PennState Integrated Hydrologic Model (PIHM)

Version: 2.0

Input File Formats

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PIHM is an integrated finite volume hydrologic model. It simulates channel routing, overland flow and groundwater flow in fully coupled scheme. It uses semi-discrete Finite Volume approach to discretize PDE (equations governing physical processes) into ODE to form a system of ODEs and solved with SUNDIALS[1].

PIHM incorporates an object-oriented model data structure which provides extensibility and efficient storage of data at the same time. PIHM v2.0 requires a total of eight [8] input files:

File		Purpose
0 projectName.txt	:	This file will have the project name as its content.
1 .mesh File	:	Spatial information of Nodes and Irregular Meshes (TINs)
2 .att File	:	Attribute defining different classes an element belongs to
3 .soil File	:	Soil properties
4 .geol	:	Geologic properties
5 .lc file	:	Vegetation parameters of different land cover types
6 .riv file	:	Spatial, geometry and material information of river segments
7 .forc file	:	All the forcing variables (forcing time-series)
8 .ibc file	:	Boundary condition information for elements
9 .para file	:	Control parameters (solver options; model modes; error control)
10. init	:	If initial condition input is through a file
11 .calib	:	Calibration parameters and process controls

This document describes the function of all the data files and the structure in which data is stored in details.

[1] SUite of Nonlinear and DIfferential/ALgebraic equation Solvers [http://www.llnl.gov/casc/sundials/]

0. projectName.txt

project Name is specified either on the command line while running the model, like

→ **./pihm** projectName

OR

it is specified in the file name **projectName.txt**.

Note: File has to be named **projectName.txt** and not the actual project name !. So if your project name is sc, then in the file projectName.txt you will have to write **sc** in it.

File Structure:

Project Name

1. .mesh File

Mesh file has all the irregular mesh (TIN) geometry information in it. It contains all the nodes and elements. For nodes, it records its location in space and for elements, it saves index of nodes of which elements comprise of and some topological relations in the form of its neighbor elements.

File Structure:

NumEle	NumNode					
Index	Node[0]	Node[1]	Node[2]	Nabr[0]	Nabr[1]	Nabr[2]
Index	Node[0]	Node[1]	Node[2]	Nabr[0]	Nabr[1]	Nabr[2]
.						
.	Repeat NumEle times…					
Index	X	Y	Zmin	Zmax		
Index	X	Y	Zmin	Zmax		
.						
.	Repeat NumNode times…					

Description:

Variable Name	**Variable Type**	**Variable Description**	**Remarks**
NumEle	Integer	Total Number of Elements	
NumNode	Integer	Total Number of Nodes	
Index	Integer	Element Index	
Node[0]	Integer	1st Node of Element	
Node[1]	Integer	2nd Node of Element	
Node[2]	Integer	3rd Node of Element	
Nabr[0]	Integer	1st Neighbor of Element	0: boundary
Nabr[1]	Integer	2nd Neighbor of Element	0: boundary
Nabr[2]	Integer	3rd Neighbor of Element	0: boundary
Index	Integer	Node Index	
X	double	x co-ordinate of node	meters
Y	double	y co-ordinate of node	meters
Zmin	double	bed elevation of node	meters
Zmax	double	surface elevation of node	meters

2. .att File

An att (attribute) file is a record which stores all the physical parameters class of each mesh elements such as soil type, land cover type, several forcing types. It allows efficient data storage.

File Structure:

Index	Soil	Geol	LC	IS_IC	Snw_IC	Srf_IC	Ust_IC	St_IC	Ppt	Tmp	RH	Wnd	Rn	G	VP	S	mF	BC[0]	BC[1]	BC[2]	mP
Index	Soil	Geol	LC	IS_IC	Snw_IC	Srf_IC	Ust_IC	St_IC	Ppt	Tmp	RH	Wnd	Rn	G	VP	S	mF	BC[0]	BC[1]	BC[2]	mP
.																					
.					Repeat NumEle times…																

Description:

Variable Name	Variable Type	Variable Description	Remarks
Index	Integer	Element Index	
Soil	Integer	Soil Class	
Geol	Integer	Geology Class	
LC	Integer	Land Cover Class	
IS_IC	Integer	Interception Storage	Initial Condition
Snw_IC	double	Snow Accumulation	Initial Condition
Srf_IC	double	Surfaceflow State	Initial Condition
Ust_IC	double	Usaturated State	Initial Condition
St_IC	double	Saturated State	Initial Condition
Ppt	Integer	Precipitation Series	
Temp	Integer	Temperature Series	
RH	Integer	Rel. Humidity Series	
Wnd	Integer	Wind Velocity Series	
Rn	Integer	Solar Radiation Series	
G	Integer	Dummy	
VP	Integer	Vapor Pressure	
S	Integer	Source/Sink	
mF	Integer	Melt Factor Series	
BC[0]	Integer	Boundary condition Type on edge	
BC[1]	Integer	…….	
BC[2]	Integer	…….	
mP	Integer	Macropore present or not	1:Yes/ 0: No

3. .soil File

All the hydrologic and hydraulic parameters related to different soil classes for surface/subsurface flow are stored in this file.

File Structure:

NumSoil								
Index	KsatV	ThetaS	ThetaR	infD	Alpha	Beta	hAreaF	macKsatV
Index	KsatV	ThetaS	ThetaR	infD	Alpha	Beta	hAreaF	macKsatV
.								
.	Repeat NumSoil times…							

Description:

Variable Name	**Variable Type**	**Variable Description**	**Remarks**
NumSoil	Integer	Number of Soil Classes	
Index	Integer	Soil Class Number	Beginning with 1
KsatV*	Double	Vertical Saturated Hydraulic Conductivity	
ThetaS	Double	Porosity	
ThetaR	Double	Residual Porosity	
infD	Double	Top soil layer across which infiltration is calculcated	Generally set to 0.1 m
Alpha*	Double	Van Genuchten Soil Parameter	
Beta*	Double	Van Genuchten Soil Parameter	
hAreaF	Double	Horizontal Area Fraction of Macropore	
macKsatV	Double	Vertical macropore Hydraulic conductivity	

* ROSETTA: Software from United States Salinity Laboratory (USDA-ARS), Riverside, California can be a useful tool for getting these parameters.

* Note: Beta in $K_u - S$ van genuchten relationship is used as $K_u = S^{0.5}(1-(1-S^{\frac{\beta}{\beta-1}})^{\frac{\beta-1}{\beta}})^2$

4. .geol File

All the hydrologic and hydraulic parameters related to different geologic classes for subsurface flow are stored in this file.

File Structure:

NumGeol										
Index	KsatH	KsatV	ThetaS	ThetaR	infD	Alpha	Beta	vAreaF	macKsatH	macD
Index	KsatH	KsatV	ThetaS	ThetaR	infD	Alpha	Beta	vAreaF	macKsatH	macD
.										
.	Repeat NumGeol times…									

Description:

Variable Name	**Variable Type**	**Variable Description**	**Remarks**
NumGeol	Integer	Number of Geology Classes	
Index	Integer	Geology Class Number	Beginning with 1
KsatV	Double	Vertical Saturated Hydraulic Conductivity	
ThetaS	Double	Porosity	
ThetaR	Double	Residual Porosity	
infD	Double	Top soil layer across which infiltration is calculcated	Generally set to 0.1 m
Alpha	Double	Van Genuchten Soil Parameter	
Beta	Double	Van Genuchten Soil Parameter	
vAreaF	Double	Vertical Area Fraction of Macropore	
macKsatH	Double	Horizontal macropore Hydraulic conductivity	
macD	Double	Macropore Depth	

5. .lc File

Lc file contains several vegetation parameters corresponding to different land cover classes present in the modeling domain.

File Structure:

NumLC							
Index	LAImax	Rmin	Rs_ref	Albedo	VegFrac	n	RzD
Index	LAImax	Rmin	Rs_ref	Albedo	VegFrac	n	RzD
.							
.		Repeat NumLC times…					
.							
Index	LAImax	Rmin	Rs_ref	Albedo	VegFrac	n	RzD

Description:

Variable Name	**Variable Type**	**Variable Description**	**Remarks**
NumLC	Integer	Number of Lanc Cover Classes	
Index	Integer	Land Cover Class Number	
LAImax	Double	Maximum LAI	
Rmin	Double	Minimum Stomatal Resistance	
Rs_ref	Double	Reference Stomatal Resistance	
Albedo	Double	Albedo	
VegFrac	Double	Vegetation Fraction	
n	Double	Manning's Roughness Coefficient	$day/m^{1/3}$
RzD	Double	Root Zone Depth	

6. .riv File

Topological information related to river segments (such as Node information; Left and Right Element) is stored in this file. Also different shape and material properties of river segments are provided. Other variables such as Initial and Boundary condition pertaining river segments are placed at the end of this file.

File Structure:

NumRiv										
Index	FromNode	ToNode	Down	LeftEle	RightEle	Shape	Material	IC	BC	Res
Index	FromNode	ToNode	Down	LeftEle	RightEle	Shape	Material	IC	BC	Res
.										
.		Repeat NumRiv times…								
"Shape"	NumShape									
Index	Depth	InterpOrd	WidCoeff							
Index	Depth	InterpOrd	WidCoedd							
.	Repeat NumShape times…									
"Material"	NumMat									
Index	n	Cwr	KsatH	KsatV	Bed					
Index	n	Cwr	KsatH	KsatV	Bed					
.	Repeat NumMat times…									
"IC"	NumIC									
Index	Value									
Index	Value									
Repeat NumIC times…										
Index	Value									
"BC"	NumBC									
Type	Index	Length								
Time	Value									
.										
Repeat Length times…										
.										
Time	Value									
Type	Index	Length								
Repeat NumBC times…										
Type	Index	Length								
"Res"	NumRes									

Description:

Variable Name	Variable Type	Variable Description	Remarks
NumRiv	Integer	Number of River Segments	
Index	Integer	River Segment ID	Beginning with 1
FromNode	Integer	From Node ID	
ToNode	Integer	To Node ID	
Down	Integer	Downstream Segment ID	
LeftEle	Integer	Left Element ID	
RightEle	Integer	Right Element ID	
Shape	Integer	Shape ID	
Material	Integer	Material ID	
IC	Integer	Initial Condition ID	
BC	Integer	Boundary Condition ID	
Res	Integer	Reservoir ID	
NumShape	Integer	Number of Shape Types	
Index	Integer	Shape ID	Beginning with 1
Dummy	-	-	
Depth	Double	Depth of the River Segment	
InterpOrder	Integer	Interpolation Order *	1 if a rectangular
WidCoeff	Double	Width Coefficient *	width if a rectangular
NumMat	Integer	Number of Material Types	
Index	Integer	Material ID	Beginning with 1
n	Double	Manning's Roughness Coefficient	
Cwr	Double	Discharge Coefficient	
KsatH	Double	Size Hydraulic Conductivity	
KsatV	Double	Bed Hydraulic Conductivity	
Bed	Double	Bed Depth	
NumIC	Integer	Number of Initial Condition Types	
Index	Integer	Initial Condition ID	Beginning with 1
Value	Double	Intial Condition Water Table	
NumBC	Integer	Number of Boundary Conditions	
Type	Integer	Boundary Condition Type	
Index	Integer	Boundary Condition ID	
Length	Integer	Length of BC TimeSeries	
Time	Double	Time	(days)
Value	Double	BC Value	(m or m/day)
NumRes	Integer	Number of Reservoirs	

* Interpolation Order (b) and Widht Coefficient (a) are parameters defining relation between Width and Depth of a river segment as: [$D = a \times (W/2)^b$].

7. .forc File

Forc file contains all the forcing variable information (time series).

File Structure:

NumPrep	NumTemp	NumRH	NumWind	NumRn	NumG	NumVP	NumLC	NumMF	NumSS
"Prep"	Index	Length							
Time	Value								
Repeat Length times…									
Time	Value								
"Prep"	Index	Length							
Repeat NumPrep times…									
"Temp" *	Index	Length							
"RH" *	Index	Length							
"Wind" *	Index	Length	Height						
"Rn" *	Index	Length							
"VP" *	Index	Length							
"LAI" *	Index	Length	IsFactor						
"DH" *	Index	Length							
"MF" *	Index	Length							
“SS”*	Index	Length							

* Same as “Prep” time-series

Description:

Variable Name	**Variable Type**	**Variable Description**	**Remarks**
NumPrep	Integer	Number of precipitation time-series	
NumTemp	Integer	Number of temperature time-series	
NumRH	Integer	Number of relative humidity time-series	
NumWind	Integer	Number of wind velocity time-series	
NumRn	Integer	Number of solar radiation time-series	
NumG	-	Dummy	
NumVP	Integer	Number of vapor pressure time-series	
NumLAI	Integer	Number of LAI time-series	
NumMF	Integer	Number of melt factor time-series	
NumSS	Integer	Number of source/sink	
Index	Integer	Time-series ID	
Length	Integer	Number of time steps	
Time	Double	Time	
Value	Double	Data value	
Height	Double	Height of wind velocity observation	
IsFactor	Double	Interception Storage Factor	

8. .ibc File

IBC file contains all the information related to boundary conditions corresponding to elements.

File Structure:

NumBC1	NumBC2	
"BC1"	Index	Length
Time	Value	
Repeat Length times…		
Time	Value	
"BC1"	Index	Length
Repeat NumBC1 times…		
"BC1"	Index	Length
"BC2"	Index	Length
Time	Value	
Repeat Length times…		
Time	Value	
"BC2"	Index	Length
Repeat NumBC2 times…		
"BC2"	Index	Length

Description:

Variable Name	**Variable Type**	**Variable Description**	**Remarks**
NumBC1	Integer	Number of Dirichlet BC	
NumBC2	Integer	Number of Neumann BC	
Index	Integer	Boundary Condition ID	
Length	Integer	Number of time steps	
Time	Double	Time	
Value	Double	Value	(m or m/day)

9. .para File

Para file provides all the control data to the model. It contains solver options; model modes; also parameters that govern model error.

File Structure:

Verbose	Debug	Init_type								
PgwD	PsurfD	PsnowD	PrivStg							
PRech	PIsD	PusD								
Pet0	Pet1	Pet2								
Priv0	Priv1	Priv2	Priv3	Priv4	Priv5	Priv6	Priv7	Priv8	Priv9	Priv10
gwDInt	surfDInt	snowDint	rivStgInt							
RechInt	IsDInt	usDInt	etInt	rivFlxInt						
UsatMode	SatMode	RivMode								
Solver	GSType	MaxK	Delta							
AbsTol	RelTol	InitStep	MaxStep	ETstep						
StartTime	EndTime	Output								
a	b									

Description:

Variable Name	Variable Type	Variable Description	Remarks
Verbose	Integer	Verbose mode?	Yes/No :: 1/0
Debug	Integer	Debug mode?	Yes/No :: 1/0
Init_type	Integer	State initialization type	Relax(0); AttFile(1); InitFile(3)
PgwD, PsurfD, PsnowD, PrivStg, Prech, PisD, PusD, Pet0, Pet1, Pet2	Integer	Print: Groundwater, Surface Water, Snow, River Stage, Rechage to Ground Water, Interception Storage, Unsaturated Storage, Interception Loss, Transpiration, Evaporation from Ground	Yes/No :: 1/0
Priv0, Priv1	Integer	Print: Longitudonal {Flow To, Flow from} a river element	Yes/No :: 1/0
Priv2, Priv3	Integer	Print: Lateral Overland Flow To a river element from {Left, Right}	Yes/No :: 1/0
Priv4, Priv5	Integer	Print: Lateral Groundwater Flow To a river element from {Left, Right}	Yes/No :: 1/0
Priv6	Integer	Print: Leakage/Base Flow To/From aquifer	Yes/No :: 1/0
Priv7, Priv8	Integer	Print: Longitudonal {Flow To, Flow from} a aquifer element	Yes/No :: 1/0

		beneath river	
Priv9, Priv10	Integer	Print: Lateral Groundwater Flow To a aquifer element from {Left, Right} beneath river	Yes/No :: 1/0
gwDInt, surfDInt, snowDint, rivStgInt, RechInt, IsDInt, usDInt, etInt, rivFlxInt	Integer	Print Interval: Groundwater, Surface Water, Snow, River Stage, Rechage to Ground Water, Interception Storage, Unsaturated Storage, Evapotranspiration, River Flow	Note: Unit is in minutes
UsatMode	Integer	Unsaturation formulation	2
SatMode	Integer	Saturation formulation	Kinematic(1); Diffusion(2)
RivMode	Integer	River formulation	Kinematic(1); Diffusion(2)
Solver	Integer	Cvode Solver Type	Iterative(2)
GSType	Integer	GS Solver Type	Modified(1); Classical(2)
MaxK	Integer	Max Krylov dimension	
Delta	Double	GMRES convergence criterion	
AbsTol	Double	Absolute Tolerance	
RelTol	Double	Relative Tolerance	
InitStep	Double	Initial time-step	[see SUNDIALS manual]
MaxStep	Double	Maximum time-step	[see SUNDIALS manual]
Etstep	Double	ET time-step	
StartTime	Double	Simulation start time	
EndTime	Double	Simulation end time	
Output	Double	Output step-size	
a *	Double	Step-size factor	
b *	Double	Base step-size	

* stepsize = $b \times a^i$

10. .init File

Init file contains all the initial state condition variables.

IS	Snow	Overland	UnSat	Sat
IS	Snow	Overland	UnSat	Sat
Repeat NumEle times…				

RiverState	Sat Beneath River
RiverState	Sat Beneath River
……..	
Repeat NumRiv times	

11. .calib File

Calib File provides control for calibrating several physical parameters.

File Structure:

geolKsatH	geolKsatV	soilKsatV	macKsatH	macKsatV
infD	RzD	macD		
Porosity	Alpha	Beta		
vAreaF	hAreaf			
VegFrac	Albedo	Rough		
Precep	Temp			
Et0	Et1	Et2		
rivRough	rivKsatH	rivKsatV	rivBedThickness	
rivDepth	rivWidCoeff			

All the variables are the calibration multiple to the original corresponding variables.

Description:

Variable Name	**Variable Type**	**Variable Description (Multiplicative Coefficients for)**	**Remarks**
infD	Double	Infiltration Depth	
RzD	Double	Root Zone Depth	
macD	Double	Macropore Depth	
Alpha, Beta	Double	Van genuchten parameters	
vAreaF, hAreaF	Double	Vertical, horizontal macropore area fraction	
VegFrac	Double	Vegetation Fraction	
Albedo	Double	Albedo	
Rough	Double	Manning's n	
Precep	Double	Precipitation	
Temp	Double	Temperature	
Et0	Double	Interception Loss	
Et1	Double	Transpiration	
Et2	Double	Evaporation from Ground	
rivRough	Double	River Manning's n	
rivKsatH, rivKsatV	Double	Conductivity of river walls andbed	
rivBedThickness	Double	River bed thickness	
rivDepth	Double	River depth	
rivWidCoeff	Double	River width coefficient	