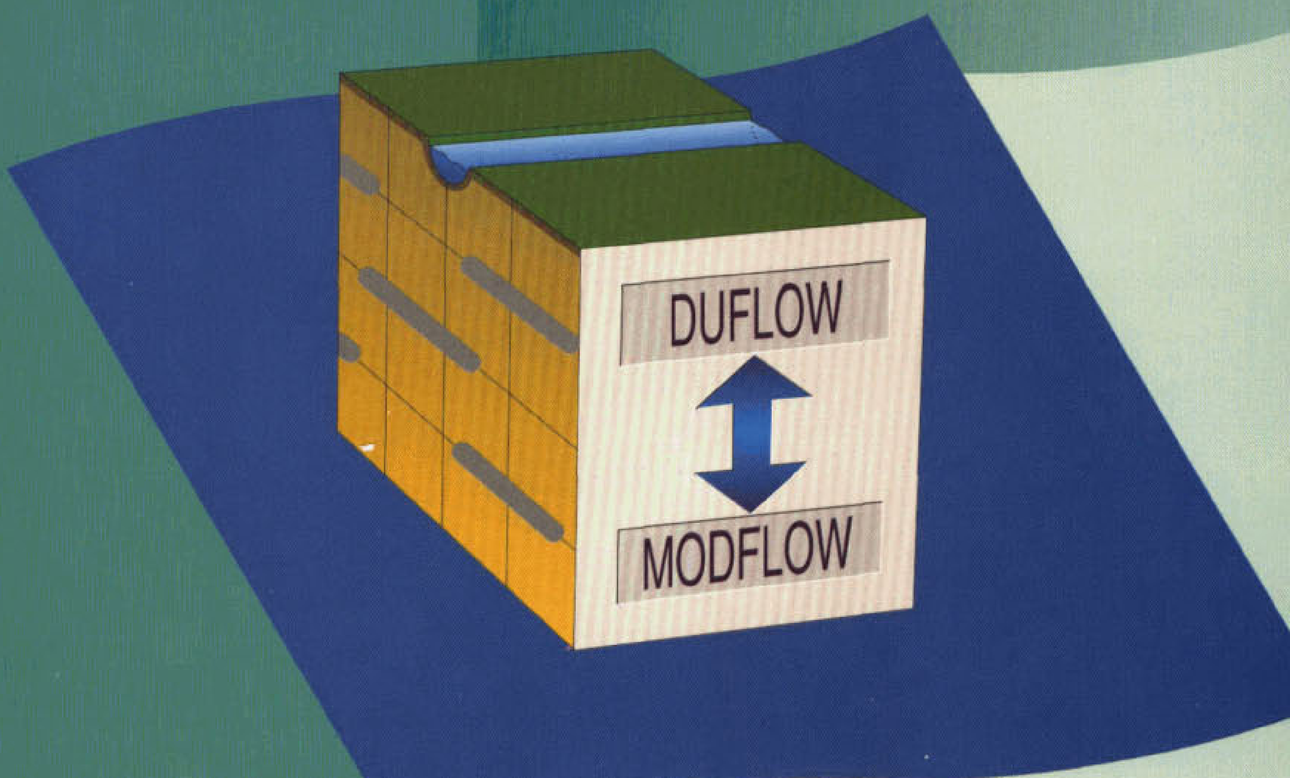
stowa

…ichting Toegepast Onderzoek Waterbeheer

MODUFLOW

Gebruikers handleiding



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Stichting Toegepast Onderzoek Waterbeheer

MODUFLOW

Gebruikers handleiding

STOWA
Arthur van Schendelstraat 816
Postbus 8090, 3503 RB Utrecht
Telefoon 030 232 11 99
Fax 030 232 17 66

KIWA N.V.
Groningenhaven 7
Postbus 1072, 3430 BB Nieuwegein
Telefoon 030 606 95 11
Fax 030 606 11 65
E-mail alg@kiwaoa.nl
Internet www.kiwa.nl

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TEN GELEIDE

Moduflow is een on-line koppeling van het grondwaterstromingsmodel MODFLOW en het oppervlakte-waterstromingsmodel DUFLOW. Dit model is uitermate geschikt om droogvallende sloten ten gevolge van infiltratie in de loop van de tijd te kunnen simuleren of om de mogelijkheden voor een beter ontwerp van het slotenstelsel met bijbehorende kunstwerken in combinatie met grondwater-ontrekkingen te kunnen bepalen of om te gebruiken bij het doorrekenen van verdrogingsprojecten.

Zowel uit de interviews verricht in het kader van het Nationaal Onderzoeksprogramma Verdroging (NOV-thema 13) als uit de vraaggesprekken ten behoeve van het opstellen van het STOWA Behoeftenonderzoek Consensusmodellenlijn (STOWA-rapport 97-01) blijkt dat men de interactie tussen de aandachtsgebieden oppervlakte- en grondwater steeds belangrijker te vinden. Dit geldt voor zowel de (regionale) waterbeheerders, als medewerkers van waterleidingmaatschappijen, als derden. Vandaar deze gezamenlijke inspanning van Kiwa en STOWA om te komen tot een dergelijke koppeling.

Moduflow gaat uit van een bestaande MODFLOW-schematisatie voor het grondwater- en een bestaande DUFLOW-schematisatie voor het oppervlaktewatermodel. Tijdens de berekening stuurt Moduflow de beide rekenmodellen aan, afwisselend wordt door DUFLOW en MODFLOW over een vastgesteld tijdsinterval gerekend.

Met behulp van Moduflow is het mogelijk om de dynamische interactie tussen het oppervlaktewater en grondwater te modelleren. Tijdens de simulatie met Moduflow worden door MODFLOW berekende toe- en afvoeren doorgegeven aan DUFLOW, terwijl de door DUFLOW berekende waterstanden in de watergangen worden doorgegeven aan MODFLOW. Moduflow legt beide schematisaties op elkaar. Bij deze overlay wordt voor alle DUFLOW-secties vastgesteld in welke MODFLOW-cellen zij liggen.

De projectleider vanuit de opdrachtgevers Kiwa en STOWA was ing. M. den Besten (Kiwa). De werkzaamheden voor het Moduflow- en het DUFLOW-gedeelte zijn uitgevoerd door een projectteam van EDS bestaande uit drs. B. van Adrichem, ir. J.J. Noort, mw. ir. S. Ooms en ir. J. Zwagemakers. Het MODFLOW-gedeelte is door de dhr. D. Baggelaars van het Kiwa gerealiseerd, terwijl de tests van het programma door ir. X.T. Ngo (WMO) en ir. W. Athmer (Kiwa) zijn uitgevoerd.

Het project is begeleid door een begeleidingscommissie bestaande uit: ir. W. Athmer (Kiwa), ing. E. Broeze (Waterschap Groot-Salland), drs. R. Eijsink (Provincie Utrecht), ir. X.T. Ngo (Waterleiding Maatschappij Overijssel - WMO), ir. K. Tamminga (Waterleiding Maatschappij voor de Provincie Groningen - WAPROG) en ir. L.R. Wentholt (STOWA)

Utrecht/Nieuwegein, mei 1997

De directeur van de STOWA

drs. J.F. Noorthoorn van der Kruijff

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Introduction

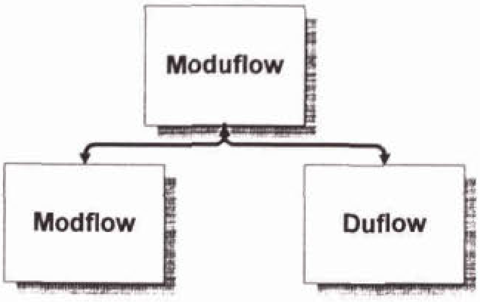
While managing watersystems, an integral view is becoming more and more a necessity. Instead of looking at only one aspect, solutions must combine waterquality and -quantity-aspects in both surface and ground-water. To make sound decisions, mathematical models are used to predict the outcome of certain measures and to analyse trends and expectations. These mathematical models focus most of the time on only a few of the relevant aspects, thereby making an integral view more difficult to obtain.

For certain problems, there was the need to look at both ground- as surface-water aspects within a region. Because both watersystems interact, a solution combining the results of the available ground-watermodel (MODFLOW) and surface-watermodel (DUFLOW) was not sufficient. It was necessary to combine both models on a timestep-basis, thus modelling the interaction. This solution was preferred over the design of a new model, because this solution left previous investments in both software as in schematisations intact. The resulting program is called Moduflow (X.T. Ngo [1]).

The Models

Moduflow

Moduflow is a softwarepackage to calculate dynamic in a problem combining surface and ground-water. Instead of developing a new model, Moduflow combines two existing models, MODFLOW and DUFLOW. It was therefor appropriate to give the program a name combining the name of the two original programs.



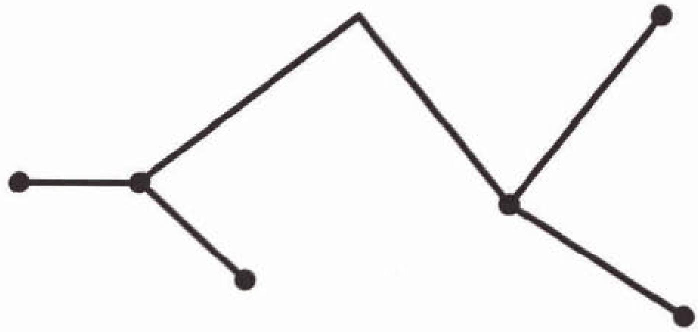
Kiwa and STOWA requested EDS to develop Moduflow. Both organisations are at present owner of Moduflow.

The initial ideas are by X.T. Ngo [1], who investigated the mathematical foundation and build a preliminary testmodel. He is also the one who came up with the name Moduflow.

DUFLOW

DUFLOW, an acronym for Dutch Flow Program, simulates the flow and quality-aspects of surface-water using a one-dimensional approach. The program models a system of waterways as a network of nodes connected by one-dimensional sections. It can also model certain constructions, for example weirs and culverts. Through a separate module, RAM, it can deal with inflow from rain.

A static form of exchange with a ground-watersystem can be modelled by specifying beforehand the amount of flux exchanged each timestep (together with flux coming from other sources).
A dynamic exchange was not yet possible.

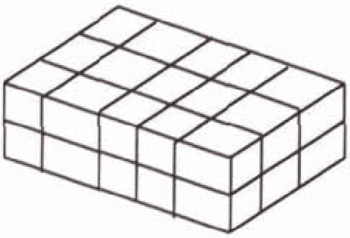


For more information about DUFLOW, please refer to the relevant documentation [4].

STOWA is the owner of DUFLOW.

MODFLOW

MODFLOW (modular finite-difference ground-water flow model), is a three-dimensional program to simulate the flow of ground-water. Although MODFLOW has the possibility to exchange fluxes with the surface (through the RIVER-section) it can only do so in a static way. The flux is calculated as a function of a static water-level in the river-element and the dynamic water-level of the ground-water.



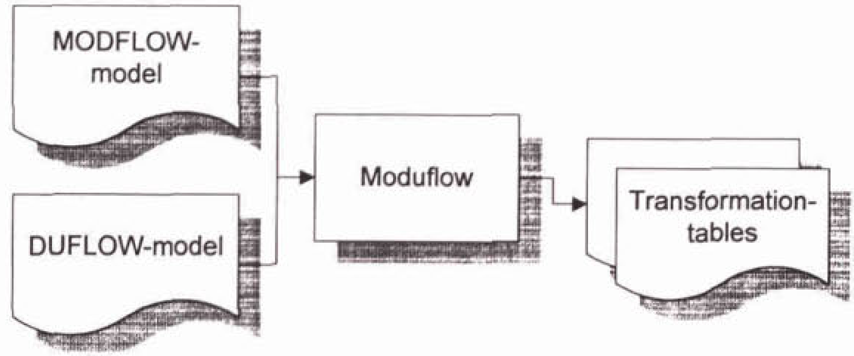
MODFLOW is a so called freeware program by the US Geological Survey (USGS). This means users can obtain a copy for free by downloading it from the web-site of the USGS (http://h20.usgs.gov) or for the costs of the disks when ordered. For more information about MODFLOW, see the relevant documentation [2] and [3]

Global architecture

Moduflow simulates an integrated ground-water and surface-water problem by combining MODFLOW and DUFLOW. The program performs the following tasks:

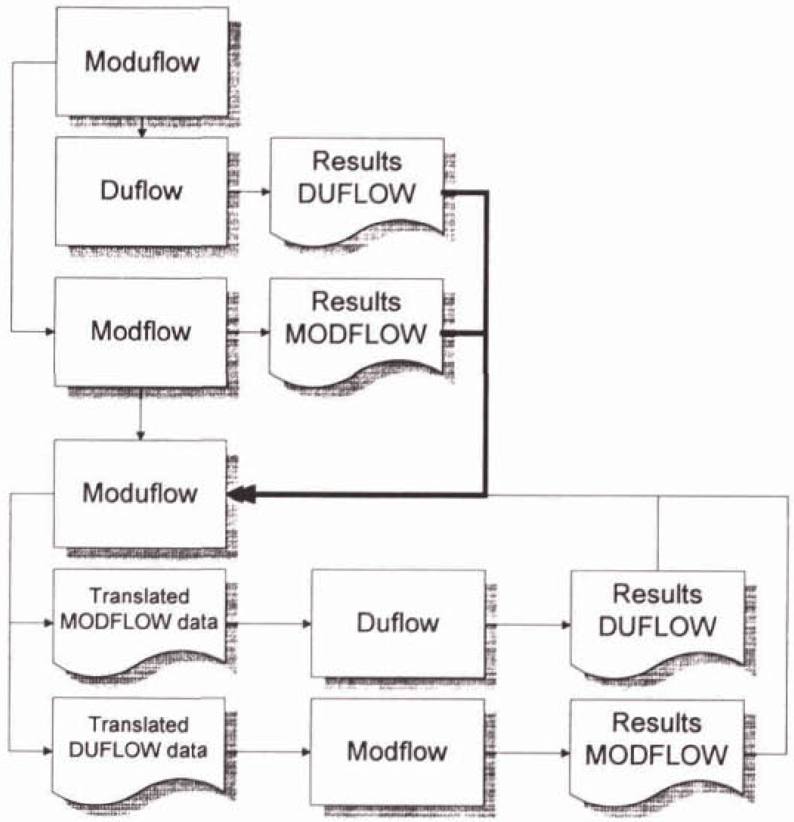
Initialisation

1. Based on input form the user and an existing DUFLOW and an existing MODFLOW model, Moduflow projects the DUFLOW-model on the MODFLOW-model. This gives the necessary transformations (transformation-tables) to exchange data from DUFLOW-nodes and sections with data from the MODFLOW-cells and vice-versa.
   The user can modify the resulting tables.



Simulation

1. Moduflow starts the DUFLOW-program and let DUFLOW finish its initialisation.
2. Moduflow starts the MODFLOW-program and let MODFLOW finish its initialisation.
3. DUFLOW performs for a number of time-steps the required calculations and writes results
4. MODFLOW performs for a stress-period the required calculations and writes the results (per time-step).
5. Moduflow translates the results of both DUFLOW as MODFLOW.
6. DUFLOW reads the translated results (fluxes) and performs a new step 3
7. MODFLOW reads the translated results (water-height, width of the water-system and infiltration and drainage-conductance) and performs a new step 4.
8. Steps 3-7 form a basic cycle and are repeated until the end of the simulation. The length of each cycle correspondents with a timestep in MODFLOW. If one of the models reaches the end of its simulation, the other one will continue until it reaches its own last time-step. During this period, no data will be exchanged.
9. The results can be analysed by using the regular MODFLOW and DUFLOW modules.

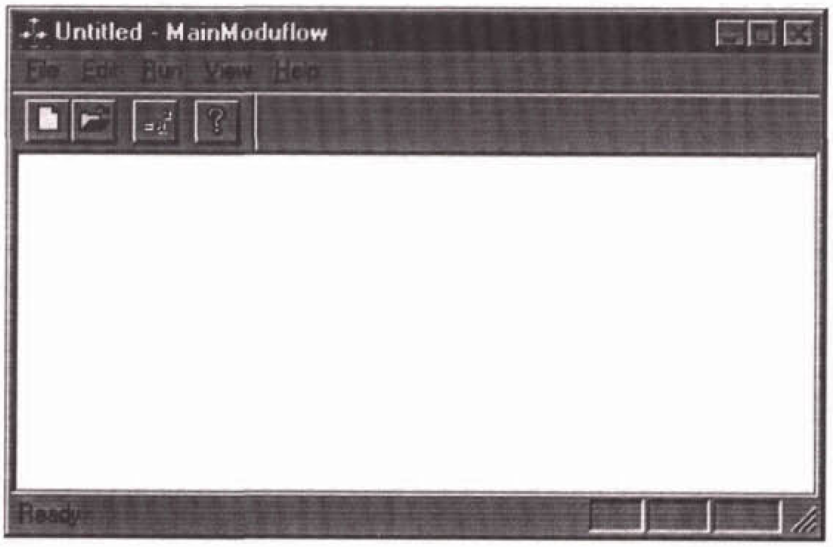

Moduflow
Duflow
Results DUFLOW
Modflow
Results MODFLOW
Moduflow
Translated MODFLOW data
Duflow
Results DUFLOW
Translated DUFLOW data
Modflow
Results MODFLOW

Using Moduflow

Starting Moduflow

Moduflow is a regular Windows-program (Windows95® or Windows/NT®), so you can start it by selecting the corresponding icon in the Taskbar or on your desktop. Please refer to the relevant Windows-documentation for more information about launching a program.

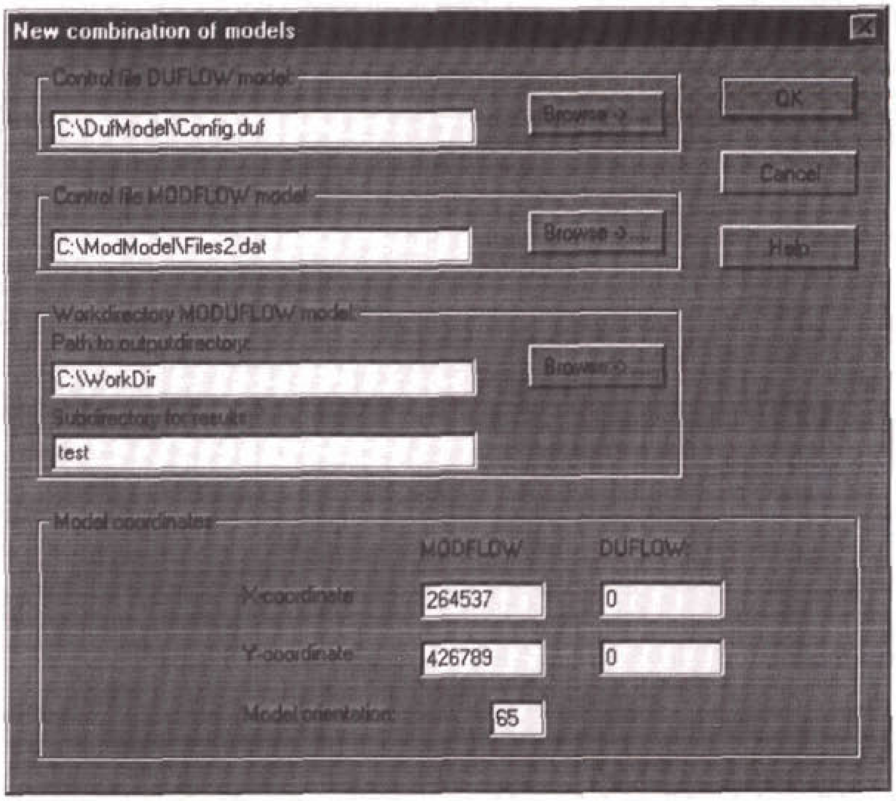
After you have started the program, you will see the following screen. In this screen you can give the commands to create and run a simulation.



This window contains a menu and a buttonbar to control the program and a statusbar to give messages to the user the state of certain events.

Creating a new Model

You can create a new Moduflow-model by combining an existing MODFLOW-model with an existing DUFLOW-model. To do so, choose the command **New** from the menu **File**. You will see the following dialogwindow:



In this dialogwindow, you can set the following parameters:

Control file DUFLOW model

In this editfield, you must enter the name of the control-file of the DUFLOW-model you want to use. This file has always the name CONFIG.DUF. You must specify the entire path to the model.

If you want to search for the file, you use the **Browse->...**-button behind it. You will get a standard Open-dialog.

Control file MODFLOW model

In this editfield, you must enter the name of the control-file of the MODFLOW-model. This file has a user-defined (free) name. It is the file containing the names and unitnumbers of the MODFLOW-model.

If you want to search for the file, you use the **Browse->...**-button behind it. You will get a standard Open-dialog.

Path to outputdirectory

In this editfield, you must enter the directory under which a subdirectory containing the Moduflow-data will be created.

You can use the **Browse->...**-button to select the directory in a directory-tree.

Subdirectory for results

This is the name of the subdirectory containing the Moduflow-specific data. This subdirectory will be created if it doesn't exist already.

The subdirectory is created under the output-directory.

X-co-ordinate MODFLOW

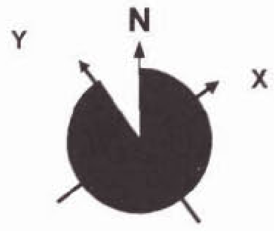
This is the X-co-ordinate in a user-defined coordinatesystem of the origin of the MODFLOW-model (upper left corner).

Y-co-ordinate MODFLOW

This is the Y-co-ordinate in a user-defined coordinatesystem of the origin of the MODFLOW-model (upper left corner).

Model Orientation MODFLOW

This parameter defines the angle between the North-direction and the positive Y-axis.(Positive values represent clockwise rotation).



X-co-ordinate DUFLOW

This is the X-co-ordinate of the origin of the DUFLOW-model (the node with co-ordinates (0,0)). The co-ordinate must be in the same coordinatesystem as the MODFLOW-co-ordinates.

Y-co-ordinate DUFLOW

This is the Y-co-ordinate of the origin of the DUFLOW-model (the node with co-ordinates (0,0)). The co-ordinate must be in the same coordinate-system as the MODFLOW-co-ordinates

OK

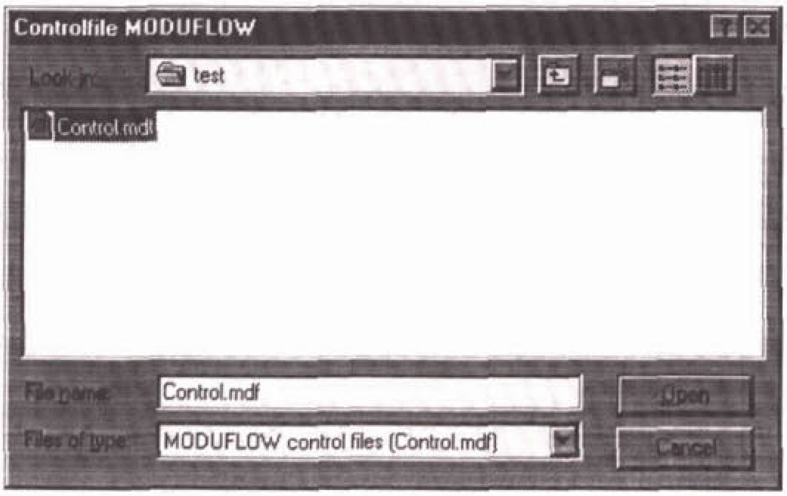
Pressing this Button will start the creation of the transformation-tables (see "Transformation-tables" on page 12). You can change these tables by using the edit-commands (see "Changing a transformation-table" on page 8)

Cancel

Cancels the operation. It is not possible to run a simulation.

Opening an existing Model

If you already created a model in a previous session, you can retrieve this model by using the **Open command** in the menu **File**. You will get a regular Windows Open-dialogwindow.



In this dialogwindow, you need to specify the control-file in the subdirectory containing the model you want to run. This file is always called CONTROL.MDF. After you have selected this file in the relevant subdirectory, pressing the button **Open** will open the model, making it possible to change the model (using the commands in Edit) or run the model (using the command Run). Please refer to your Windows-documentation for further information about the Open-dialog.

Moduflow will verify whether the corrsponding DUFLOW and/or MODFLOW models are modified between creating this specific Moduflow-model and opening this file.

Changing a transformation-table

The standard transformation-tables (see "Standard transformation" on page 9) give a best guess about the way the translation should occur. Because actual conditions can vary and the intrinsic knowledge of the area involved is only known to the user, the standard transformation-tables can be changed.

To change the transformation-tables, choose the appropriate command in the **Edit**-menu. You will get the transformation-tables in the installed editor. Because both tables are in ASCII-format, you can change the transformation.

NOTE:

- You must keep the format as is.
- Random changes can get you strange results or lead to a not-functional simulation.
- Save the file and exit the editor before starting the simulation.

Running a model

After an existing model has been opened or a new one has been created, you can start the simulation by choosing the Run-option in the menu. Moduflow will start both MODFLOW and DUFLOW. During the simulation, Moduflow acts as an intermediate between DUFLOW and MODFLOW, making the necessary transformations. You will see two windows, one running a DUFLOW-simulation and one running a MODFLOW-simulation. Both programs will show their progress by giving messages in their own windows.

During simulation, each program (DUFLOW, MODFLOW and Moduflow) will get its turn. To get an optimal synchronisation, during any time only one of the programs will run while the other two will wait.

Requirements of the models

To get a working model at least the following requirements must be met:

- In DUFLOW, the timestep for the flow must equal the timestep for quality.
- The timestep of MODFLOW must be an integral multitude of the timestep in DUFLOW. This means that during each timestep of MODFLOW an integral number of timesteps of DUFLOW are executed. Because MODFLOW does not have a fixed time to start, it is assumed that DUFLOW and MODFLOW start at exactly the same time.

- After creating a new model or editing an existing one, you must modify the existing river-file of MODFLOW. The parameter MXRIVR in line 1 must be enlarged with the number of DUFLOW-section per cell. This is the number of lines in the file LCCONV.MDF. In line 2+ (each line before data about a stressperiod), a second number must be added. This is also the number of lines in the file LCCONV.MDF.
- The nodes in DUFLOW should have correct geographical (x and y-co-oordinates).
- Each MODFLOW-cell may contain no more than one DUFLOW-node; it may contain more than one section.
- The RIV-file in MODFLOW must be changed (see "MODFLOW-files" on page 14).
- Both models must be modelled to the same datum-level, e.g. N.A.P.

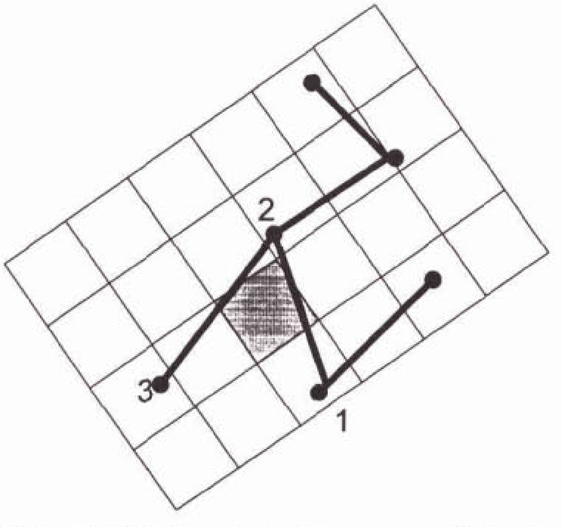
Standard transformation

Moduflow uses a simple mapping of DUFLOW onto MODFLOW to create the transformation-tables. The mapping tells Moduflow how to transform the MODFLOW cell data to DUFLOW nodes data and DUFLOW section data to MODFLOW cell data.

NOTE: The tables can be modified by the user, according to his needs when mapping results in topographically incorrect results (changing primary cells) or when secondary cells are needed (see "Changing a transformation-table" on page 8).

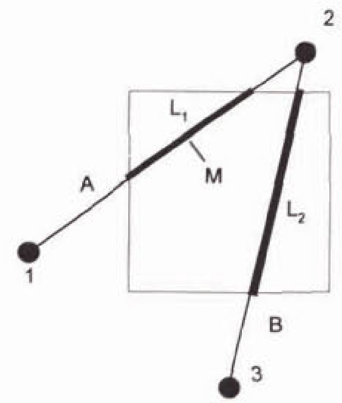
MODFLOW to DUFLOW

Data from MODFLOW to DUFLOW is mapped on a per cell mode from one cell to several nodes. (See Transformation-tables, From MODFLOW to DUFLOW for which data is transferred in what format).



Each cell will distribute the fluxes among the begin- and end-nodes of those sections crossing the cell. In the picture, the fluxes in the grey cell will be distributed among nodes number 1, 2 and 3.

The amount of flux is distributed by determining the portion for each node.



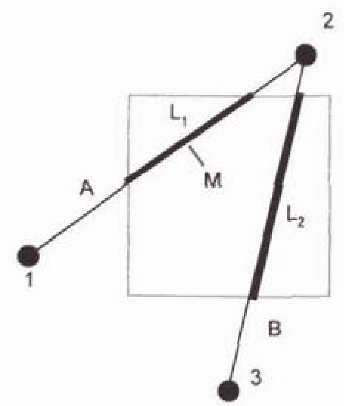
This distribution takes two steps:

1. The flux is divided over de sections according to the length of the intersections with the cell. In the example above, $L_1 / (L_1 + L_2)$ to section A and $L_2 / (L_1 + L_2)$ to section B.
2. Per section, the flux is distributed to its ending nodes using linear interpolation. Using section A, a fraction of P goes to node 1 and a fraction of 1- P to node 2 ($0 \le P \le 1$). P is the length of the section from node 1 to point M (the middle of section L_1) divided by the length of section A.

Because these numbers are all known beforehand, the fraction is calculated during the initialisation-phase. Note that the sum of all the fractions out of a specific cell equals one.

DUFLOW to MODFLOW

Data is mapped from DUFLOW to MODFLOW on a per section basis, mapping one section onto several cells. (See Transformation-tables, From DUFLOW to MODFLOW for details on which data in what format is transferred)



The relevant data (e.g. width of the section) is calculated in the middle of the crossing section. In the example above, the width of section L_1 is calculated by using linear interpolation in point M out of the values at Point (node) 1 and 2.

Fileformats

Transformation-tables

The transformation tables are created by Moduflow during the mapping of Duflow onto Modflow. These tables describe the mapping and are used during the Moduflow execution as translation files for the transfer of data from one model to the other. The result of the translation are the intermediate files MDMF.MDF and MDDF.MDF (see also "Intermediate files" on page 14).

From MODFLOW to DUFLOW

The transformation-table from MODFLOW to DUFLOW tells Moduflow how the fluxes from MODFLOW-cells are divided among DUFLOW-nodes. One cell can add its flux to the discharge of several DUFLOW-nodes.

The information is stored in an ASCII-formatted file. The file containing this transformation-table is always called FQCONV.MDF. It resides in the directory specified in the New-window (**Sub-directory for results** under **path to output-directory**)

This file consists of several lines with the following format: (first row parameter, second Fortran-style format).

Layer	**Row**	**Column**	**Node**	**Factor**	**Drain / River**
I10	XI10	XI10	XI10	XG13.6	I10

The **Layer**, **Row** and **Column**-parameters specify uniquely a cell in MODFLOW.

The **Node**-parameter indicates the node in DUFLOW to which a discharge of **Factor** (see "Standard transformation" on page 9 for further details about this parameter) times the flux from the specified MODFLOW-cell will flow.

The parameter **Drain / River** indicates whether the cell is a secondary cell (the parameter equals **2**) or a primary cell (parameter equals **1**). Primary cells have a direct relation to a DUFLOW-section, secondary cells an indirect one. At this stage of development of Moduflow, the difference is irrelevant in the way Moduflow treats the flux.

A Layer, Row, Column combination can (and will most of the time) occur several times. The sum of the factors for such a combination will equal to 1.

NOTE:

- Specifying a non-existent MODFLOW-cell or DUFLOW-node will result in a system-crash.
- If the sum of factors of coming from a specific MODFLOW-cell doesn't equal 1, water will be gained or lost.
- When changing information about primary cells, be sure to add the corresponding changes to the file LCCONV.MDF (see From DUFLOW to MODFLOW)

From DUFLOW to MODFLOW

The transformation-table from DUFLOW to MODFLOW defines how waterheight, sectionwidth height of the bottom of the section and conductance's are translated from a DUFLOW-section to a MODFLOW-cell. One section can translate to several MODFLOW-cells.

This information is stored in an ASCII-formatted file. This file always has the name LCCONV.MDF. It resides in the directory specified in the New-window (**Subdirectory for results** under **path to outputdirectory**)

The file has the following format (first row - parameter, second row -Fortran-style format)

section	Layer	Row	Column	C_{drn}	C_{inf}	Width	Bottomheight	Factor
I10	XI10	XI10	XI10	XF10.6	XF10.6	XF10.6	XF10.6	XG13.6

The **section** defines the DUFLOW-section exchanging discharge with the MODFLOW-cell. This discharge is calculated by MODFLOW, DUFLOW delivers MODFLOW the relevant parameters: conductance's for drainage ($\mathbf{C_{drn}}$) and infiltration ($\mathbf{C_{inf}}$), current **width** of the section at the location of the cell and **bottomheigth** at the location of the cell. The latter two are interpolated between the values of the begin-node and end-node of the current section.

The parameter **factor** is used to make this interpolation :

$$newval = (factor*val_{beginnode} + (1-factor)*val_{endnode}$$

See Standard transformation, DUFLOW to MODFLOW how factor is determined.

The parameters C_{drn}, C_{inf} , Width and Bottomheigth in this file are the initial values for the simulation. Initial values are obtained from the relevant DUFLOW-files and the first stressperiod of the relevant MODFLOW-files.

NOTE:

- A factor greater than 1 or less than 0 will result in unexpected results or system-crashes.
- Width must be greater than 0
- Initial Conductance's must be greater then 0

MODFLOW-files

The RIV-file of MODFLOW must be changed to give MODFLOW the correct number of river-sections coming from DUFLOW. The file has the following format: (bold fields are changed or added)

Data-item Fields

1	**MXRIVR**	IRIVCB					
2	ITMP	**INDF**					
3	LAYER	ROW	COLUMN	STAGE	**COND**	RBOT	**COND2**

Data-item 1 is the first line of file; data-item 2 is line 2 and is followed by ITMP lines of data-item 3 (or zero if ITMP equals -1). This block can be followed by a new pair of data-items 2 and 3 and is repeated for each stress-period.

The changed or added fields mean:

MXRIVR (changed)	The maximal number of river reaches (i.e. the sum of ITMP and INDF) active at any one time
INDF (added)	Number of river reaches coming from DUFLOW
COND (changed)	C_{inf}
COND2 (added)	C_{drn}

For information about the other fields, refer to [2] or [3].

Intermediate files

Each cycle, four files are created to exchange data between MODFLOW and DUFLOW.

1. DUFLOW creates a file containing new heights and widths per section. This file is called DFMD.MDF.
2. MODFLOW creates a file containing two fluxes per cell, a flux for drainage and a flux for the river. This file is called MFMD.MDF.
3. Moduflow translates the DUFLOW-information to MODFLOW-information (conductance's, water-heigths, widths). This information is stored in the file MDMF.MDF.
4. Moduflow converts the MODFLOW-information to DUFLOW-information (Additional discharge per node). This information is stored in the file MDDF.MDF.

System requirements

Software

To use Moduflow several general and technical requirements must be met. The user should own the correct version of DUFLOW, i.e. the Windows-version. A DUFLOW-license is not included with the Moduflow-license. The relevant MODFLOW-executable is included when obtaining Moduflow, as it is an adapted version of the freeware package. Visual Modflow can be used for generating MODFLOW-input, but additional parameters, specific to Moduflow, in the RIV-file should be added manually.

Hardware and Operation System

Moduflow requires a PC capable of running Windows95® or WindowsNT® smoothly. To obtain a reasonable performance, a Pentium is recommended as is enough internal (Windows95≥ 24 Mb WindowsNT ≥ 64Mb) and external memory (250Mb free).

Installation

Moduflow is at present not equipped with an automatic install procedure, so it must be installed manually. To install Moduflow, please follow the next procedure:

- **Create** the appropriate **directories.** It is recommended to create a directory for the program (the program-directory), e.g. C:\MODUFLOW and a separate directory to store results, e.g. C:\MODUFLOW\RESULTS. The location and name of these directories is up to the user.
- **Copy** the following files to this **program-directory**

CALCMDF.EXE	program to control program-flow and convert intermediate files
CREATMDF.EXE	program to create standard mapping
DUFMDF.EXE	Modified DUFLOW program (replaces CDUFLO.EXE)
MODMDF.EXE	Modified MODFLOW program (replaces MODFLOW.EXE)
MODUFLOW.EXE	User- interface and main program

MODUFLOW.HLP	Moduflow help-file
MODUFLOW.GID	Index for Moduflow help-file
SIMETF	SIMONA message file for DUFLOW

- **Copy** the file **MODUFLOW.INI** to the **Windows**-directory (this is mostly the directory C:\WINDOWS).
- **Copy** the files **Msvctr.dll** and **Mfc42.dll** to the Windows system directory (this is the directory SYSTEM in the Windows-directory).
- **Change MODUFLOW.INI** (see below)
- If needed, an example is given in TESTDATA. YOU can copy these files to a directory under the RESULLT-directory.

NOTE: When working with Windows Explorer, make sure to let Explorer show all files (set the option **Show all files** in the command **Options...** in the menu **View**).

Two new programs to replace CDUFLO.EXE (the calculation-part of DUFLOW) and MODFLOW.EXE are provided. These files are called respectively DUFMDF.EXE and MODMDF.EXE. It is up to the user to replace the original files or let these new programs coexist with the old ones.

To let Moduflow perform, the file MODUFLOW.INI must be changed to represent the current situation. Below is an example of the MODUFLOW.INI-file:

```
[directories]
PROGDIR=C:\Moduflow\

[executables]
DUFLOW=C:\MODUFLOW\DUFMDF.EXE
MODFLOW=C:\MODUFLOW\MODMDF.EXE
MDFCALC=C:\MODUFLOW\CALCMDF.EXE
MDFCREA=C:\MODUFLOW\CREATMDF.EXE

[text_editors]
EDITOR=C:\WINDOWS\NOTEPAD.EXE
```

Load this file into notepad. You must change the following parameters to depict your current situation:

PROGDIR	This is the directory containing the Moduflow-program and the helpfile
DUFLOW	This is the name and the directory of the modified DUFLOW computational module (DUFMDF.EXE)
MODFLOW	This is the name and the directory of the modified MODFLOW computational module (MODMDF.EXE)
MDFCALC	This is the name of the program doing the Moduflow-translations during model-execution. It is the file called CALCMDF.EXE.
MDFCREA	This is the name of the program creating the translation-tables. The program originally is called CREATMDF.EXE.
EDITOR	To edit the transformation-tables, you can add the name and location of your favourite ASCII-editor.

Make sure the names and locations are spelled correctly.

Error-codes

Input errors

* 1	unable to open a file *
* 2	unable to close a file •
* 3	attempts to read past the end of file *
* 4	error while reading string from file *
* 5	error while writing to file *
* 6	error while scanning (number of values) •
* 7	inconsistency with MODFLOW logical unit numbers *
* 8	error while flushing stream •

Memory errors

* 9	not enough memory available for allocation*
* 10	not enough memory available for reallocation*

Data errors reading DUFLOW

* 11	incomplete controldata *
* 12	incomplete sectiondata *
* 13	incomplete nodedata *
* 14	unknown error reading CONFIG.DUF *
* 15	IO error reading CONFIG.DUF *
* 16	data error reading CONFIG.DUF, data on floppy *
* 17	data error reading CONFIG.DUF, wrong calculation mode *
* 18	data error reading CONFIG.DUF, control file missing •
* 19	data error reading CONFIG.DUF, network file missing *
* 20	data error reading CONFIG.DUF, nodes file missing *

Data errors reading MODFLOW

* 21	error reading MODFLOW .BAS-file *
* 22	error reading MODFLOW .BCF-file *
* 23	error reading MODFLOW .RIV-file *

Data errors converting models

* 24	models don't have an overlap in space *

internal data error

* 25	internal error on LC conversion table *
* 26	error on FQ conversion table *

Errors on time steps

* 27	shift of start-
* 28	length stress period not a multiple of the DUFLOW timestep *
* 29	multiplier of MODFLOW 'TSMULT' has value for unequal timesteps *
• 30	unit of MODFLOW timestep is undefined *
* 31	MODFLOW timestep is too long relative to the DUFLOW timestep
* 32	models don't have an overlap in time *

Errors on synchronisation processes

* 33	error while starting processes •
* 34	error while creating event *
* 35	error while opening event *
* 36	error while setting event •
* 37	error while resetting event *
* 38	time for waiting on DUFLOW exceeded *
* 39	time for waiting on MODFLOW exceeded *
* 40	time for waiting on MODUFLOW exceeded •
* 41	time for waiting on MODUFLOW creation process exceeded •
* 42	undefined error while waiting on processes •
* 43	error getting exit-code of child process *
* 44	incorrect argument list for child process *

Errors on file

* 45	error while making directory •
* 46	error while searching for path •
* 47	error while searching for file *
* 48	error with file copy *
* 49	error while appending path's *
* 50	error while analysing file name *
* 51	error with getting file times *

Errors on comparison original model descriptions with the current

* 52	dimensions (#layers,#columns, #stressperiods, timeunit) wrong
* 53	length stress periods changed *
* 54	modification times DUFLOW of the section- and
* 55	error reading path DUFLOW from .INI file *
* 56	error reading path MODFLOW from .INI file *
* 57	error reading path CalcMdf from .INI file *
* 58	error reading path CreateMdf from .INI file *
* 59	error reading path editor from .INI file *
* 60	undefined error *

Glossary of Terms

secondary cell

A secondary cell is a MODFLOW cell which drains water to DUFLOW, but doesn't have a direct relation. The cell does not contain a DUFLOW-section.

primary cell

A MODFLOW cell with a direct relation to DUFLOW. This cell contains a part of a DUFLOW-section.

Config.duf

This is a standard configuration-file for DUFLOW. It defines among other things which files are used to run a DUFLOW-simulation

translation-table

A table defining the transformation from the DUFLOW-model (nodes) to the MODFLOW-model (cells) or vice-versa.

Schematisations

The modelling of an actual situation. It is the input for the specific program. Most of the time, this is referred to as "the model".

References

Literature

[1] Ngo, Koppeling tussen grondwatermodel en oppervlaktewatermodel Moduflow, Technische Universiteit Delft/ Waterleiding Maatschappij Overijssel NV, august 1994

[2] McDonald, M.G., and Harbaugh, A.W., 1984, A modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Open-FIle Report 83-875, 528 p.

[3] McDonald, M.G., and Harbaugh, A.W., 1988, A modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Techniques of Water-Resources Investigations, book 6, chap. A1, 586 p.

[4] DUFLOW, a micro-computer package for the simulation of one-dimensional unsteady flow and water quality in open channel systems, STOWA/EDS, version 2.1 December 1995.

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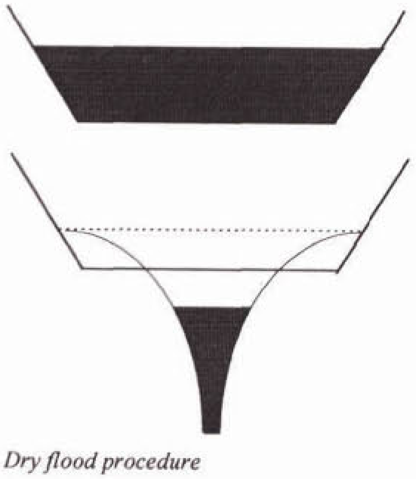
Dry flood procedure

A dry flood procedure is developed for DUFLOW, which makes it possible to perform calculations with sections that become dry. At the same time, this method enlarges the stability of inclined systems with shallow brooks. A dry section is defined by a section where the calculated water level has dropped beneath the defined bottom level of the section. Consequences of a dry section are that the flow area and the hydraulic radius of the section become equal to zero.

The dry flood procedure is as follows: the user defines a threshold value; when the calculated water level drops beneath this value, the width of the cross sectional profile decreases with an exponential function.

The advantage of this approach is that the transition to the dry flood procedure progresses smoothly, there is always water present in the system[1] and the user does not notice that the system has gone dry. In the model, all of the sections will remain containing water, which leads to the fact that dry sections never occur. In dry sections, therefore, the flow of water is always present. The measure to which this occurs depends on the value of the threshold defined by the user. A smaller threshold value will lead to a faster decrease, but in turn will increase the chance of instabilities.

The form of the exponential function is chosen in such a way that the water capacity of the original section beneath the threshold value is equal to the water capacity contained by the tube that arises with the new profile. This means that mass conservation is guaranteed. A mass conservative scheme is essential for a correct simulation of the water quality.



Dry flood procedure

[1] In theory, the width of the profile never reaches zero. However, because of limited machine accuracy, the width will reach the value zero eventually. On the other hand, in practice this does not lead to problems.

Pumps

A pump is assumed to be in full operation or not at all. Operation of the pump is controlled by the water level at upstream or begin node i.

There are two types of pumps that can be defined by the user. The first type is a drainage pump and the second is a so-called supply pump.

In the first type, the drainage pump, water is carried from begin node to end node. For this type of pump the switch-on level (start level) must be higher than the switch-off (stop level). When the water level rises above the switch-on level, given by the user, the discharge is set to the pump capacity Q_p ,which is carried to the end node of the section. When the water level drops below the user defined switch-off level, the discharge is set to zero(see figure 2.4).

For reasons of stability it may be necessary to define a reasonable additional storage capacity by introducing an extra section at node i.

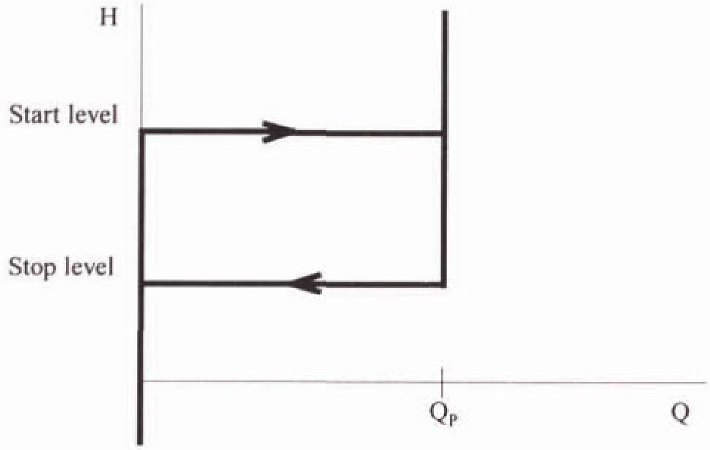


Figure 2.4 Dependence of pump operation on upstream water level

The second type of pump is the supply pump. Here water is carried from the end node to the begin node of the section. In other words, from a begin node viewpoint, a negative discharge is carried to the end node. In order for the user to define this supply pump, the switch-on level (start level) must be below the switch-off level (stop level). When the water drops below the switch-on level, the supply of water by the pump is activated and the discharge is set to pump capacity $-Q_p$. When the water level rises above the switch-off level, the discharge is set to zero.

Note that the function of the pump will determine itself if the discharge is positive or negative. The user must therefore give an absolute value of the pump capacity.

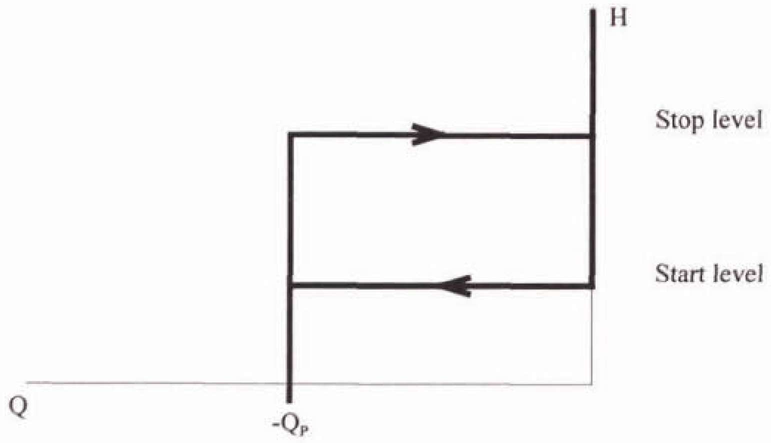


Figure 2.5 Dependence of supply pump operation on upstream water level