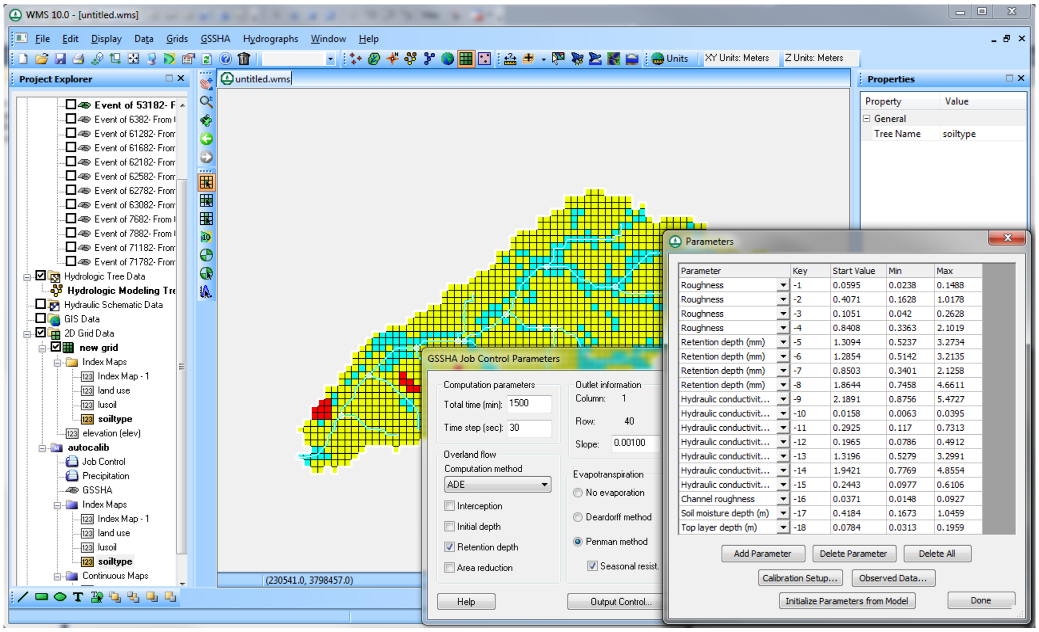
v. 10.1

WMS 10.1 Tutorial

GSSHA – Calibration – Computer-based Calibration of GSSHA models

Define parameters to be specified as adjustable, the objective function to be used to support that estimation, and automatically calibrate a GSSHA model



Objectives

This tutorial shows how to set up and run a GSSHA model that automatically calibrates specified adjustable parameters using a documented efficient local search method.

Prerequisite Tutorials

- GSSHA – Calibration – Stochastic Simulations of GSSHA models

Required Components

- Data
- Drainage
- Map
- Hydrology
- 2D Grid
- GSSHA

Time

- 20-40 minutes

1 Open an Existing GSSHA Project

Open the GSSHA model for Goodwin Creek Watershed

1. In the *2D Grid Module* select ***GSSHA* | *Open Project File…***
2. Locate the tutorial files. If needed, download the tutorial files from www.aquaveo.com.
3. Browse and open the file ***Calibration\Automated\goodwin.prj.***
4. Select ***GSSHA* | *Save Project File*** to save the base project with a different name, so that the original project remains unchanged. Save the project as ***\Personal\Calibration\Automated\autocalib.prj.***
5. Turn off the display of all the coverages except the *GSSHA coverage.*

2 Selecting Rainfall Events

First select the rainfall events simulation to calibrate, then run an initial simulation to ensure the simulation is set up correctly.

1. Before creating a calibration run, make sure all the Rainfall events that will be used in the forward model simulation are selected. Select ***GSSHA* | *Precipitation…*** and toggle on the first three events only (Event 52282 – Event 53182). Click *OK.*
2. The simulation should be run once in the forward simulation mode to make sure the model runs. A model that cannot run cannot be calibrated. Select ***GSSHA* | *Run GSSHA…***. Click *OK* to accept the default run parameters. After the run is completed, click *Close* on the model wrapper window and wait for the solution to be read.

2.1 Assigning keys to map tables and other parameters

First, use the WMS GSSHA interface to indicate which parameters should be adjustable calibration parameters. Generally, the calibration parameters are those which involve uncertainty in measurement or the ones that affect the outflow hydrograph the most. This is done by defining negative “key” values for each of the parameters needing calibration.

1. Select ***GSSHA* | *Map Tables…*** and switch to the *Roughness* tab.

2. Enter the keys -1, -2, -3 and -4 for the roughness values shown below. Entering a negative numbers tells WMS that these are the calibration parameters. WMS then associates the values that will be defined in the calibration dialog (in a future step) with these parameters.

Roughness					
ID	1	2	3	4	5
Description1	pine 27% ...	water 0.3% ...	cotton 14% ...	pasture 42%...	gullied land ...
Description2	...	...	...	...	...
Surface roughness	-1.000000	0.358000	-2.000000	-3.000000	-4.000000

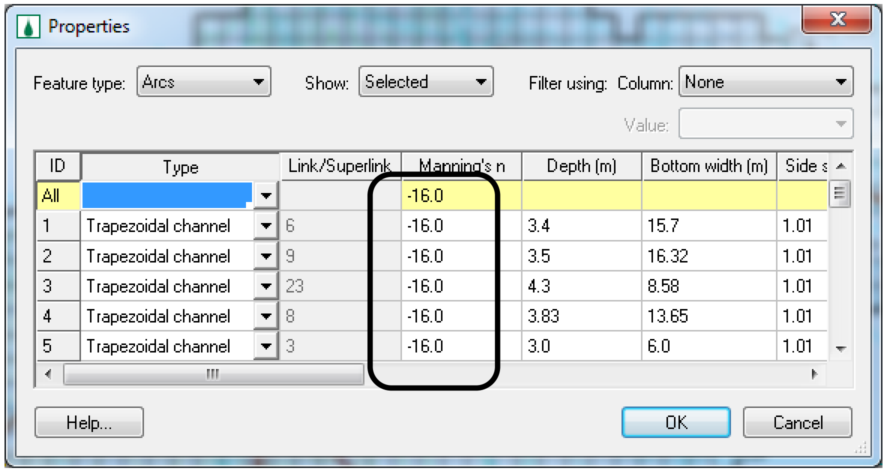
3. In the *Retention* tab, enter the following keys:

Retention					
ID	1	2	3	4	5
Description1	Pine 27% ...	Water 0.3% ...	Cotton 14% ...	Pasture 42%...	Gullied land ...
Description2	...	...	...	...	...
Retention depth (mm)	-5.000000	1.300000	-6.000000	-7.000000	-8.000000

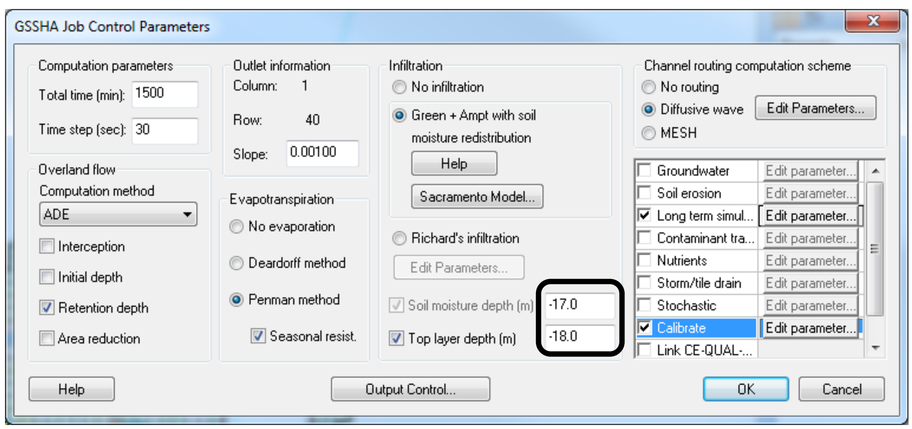
4. Switch to the *Infiltration* tab and enter the following keys for *Hydraulic Conductivity*.

Infiltration									
ID	1	2	3	4	5	6	7	8	9
Description1	gullied-land-...	gullied-land-...	water-.3% ...	pasture-clay...	cotton-clay-l...	pine-clay-loa...	pine-silt-loa...	cotton-silt-lo...	pasture-silt-l...
Description2		...	...	...	...	...	...	...	...
Hydraulic conductivity (cm/hr)	-9.000000	1.410000	0.003000	-10.000000	-11.000000	-12.000000	-13.000000	-14.000000	-15.000000
Capillary head (cm)	16.680000	4.950000	0.003000	20.880000	20.880000	20.880000	16.680000	16.680000	16.680000
Porosity (m^3/m^3)	0.486000	0.437000	0.582000	0.464000	0.464000	0.464000	0.486000	0.486000	0.486000
Pore distribution index (cm/cm)	0.234000	0.694000	0.001000	0.242000	0.242000	0.242000	0.234000	0.234000	0.234000
Residual saturation (m^3/m^3)	0.015000	0.020000	0.015000	0.075000	0.075000	0.075000	0.015000	0.015000	0.015000
Field capacity (m^3/m^3)	0.330000	0.091000	0.436500	0.318000	0.318000	0.318000	0.330000	0.330000	0.330000
Wilting point (m^3/m^3)	0.133300	0.033000	0.133300	0.133300	0.133300	0.133300	0.197000	0.133000	0.133000

5. The last column in the *Hydraulic Conductivity* field should be -15. Click *Done* to close the *Job Control* dialog.
6. In the *Map module* , click on the *Select feature line branch tool*  and double click on the downstream most channel arc (the one closest to the watershed outlet) which will open the *Properties* dialog.
7. Enter -16 for Manning's n for all arcs and click OK.



8. Select the *2D Grid* module, select ***GSSHA* | *Job Control***, and enter -17 for *Soil Depth* and -18 for *Top Layer Depth*. Click *OK* to save the edits and close the Job Control dialog.

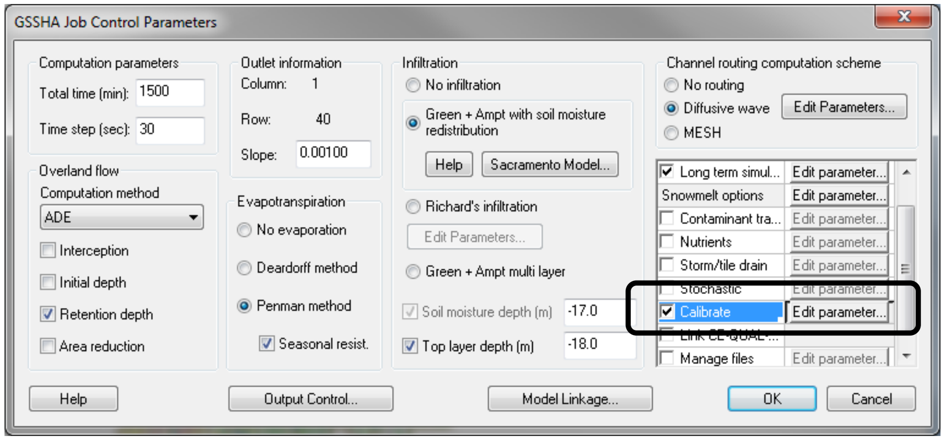


So, altogether there are 18 parameters that will be used in the automated calibration for this tutorial example problem.

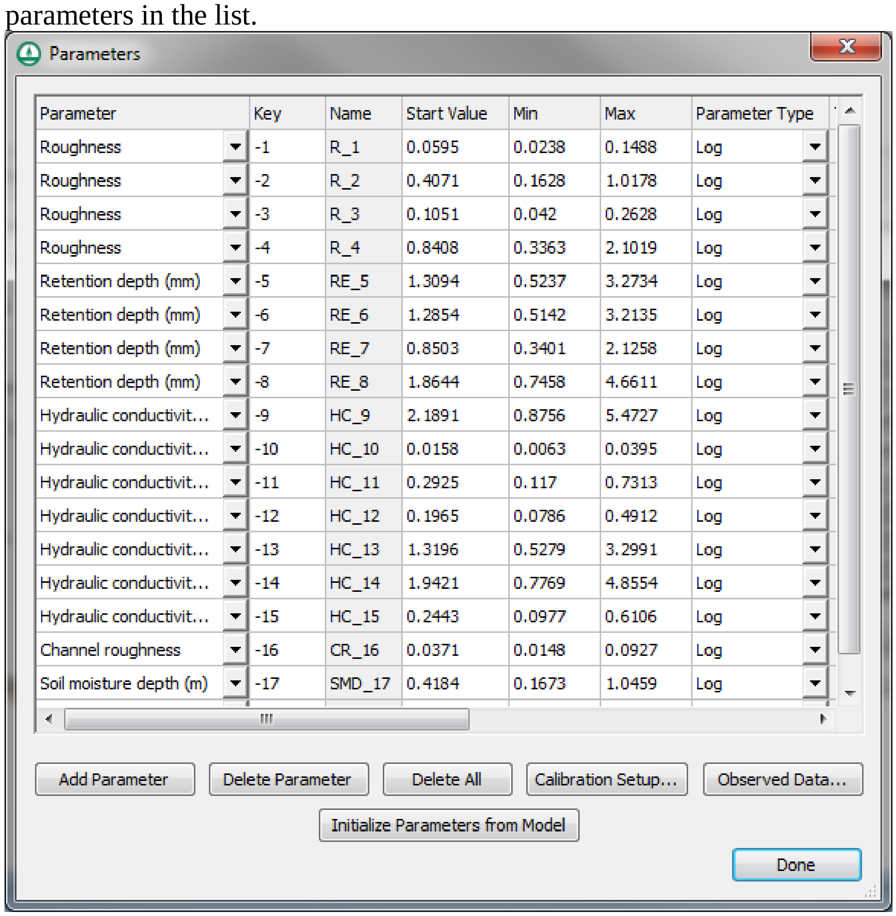
2.2 Defining calibration parameters

Next, define the define the upper and lower boundary parameters which have values that can vary during the calibration run.

1. Select ***GSSHA* | *Job Control…*** and select the *Calibrate* Option (See the following figure).



2. In the *Job Control* dialog, click on the *Edit Parameter* button for calibration option.
3. Select the *Initialize Parameters from Model* button so that there will be 18 parameters in the list.



Parameter	Key	Name	Start Value	Min	Max	Parameter Type
Roughness	-1	R_1	0.0595	0.0238	0.1488	Log
Roughness	-2	R_2	0.4071	0.1628	1.0178	Log
Roughness	-3	R_3	0.1051	0.042	0.2628	Log
Roughness	-4	R_4	0.8408	0.3363	2.1019	Log
Retention depth (mm)	-5	RE_5	1.3094	0.5237	3.2734	Log
Retention depth (mm)	-6	RE_6	1.2854	0.5142	3.2135	Log
Retention depth (mm)	-7	RE_7	0.8503	0.3401	2.1258	Log
Retention depth (mm)	-8	RE_8	1.8644	0.7458	4.6611	Log
Hydraulic conductivit...	-9	HC_9	2.1891	0.8756	5.4727	Log
Hydraulic conductivit...	-10	HC_10	0.0158	0.0063	0.0395	Log
Hydraulic conductivit...	-11	HC_11	0.2925	0.117	0.7313	Log
Hydraulic conductivit...	-12	HC_12	0.1965	0.0786	0.4912	Log
Hydraulic conductivit...	-13	HC_13	1.3196	0.5279	3.2991	Log
Hydraulic conductivit...	-14	HC_14	1.9421	0.7769	4.8554	Log
Hydraulic conductivit...	-15	HC_15	0.2443	0.0977	0.6106	Log
Channel roughness	-16	CR_16	0.0371	0.0148	0.0927	Log
Soil moisture depth (m)	-17	SMD_17	0.4184	0.1673	1.0459	Log

4. Enter the *Starting, Minimum and Maximum* values shown in the figure above by copying and pasting the values from the file ***\Calibration\Automated\InitialParams.txt.*** Guidance for starting parameter estimates can be found on http://gsshawiki.com.

Do not close this dialog yet.

2.3 Defining the Observed Data for Model Calibration

A quantitative measure of closeness of fit is called an objective function, and it is an important component of the automatic calibration process. For this example GSSHA problem, the objective function will be defined by comparing observed flow data at the Goodwin Creek watershed outlet with the model simulated counterparts. The best set of parameters corresponds to the lowest objective function value.

For this example problem, the GSSHA model is calibrated for a long term event where there are multiple storm events.

1. In the *Parameters* dialog, click on the *Observed Data…* button to bring up the *GSSHA Observations* dialog.
2. Click the *Add* button.
3. Change the ***Observation Type*** to *Outlet Hydrograph*.
4. Click on the *Define* button under the *Observed Data* column and select *Define Series….*
5. With Show Dates turned off, copy and paste the values from the file ***\Calibration\Automated\observed.txt*** into the XY Series Editor.
6. Change the Curve name to *hydro*.
7. Select *OK* and *Done*. Click on the Define Weights button and notice an XY Series has been defined to correspond to the observation data. These weights could be edited to put a greater emphasis on peak values if desired. Select *Cancel* and then *OK* to close the GSSHA Observations.

2.4 Defining Levenberg-Marquardt (LM)/Secant LM (SLM) data

1. In the *Parameters* dialog, click on the *Calibration Setup…* button which will open the *Calibration Setup* dialog.
2. Notice that there are several calibration methods from which to choose. The default LM/SLM methods are recommended for routine use. However, if sufficient time is available for a more exhaustive exploration, then of the three global optimization methods (Multistart, TR, and MLSL), the MLSL method is recommended. Use the *LM/SLM* calibration method with the *Run Secant LM (SLM) method* toggle turned on for this simulation. The SLM calibration option will compute a set of optimum values using a local search. If the model can be run for several hours, select *MLSL* for the calibration method. The MLSL option computes a set of optimum values using a global search, but will require more time than the SLM method. Do not modify any of the calibration setup parameters at this time.
3. Click *OK*.
4. Click *Done* to close the *Parameters* dialog.
5. Click *OK* to close the *Job Control*.

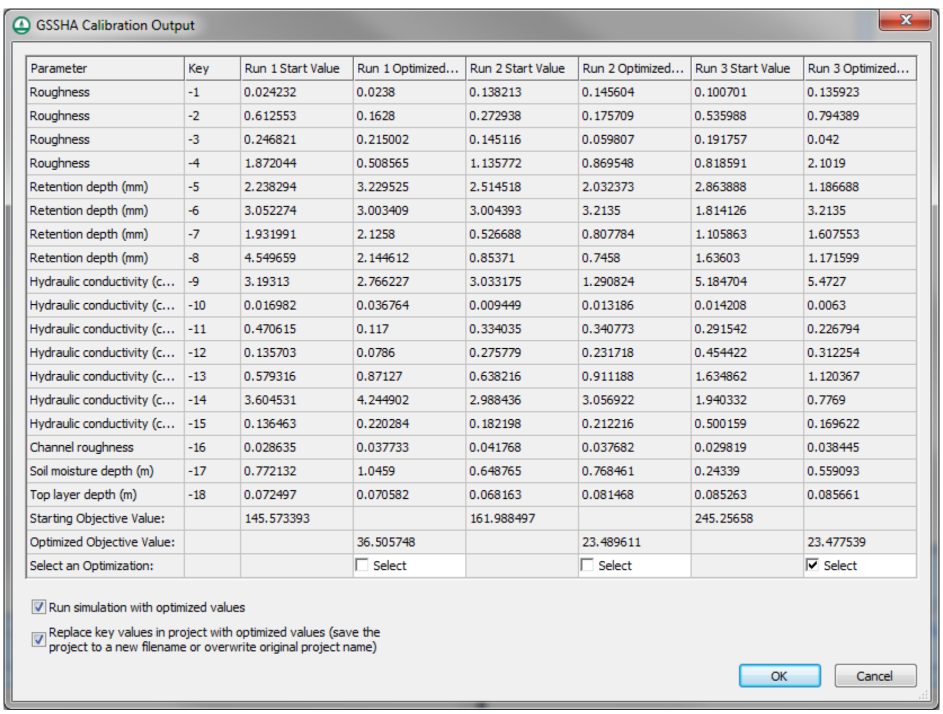
3 Save and Run the Model

1. Save the GSSHA project as ***Personal\Calibration\Automated\autocalib.prj***. Notice that WMS runs an initial forward simulation before saving so it can compare the observed with computed values and prepare the necessary calibration input files.
2. Select ***GSSHA | Run GSSHA…***
3. Select the *OK* button. This run will take some time to finish. It is recommended to run the calibration overnight or in the background while working on other tasks.

4 Run the Forward Simulation with the Optimized Parameters

Once the calibration completes, GSSHA writes the best set of parameters (the set of parameters which produce minimum cost function). WMS can read the best parameters, and then save the project file using a new filename so the original calibration input file is not overwritten. Some of the input or output control data can be modified in order to run a new forward simulation with the calibrated parameters.

1. The GSSHA model wrapper displays an evolution of the automatic calibration. It indicates if the maximum number of specified optimization iterations was met or if the local (global, if such a method is chosen) search terminated by virtue of other specified stopping criteria.
2. Close the model wrapper after the calibration completes. The *GSSHA Calibration Output* dialog shows the starting and optimized parameter values along with the starting and optimized objective function values.



Parameter	Key	Run 1 Start Value	Run 1 Optimized...	Run 2 Start Value	Run 2 Optimized...	Run 3 Start Value	Run 3 Optimized...
Roughness	-1	0.024232	0.0238	0.138213	0.145604	0.100701	0.135923
Roughness	-2	0.612553	0.1628	0.272938	0.175709	0.535988	0.794389
Roughness	-3	0.246821	0.215002	0.145116	0.059807	0.191757	0.042
Roughness	-4	1.872044	0.508565	1.135772	0.869548	0.818591	2.1019
Retention depth (mm)	-5	2.238294	3.229525	2.514518	2.032373	2.863888	1.186688
Retention depth (mm)	-6	3.052274	3.003409	3.004393	3.2135	1.814126	3.2135
Retention depth (mm)	-7	1.931991	2.1258	0.526688	0.807784	1.105863	1.607553
Retention depth (mm)	-8	4.549659	2.144612	0.85371	0.7458	1.63603	1.171599
Hydraulic conductivity (c...	-9	3.19313	2.766227	3.033175	1.290824	5.184704	5.4727
Hydraulic conductivity (c...	-10	0.016982	0.036764	0.009449	0.013186	0.014208	0.0063
Hydraulic conductivity (c...	-11	0.470615	0.117	0.334035	0.340773	0.291542	0.226794
Hydraulic conductivity (c...	-12	0.135703	0.0786	0.275779	0.231718	0.454422	0.312254
Hydraulic conductivity (c...	-13	0.579316	0.87127	0.638216	0.911188	1.634862	1.120367
Hydraulic conductivity (c...	-14	3.604531	4.244902	2.988436	3.056922	1.940332	0.7769
Hydraulic conductivity (c...	-15	0.136463	0.220284	0.182198	0.212216	0.500159	0.169622
Channel roughness	-16	0.028635	0.037733	0.041768	0.037682	0.029819	0.038445
Soil moisture depth (m)	-17	0.772132	1.0459	0.648765	0.768461	0.24339	0.559093
Top layer depth (m)	-18	0.072497	0.070582	0.068163	0.081468	0.085263	0.085661
Starting Objective Value:		145.573393		161.988497		245.25658	
Optimized Objective Value:			36.505748		23.489611		23.477539
Select an Optimization:			☐ Select		☐ Select		☑ Select

3. If using the SLM local optimization method, only a single set of optimized values will be visible. If using the MLSL method described above, there will be multiple sets of optimized values. Select the desired set of optimized values from the dialog.
4. Turn off both options: *Run simulation with optimized values* and *Replace key values…*. Click *OK* or *Cancel* to close the *GSSHA Calibration Output* dialog. This dialog can be accessed at any time to replace the key values in the simulation by selecting the ***GSSHA* | *Read Calibration Output…*** menu command.
5. Select ***GSSHA* | *Read Solution…*** to read the calibration results.

5 Observe the Full Calibration Results

GSSHA writes several calibration files during and after a calibration run. Here are a couple of files to view:

1. Scroll down in the project explorer and double-click or right-click to open the ***Calibration Record (.rec) File.*** This file shows detailed results for the calibration run.
2. Double-click or right-click to open the ***Parameter Estimate (.par)*** and ***Parameter Sensitivity (.sen)*** files. These file show additional parameter information about the calibration run.
3. If running an MLSL calibration, open the ***Optimization File (slm_chl_mlsl.rec)***. This file contains overview information about the global optimization method.

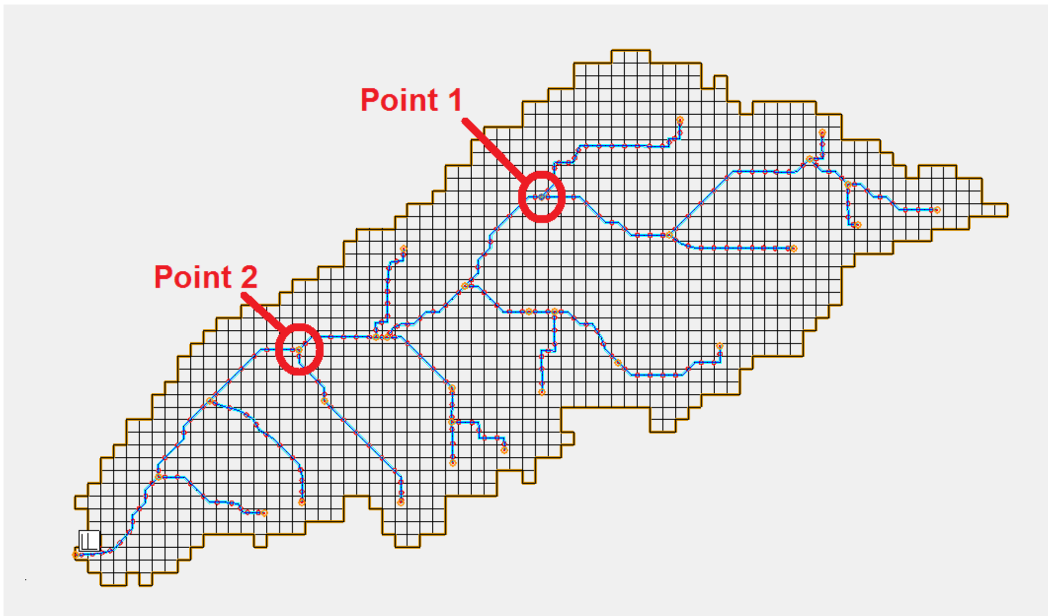
6 Automated Calibration to Additional Observation Points

There will frequently be stream gages or other measured data at locations other than the outlet point that can be used to calibrate the model. The model can easily be calibrated to include these additional data values. The following data types can be calibrated at any applicable point in the watershed:

- Overland Depth
- Infiltration Depth
- Surface Moisture
- Channel Depth
- Channel Flow
- Groundwater Head
- Outlet Hydrograph (Only at the watershed outlet point)
- Snow Water Equivalent
- Tile Drain Discharge (In a GSSHA Storm Drain coverage)

This section describes how to add additional observation points to the model.

1. In the *2D Grid Module*, select ***GSSHA* | *Save Project File*** to save the current project with a different name, so that the original project remains unchanged. Save the project as ***\Personal\Calibration\Automated\autocalibMult.prj.***
2. In the project explorer, select the *GSSHA coverage* to make this the active coverage.
3. Select the *Select Feature Point/Node* tool



4. Double-click on Point 1 in the figure above to bring up the **GSSHA Feature Point/Node** attribute dialog.
5. Select the *Observations* button for the point.
6. Select the *Add* button to add an observation.
7. Change the observation type to *Channel Flow*.
8. Click on the *Define* button under the *Observed Data* column and select *Define Series….*
9. With Show Dates turned off, copy and paste the values from the file ***\Calibration\Automated\Pt1.txt*** into the XY Series Editor.
10. Change the Curve name to *point1*.
11. Select *OK* and *Done*. Then select *OK* twice to return to the main graphics window.
12. Repeat steps 4 through 11 for point 2, using data from the file named *Pt2.txt* and naming the curve *point2*.
13. Save the modified GSSHA project as ***Personal\Calibration\Automated\autocalibMult.prj***.
14. Select *GSSHA* | *Run GSSHA…*
15. Select the *OK* button. Once again, this run will take some time to finish.

16. Close the model wrapper after the calibration completes. Notice that the *GSSHA Calibration Output* dialog shows the starting and optimized parameter values.
17. Select *OK* on the *GSSHA Calibration Output* dialog and save the project as ***\Personal\Calibration\Automated\autocalibMultOpt.prj***. Now run the simulation and compare the observed with the simulated values.

