MODMAN 4.0

WINDOWS-BASED PREPROCESSOR

PREPROCESSOR VERSION 1.02

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PREFACE

The preprocessor for the MODMAN code, documented herein, was prepared for the USEPA under Dynamac Contract No. 68-C4-0031. The technical work was performed by HSI GeoTrans under Subcontract No. S-0K00-001.

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1.0 OVERVIEW

This document describes a windows-based preprocessor for the MODMAN code, Version 4.0. The preprocessor is capable of reading and writing a properly formatted MODMAN input file, referred to as the "MODINP" file. MODMAN and LINDO can be run from the preprocessor as well.

The description of the preprocessor included herein does not replace the MODMAN User's Guide (Greenwald, 1998). The preprocessor is simply a tool for creating and/or editing valid input data files for MODMAN. Therefore, this document is generally limited to the functions of the preprocessor, and the reader is referred to the MODMAN User's Guide for details regarding MODMAN.

1.1 WHAT IS MODMAN?

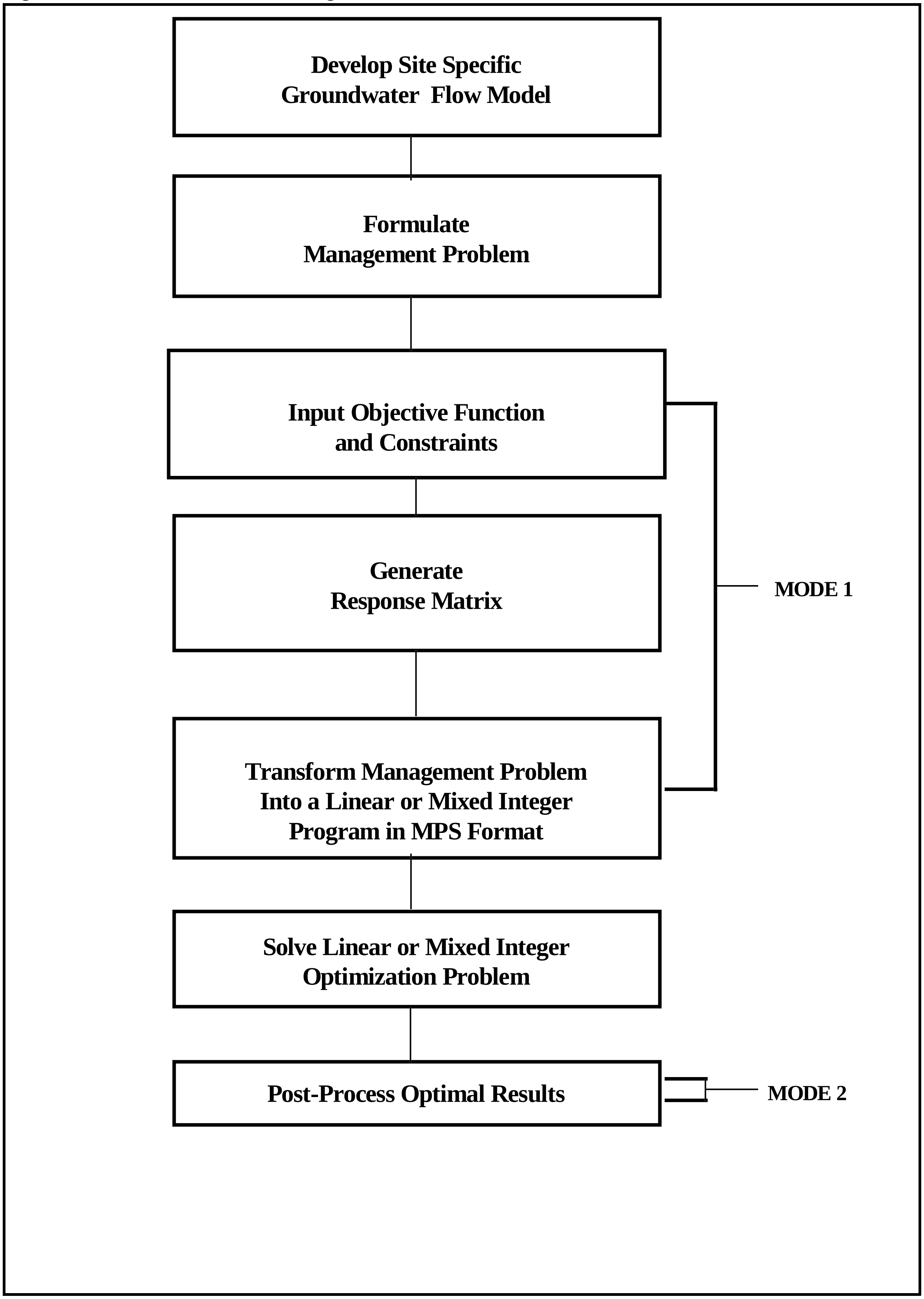
MODMAN (MODflow MANagement) is a FORTRAN code, developed by HSI GeoTrans, Inc. that adds optimization capability to the U.S.G.S. finite-difference model for groundwater flow simulation in three dimensions, called MODFLOW-96 (Harbaugh and McDonald, 1996a,b). MODMAN, in conjunction with optimization software, yields answers to the following groundwater management questions: (1) where should pumping and injection wells be located, and (2) at what rate should water be extracted or injected at each well? The optimal solution maximizes or minimizes a user-defined objective function and satisfies all user-defined constraints. A typical objective may be to maximize the total pumping rate from all wells, while constraints might include upper and lower limits on heads, gradients, and pumping rates. A variety of objectives and constraints are available to the user, allowing many types of groundwater management issues to be considered.

A flowchart illustrating the execution of MODMAN is presented in Figure 1. First, a groundwater model is calibrated with MODFLOW. Then a management problem is formulated and a MODMAN input file indicating user-defined choices for the objective function and constraints is created by the user. The decision variables are the pumping and/or injection rates at potential well locations. MODMAN utilizes the response matrix technique to transform the groundwater management problem into a linear or mixed-integer program. To perform the response matrix technique, a slightly modified version of MODFLOW is called repeatedly as a subroutine. The linear or mixed-integer program is written to an ASCII file in MPS (Mathematical Programming System) format. At this point, the execution of MODMAN in "mode 1" is complete.

The next step is to solve the linear or mixed-integer program. The MPS file is read into an optimization code (LINDO, by Lindo Systems) to determine the optimal solution. Specific LINDO commands generate an output file containing the optimal solution. MODMAN is then executed a second time ("mode 2") to read this file and post-process the optimal results. As part of the post-processing, MODMAN automatically inserts the optimal well rates into MODFLOW, performs a simulation based on the optimal well rates, indicates which constraints are "binding" (exactly satisfied by the optimal solution), and indicates if nonlinearities have significantly affected the optimization process. A methodology is suggested in the documentation to solve problems where nonlinearities significantly affect optimal results.

The preprocessor described herein is Microsoft Windows-based, and allows complete MODMAN input data sets to be developed. The preprocessor has a menu-driven text-based interface, as opposed to a graphical finite-difference based interface. The menus help the user create the MODMAN input (objective function, well locations, constraints) via screens. The preprocessor is able to read and write properly formatted MODMAN input files. This allows the user to easily understand existing files, to edit existing files, and to create new files. MODMAN and LINDO can be run from the preprocessor as well.

Figure 1. Flowchart illustrating the execution of MODMAN.



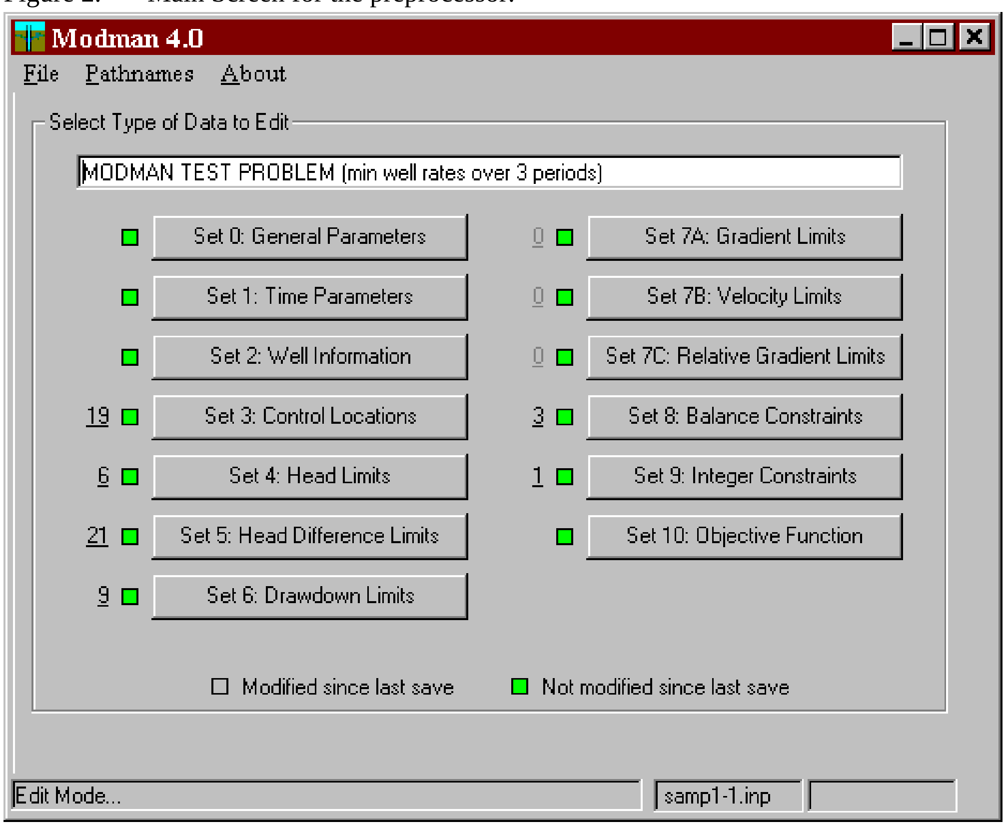
1.2 STRUCTURE OF THE MODMAN INPUT FILE (MODINP)

The MODMAN input file, referred to as the "MODINP" file, is comprised of a series of data sets within one file. The data sets are:

Title	
Set 0:	General Parameters
Set 1:	Time Parameters
Set 2:	Well Information
Set 3:	Control Locations
Set 4:	Head Limits
Set 5:	Head Difference Limits
Set 6:	Drawdown Limits
Set 7A:	Gradient Limits
Set 7B:	Velocity Limits
Set 7C:	Relative Gradient Limits
Set 8:	Balance Constraints
Set 9:	Integer Constraints
Set 10:	Objective Function

The preprocessor is organized according to these data sets. The main screen of the preprocessor is illustrated in Figure 2. Each data set within the overall input file can be edited by pushing the appropriate button with the mouse. Only one data set can be edited at a time. However, there are some cases where edits in one data set cause automatic changes in other data sets (discussed in Section 5).

Figure 2. Main Screen for the preprocessor.



1.3 STRUCTURE OF THIS DOCUMENT

This document has the following sections:

- Section 2: The "Files" Menu
- Section 3: The "Pathnames" Menu
- Section 4: Editing Options
- Section 5: Special Considerations for Well Information (Set 2)
- Section 6: When Changes in one Data Set Impact Other Data Sets
- Section 7: References

2.0 THE "FILES" MENU

The "Files" menu may be selected from the main screen of the preprocessor. The options available to the user are:

New File	Run MODMAN
Open File	Run LINDO
Save File	Exit
Save As	

Each option is briefly described below.

2.1 NEW FILE

This option is selected to create a new MODMAN input file. All input parameters in sets 0 to 2 will be set to default values. There will be no wells (set 2), no control locations (set 3), and no constraints specified (sets 4 to 9). The objective function (set 10) will be set to the default option, which is minimize or maximize the sum of all well rates in all stress periods. The user should then edit each data set as appropriate for the specific problem.

2.2 OPEN FILE

This option is selected to edit an existing MODMAN input data set. The user should then edit each data set as appropriate for the specific problem. If this option is selected while another file is open and has been edited, the user will be asked whether or not to save the existing work.

2.3 SAVE FILE

This option is used to save any changes that have been made since the last "Save" to a disk file, to the same filename currently being edited. If a new file is being created, this option will function the same way as the "Save As" option. Note that no changes are ever made to a disk file unless the "Save" or "Save As" options are selected.

2.4 SAVE AS

This option is used to save the current data file to a name that is different than the one being edited. If an existing filename is selected, the user will be asked whether or not to overwrite the current contents of that file. Note that no changes are ever made to a disk file unless the "Save" or "Save As" options are selected.

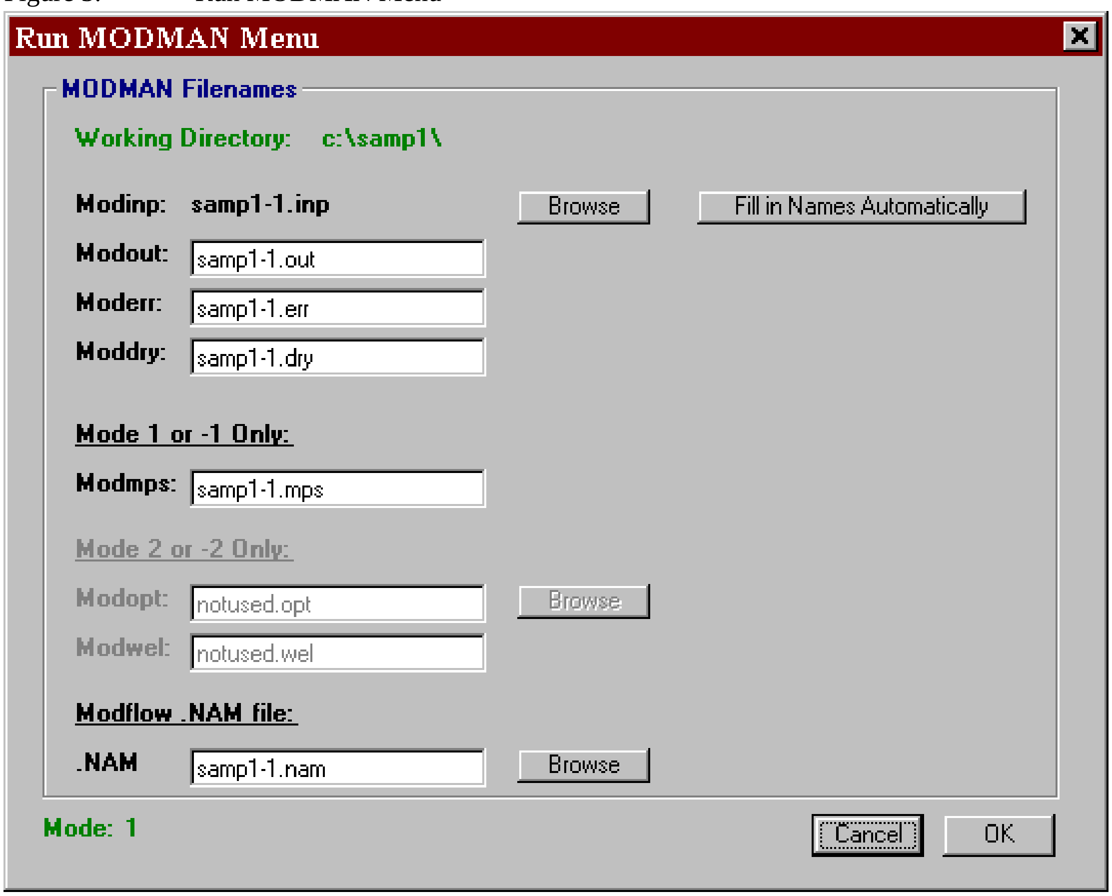
2.5 RUN MODMAN

This option runs the MODMAN code within a DOS Window. First, the user will be prompted to save any edits that have been made to the data file being edited. Next, the user will be asked to confirm the name of the MODINP file desired for the MODMAN run. Then, the user will be prompted as to whether or not to automatically fill in the name of the other required filenames. This is very convenient when the following naming convention is utilized (substitute the actual filename for *file*):

Mode 1	Mode 2	
file-1.INP	*file*-2.INP	(Modinp file)
file-1.OUT	*file*-2.OUT	(Modout file created by MODMAN)
file-1.ERR	*file*-2.ERR	(Moderr file created by MODMAN)
file-1.DRY	*file*-2.DRY	(Moddry file created by MODMAN)
file-1.MPS	-----	(Modmps file created by MODMAN in Mode 1)
-----	*file*-2.OPT	(Modopt file created by LINDO after Mode 1)
-----	*file*-2.WEL	(Modwel file created by MODMAN in Mode 2)
file-1.NAM	*file*-2.NAM	(Modflow filenames file)

The preprocessor automatically determines from the MODINP file if Modman will be run in Mode 1 or Mode 2, and will only allow entries for the required files. Then the user will be placed in the "Run Modman" menu illustrated in Figure 3.

Figure 3. Run MODMAN Menu



When running MODMAN from the preprocessor, all of the files described above must be located in the same directory (called the "working directory"). Note that although the Modflow .NAM file must be in the working directory, the specific MODFLOW files can be located in any directory, based on the pathnames in the .NAM file. When the user selects "OK", MODMAN will be executed with the filenames specifed. The filenames are stored in a temporary disk file call "ppmman.fil", and a temporary batch file called "ppmman.bat" is launched to run MODMAN

If the pathname of the MODMAN executable code (e.g., MODMAN40.EXE) has not yet been specified in the "Pathnames" menu (see section 3), the preprocessor will prompt the user for that pathname.so that the code can be run.

2.6 RUN LINDO

This option runs the LINDO code. Either a Windows or DOS version of LINDO may be executed. The user will be prompted for the name of the MODMPS file. If a Windows version of Lindo is utilized, the MODMPS file will be automatically loaded into LINDO. If a DOS version of LINDO is utilized, the MPS file must be loaded into LINDO using the RMPS command. Additional instructions for LINDO are found in the MODMAN User's Guide.

If the pathname of the LINDO executable code (e.g., LINDO.EXE) has not yet been specified in the "Pathnames" menu (see section 3), the preprocessor will prompt the user for that pathname.so that the code can be run.

2.7 EXIT

This option is used to exit the preprocessor. If any changes have been made since the last "Save", the user will be asked if the changes should be saved.

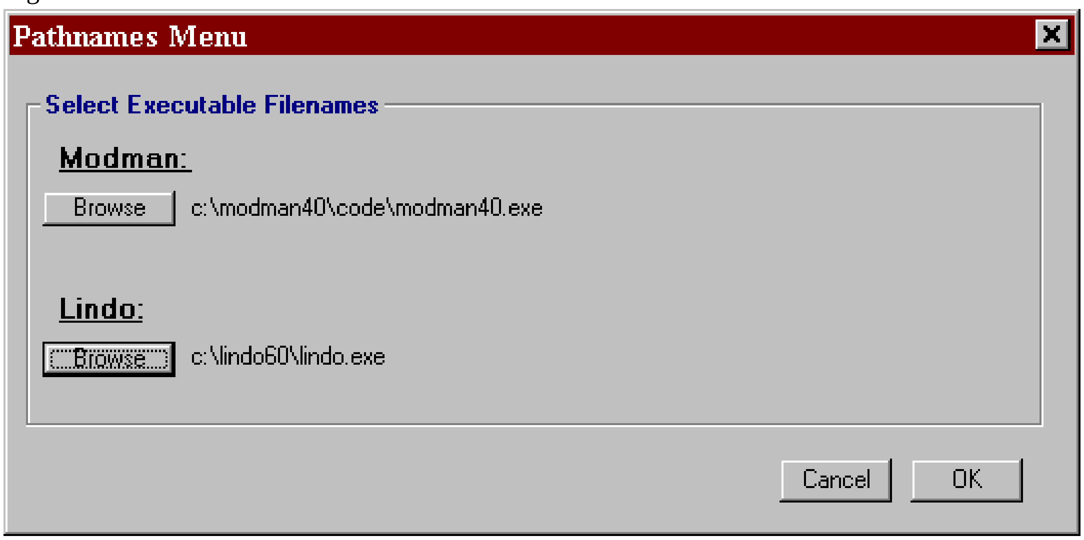
3.0 THE "PATHNAMES" MENU

The "Pathnames" menu may be selected from the main screen of the preprocessor. This menu, illustrated in Figure 4, allows the user to specify the following pathnames:

- The name of the executable file for the MODMAN code; and
- The name of the executable file for the LINDO code.

Once these pathnames are specified, they will be stored in file "ppmman.dat" in the current "Working Directory", which is the directory that contains the file currently being edited. The preprocessor will load the pathnames from this file automatically, each time a MODINP file is subsequently opened from that directory.

Figure 4. Pathnames Menu

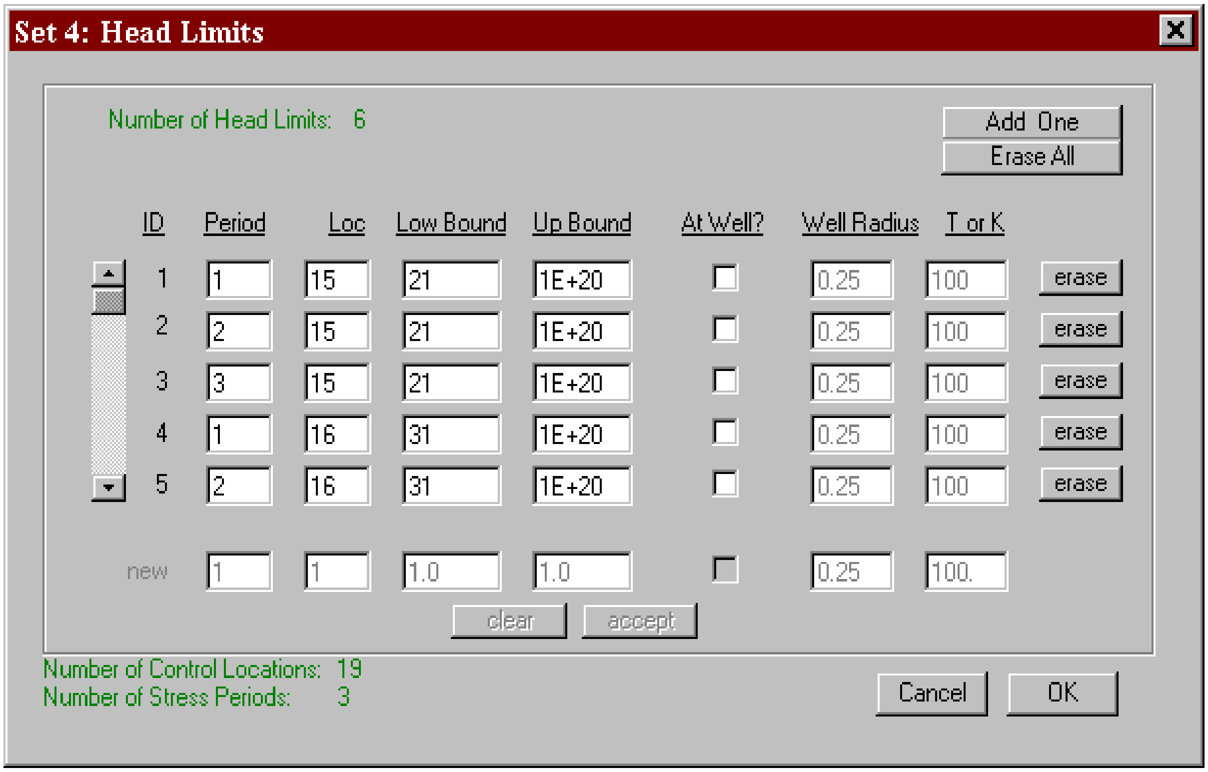


4.0 EDITING OPTIONS

The use of input screens for the various data sets that comprise a MODMAN input file are generally self-explanatory. Of course, to understand the meaning of each parameter requires that the user be familiar with the MODMAN User's Guide.

To illustrate key editing options, the input screen for Set 4 (Head Limits) is presented in Figure 5, and the input screen for Set 8 (Balance Constraints) is presented in Figure 6. The vertical scroll bar allows the user to scroll through the entries for the specific data set. Existing values in text fields can typically be changed by typing a value in the appropriate text field. In some cases, the user can also double-click in a particular field, and then select a value from a series of choices.

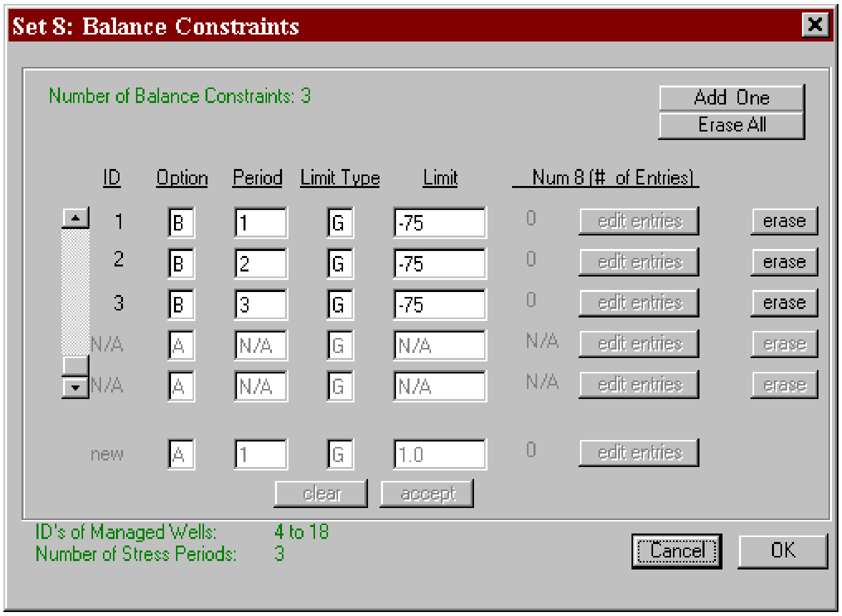
Figure 5. Menu for Set 4 (Head Limits).



In some cases, a portion of the menu will be "disabled" unless the user selects a specific option. On Figure 5, the last two text fields ("Well Radius" and "T or K") will only be active for the specific head limit if the user has checked the box indicating the head limit is applied at a well.

In most cases, the "Cancel" button will nullify any changes made since the specific data screen was entered. However, there are some cases where modifications in one data set immediately alter values in other data sets. Such changes are indicted to the user as they occur, and nevertheless are not permanent until the user selects "Save" or "Save As" from the main screen of the preprocessor. These types of changes are detailed in Section 6.

Figure 6. Menu for Set 8 (Balance Constraints)



The input screens for the various data sets are similar in design. Major editing options that appear within one or more input screens are described below.

4.1 "ADD ONE"

This allows a new line of data (e.g., a new head limit) to be added. The ID of the new limit is automatically set to be one greater than the maximum ID currently defined for that data set. After the user selects "Add One", the bottom portion of the menu will become enabled, including the "Clear" and "Accept" options.

4.1.1 "CLEAR"

Use this option if the "Add One" button was selected by mistake. This option will nullify the input for the new line of data.

4.1.2 "ACCEPT"

Use this option to accept the input for the new line of data.

4.2 "ADD MANY"

This option is only available on the input screen for Set 3 (Control Locations). It allows a large number of control locations to be added at one time by specifying:

From Layer	__ to __	(e.g., from 1 to 3)
From Row	__ to __	(e.g., from 1 to 1)
From Column	__ to __	(e.g., from 1 to 60)

For example, the values above would cause 180 control locations to be added (60 in layer 1, 60 in layer 2, and 60 in layer 3).

Note that duplicate entries for the same control location is acceptable within MODMAN, but should generally be avoided because it causes inefficiencies and can be confusing.

4.3 "ERASE"

This causes an entire line of entries to be erased. As a result, ID's for all subsequent entries are automatically updated. For instance, if there are 20 head limits, and the line for ID 15 is erased, the following changes will be automatically made:

ID 15	will be erased
ID 16	will be changed to ID 15
ID 17	will be changed to ID 16
ID 18	will be changed to ID 17
ID 19	will be changed to ID 18
ID 20	will be changed to ID 19

In some cases, these changes in ID's will impact other data sets. This is detailed in Section 6.

4.4 "ERASE ALL"

This causes all entries in a data set to be erased. In some cases, this will impact other data sets, which is detailed in Section 6.

4.5 "EDIT ENTRIES"

This option is available in Set 8 (Balance Constraints) and Set 9 (Integer Constraints). In these data sets, there is an option to input a list of wells associated with a specific constraint. When that option is selected by the user, the option to "Edit Entries" becomes enabled. Selecting that option opens a menu for editing the list of wells associated with that specific constraint.

4.6 "CANCEL"

In most cases, the "Cancel" button will nullify any changes made since the specific data screen was entered. However, there are some cases where modifications in one data set immediately alter values in other data sets. Such changes are indicted to the user as they occur, and nevertheless are not permanent (with respect to the MODMAN input file stored on disk) until the user selects "Save" or "Save As" from the main screen of the preprocessor. These types of changes are detailed in Section 6.

4.7 "OK"

Selecting this option causes edits made in the specific input screen to be accepted by the user. The user is then returned to the main screen of the preprocessor. However, changes to the actual MODMAN input file stored on disk are not permanent until the user selects "Save" or "Save As" from the main screen of the preprocessor.

4.8 DOUBLE-CLICKING INPUT FIELDS

In some input fields, the user may double-click with the mouse to display a list of choices. This is particularly useful when a control location or well-id is the required input, because the "layer-row-column" of the control location or well-id will be included in the list of choices. This is also particularly useful when an letter must be selected by the user, because the list of choices provides more detail for the user to read. For example, Figure 6 contains two fields requiring letter-based input. Figure 7 illustrates the choice list for "Option", and Figure 8 illustrates the choices for "Limit Type". The user makes a selection by double-clicking on the desired choice.

Figure 7. "Double-Click" choices for "Option" in set 8.

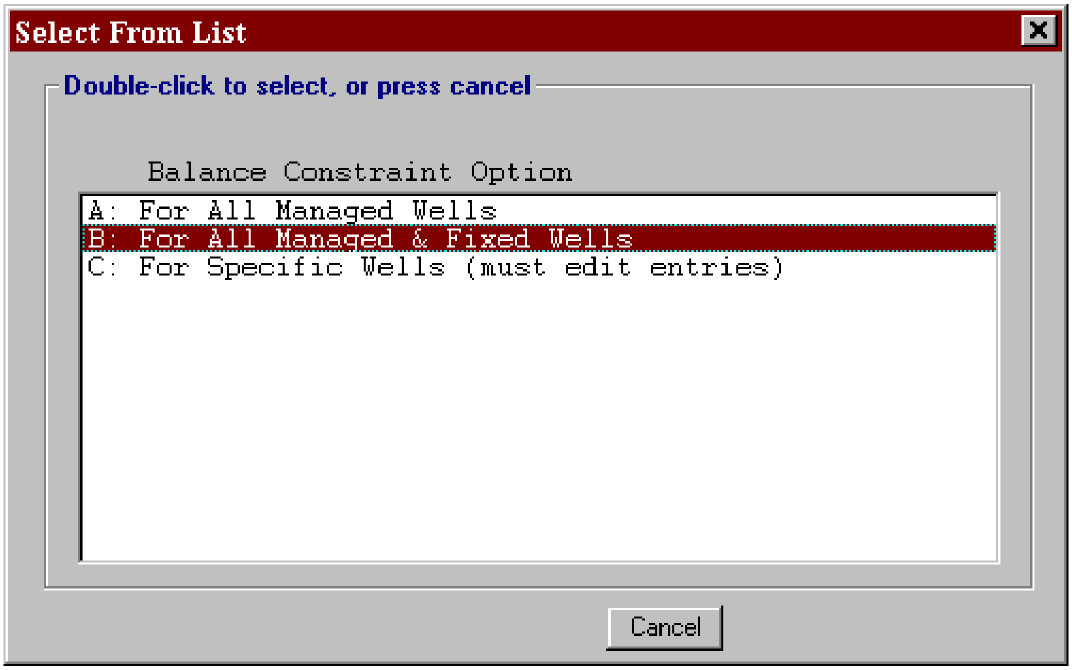
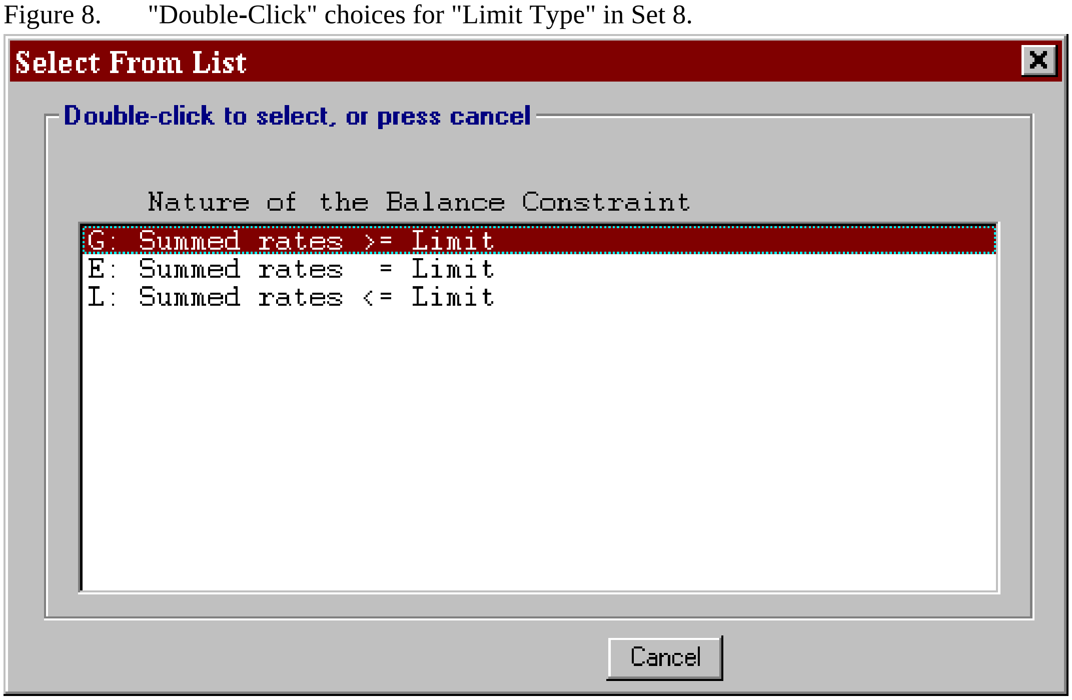


Figure 8. "Double-Click" choices for "Limit Type" in Set 8.



5.0 SPECIAL CONSIDERATIONS SET 2 (WELL INFORMATION)

The input for Set 2 (Well information) is somewhat more complicated than the other data sets, and therefore requires a more detailed description. MODMAN has two types of wells:

- Type A: Fixed at the same rate in every stress period
- Type B: Rate is to be determined by MODMAN (e.g., a managed well) or rate varies by stress period

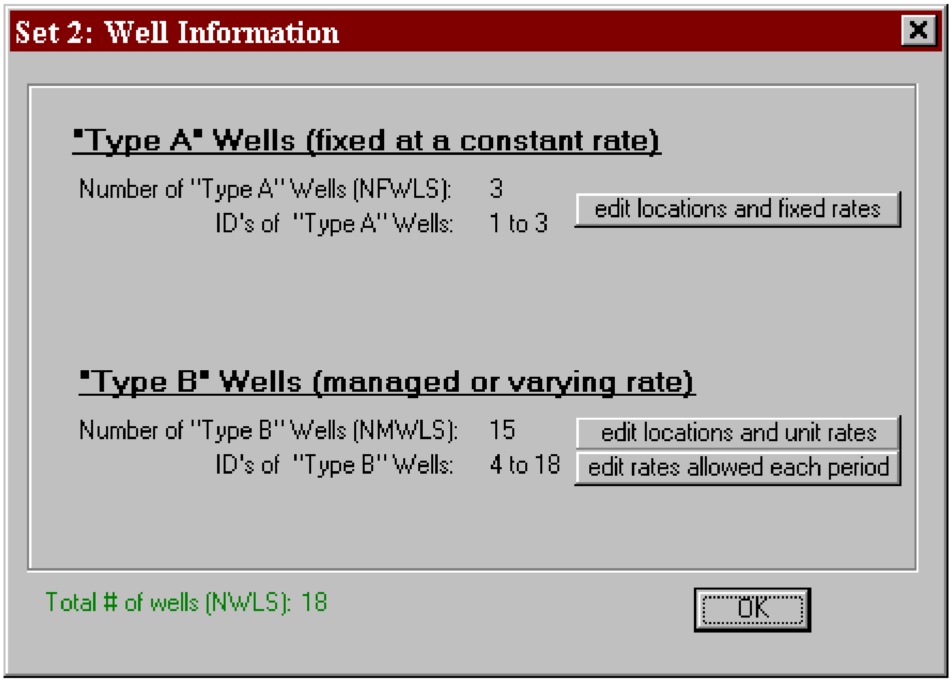
Assume there are 3 "Type A" wells, 6 "Type B" wells, and 3 stress periods. The Set 2 input for MODMAN has the following structure (consisting of three main components):

(1) Locations and rates for Type A wells (one line per well)
ID 1
ID 2
ID 3
(2) Locations and rates for Type B wells (one line per well)
ID 4
ID 5
ID 6
ID 7
ID 8
ID 9
(3) Rates allowed for each Type B well in each stress period
Period 1, ID 4
Period 1, ID 5
Period 1, ID 6
Period 1, ID 7
Period 1, ID 8
Period 1, ID 9
Period 2, ID 4
Period 2, ID 5
Period 2, ID 6
Period 2, ID 7
Period 2, ID 8
Period 2, ID 9
Period 3, ID 4
Period 3, ID 5
Period 3, ID 6
Period 3, ID 7
Period 3, ID 8
Period 3, ID 9

The main menu for Set 2 input, illustrated in Figure 9, has a button corresponding to each of these three components.

Note that changes in one part of Set 2 can have a "ripple effect" in other parts of Set 2. For instance, adding or erasing a "Type A" well will alter the ID's for all the "Type B" wells. The preprocessor makes such changes automatically. Please note that this, in turn, can impact other data sets (see Section 6 for details).

Figure 9.   Main menu for Set 2 (Well Information).



6.0 WHEN CHANGES IN ONE DATA SET IMPACT OTHER DATA SETS

There are some cases where modifications in one data set immediately alter values in other data sets. Such changes are indicted to the user as they occur, and nevertheless are not permanent (with respect to the MODMAN input file stored on disk) until the user selects "Save" or "Save As" from the main screen of the preprocessor. These types of changes are detailed below.

6.1 ADDING OR ERASING “TYPE A” WELLS (SET 2)

As explained in Section 5, adding or erasing a "Type A" well will alter the ID’s for all the "Type B" wells. The preprocessor makes such changes automatically. This can cause impacts in other data sets. Specifically, the following changes will be made automatically by the preprocessor:

- If a "Type A" well is erased, ID’s for all subsequent "Type A" wells will be updated;
- ID’s for all "Type B" wells will be updated;
- In Set 8 (Balance Constraints), if any constraints have specific wells included (Option C), the well ID’s will be updated if they have changed in Set 2;
- In Set 9 (Integer Constraints), if any constraints have specific wells included (Option B), the well ID’s will be updated if they have changed in Set 2;
- In Set 10 (Objective Function), if specific wells are included (ICODE = 1 and NUM10 > 0), the well ID’s will be updated if they have changed in Set 2.

6.2 ERASING “TYPE B” WELLS (SET 2)

Erasing a "Type B" well will alter the ID’s for all the subsequent "Type B" wells. The preprocessor makes such changes automatically. This can cause impacts in other data sets. Specifically, the following changes will be made automatically by the preprocessor:

- In Set 8 (Balance Constraints), if any constraints have specific wells included (Option C), the well ID’s will be updated if they have changed in Set 2, or removed if the specific well was erased in Set 2;
- In Set 9 (Integer Constraints), if any constraints have specific wells included (Option B), the well ID’s will be updated if they have changed in Set 2, or removed if the specific well was erased in Set 2;
- In Set 10 (Objective Function), if specific wells are included (ICODE = 1 and NUM10 > 0), the well ID’s will be updated if they have changed in Set 2, or removed if the specific well was erased in Set 2.

6.3 ERASING CONTROL LOCATIONS (SET 3)

Erasing a control location will alter the ID’s for all the subsequent control locations. The preprocessor makes such changes automatically. This can cause impacts in other data sets. Specifically, the following changes will be made automatically by the preprocessor:

- Control locations will be updated in Set 4 (head limits), Set 5 (head difference limits), Set 6 (drawdown limits), Set 7a (gradient limits), and Set 7b (velocity limits) if they have changed in Set 3;

- Limits will be removed in Set 4 (head limits), Set 5 (head difference limits), Set 6 (drawdown limits), Set 7a (gradient limits), and Set 7b (velocity limits) if the associated control location was erased in Set 3;

- If any limits in Set 7a (gradient limits) are erased, there may be subsequent changes to Set 7c (relative gradient limits), as described in Section 6.4;

- In Set 10 (Objective Function), if specific control locations are included (ICODE > 1 and NUM10 > 0), the control locations will be updated if they have changed in Set 3, or removed if the specific control location was erased in Set 3.

6.4 ERASING GRADIENT CONSTRAINTS (SET 7A)

Set 7c (relative gradient limits) are defined on the basis of gradient limit ID's (Set 7a). Therefore, if ID's in set 7a are erased, subsequent ID's in SET 7a will be modified. Relative gradient limits in Set 7c will be automatically removed if they are based on a gradient limit that has been erased in Set 7a. Gradient limit ID's in Set 7c will be automatically updated if they are based on a gradient limit that has been changed in Set 7a.

6.5 DECREASING THE NUMBER OF STRESS PERIODS (SET 1)

Decreasing the number of stress periods has a number of impacts on other data sets. The preprocessor assumes the last "n" stress periods are removed. For instance, if the number of stress periods is changed from 4 to 1, input data pertaining to the last 3 stress periods are removed. When stress periods are removed, the following changes will be made automatically by the preprocessor:

- In Set 2 (well information), the rates allowed for each "Type B" well will be removed for each stress period that has been removed;

- Limits will be removed in Set 4 (head limits), Set 5 (head difference limits), Set 6 (drawdown limits), Set 7a (gradient limits), and Set 7b (velocity limits) if they are assigned in a stress period that has been removed;

- If any limits in Set 7a (gradient limits) are erased, there may be subsequent changes to Set 7c (relative gradient limits), as described in Section 6.4;

- Limits in Set 8 (Balance Constraints) will be removed if they pertain to a stress period (i.e., NPER8 > 0) and that stress period has been removed;

- In Set 8 (Balance Constraints), if any constraints have specific wells included (Option C), the well ID's will be removed if they pertain to a stress period that has been removed;

- Limits in Set 9 (Integer Constraints) will be removed if they pertain to a stress period (i.e., NPER9 > 0) and that stress period has been removed;

- In Set 10 (Objective Function), if a specific stress period is defined (NUM10 = -1), the specified stress period (NPER10) will be reset to 1 if the stress period previously defined by NPER10 has been removed;

- In Set 10 (Objective Function), if specific wells or control locations are included (NUM10 > 0), the specific wells or control locations will be removed if they pertain to a stress period that has been removed.

6.6 INCREASING THE NUMBER OF STRESS PERIODS (SET 1)

Increasing the number of stress periods requires that the rates allowed for each "Type B" well in each stress period be added for the stress periods added. The preprocessor assumes the added stress periods come after the stress periods already defined.

7.0 REFERENCES

Greenwald, R.M., 1998. Documentation and User's Guide: MODMAN, an Optimization Module for MODFLOW, Version 4.0 (HSI GeoTrans, Freehold, New Jersey).

Harbaugh, A.W. and McDonald, M.G., 1996a. User's documentation for MODFLOW-96, An update to the U.S. Geological Survey modular finite-difference ground-water flow model, U.S. Geological Survey Open-File Report 96-485, 56 p.

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