# Applied Hydrogeology Introduction to Modflow



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# **Modflow – introduction**

# The most widespread computer code for groundwater flow - **MODFLOW**

# Modflow versions: 88, 96, 2000 and 2005

Software packages with modflow code: PMWIN (version 96), Processing modflow Pro (version 96), Visual Modflow (version 2000), GMS (version 2000)

# PMWIN:

Finite differences, saturated flow, steady-state and transient flow, water budget, inverse modelling (PEST, UCODE), transport advective modelling (MT3D, MT3DMS, MOC3D), advective modelling (PMPATH)

New model – crate new folder choose simple path (e.g. C: Document: My model folder)

Processing Modflow						
ile Grid Parameters Models Tools He	elp					
New Model						
Open Model						
Convert Model						
Model Information						
Save Plot As						
Print Plot						
Animation						
1 c:\čerťák1-střední stav\čerťák.pm5 2 c:\pm5_3\mb - brezen 2003.pm5 3 c:\documents and sb - brezen 2003.pr	m5					
Exit						

# **Modeled area discretization**

Keep the mine basical principles and rules in the grid preaparation! (see previous presentation)

Grid creation – define modeled area extent and consequently define number and size of rows, columns and layers

Define the layer type – preferable is the confined/unconfined layer with transmissivity varies



### **Environment and Maps**

### Environment

### Find out:

- Extent of modeled area discretized by grid
- Extent of the underlying map set up the same size for the worksheet
- Define X and Y coordinates Universal Trasnverse mercator – UTM – depiction of elipsoid's parts in plan

Latitude – 60 zones marked by numbers

Longitude – 20 zones marked by letter of the alphabet



🗗 Processing Modflow - [ČERŤÁK.PM5]

Environment... Ctrl+E

Ctrl+M

Maps..

Display Mode

Input Method

File Value Options Help





### **Environment and Maps**

### Maps

Underlying map – vector map (DXF) or raster map (bmp, jpg)

• Define the left-lower and right-upper edge of the map (Ctrl + left mouse button - decrease the map view, Shift + left mouse button - increase the map view)

#### Environment

move and rotate the model grid to desired position according to underlaid map

😌 Environment Options	×
Appearance Coordinate System	Contours
Grid Position	Worksheet / Coordinate System
Xo= -543892	(X2, Y2)
Yo= -1179544	Your model grid
A= 27	(Xo, Yo)
Worksheet Size	HHAT A
×1= -544100	
Y1= -1182700	x x
×2= -535900	(A=Rotation angle in degree)
Y2= -1176300	(×1, Y1)
Display zones in the cell-by-cell r	
	OK Cance Help
Maps Options	×
Vector Graphics Raster Graphics	
Filename: c:\map.jpg	
Point 1	Point 2
Raster X= -544100 ✓ Graphic	Set X= -535900 Set
Visible Y= -1182700	Y= -1176300
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	KE war
HRADIS	STE
	OK Cancel Help

# Define the boundary conditions –

assign number:

- Active cell = 1
- Inactive cell = 0 (II. type)
- Constant cell = -1 (I. type)



### Define the top and bottom of layers:

- Manual cell by cell or zonal input method
- Interpolation Digitizer, Field interpolator



# Input parameters – time, observations, starting

heads and hydraulic parameters

### Time:

Steady state flow type - steady-state flow even for several Stress periods

Transient flow type – time is discretizated to Time steps in Stress periods Choose time unit

### Initial starting heads:

- Steady-state flow require exactly determined heads only in boundary conditions
- Transient flow require exactly determined heads in the whole model





# **Boreholes and Observations** - insert name, coordinate system and observed hydraulic head

~	Bore	holes and C	)bservat	ions			×	~	Borehole	es and Observat	tions			×
(	Boreho	les.) Observal	ions ]					Ĺ	Boreholes .	Observations				
	No.	Borehole Name	Active	X (easting)	Y (north	hing) Layer_	-		Borehole Name	Observation Time	Weight	Head	Drawdown	Concent
	1	W1		1320	1	1080 1-	-11		W1	1	1	195,8	0	
	2	W2		1525		905 1			W2	1	1	196,15	0	
	3	3		0		0 1				0	1	0	0	
	4	4		0		0 1				0	1	0	0	
	5	5		0		0 1				0	1	0	0	
	6	6		0		0 1				0	1	0	0	
	7	7		0		0 1				0	1	0	0	
	8	8		0		0 1				0	1	0	0	
	9	9		0		0 1				0	1	0	0	
	10	10		0		0 1				0	1	0	0	
	11	11		0		0 1				0	1	0	0	
	12	12		0		0 1				0	1	0	0	
	13	13		0		0 1					•			<u> </u>
	14	14		0		0 1			Options					
	15	15		0		0 1				bserved heads for th				
	16	16		0		0 1	<b>,</b>		🔘 Use o	bserved drawdowns	for the calibra	ation		
	47	47	-	0		- 1	<u> </u>			1	1			
	Sav	e Loa	±	Clear					Save	Load	Clear			
-														
					ок   с	ancel Help						0K	Cancel	Help
								-						

- Real-world coordinate system UTM (The Universal Transverse Mercator)
   557935.1, 1031526 272, 289, 1
- Relative coordinate system relative position of modeled grid in the status bar

tive position	of m	odeled
917.7288, 2050	.985	1,1,1
0		

3197.448

### Hydraulic parameters:

- Horizontal hydraulic conductivity one or more values
- Vertical hydraulic conductivity in the multi-layer model, the ratio of horizotnal to vertical conductivity is vertical conductivity ranging from 3:1 to 10:1
- Anisotropy factor the ratio of horizontal conductivity (or transmissivity) along the x and y direction
- Vertical leakance quasi-three dimensional models replace the modeled layer and represent semiconfining unit - resistance to the vertical flow



• Transmissivity – define in Layer Type  $\rightarrow$  User specified or Calculated

**Storage parameters** - transient simualation – water is released from or taken into storage within the porous material

• Specific storage  $(S_s)$  – volume of water released from storage within a unit volume of porous material per unit decline in head

 Storage coefficient (S) – in the 2-D areal simulations, vertically averaged parameter equal to the volume of water released per unit area of aquifer per unit decline in head

 $S = bS_s$  b = aquifer thickness

• Specific yield – storage parameter of the unconfined aquifer, volume of gravity drainaged water per volume of porous material

**Effective porosity** – advective modelling, from 1 % (fractured rocks) to 35 % (coarse grained sand or gravel)

# **PMWIN – Models**

🚭 Processing Modflow - [MY VERY FIRST MODEL.PM5]								
File	Grid	Parameters	Models	Tools	Help			
	1		MODF	MODFLOW				1
			MOC3D				×	
_	-		MT3D			•		
			MT3D	MT3DMS			•	
			PEST (Inverse Modeling)			•		
			UCODE (Inverse Modeling)			×		
			PMPATH (Pathlines and Contours)					

### MOC3D, MT3D, MT3DMS – transport modeling

### MODFLOW – flow field







# PMPATH – advective modeling



### **PEST, UCODE** – automated parameter estimation

OPTIMISATION RESULTS

Parameters ---->

Parameter	Estimated	95% percent con	fidence limits
	value	lower limit	upper limit
rch_1	4.000760E-09	3.275596E-09	4.886464E-09

Note: confidence limits provide only an indication of parameter uncertainty. They rely on a linearity assumption which may not extend as far in parameter space as the confidence limits themselves - see PEST manual.

See file PESTCTL.SEN for parameter sensitivities.

# **PMWIN – Models**

### Flow packages - inflow and outflow to/from model and within the model

f

### III. Type of boundary condition

Drain, GHB, Evapotranspiration, Reservoir, River, Streamflow-Routing

Sources and Sinks

Recharge, Well

### Additional

Horizontal-Flow barriers

Density

**Interbed Storage** 

Wetting Capability

Processing Modflow - [MY VERY FIRST MODEL.PM5]								
File Grid	Parameters	Models	Tools Help					
		UCOE	BD		Density         Drain         Evapotranspiration         General Head Boundary         Horizontal-Flow Barriers         Interbed Storage         Recharge         Reservoir         River         Streamflow-Routing         Time-Variant Specified-Head         Well         Wetting Capability         Voltput Control         Solvers         Run			

# **PMWIN – Models**

**III. Type of boundary condition**: flux across is dependent on the difference between a user-supplied specified head on one side of the boundary and the model-calculated head on the other side

$$L = Q_L / A = K_z / b'(h_{source} - h)$$

L = leakage rate  $Q_L$  = volumetric flux A = area of the cell  $K_z'$  = vertical hydraulic conductivity of the interface b' = thickness of the interface  $h_{source}$  = head in the source reservoir h = head in the aquifer

- Drain water releases model
- **GHB** simulation of the distant constant head boundary condition
- Evapotranspiration water releases model in accordance with extinction depth
- River upper limit for water inflow
- Streamflow Routing allow hyraulic parameters of the stream channel flow
- Reservoir similar to River package, allow simulate more reservoirs

# **PMWIN – MODFLOW**

### **General Head Boundary - III.** Type of boundary condition

$$Q_b = C_b - (h_b - h) \qquad C_b = K \cdot A / L$$

High C<sub>b</sub> represents equivalent of constant head



### **River - III.** Type of boundary condition

$$C_{riv,str} = \frac{KLW}{W}$$
  $Q_{riv,str} = \frac{KLW}{M}(h_s - h_a)$ 

K is vertical hydraulic conductivity of riverbed sediments, L is lenght of the river in the cell, W is wide of the river and M is thickness of the rvierbed sediments

# **PMWIN – MODFLOW**

### Sources and Sinks:

- Recharge upper boundary condition
- Well injection well + injected rate
  - pumping well pumped rate

### Well in multi-layer model:

• **Confined layer** - divide of pumped/injected rate in model in accordance with transmissivity of each layer  $T_{L}$ 

$$Q_k = Q_{total} \frac{T_k}{\sum T}$$

Unconfined layer – to set a very large vertical hydraulic conductivity (e.g. 1 m/s) to all cells of the well

• **Exact extraction rate** from each penetrated layer – to set a minimal pumped rate to the each layer (e.g. 1.10<sup>-10</sup>) and than use the water budget calculator

🖬 Reset	Matrix 🗵
	Recharge Flux [L/T]: 43E-09
	Layer Indicator (IRCH): 0
	Parameter Number [-]: D
<ul> <li>Recha</li> <li>Vertica</li> </ul>	je Options irge is only applied to the top grid layer I distribution of recharge is specified in IRCH irge is applied to the highest active cell.
Caution: All cell valu above.	es in the current layer will be replaced by the values specified
	OK Cancel Help
	🔊 Cell Value 🛛 🔀
	Recharge Rate of the Well [L^3/T]: -0.05
	Parameter Number [-]: 0
	Current Position (Column, Row) = (91, 99)

# **PMWIN – MODFLOW**

### Next flow packages:

- Horizontal-Flow barrier thin impermeable geologic feature (fault, slurry wall), impede the horizontal flow
- **Density** approximation of density flow model without considering the salinity distribution
- Interbed Storage water volume released from storage by elastic adn inelastic compaction of compressible fine-grained beds in a aquifer due to groundwater extraction
- Wetting capability the simulation of a rising water table into dry model cells

# **PMWIN – PEST, UCODE**

### Automated parameter calibration:

- Assign parameter number to calibrated value
- Calibrated value : hydraulic parameters, storage parameters, recharge and boundary conditions III. type



Output file PESTCTL.REC includes
 optimized results
 Parameters ---->

OPTIMISATION RESULTS						
Parameters	->					
Parameter	Estimated Value	95% percent confid lower limit				
rch_1	4.000760E-09	3.275596E-09				
Note: confidence limits provide only an indication of parameter uncertainty. They rely on a linearity assumption which may not extend as far in parameter space as the confidence limits themselves - see PEST manual.						
See file PESTCTL	.SEN for parameter	sensitivities.				

Number         Active         Description         PARVAL1         PARLBND         PARUBND           1         Image: Active         Description         PARVAL1         PARLBND         PARUBND           1         Image: Active         Description         PARVAL1         PARLBND         PARUBND           1         Image: Active         Description         PARVAL1         PARLBND         PARUBND           2         Image: Active         Description         PARVAL1         PARLBND         PARUBND           2         Image: Active         Description         PARVAL1         PARLBND         PARUBND           2         Image: Active         Description         PARVAL1         PARLBND         PARUBND           3         Image: Active         Description         Image: Active         PARVAL1         PARUBND           3         Image: Active         Description         Image: Active         Image: Active         Image: Active         Image: Active           3         Image: Active         Description         Image: Active					- D (DECT)	124	5 15-1-6C	
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		0	0	0			14	
		0	0	0			15	
		0	0	0			16	
	<u> </u>				1			
Load Save OK Cancel Hel		el Help	Cancel	OK	Load Save.			



# **PMWIN – PMPATH**

Advective modeling - based on flow field from Modflow, 3-D demonstration of the flow

😯 Environment Options 🛛 🚺	Particle Tracking (Time) Properties	
Appearance       Cross Sections         Visible       Visible         Visible       Show grid         Show groundwater surface (potential)         Exaggeration:         Projection Row:         273         Projection Column:         256         Minimum Elevation:         1000         Maximum Elevation:	Simulation Mode/Time       Pathline Colors       RCH/EVT Options         Current Time       Tracking Step       Unit:       years         Stress Period:       1       Step Length:       1.00413490930961         Time Step:       1       Maximum steps:       1000         Time Mark       Plan View       Cross Sections         Interval:       5       If Visible       Size:       3         Simulation Mode       Flowlines, use the flow field from the current time step       Size:       3         Stop Condition       Interval: stop, when they enter cells with internal sinks       Stop Condition	Velocity Vectors
Dk       Cancel         Ontrol panel         PMPATH - [chacha2layer.pm5]         File Run Options Help         Image:	Particles stop, when the simulation time limit is reached OK Cancel	
	Position of the	On board
	mouse pointer – real coordinates	270, 275, 1 3,0232E+03 1,1051E-06 4,5228E-09 1 1 1
Streamline V	Position of the Head at mouse pointer the cell – cell indices	Horizontal Vertical Stress Current pore velocity pore period time step

# PMWIN – MOC3D, MT3D, MT3DMS

### Transport models:

- based on the flow field from modflow
- solute transport advection, affected by disperzion, diffusion and retardation

MOC3D – define the subrid for solute-transport equations

MT3D, MT3DMS – similar, solute-transport within Modflow grid with own boundary conditions

### **Input parameters**

- Initial Concentration and Source/Sink Concentration
- Advection (from Modflow)
- Disperzion:

Horizontal transverse dispersivity Vertical transverse dispersivity Longitudinal dispersivity

Chemical reaction

The effective molecular diffusion coefficient

Sorption - Linear and unlinear Freundlich and Langmuir equilibrium isotherm

Rdioactive decay or biodegradation - First order decay rate and First order sorbed rate



# **PMWIN – Tools**

🖶 Processing Modflow - [ČERŤÁK.PM5]							
File Grid I	Parameters	Models	Tools	Help			
1			Digitizer Field Interpolator (PMDIS) Field Generator (PMFGN)				
			Presentation Results Extractor Water Budget Graphs				

• Digitizer – digitized points



Field Interpolator – interpolation of digitized points to the 3-D surface

Х

• Field Generator – stochastic modeling – generate field with heterogeneously-distributed hydraulic conducitivity values

# **PMWIN – Tools**

204

197

Variance = .1487915

Observed Heads

#### **Results Extractor:** 😴 Processing Modflow - [ČERŤÁK.PM5] File Grid Parameters Models Tools Help Digitizer 2 Field Interpolator (PMDIS).. Field Generator (PMFGN)... Resultant data sets in the sheet Presentation Results Extractor... Water Budget.. Head-Time Graphs Drawdown-Time **Presentation**: Load resultant data sets Mead-Time Curves Head Comparison of Calculated and Observed Heads Name Plot Color 2.13E+2-204 P1 OP1 OP3 OI1 OI2 OI3 Graphs: lated Heads 11 Time dependent results ۲ Graph Style 1.87E+2-→ Time 8.64E+6 Linear C Semi-Log X-Axis (Time) Min. time: Y-Axis Data Types Save Plot As.. Min. value Scatter diagram Calculated $\bullet$ 187.4237 ✓ Observation Data >> Max. time: Max. value Options Scatter Diagram >> 8640000 212.6811

Ticks:

Ticks:

10

Draw horizontal grid

Draw vertical grid

🔽 Auto Adjust Min/Max

Help

Close

# **PMWIN – Tools**

### Water Budget

- Check the quality of the simulation results
- Allow flow rates between all faces of model cell
- Zone flow rate exchange across the cell
- Whole model compare the discrepancy.

Water balance Discrepancy:

- Recommended discrepancy < 1%</li>
- Discrepancy > 1% denotes coarse grid, high closure (convergence) criterium, too long time step
- Discrepancy > 10% denotes incorrect conceptual model

WATER BUDGET OF	ZONES WITHIN EAC	H INDIVIDUAL L	AYER
ZONE 1 IN LAY	′ER 1		
FLOW TERM STORAGE CONSTANT HEAD HORIZ. EXCHANGE EXCHANGE (UPPER) EXCHANGE (LOWER) WELLS DRAINS RECHARGE ET RIVER LEAKAGE HEAD DEP BOUNDS STREAM LEAKAGE INTERBED STORAGE MULTI-AQIFR WELL SUM OF THE LAYER DISCREPANCY [%]	0.000000E+00 7.8715780E-04 0.000000E+00 1.6763251E-02 0.000000E+00 0.000000E+00 0.000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00	OUT 0.000000E+00 3.2653283E-05 0.0000000E+00 1.3197104E-03 0.000000E+00 0.000000E+00 0.000000E+00 1.7783154E-02 0.000000E+00 0.000000E+00 0.000000E+00 1.9135518E-02	IN-OUT 0.000000E+00 7.5450452E-04 0.0000000E+00 1.543541E-02 0.0000000E+00 1.5850021E-03 0.0000000E+00 -1.7783154E-02 0.0000000E+00 0.0000000E+00 0.0000000E+00 -1.0617077E-07
ZONE 1 DOES M	OT EXIST IN LAYE	R 2	
WATER BUDGET OF 2	ONES OVER THE EN	ITIRE MODEL	
ZONE: 1			
STDRAGE CONSTANT HEAD HORIZ. EXCHANGE EXCHANGE (UPPER) EXCHANGE (LOWER) WELLS DRAINS RECHARGE HEAD DEP BOUNDS STREAM LEAKAGE INTERBED STDRAGE MULTI-AQIFR WELL SUM OF ZONE( 1) DISCREPANCY [%]	0.000000E+00 7.8715780E-04 0.000000E+00 1.6763251E-02 0.000000E+00 1.5850021E-03 0.000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00	OUT 0.000000E+00 3.2653283E-05 0.0000000E+00 1.3197104E-03 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 1.9135518E-02	IN-OUT 0.0000000E+00 7.5450446E-04 0.000000E+00 1.5445541E-02 0.0000000E+00 1.5850021E-03 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 -1.0617077E-07
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	6.3901342E-02	6.3907348E-02	

### References

Anderson, M. P., Woessner, W. W. (1992): Applied Groundwater Modeling, Simulation of Flow and Advective ransport.- Academic Press Inc., San Diego, California.

Andersen, P. F. (1998): A manual of instructional problems for the U.S.G.S. Modflow model.- Robert S. Kerr environmental research laboratory office of research and development U.S. environmental protection agency, Oklahoma.

Hsing Chiang, W., Kinzelbach, W. (2000): 3D-Groundwater Modeling with PMWIN.- Springer.

www.Wikipedia.com