Producing a good hydrological simulation

I have been asked on many occasions how to go about doing a good hydrological simulation using Shetran. The techniques would be similar in any model. Here are some thoughts I have put together from over 20 years of carrying out hydrological simulation. I am sure other people will have different ideas but it works for me. Any thoughts on this or other ideas would be really useful.

1. Do not carry out a simulation – look at the data.

It is really important that the rainfall, potential evaporation and discharge data is of good quality and consistent before any hydrological simulation is carried out. You need a time series with no missing data (filling in data is another topic that I should talk more about). The first thing to do is plot the data, I use Excel but there are loads of way this could be done. Assuming you have hourly rainfall (mm/hr), PE (mm/hr) and discharge data (m3/s) put these in adjacent columns in Excel, with a time function (dd/mm/yyyy hh:mm) in the first column . The discharge in m3/s needs to be converted to mm/hr. This is the value*3600*1000/area in m2. Then plot the time series of rainfall, PE and discharge. This should show up any spurious or missing values. Look at some major events and compare the rainfall and discharge – what is the time lag, is the recession steep or gentle? Also plot the values for rainfall, PE and discharge on a monthly and annual basis using the "Month" and "Year" functions and Pivot Tables. Look at the monthly trends in rainfall, discharge and PE does this follows the expected trends in the catchment. Look at the annual and monthly runoff ratios are these about right are any runoff ratios greater than 1.

If there is sufficient data select two periods a calibration and validation period

2. Set-up a basic simulation – keep it simple

In Shetran you will need a DEM dataset and a catchment mask created using GIS software in ASCII format. When setting up a basic simulation I use the Shetran GUI. A river network is automatically setup and the standard Shetran input files are produced. At this stage I keep everything simple and use a single (the dominant) soil category and vegetation type. I would compare the measured and simulated discharge. Is the simulation producing sensible results? For example the simulated discharge may always be much too small – this could be because the timestep for the PE data has been set incorrectly.

It is at this stage that I revert to using the Standard version of Shetran – although most of the following analysis can be carried out equally easily using the Shetran GUI

3. Is the Mass Balance correct?

The first calibration of the model is to get the annual mass balance correct. Plot the simulated and measured discharge in Excel and use the Month and Year functions and pivot tables. The simulated mass balance values are also shown in the output_CATCHMENT_mb.txt file.

The important parameter here is the actual evaporation (AE)/ potential evaporation (PE) ratio for the vegetation type. If the simulated discharge is too large, more evaporation is needed, so the AE/PE ratio needs increasing.

4. Calibrate the important parameters

Keep a list of changes made to the parameters, the changes in the simulated discharge and the results.

Change only one parameter at a time. It is really tempting to change more than one but very hard to understand the changes in the simulated discharge which results from these changes (I still sometimes change more than a single parameter at once and then wish I had not).

Change the parameter by more than you think to start with. For example, if you are increasing the saturated hydraulic conductivity do not just change it by a factor of 2, change it by a factor of 10. If the new value is too high you can reduce it at the next simulation and select a sensible value.

The most important parameters are (as well as the AE/PE ratio – see 3):

Soil depths (each soil category can have up to 3 soil types in the GUI) – generally deeper soils have more storage and larger subsurface flows (transmissivity), this means they produce greater base flows and smaller peak flows at the catchment outlet

Saturated hydraulic conductivity – a higher conductivity increases the baseflow at the catchment outlet, as a result it also increases the available storage and so reduces the peak flows

Strickler Overland flow (inverse of Manning's resistance) – A higher value increases the speed of flow overland and so increases the peak discharges

Changing these will give a good understanding to how the catchment is responding. Remember the parameters do NOT act independently – they are all related. For example increasing the saturated conductivity will make the soil drier and so lower the transpiration, so the AE/PE ratio may need increasing.

It is important NOT to only look at the simulated outlet discharge (if that is all you are interested in you should probably be using a simpler conceptual model!!). The point of a physically-based spatially distributed model such as Shetran is it gives you information about is happening within the catchment. For example look at the soil moistures, water table depths and soil moistures (theta, ph_depth and srf_dep in the visualisation_plan file)

5. Add complexity

Once you have a good comparison between the measured and simulated discharges it is then a good idea to add complexity. This includes:

Vegetation distribution

Soil category distribution

Long simulations

Uncertainty bounds etc.

6. Automatic Calibration

Automatic calibration is OK to fine tune the parameters between well defined bounds. It does not let you know what is going on within the catchment and it can often give you “the right results for the wrong reason”.

This is not currently a standard procedure to carry out automatic calibration within the GUI. It has been achieved by writing code to change either the standard Shetran input files or the XML file that the GUI produces.