RECLAMATION
Managing Water in the West

Working Document

User's Manual for ArcTim
A GIS based interface for Tim^{ML}

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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1 Introduction

ArcTim is a GIS based interface for TimML, a multi-aquifer analytic element model (AEM). AEMs have been used by many different entities to evaluate groundwater systems and groundwater/surface water interactions. AEMs solve the equation for groundwater flow everywhere, unlike finite element or finite difference models that solve the equation at the center of a discrete region. This makes them especially useful for investigating situations where hydrologic features are very close to one another.

Analytic element models can require large amounts of data, since a solution will be given at the resolution of the input data. Introducing GIS into the development of an AEM can greatly increase the speed at which a user can develop and model and produce a solution making AEMs very efficient tools for solving groundwater related problems.

Other single aquifer AEMs have been used in the past in conjunction with GIS to develop groundwater surface water interaction models (USBR, 2008). ArcTim combines a multi-aquifer AEM with GIS to investigate problems that include interactions between aquifers.

1. Introduction

2 Installation

2.1 Software Requirements

ArcTim requires the following software to work properly.
- ArcMap 9.3 with service pack 1
- Python 2.6.X
- TimML 3.4

2.2 Installing ArcTim

Tim^{ML} should be installed on your computer by following the instructions provided by the developer, Mark Bakker. They are provided here for convenience:

Although it is possible to download all required Python packages separately, it is much easier to install one of the Python installers that comes with a large selection of popular packages. Two of the best options on Windows are PythonXY and the Enthought Python distribution. PythonXY is free for everybody, the Enthought distribution is free for use in Academia and available for a small fee to others. The installation is straightforward and consists of the following steps:
- When you use want to use PythonXY, download the PythonXY installer for Python 2.6 from http: //www.pythonxy.com/download.php (Version on March 10, 2010 is 2.6.2.0). Once downloaded, install PythonXY.
- When you want to use the Enthought distribution, download the Enthought installer for Python 2.6 from http://www.enthought.com (Version on March 10, 2010 is EPD6.1). Once downloaded, install the Enthought distribution.
- Download the Shapely library for Python 2.6 from http://pypi.python.org/pypi/Shapely/1.0.14 (The version on March 10, 2010 is 1.0.14, so download the file Shapely-1.0.14.win32.py26.exe). Install Shapely.
- Download and install the latest version of TimML from http://code.google.com/p/timml/ (The version on March 24, 2010 is TimML-3.4.0.py26.win32.exe).

(Bakker, 2010)

ArcTim can then be installed by clicking on the provided ArcTimInstaller.msi and following the instructions. Once it is installed, the toolbar can be activated in ArcMap by clicking on View>Toolbars>ArcTim 2.0.

3 ArcTim Toolbar

The ArcTim toolbar provides a number of tools that can be used to develop, run and view output from a Tim^{ML} model. Figure 3-1 shows the toolbar that is available in ArcMap and that can be installed following the instructions in section 4.0 of this report.

Figure 3-1: ArcTim toolbar available in ArcMap.

3.1 Model Menu

The first menu item, called the *Model* dropdown menu, lists some of the basic functions of the ArcTim toolbar (Figure 3-2). As in many programs, there is a save function that will allow the user to save the settings that are set in the *Model Settings* and *Output Setting* windows. Saved model files are in XML format and the save function automatically sets the saved model file as an XML file. In addition, there is an open function that will open previously saved model and output settings.

Figure 3-2: Model Dropdown menu

The *Model Settings* window is where the user sets the basic information about the Tim^{ML} model. Figure 3-3 shows the Aquifer Properties tab of the Model Settings window. The user first sets the number of aquifer layers by clicking the *Change Number of Layers* button. Once the number of layers is defined, the user can click on the *Layer* dropdown box and select the layer that will correspond to the properties displayed in the boxes. The properties can be changed simply by typing in the boxes. If the user has saved a model file, the properties will be updated in the saved file when the user clicks OK on the *Model Settings* window. Otherwise, the parameters will be saved in a temporary file until the user creates a saved model file or when ArcMap is closed. More information about the required

properties for a Tim^{ML} file can be found in the Tim^{ML} User's Manual (Bakker, 2008).

Figure 3-3: Model Settings window where user sets basic model input.

The shapefiles that will be used in the Tim^{ML} model can be indicated in the *Shapefiles* tab of the *Model Settings* window (Figure 3-4). Shapefiles that are listed in the tree in the open ArcMap document will populate the dropdown menus under *Shapefile Name*. All shapefiles that will be used in the current model need to be listed in the tree. The dropdown boxes under *Tim Feature Type* will be populated with all of the available Tim^{ML} hydrologic feature types. The user should select the shapefile name and the time file type that corresponds to the shapefile. There can be more than one shapefile for a given feature type, but not more than one feature type for a shapefile. If the shapefile is to be used in the current model, the *Active* box should be checked.

Figure 3-4: Shapefiles tab of the Model Settings window.

Figure 3-5 shows the Output Settings window. The user can set the extents to which the model develops a solution by either selecting *Use Current Extents* or *Define Extents*. *Use Current Extents* will use the extents of the current map view and Define Extents allows the user to set the extents which can be useful if it is desired that the solution extents remain the same no matter how the user moves around within the map. Also in this window, the resolution of the solution can be selected by selecting *Use Pre-Defined resolution* and either low, medium or high, where the extents will be divided by either 10, 100 or 1000 units (the higher the resolution, the longer the output files will take to be created). The user can also specify the number of cells by which to divide the extents by selecting *Use Number of Cells* and entering the number of cells in each direction. Output will always be produced for each aquifer layer.

Figure 3-5: Output Settings window.

3.2 Shapefile Tools Menu

Each hydrologic feature in a Tim^{ML} model requires specific inputs (Table 3-1). The names listed in the Attribute Name column are required attribute names for the TimML interpreter and it is these attribute names that are used in the *Convert Existing* Shapefile and *Create New Shapefile* tools.

Table 3-1: Tim^{ML} hydrologic features and input requirements.

TimML feature type	Attribute Name	Description of Attribute
Constant	Head	Head at the reference point
	Layer*	Layer in which the reference point is located
	Name	Name of the reference point
Well	Discharge	Discharge [L3/T] of the well
	Radius	Radius of the well
	Layer*	Layer(s) in which the well is located
	Name	Name of the well
FlowLineSink	Sigma	Strength (or flux per unit length) of the linesink [L2/T]
	Layer*	Layer(s) in which the linesink is located
	Name	Name of the linesink
HeadLineSink	Head	Head in the linesink at the center of the linesink
	Layer*	Layer(s) in which the linesink is located

	Name	Name of the linesink
ResLineSink	Head	Head in the linesink at the center of the linesink
	Resistance	Resistance of the linesink to inflow and outflow
	Width	With of the linesink
	Layer*	Layer(s) in which the linesink is located
	Name	Name of the linesink
	BotElev	Leaky resistance layer at the bottom of the linesink
CircAreaSink	Radius	Radius of the circular infiltration zone
	Infil	Infiltration
	Label	Name of the CircAreaSink
	Layer	Layer in which the CircAreaSink is located.

The *Shapefile Tools Menu* options allow the user to easily develop formatted shapefiles that contain the required input data for Tim^{ML}. The first option, *Convert Existing Shapefile,* allows the user to convert an existing shapefile of hydrologic features to a format that can be interpreted by the Tim^{ML} model. The second option, *Create New Shapefile*, allows the user to create an empty shapefile with the attributes that will be necessary for a particular feature in Tim^{ML}, as shown in Table 3-1.

3.3 Grid Tools

The grid tools were developed to facilitate the use of MODFLOW solutions as boundary conditions for Tim^{ML} models. This feature is based on the theory that some hydrogeologic questions are better answered by analytic means versus using a grid based solution. Examples of such questions are how do nearby wells impact each other when pumping or how does a pumping well impact a nearby stream? This feature allows the user to extract output from a MODFLOW grid solution and use it as boundary conditions for a Tim^{ML} model simulation.

There are three tools, *Create Grid.shp from MODFLOW*, *Add Head from MODFLOW*, and *MODFLOW to Tim. Create Grid.shp from MODFLOW* utilizes the discretization file from MODFLOW to generate a grid with the number of cell and cell sizes that are used in the MODFLOW calculation. The MODFLOW discretization file does not contain a geographic projection, so the user has the option to translate and rotate the grid so that it lines up with other projected map features. The *Add Head from MODFLOW* tool adds the output from the MODFLOW calculation to the grid developed by the *Create Grid.shp from MODFLOW* tool. The *MODFLOW to Tim* tool selects output from the MODFLOW grid and populates boundary line segments that overlap the grid.

3.4 Run TimML

The *Run Tim^{ML}* button (Figure 3-6) creates a Tim^{ML} input file from the data set up in the *Model Settings Window*, runs the Tim^{ML} model and then imports the solution based on the resolution defined in the *Output Settings Window*.

Figure 3-6: The Run TimML button circled on the ArcTim 2.0 toolbar.

3.5 ArcTim Troubleshooting

Since ArcTim resides in ArcMap, there are a couple of ArcMap related issues that can come up if the following criteria are not followed:
1. All of the shapefiles need to be in the same directory.
2. No spaces are allowed in the file path.
3. All of the shapefiles need to be in the same projection and spatial reference.

4 Example 1: Develop and run a simple Tim^{ML} model using ArcTim

This example uses Example 1 that was developed for Tim^{ML}. It will show the user the necessary formats for the shapefiles, the process used to run a Tim^{ML} model and methods for viewing the model output.

Example 1 defines a model with three layers separated by two leaky layers. This is a slightly different way of defining an aquifer than would be done using MODFLOW and more details about the way that Tim^{ML} defines aquifer layers can be found in the Tim^{ML} manual (Bakker, 2010). The aquifer for Example 1 is defined by the following properties (Table 4-1):

Table 4-1: Example 1 aquifer properties (adapted from Bakker 2010).

	Hydraulic Conductivity	Bottom Elevation	Top Elevation	Resistance	Porosity	Vertical Porosity
	K (m/d)	Bottom (m)	Top (m)	C (days)	N (-)	Nv (-)
Aquifer 1	2	140	165		0.3	
Leaky Layer 2		120	140	2000		0.2
Aquifer 2	6	80	120		0.25	
Leaky Layer 3		60	80	20000		0.25
Aquifer 3	4	0	60		0.3	

Step 1: Open the Example1 map document and view the setup of the shapefiles. Open the map document C:/ArcTim/Example1Files/Example1.mxd. Note the four shapefiles in the tree, Constant.shp, headLineSink2.shp, wells.shp and cricareaSink.shp. Open the individual attribute tables and look at the format and verify that the names of the individual attributes correspond to the required attributes listed in Table 3-1. This is the required format for ArcTim to work properly, so any new shapefiles added to a Tim^{ML} model should follow this format (listed in Table 3-1).

Step 2: Input the model properties. The model properties are set up slightly different than the properties that are defined in Table 4-1. Only the properties of the aquifer layers themselves are included in the model setup, and the resistance and vertical porosity are assigned the layer that is above the leaky layer they are associated with. Set up the model settings by opening the Model Setting Window in Model>Model Settings. Table 4-1 lists the aquifer properties for Example 1.

Enter the properties in the Model Settings Window. When the Model Properties Window is closed (by clicking OK), when asked for the model name, navigate to C:/ArcTim/Example1/Example1Files and save the model as Example1.xml.

Table 4-2: Aquifer properties for Example 1 TimML model.

Layer	Top	Bottom	K	Resistance	Porosity	PorosityV
1	165	140	2	2000	0.3	0.2
2	120	80	6	20000	0.25	0.25
3	60	0	4		0.3	

Step 3: View the parameters in the Output Settings Window. Open the Output Settings Window. In the *Define Output Extents* box, click the *Define Extents* button and verify that the values in the boxes match those in Table 4-3. In the *Output Resolution* box, click the *Use number of cells* and verify that the number of cells in both boxes is 101.

Table 4-3: Output extents for Example 1.

	X	Y
Min	-4467.06623164764	24.7999999999992
Max	25115.9675562806	29607.8337879282

Step 4: Run Tim^{ML}. Click the Run Tim^{ML} button. This button will generate a Tim^{ML} input file, run Tim^{ML} and import a raster file of the solution for each aquifer layer. Notice that the raster files are named with the first 6 characters of the model name followed by the layer number that the raster represents.

Step 5: Use ArcGIS tools to explore the Tim^{ML} output. The raster output from the TimML model will be imported in the order it is created which results in the top most aquifer layer being imported first and therefore underneath the other layers. Turn the raster layers on and off to view individual model layers. The raster files can be colored using the properties menu for each of the individual raster layers. Spatial Analyst can be used to create contours for each of the raster layers.

5 Example 2: Develop and run a TimML model with MODFLOW generated boundary conditions

Example 2 will use the shapefile tools to develop a TimML model that will utilize output from a MODFLOW model as boundary conditions.

Step 1: Convert headLinesink2.shp to a file with TimML compatible attributes. Open the attribute table of headLineSink2.shp and note that the attribute names do not match those listed in Table 3-1. Convert the shapefile to a TimML compatible file by clicking on Shapefile Tools>Convert Existing Shapefile which will bring up a menu. Select a working directory (the same directory that the other shapefiles are in), select the shapefile that will be converted and select the type of TimML feature that the shapefile represents as shown in Figure 5-1 and Figure 5-2. The output will be a new shapefile called headLineSink2_Tim.shp. All shapefiles resulting from this tool will end with _Tim.shp.

Figure 5-1: Step one to convert the headLineSink2.shp to a TimML compatible file.

5. Example 2: Develop and run a TimML model with MODFLOW generated boundary conditions

Figure 5-2: Step two to convert the headLineSink2.shp to a TimML compatible file.

Step 2: Use the Create New Shapefile tool to create a new TimML compatible shapefile. Note that the current map document does not have the required constant.shp. Create the constant.shp shapefile using the Create New Shapefile tool by clicking on Shapefile Tools>Create New Shapefile (Figure 5-3). Enter the working directory (again, the directory that all of the other shapefiles are in), select the Tim Feature Type (constant, in this case), and type in the new file name, without the .shp extension. A shapefile called constant_Tim.shp will be created when OK is clicked.

Figure 5-3: Create New Shapefile tool.

Step 3: Edit the new constant_Tim.shp shapefile. Open the attribute table of the newly created constant_Tim.shp. Since this tool is designed to only format the shapefile so that it is compatible with TimML, only the required attributes were created, but the table was not populated with data. It is assumed that the user will use the ArcMap editor function to create the shape and data to add the appropriate attributes. Start the editor function by opening the editor toolbar, View>Toolbar>Editor then click Editor>Start Editing on the toolbar. Click on the pencil icon to create a new feature, right click on the map and click on the Absolute X, Y… function. Enter 20000 for both X and Y. This will create a constant feature at 20000,20000. Open the constant_Tim.shp attribute table and enter 175 under Head, "constant" under Name, and 1 under Layer1. Save the edits by clicking on Editor>Stop Edits.

Step 4: Run TimML. At this point, the same model has been created that was run in Example 1. To be sure that all of the shapefiles were created properly, run the model by setting up the model attributes and run TimML.

Step 5: Add the MODFLOW Grid and Output to the map document.

Step 6: Extract boundary conditions from the MODFLOW grid.

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Step 7: Run the new TimML model with MODFLOW derived boundaries.

6 References

Bakker, Mark (2010). TimML: A Multiaquifer Analytic Element Model, Version 3.4. www.bakkerhydro.org/timml.