Training session for the

Firm Yield Estimator

Version 1.0

Prepared for the Massachusetts Department of Environmental Protection

June 6, 2000

Firm Yield Estimator - Introduction

- Software tool for estimating the firm yield of Massachusetts surface water reservoir systems
- Designed to assist communities in fulfilling the requirements of the Massachusetts Water Management Act
- Algorithms employed by the software are those in *Estimating the Firm Yield of a Surface Water Reservoir Supply System in Massachusetts* (DEP, 1996)
- Firm yields can be calculated for a single reservoir or for a system of multiple reservoirs in series and parallel

Firm Yield Estimator - Software design

- Designed for Microsoft® Windows® 95, Windows® 98, or Windows® 2000
- Developed in Borland® Delphi® 4 - an object-oriented, visual programming language based on Pascal
- The Firm Yield Estimator (FYE) is menu-driven and contains help files that include the same technical documentation that appears in the software manual

Firm Yield Estimator - Data needs

- Meteorological data for a station near the reservoir - a database of stations in Massachusetts is included with the FYE (data obtained from NOAA, NCDC)

- Streamflow data for a station near the reservoir - FYE database based on USGS streamgauges

- Reservoir-specific properties:
  - Area of the reservoir's watershed
  - Area of the watershed for the streamgauge
  - Reservoir capacity
  - Required releases from the reservoir
  - Bathymetry data
  - Evaporation rates (can be estimated by FYE)
  - Peak use factors (adjust for seasonal variations)
  - Withdrawals by other users
  - Average watershed elevation
  - Mean channel slope
  - Maximum soil retention

Meteorological Database

- National Oceanic and Atmospheric Administration's National Climatic Data Center
- DEP guidance requires the firm yield analysis to be conducted over a minimum of the 30 year period between April 1960 and March 1990
- The meteorological database contains temperature, precipitation and snowfall data for all Massachusetts weather stations having data for the required 30 year period
- In neighboring states, stations within about 15 miles of the Massachusetts border are also included in the database
- Data from 45 stations are included in the database

Streamflow Database

- Data were downloaded from the USGS website (http://waterdata.usgs.gov)
- Includes all stations (for which the 30 year period of data is available) within Massachusetts and within approximately 15 miles of the border
- Daily streamflow values
- The software documentation will contain a table describing the extent to which each stream is regulated above the streamgauge - DEP must be consulted about the proposed streamgauge to determine if it is “sufficiently unregulated”
- Data from 63 stations are included in the database

Firm Yield Estimator - Scanning Analysis

- Purpose of the scanning analysis - to determine whether synthetically generated precipitation and streamflow data are necessary for the firm yield assessment

- Generates a rough estimate of the reservoir yield by using simplifying assumptions (no precipitation on nor evaporation from the reservoir, default peak use factors, simplified algorithm to estimate streamflow into the reservoir)

- DEP has determined that if a reservoir does not refill at least one month a year during 15% or more of the years in the simulation period-of-record, a 1,000 year long sequence of streamflow and precipitation is required for the firm yield assessment

Firm Yield Estimator - Firm Yield Analysis

- Precipitation on and evaporation from the reservoir surface are included in the analysis
- Site-specific peak use factors are now used
- The analysis can use actual meteorological data or use the 1,000 year sequence of meteorological data if the scanning analysis determined this was necessary
- To calculate the firm yield, the FYE iterates over the yield, increasing it incrementally until the reservoir empties exactly once during the period of record

Multiple Reservoirs

- The FYE can calculate the firm yield for a system of up to 10 reservoirs in series, parallel, or a combination of series and parallel

- A firm yield must first be calculated for each reservoir in the system

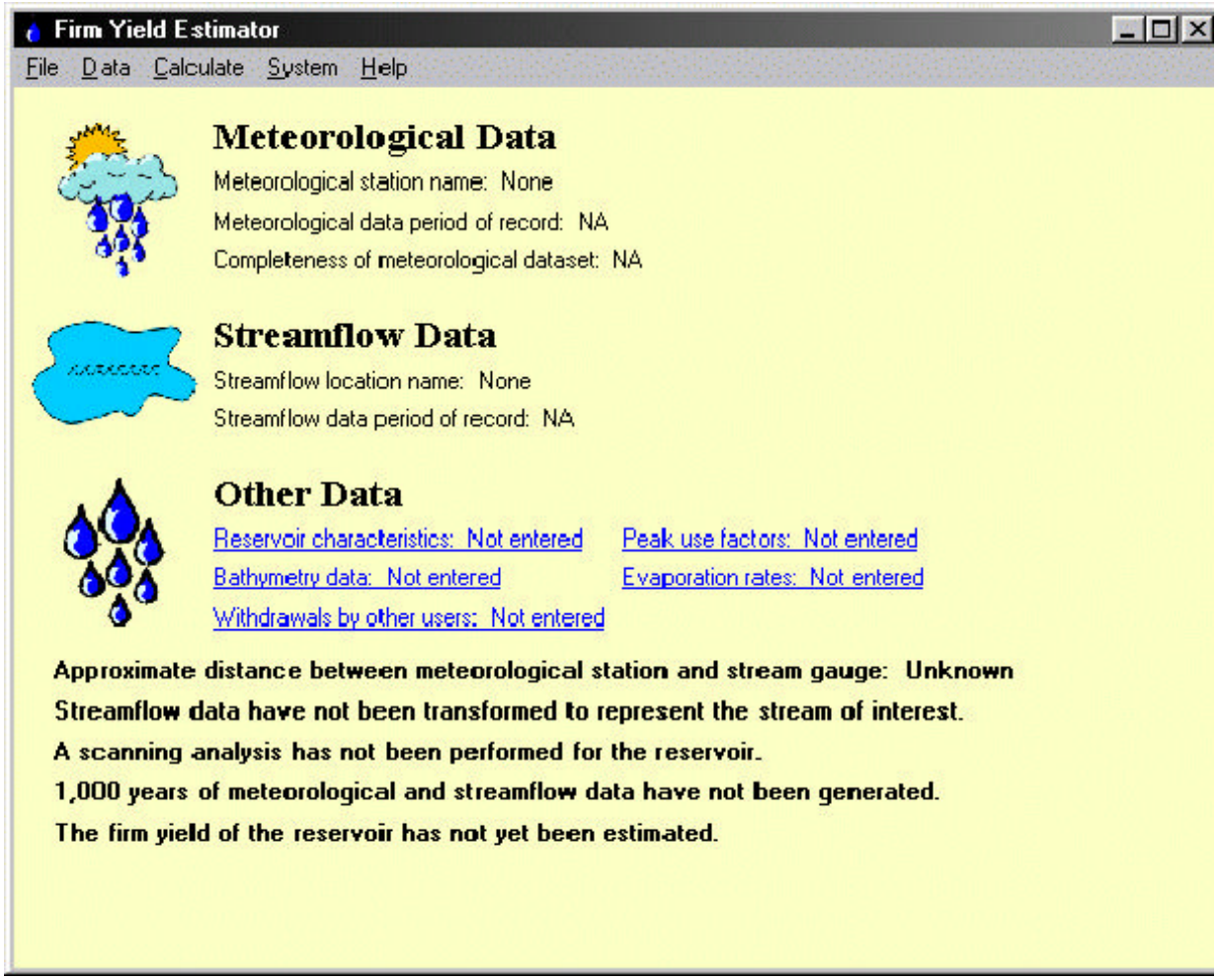
- The relationships between the reservoirs must be specified

- The FYE will calculate the firm yield of the system using the algorithms in DEP's 1996 Guidance Document

Installing and Running the Firm Yield Estimator

- The FYE and databases will be provided in CD-ROM format (approximately 27 MB total)
- For the training session - use Windows Explorer to create a new folder called *FYE*
- Copy the file *FirmYld.exe* and the entire *Data* directory into the new folder *FYE*
- Double-click on *FirmYld.exe* to run the program

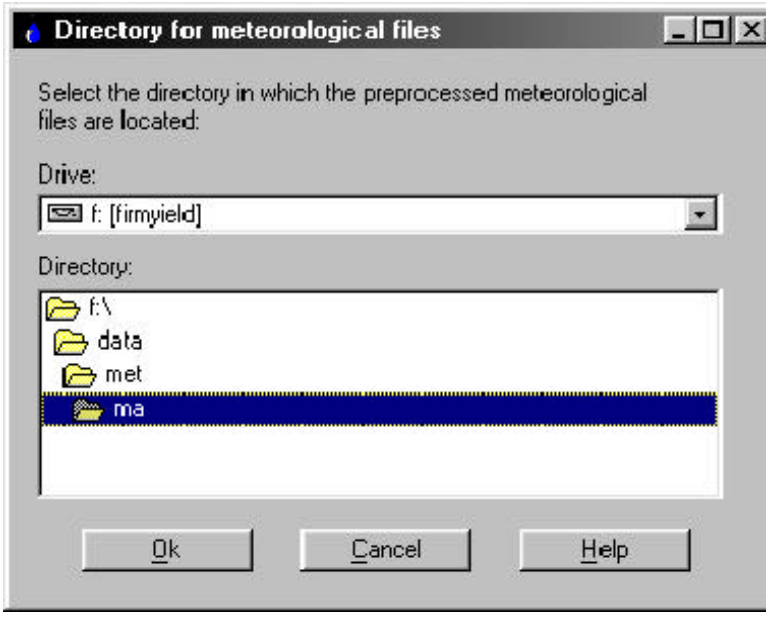
Title Screen
Press the *Continue* button



Main Window

Step 1: Specify the meteorological station to use

Click on the *Select met file from list* option on the *Data* menu



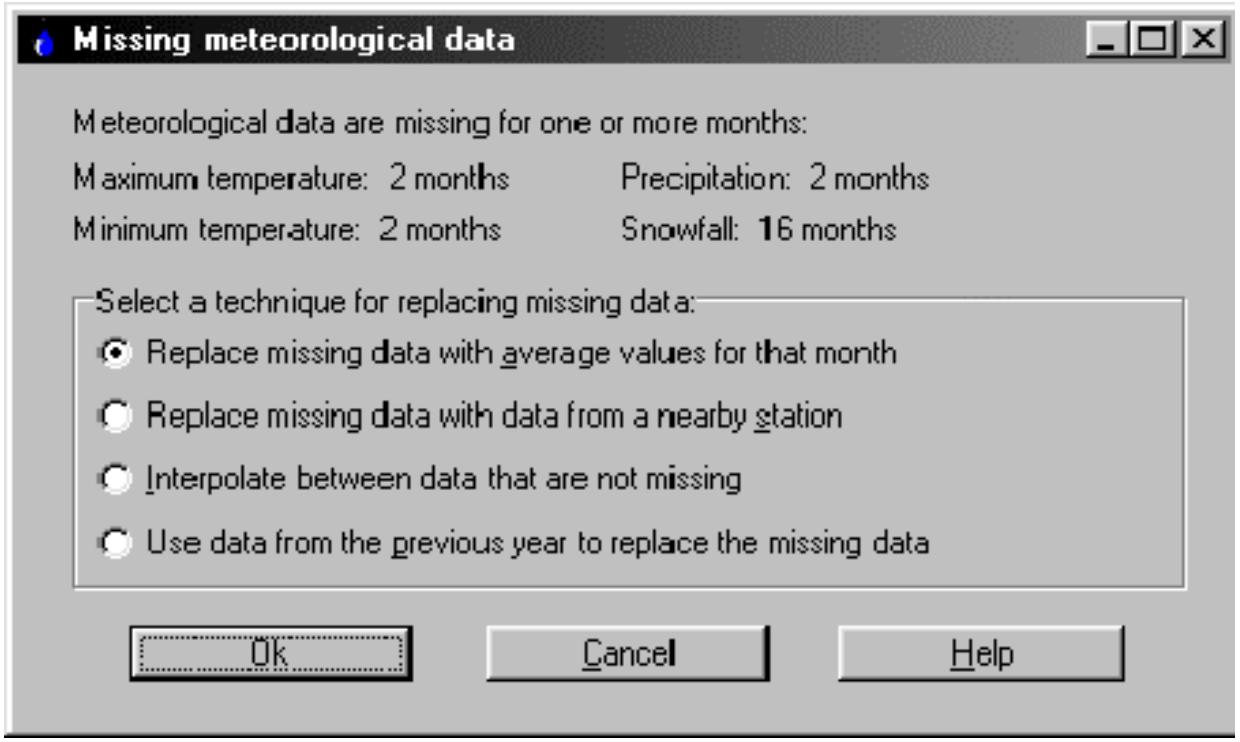
Double click on the directories until reaching the *met/ma* directory

The selected directory is the bottom-most directory with an open folder next to it

Click the *Ok* button

Select *AMHERST* from the drop down list of meteorological stations in the database

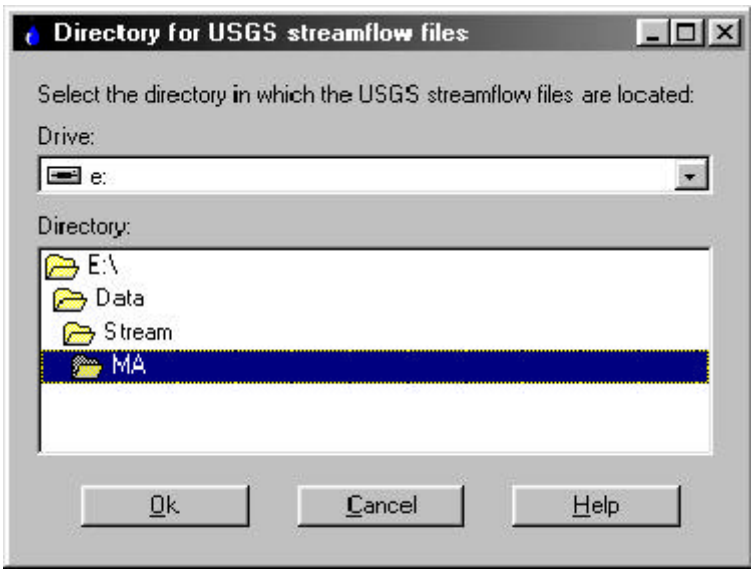
Click the *Ok* button



Because some meteorological data are missing, a dialog box appears to allow the user to fill in missing data

Make sure the *Replace missing data with average values for that month* radio button is selected

Click the *Ok* button



Step 2: Specify the stream gauge to use

Click on the *Select USGS file from list* option from the *Data* menu

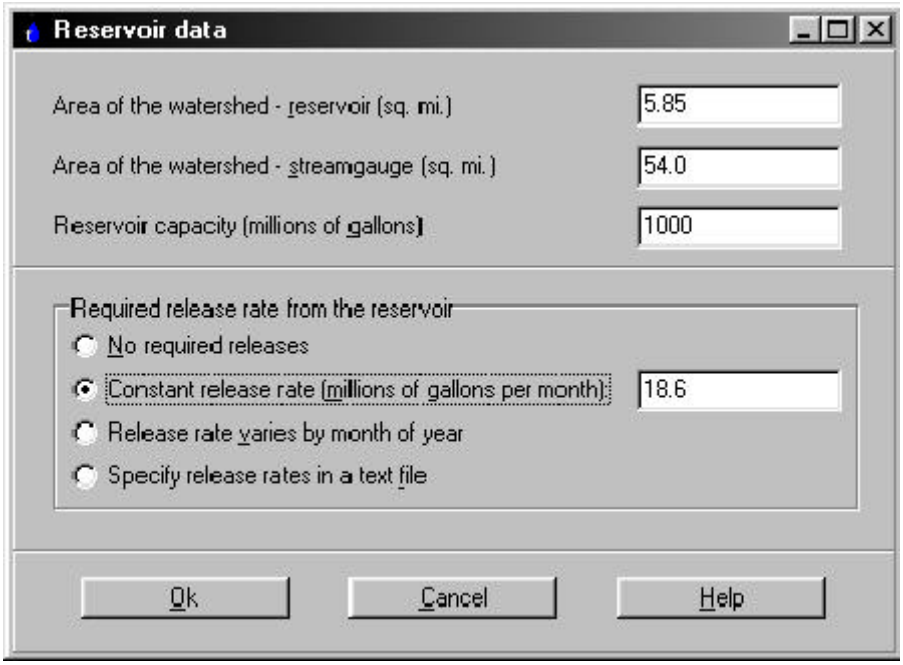
Double click on the directories until reaching the *Stream/MA* directory

The selected directory is the bottom-most directory with an open folder next to it

Click the *Ok* button

Select *AMHERST* from the drop down list of meteorological stations in the database

Click the *Ok* button



Step 3: Specify reservoir characteristics

Click on *Reservoir characteristics* from the *Data* menu

Enter the reservoir characteristics shown above

Ensure the *Constant release rate* radio button is selected

Press the *Ok* button

Step 4: Specify Bathymetry Data

- The DEP Firm Yield guidance document recommends fitting a polynomial to bathymetry data to obtain a relationship between reservoir surface area and depth

- The polynomial is of the form:

$$A = C + C_1 S + C_2 S^2 + C_3 S^3 + \ldots$$

where the terms are:

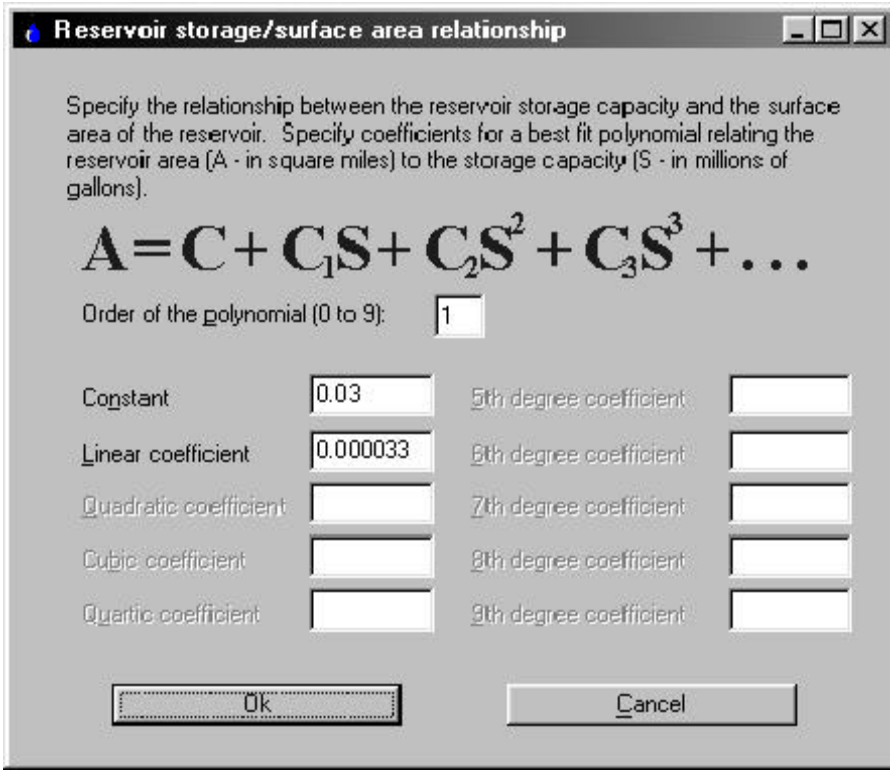
A	area of the reservoir (square miles)
C_n	the nth coefficient ($mi^2/Mgal^n$)
S	the volume of water in the reservoir in Mgal (millions of gallons)

- We will use a simple linear polynomial to describe bathymetry

- The equation we will use is:

$$A = (0.03\ mi^2) + (0.000033\ mi^2/Mgal) \times S$$

- This describes a reservoir with a maximum area of 0.063 mi^2 when full (1,000 Mgal) and 0.03 mi^2 when “empty”

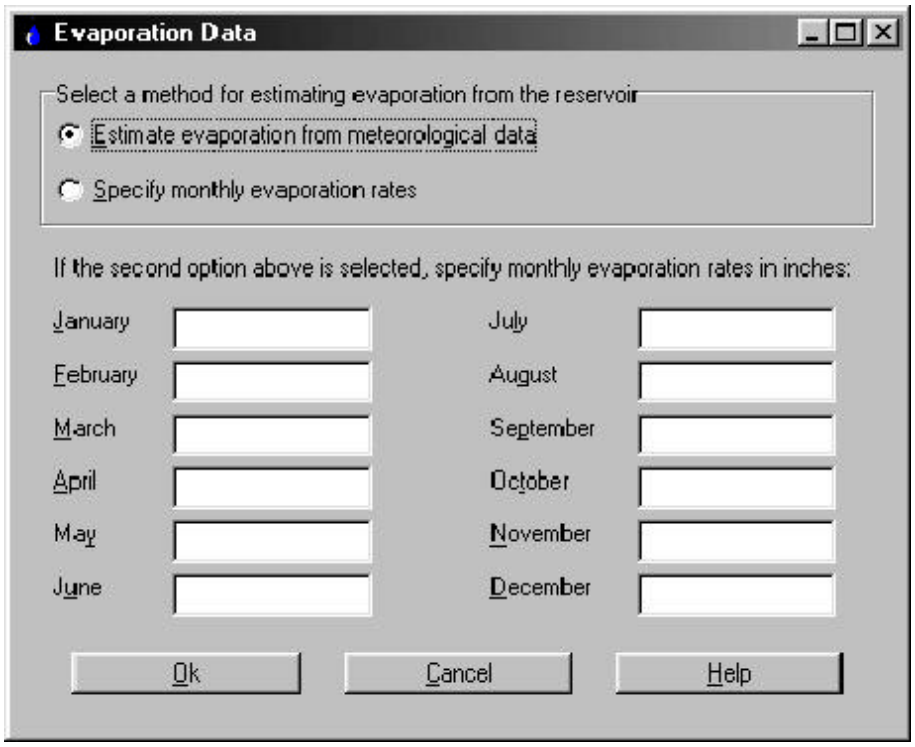


Select *Bathymetry* from the *Data* menu

Specify the order of the polynomial to be 1

Specify the constant and linear coefficients

Press the *Ok* button

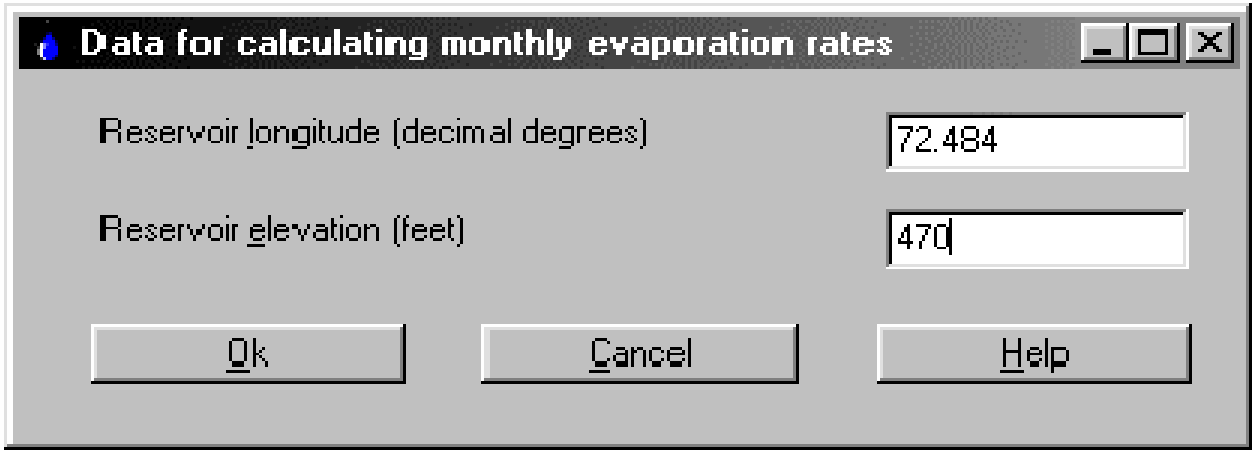


Step 5: Specify evaporation rates from the reservoir

Select *Evaporation rates* from the *Data* menu

Allow *Estimate evaporation from meteorological data* to remain checked

Press the *Ok* button

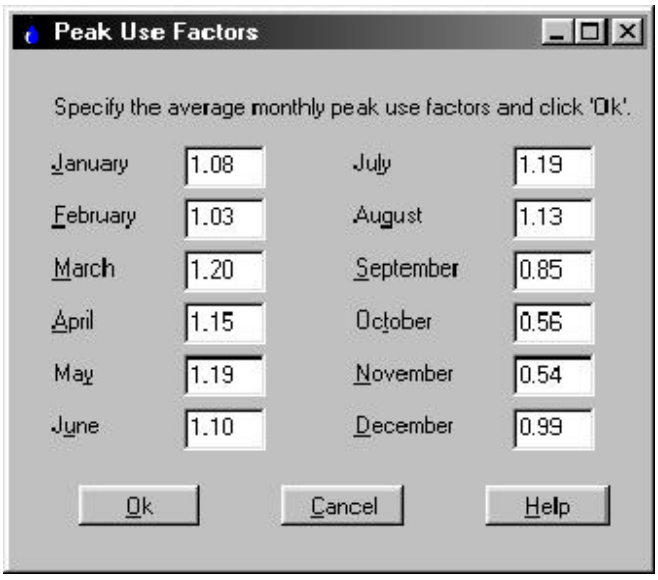


Evaporation rates in Massachusetts can be estimated using an empirical relationship between evaporation, elevation, and longitude (see the DEP Firm Yield guidance)

Specify the reservoir longitude (72.484EW)

Specify the reservoir elevation (470 ft)

Press the *Ok* button



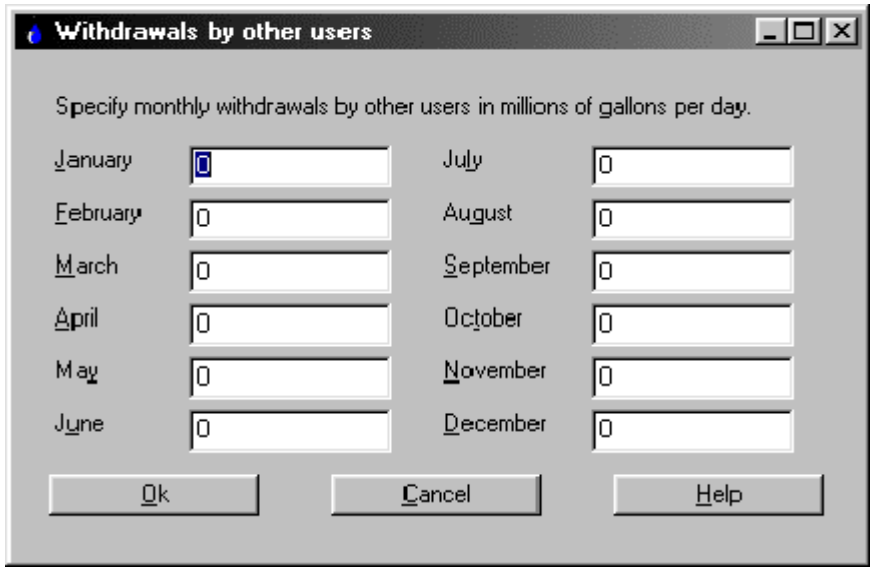
Step 6: Specify Peak Use Factors

Specify the peak use factors that should be used to adjust for seasonal variations in water use

Select *Peak use factors* from the *Data* menu

Replace the default factors with the peak use factors shown above

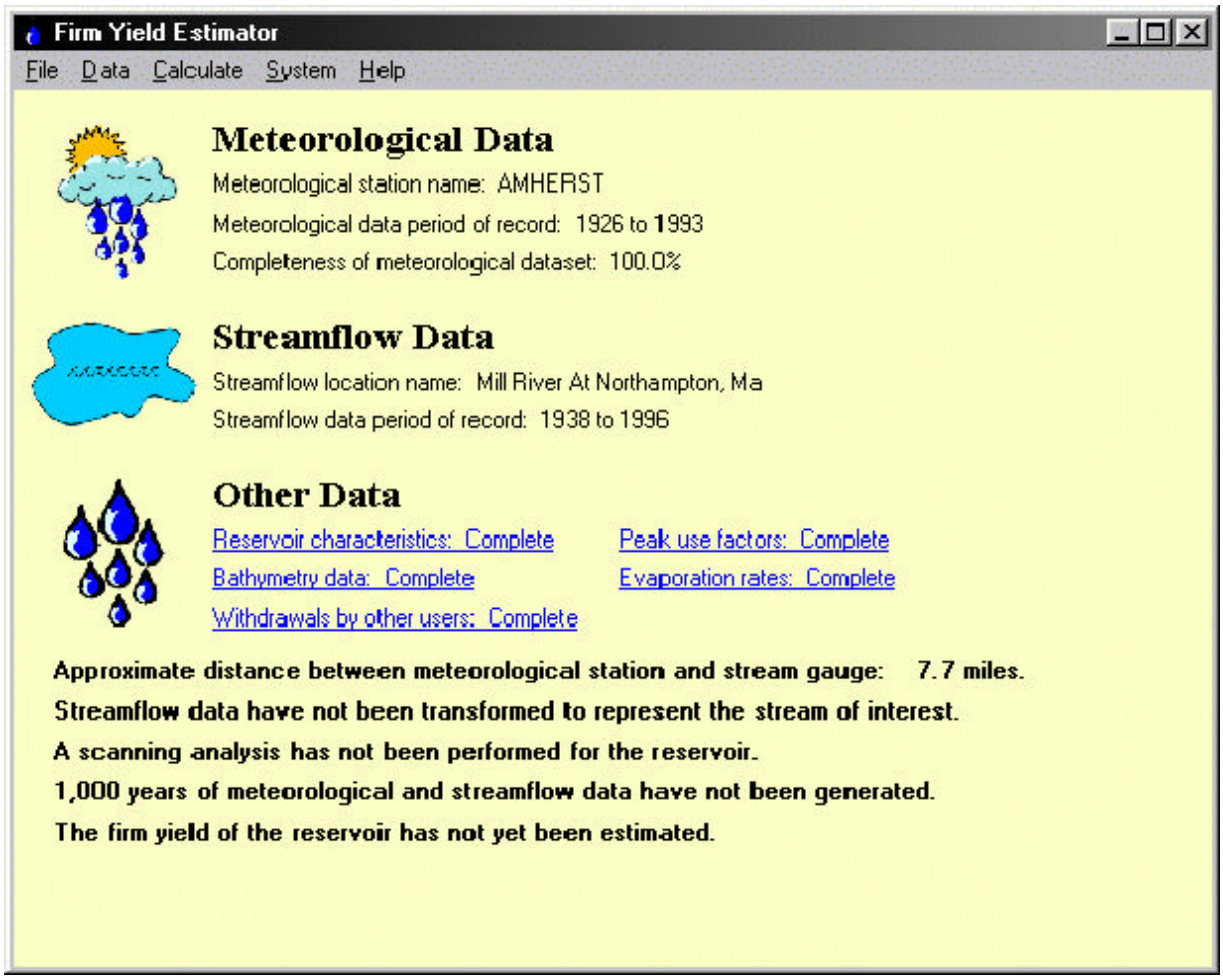
Press the *Ok* button



Step 7: Specify withdrawals by other users

Select *Withdrawals by other users* from the *Data* menu

Accept the default of zero withdrawals by clicking the *Ok button*

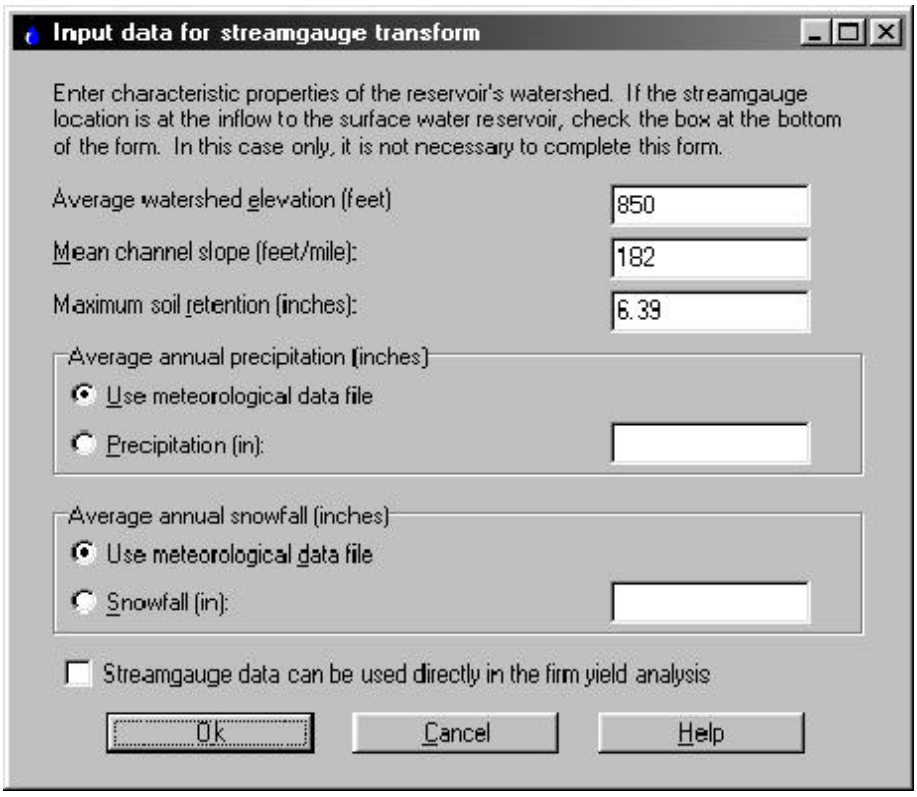


The main screen should appear as above at this point.

Step 8: Transform the streamflow data

- Because the nearest stream gauge to the reservoir is not typically located on the stream that feeds the reservoir, these data must be “transformed” to estimate inflow to the reservoir

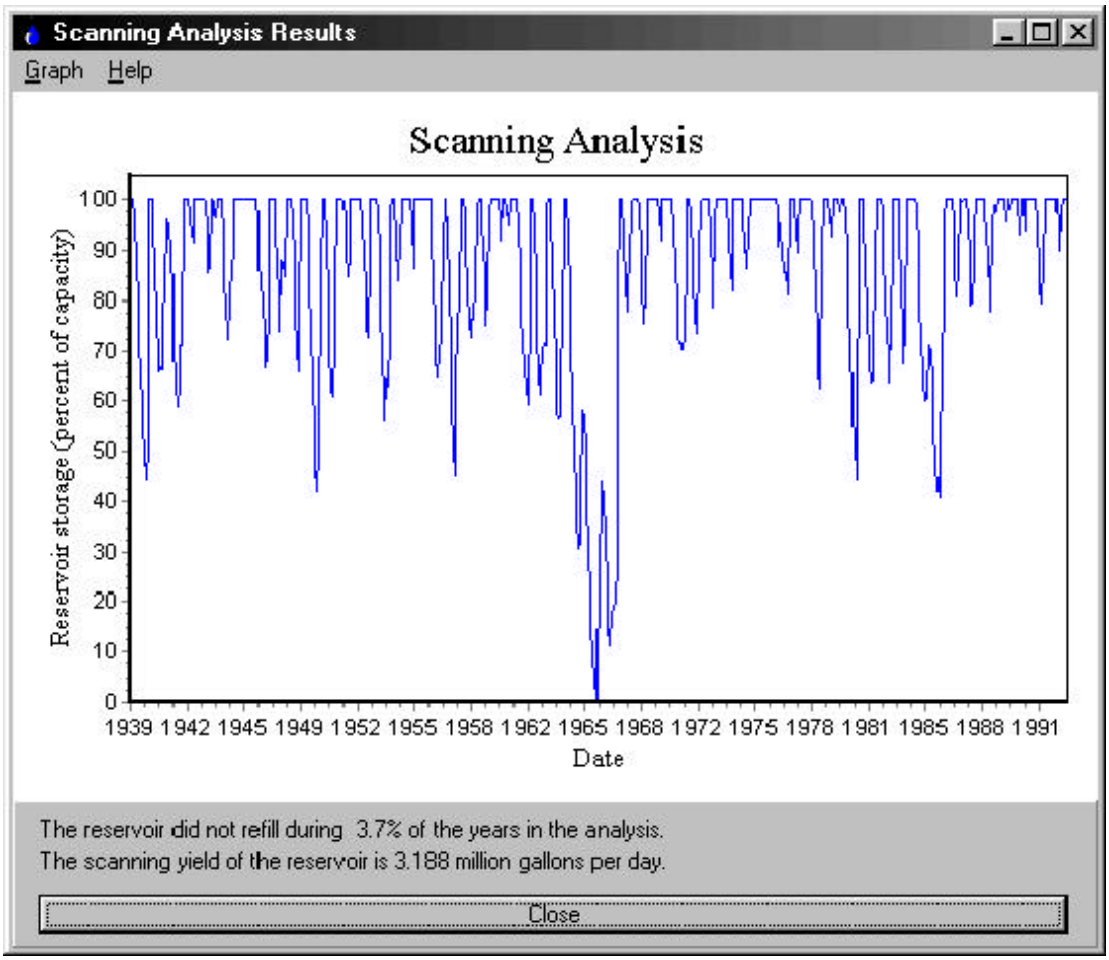
- Select *Transform USGS data* from the *Calculate* menu



Specify the watershed elevation, mean channel slope, and maximum soil retention shown above

Allow the FYE to use the meteorological data file to calculate average precipitation and snowfall and press *Ok*

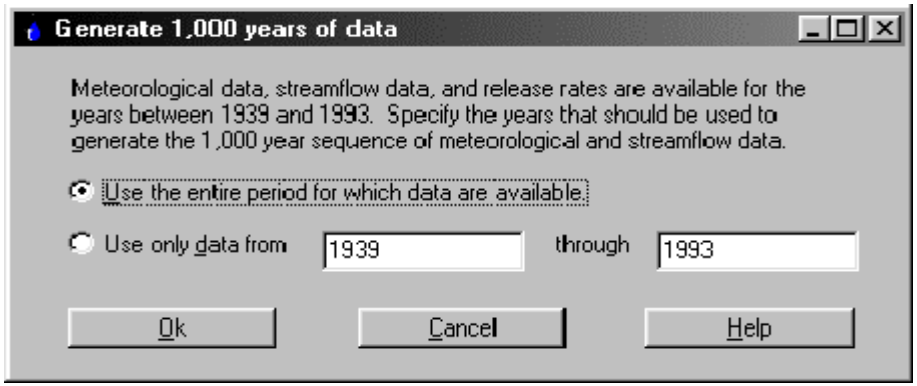
The FYE will display an error message stating that some November 1938 data are missing. This is expected because data were first collected at this station on November 18, 1938. Click the *Ok* button.



Step 9: Perform the scanning analysis

Select the *Perform scanning analysis* option from the *Calculate* menu

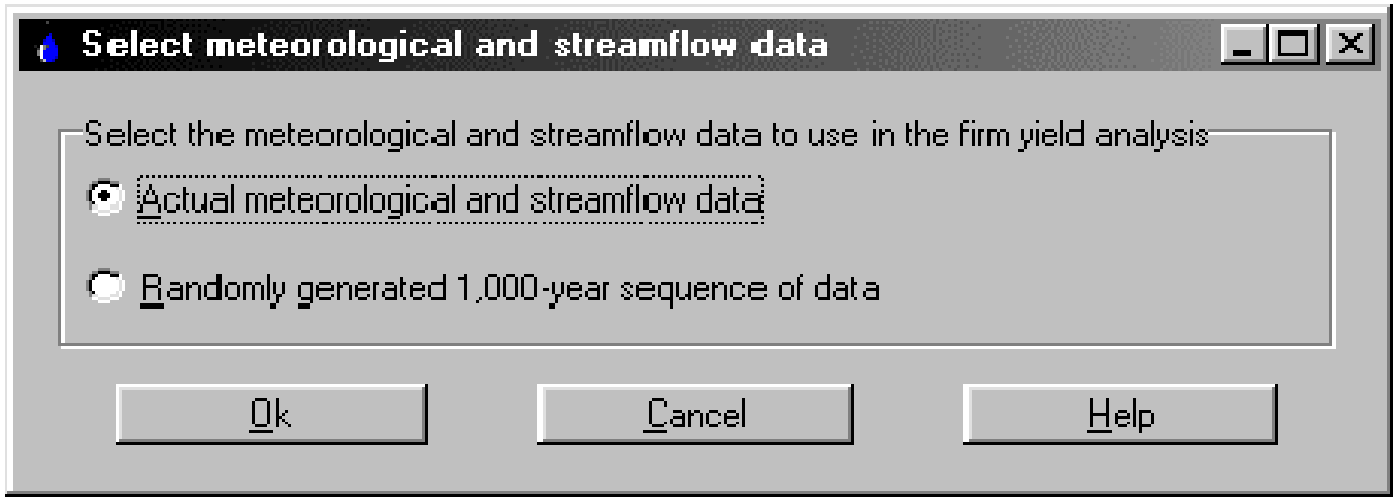
The FYE displays a graph showing the scanning yield of the reservoir and the percentage of years during which the reservoir did not refill



Step 10: Generate a 1,000 year series of meteorological data

As described in the guidance, 1,000 years of data are generated by randomly selecting 500 2-year sequences of meteorological data

Select *Use the entire period for which data are available*
Press the *Ok* button

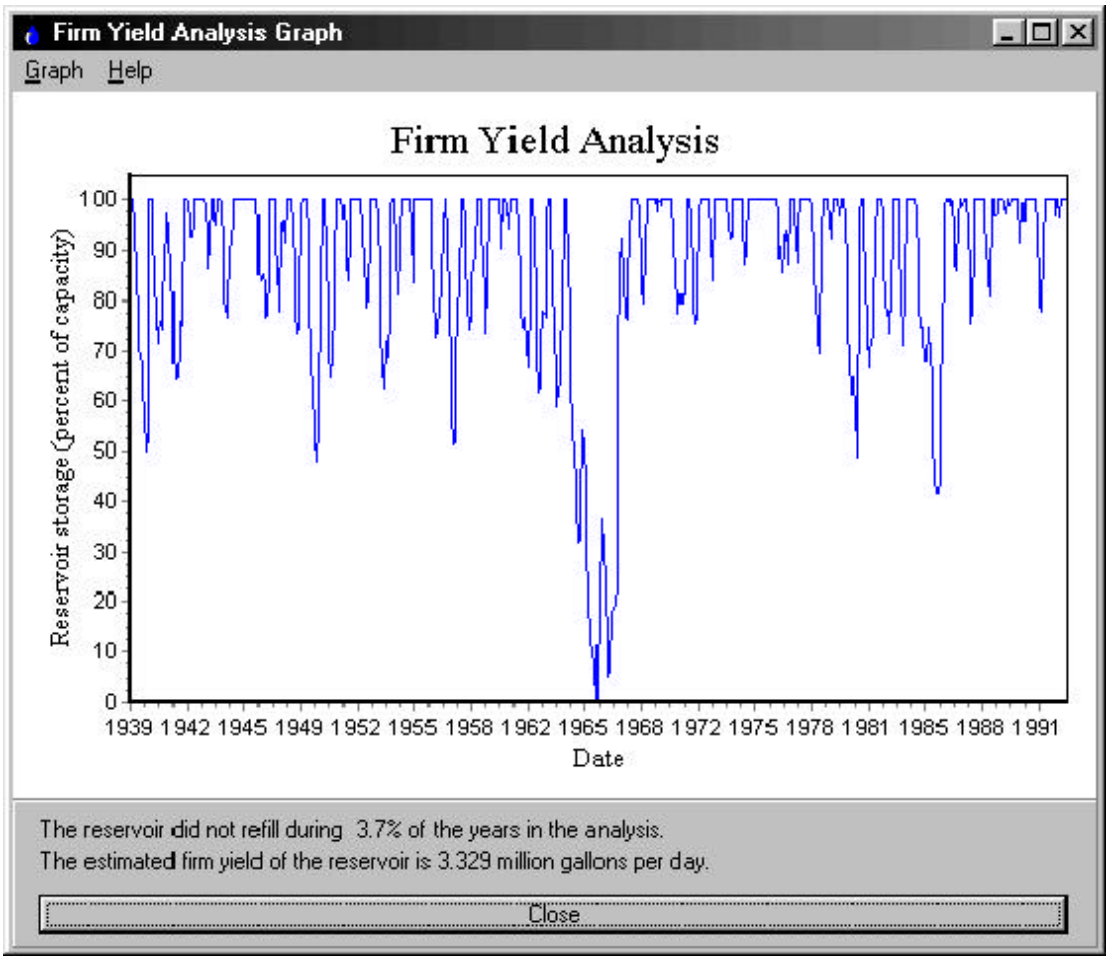


Step 11: Calculate the firm yield for the reservoir

Select *Estimate firm yield* from the *Calculate* menu

Because the scanning analysis indicated that the reservoir did not refill during 3.7% of the years in the analysis, actual meteorological and streamflow data can be used in the analysis

Select *Actual meteorological and streamflow data* *Press the Ok button*



The FYE displays a graph of the firm yield assessment. The firm yield of the hypothetical reservoir is
3.329 million gallons per day.

Step 12: Save the analysis

- Click *Close* to close the graph window
- Select *Save* from the *File* menu
- Specify the directory and filename
- The analysis is now complete and can be opened at a later date

Firm Yield Estimator - Additional Capabilities

- The FYE can print a summary file of the analysis listing all input data and the results of the calculations

- The graphs can easily be printed by selecting *Print* from the *Graph* menu that appears at the top of the graph window

- Text files of reservoir storage vs. time

- When new meteorological data become available from NOAA/NCDC, the FYE can create a new database from the daily data provided by NOAA on CD-ROM

- Updated USGS streamflow data can be downloaded from the USGS website and used directly in the FYE