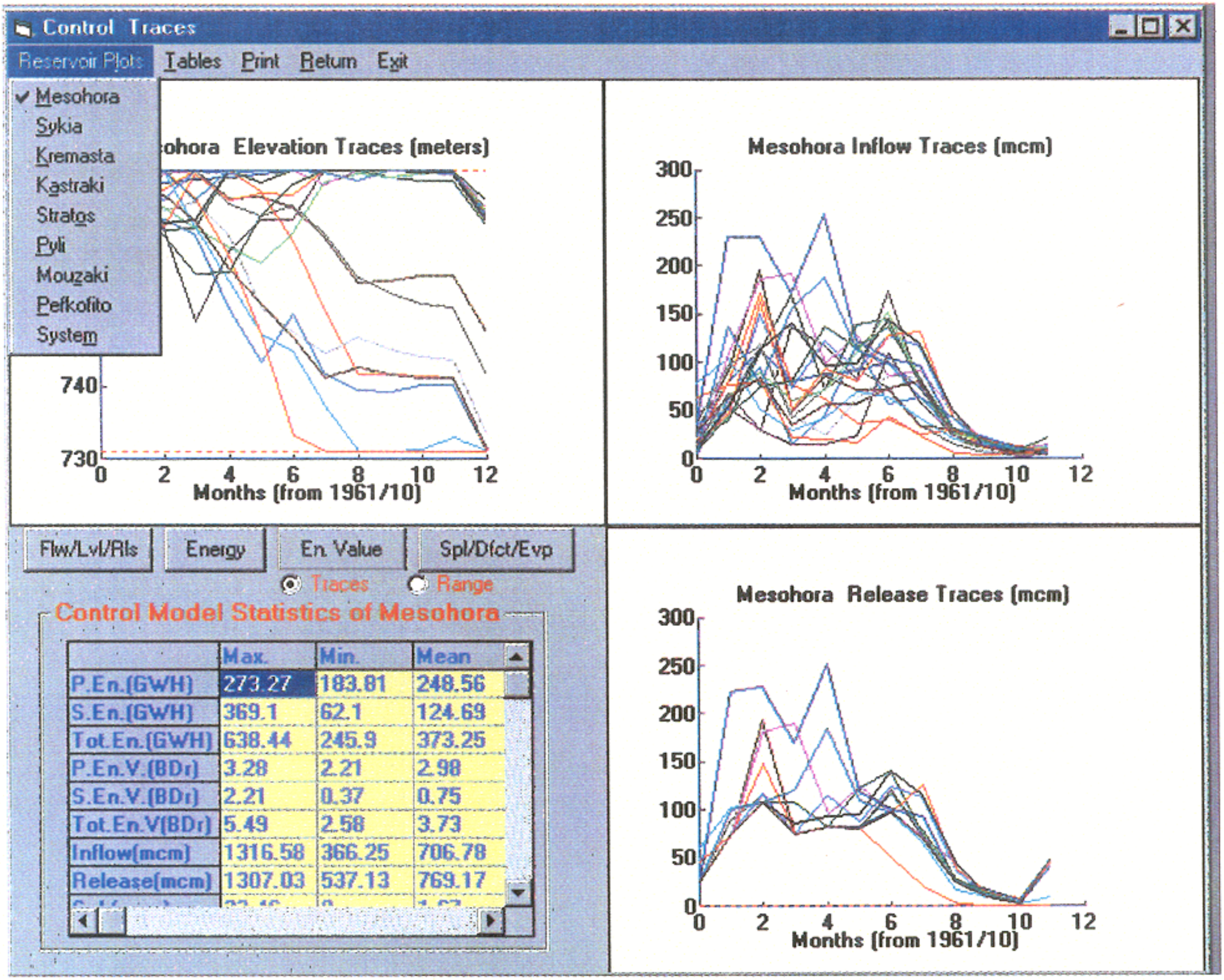


**Figure 7**: Control Output Sample

# 6. Forecast-Control-Simulation Model

## 6.1 Forecast-Control-Simulation Model Input

To run the **Forecast-control-simulation** model, select it from the menu of the model selection window (Figure 3). The forecast-control-simulation model data input window appears on the screen. The interface structure of the Forecast-control-simulation model is very similar to that of the control model. The input data are also grouped in three folders**: Data Files, Control Parameters,** and **Reservoir Parameters**.

Folders **Data Files** and **Reservoir Parameters** contain the same information as those in the control model input windows. In the **Control Parameters** folder (Figure 8), a few differences are noted in comparison to the same folder in the control model. You do not need to provide the **Inflows** file. Instead, you provide a **Simulation Inflow** file, which contains the historical flows used for the simulation. This file has the same format as the **Historical Inflows** file. The sample file, **grksimfl.dat,** has the same contents as **grkhisfl.dat.** However, they are not necessarily the same since they serve different purposes in the program. The embedded inflow forecasting model will automatically take the recent inflows from the simulated flow file as the simulation proceeds.

A **Perfect Forecast** option is provided in the inflow forecast model. It selects the actual inflow sequences from the historical record and uses them as the forecasts in the control model in the control-simulation process. This is an ideal case and can be used to investigate the benefit of more accurate forecasting schemes.

For the simulation, you need to provide the **Ending Time**. As for the **Starting Time,** the **Ending Time** is also specified with the format of year, month. Both **Starting Time** and **Ending Time** should be within the historical record given in the **Simulation Inflow** file.

After providing the required input data, you can run the simulation model by pressing the **Run** button. The execution of the simulation model varies from several minutes to several hours depending on the simulation length and the control horizon. When it finishes, **WSHDSS** brings the simulation output window up on the screen.

You can simply display the results obtained from the previous run by specifying the corresponding output file names in folder **Data Files,** and pressing the **Display** button on the bottom.

Then the output screen will also appear.

You can run the forecast-control-simulation model without the interface as well. The corresponding input file generated by the interface is called "grksim.in". To launch the run without the interface, simply type "grksim.exe" in the DOS window or run it from the Window Explorer. The full list of a sample input file is listed below:

```
This file contains data from the interface for the control-simulation program
Historical Inflow Database file
grkhisfl.dat
Simulation Inflow file
grksimfl.dat
Time Dependant Parameter File
grktimepara.dat
DP Parameter File
grkdppara.dat
Elevation Output File
h1612.out
Inflow Output File
w1612.out
Release output File
u1612.out
Primary Energy File
ep1612.out
Secondary Energy File
es1612.out
Total Energy File
e1612.out
Primary Energy Value File
epv1612.out
Secondary Energy Value File
esv1612.out
Total Energy Value File
ev1612.out
Annual Stats File
stats1612.out
Spillage Output File
spl1612.out
Deficit File
dfct1612.out
Evaporation Loss File
evpls1612.out
Irrigation Value File
irrigv1612.out
Control Horizon in Month LT:
 12
Starting Year and Month:
 1961          10
Ending  Year and Month:
 1962          9
Number of Forecasting Traces NTRC
 20
Lag-Time of Previous Flow Used for Corridor Model NCOR (Months)
 3
Elevation Reliability Level (%)        PCT
 50            50            50            50            50            50            50
Price for Primary Energy RATEENP, Secondary Energy, PUMPING RATEENS (dr/kwh)
 12            6             6
Price for Irrigation RATEIRRIG(dr/m^3)
 20
Number of Peak Hours Per working day NPKHR0(Max. 24)
 6
Max. Pumping Hours Per working day NPMPHR0(Max. 24)
 8
Initial Elevations (m)
```

```
 768          540           275           143           68            335           285
Max. Elevations (m)
 770          550           282           144.2         68.6          335           290
Min. Elevations (m)
 731          485           227           142           67            310           250
Running Target Elevation (m)
 770          550           282           144.2         68.6          335           290
Environmental Flow (m^3/s)
 1.5          5             0             0             0             0.5           0.15
Seepage Loss  Flow (m^3/s)
 0            0             6             0             4             0             0
Annual Water Transferred from Sykia to Mouzaki (million m^3/Yr, Max 600)
 600
System Configuration Option 1: Original; 2: Left 5 Reservoir; 3: Full System ; 4: Pyli is out
 3
State Existence Option (0: not; 1: yes)
 1            1             1             1             1             1             1
Pumping Operation Option (0: not; 1: yes)
 1
Forecasting Model Option (0: Perfect; 1: Corridor)
 1
```

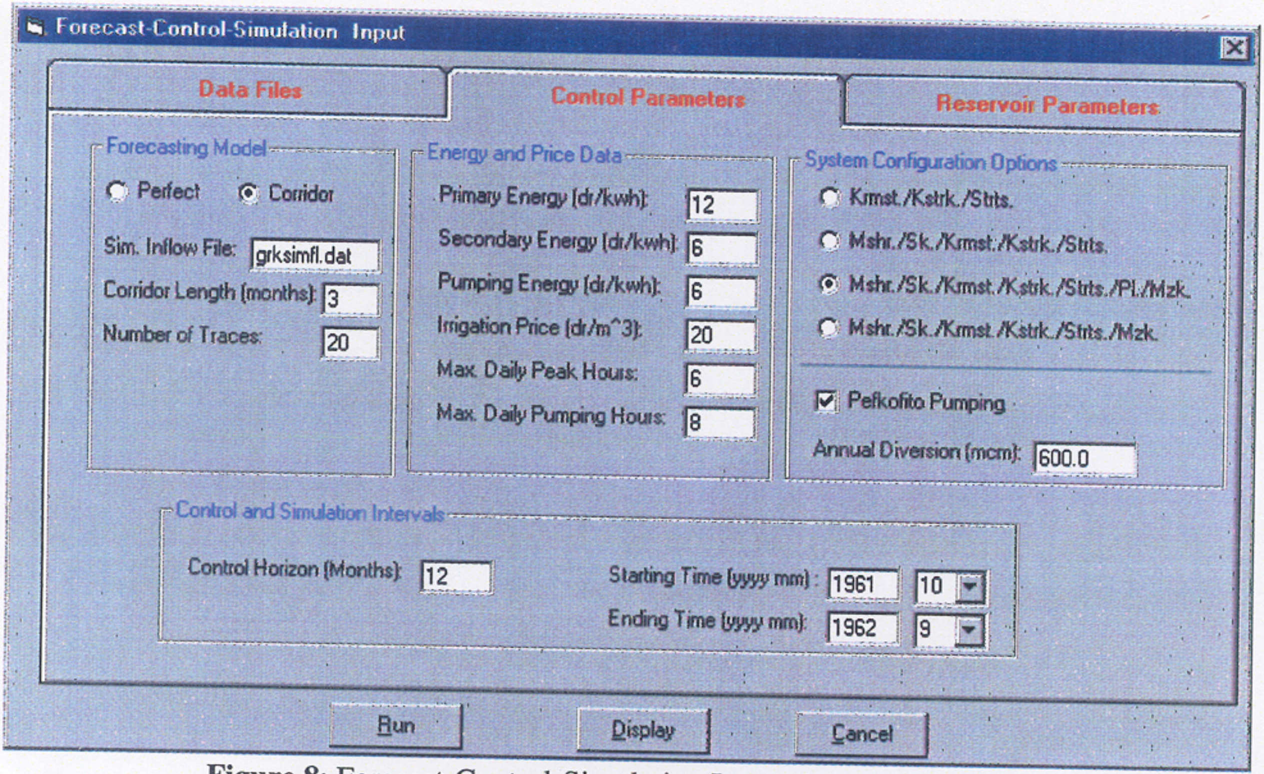


**Figure 8**: Forecast-Control-Simulation Input; Control Parameters

## 6.2 Forecast-Control-Simulation Model Output

The Forecast-control-simulation output window is similar to the control output window. It displays the simulation sequences over the selected historical periods. As in the control model, the results are displayed by reservoir. For each reservoir, the simulated sequences are shown on four different screens. You can switch the screens by pressing the corresponding buttons located in the middle of the screen. The simulated annual statistics are displayed in the table located in the lower left of the screen. Figure 9 shows a picture from the sample run. You can also view the actual data of the simulation sequences and the annual statistics directly from the interface by selecting the menu item under **Tables**. This gives access to the output files specified in the **Data Files** screen box. All output files are saved in a tabular format. You can use them to generate plots using your favorite graphical software. The simulated annual statistics for some important quantities are saved in a separated file. Probably, this is the only file you will need when you conduct simulation runs for different scenarios. A full list of the statistics file from the sample run is given below:

```
Simulation Statistics
 1:MESOHORA   2:SYKIA   3:KREMASTA   4:KASTRAKI    5:STRATOS       6:PYLI    7:MOUZAKI 8:PEFKOFITO
9:PUMPING   10:SYSTEM
 Annual Inflows (mcm)
    1     834.61
    2     803.58
    3    2089.33
    4     585.46
    5     215.65
    6     183.01
    7      97.32

 Annual Release (mcm)
    1     799.11
    2    1101.02
    3    3137.17
    4    3686.50
    5    3769.48
    6     176.26
    7     972.22
    8     600.00

 Annual Net Evaporation Loss (mcm)
    1      -4.48
    2      -9.23
    3      13.15
    4       6.63
    5       2.03
    6      -1.04
    7      -1.54
```

Annual Spillage (mcm)

| | |
|---|---|
| 1 | .00 |
| 2 | 10.42 |
| 3 | .00 |
| 4 | .00 |
| 5 | .00 |
| 6 | .00 |
| 7 | .00 |

Annual Deficit(mcm)

| | |
|---|---|
| 1 | .00 |
| 2 | .00 |
| 3 | .00 |
| 4 | .00 |
| 5 | .00 |
| 6 | .00 |
| 7 | .00 |

Terminal Storage (mcm)

| | |
|---|---|
| 1 | 325.95 |
| 2 | 331.69 |
| 3 | 4096.84 |
| 4 | 795.44 |
| 5 | 73.33 |
| 6 | 54.09 |
| 7 | 50.68 |

Annual Irrigation Volume (mcm) and Value (BDr)

| | | |
|---|---|---|
| 1 | .00 | .00 |
| 2 | .00 | .00 |
| 3 | .00 | .00 |
| 4 | .00 | .00 |
| 5 | 462.67 | 9.25 |
| 6 | 4.00 | .08 |
| 7 | 761.18 | 15.22 |

Annual Energy, Primary, Secondary, Total(GWH)

| | | | |
|---|---|---|---|
| 1 | 263.33 | 133.81 | 397.15 |
| 2 | 176.25 | 218.40 | 394.66 |
| 3 | 782.59 | 345.60 | 1128.19 |
| 4 | 524.03 | 130.74 | 654.77 |
| 5 | 256.56 | 77.19 | 333.75 |
| 6 | .00 | .00 | .00 |
| 7 | 266.19 | 21.94 | 288.13 |
| 8 | 504.78 | 77.00 | 581.79 |
| 9 | .00 | -350.17 | -350.17 |

Annual Energy Value, Primary, Secondary, Total(BDr)

| | | | |
|---|---|---|---|
| 1 | 3.16 | .80 | 3.96 |
| 2 | 2.12 | 1.31 | 3.43 |
| 3 | 9.39 | 2.07 | 11.46 |
| 4 | 6.29 | .78 | 7.07 |
| 5 | 3.08 | .46 | 3.54 |
| 6 | .00 | .00 | .00 |
| 7 | 3.19 | .13 | 3.33 |
| 8 | 6.06 | .46 | 6.52 |
| 9 | .00 | -2.10 | -2.10 |

Annual System Primary Energy (GWH)
2773.74
Annual Secondary Energy (GWH)
654.52
Total Annual Energy (GWH)
3428.26
Annual Primary Value (BDr)

```
    33.28
Annual Secondary Value (BDr)
     3.93
Ann.Tot.Energy Value (BDr)
    37.21
Ann.Tot.Irrigation Value (BDr)
    24.56
```

This file contains the annual simulation statistics for some important quantities such as inflow, release, spillage, deficit, net evaporation loss, energy, energy value, and irrigation value. It has a format similar to the statistics file of the control model. The results are listed by quantity. For each quantity, the results are listed by reservoir index, which is the same as in the control model. The system statistics are listed at the end of the file.

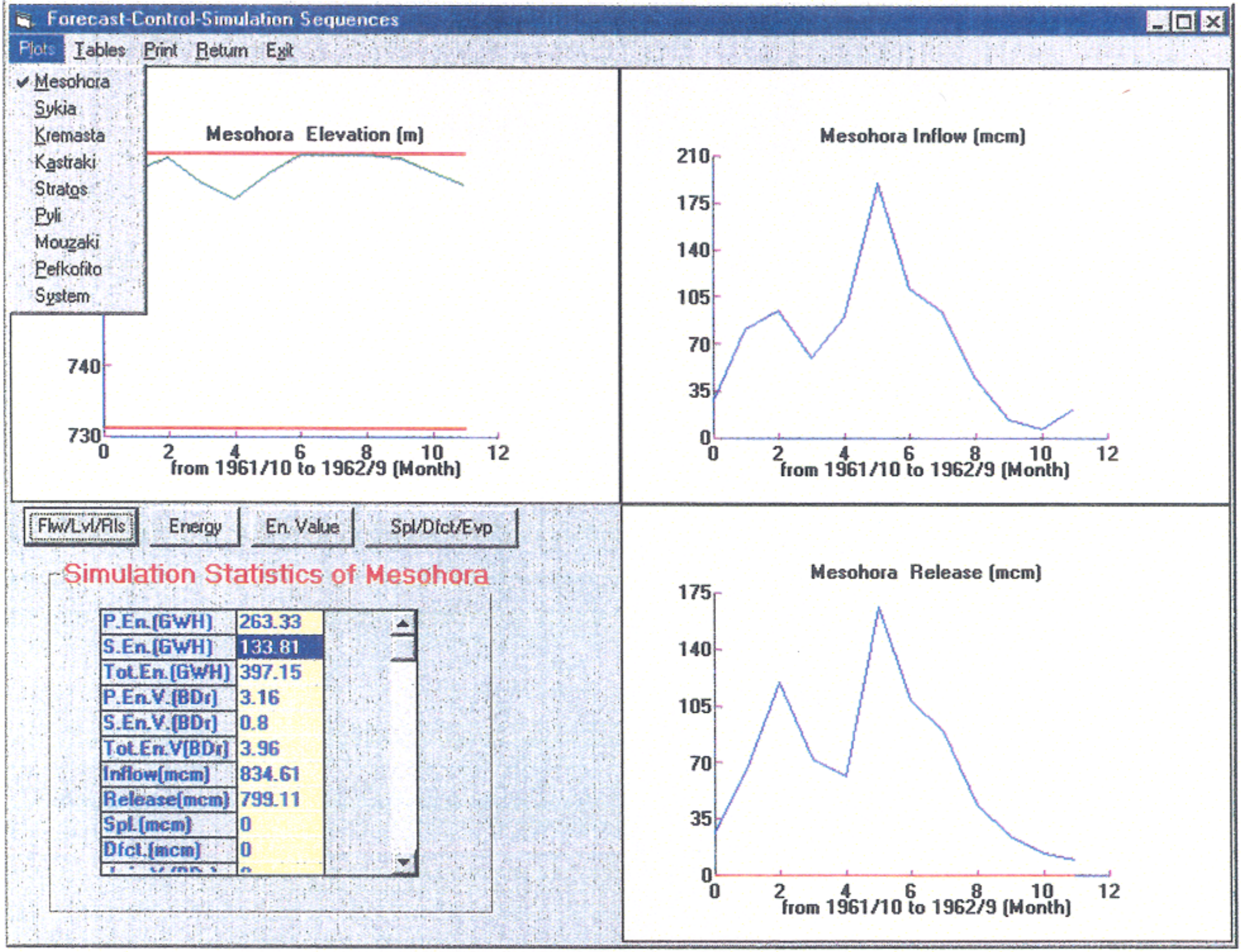


**Figure 9**: Forecast-Control-Simulation Sample Output

# 7. Concluding Remarks

**WSHDSS** is a decision support system for the Western Sterea Hellas Reservoir System that combines advanced models with a user-friendly, graphical interface. The system's design is modular with the ability to incorporate additional features and models.

The forecast-control model can be used to determines optimal release sequences for all reservoirs in the system given a certain set of objective priorities. The forecast-control-simulation model can be used to assess the benefits and impacts of various system configurations.