SDMProjectBuilder

SWAT Simulation and Calibration for Nutrient Fate and Transport

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SUMMARY

This tutorial reviews screens, icons, and basic functions for downloading flow, sediment, and nutrient observations for a watershed of interest; how to prepare SWAT-CUP input files for SWAT parameter calibration; and how to perform SWAT parameter calibration with SWAT-CUP. It demonstrates how to

- Identify a USGS gaging station where flow, sediment, and nutrient data are available for a watershed of interest.
- Download flow, sediment, and nutrient observations associated with a USGS gage station.
- Prepare SWAT-CUP input files for SWAT parameter calibration.
- Calibrate SWAT parameters.
- View SWAT parameter calibration results with SWAT-CUP.

SWAT Simulation and Calibration for Nutrient Fate and Transport

PURPOSE

Automate SWAT parameter calibration, as much as possible, with SWAT-CUP.

OBJECTIVE

Prepare flow, sediment, and nutrient observation time series for SWAT parameter calibration; prepare SWAT-CUP input files for SWAT parameter calibration; and perform SWAT parameter calibration with SWAT-CUP

DEMONSTRATION

This tutorial reviews how to download flow, sediment, and nutrient observations for a watershed of interest; how to prepare SWAT-CUP input files for SWAT parameter calibration; and how to perform SWAT parameter calibration with SWAT-CUP. It demonstrates how to

- Identify a USGS gaging station where flow, sediment, and nutrient data are available for a watershed of interest.
- Download flow, sediment, and nutrient observations associated with a USGS gage station.
- Prepare SWAT-CUP input files for SWAT parameter calibration.
- Calibrate SWAT parameters.
- View SWAT parameter calibration results with SWAT-CUP.

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DISCLAIMER

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SOFTWARE ACCESS, RETRIEVAL, DOWNLOAD, AND INSTALLATION

Kim et al. (2016a) provide software access, retrieval, download, and installation instructions that must be implemented prior to executing the tutorial. The authors review screens, icons, and basic functions of the SDMProjectBuilder (SDMPB) and explain how to use SDMPB output to populate the Soil and Water Assessment Tool (SWAT) input files for nutrient fate and transport modeling in the Salt River Basin. They demonstrate how to choose and delineate a HUC-8 which includes the Salt River Basin; collect environmental data used in watershed modeling; address isolated subwatersheds which are disconnected from the waterbody network; modify a local data file to define an outlet point within a HUC-8; and develop input files necessary to execute SWAT successfully. By following Kim et al. (2016a) tutorial, appropriate folder structure and files associated with nutrient simulation and calibration are created and saved, including initial execution and results of SWAT for flow and nutrient fate and transport. SWAT-related software covered by Kim et al. (2016a) are summarized in Table 1.

SOFTWARE	PURPOSE	SOURCE		
SDMProjectBuilder	SWAT input file generator	O:\Public\QMRA\Software for		
SDIVIFTOJECIBUILLEI	SWAT input the generator	Download\SDMPB		
	SWAT parameter calibration	http://swat.tamu.edu/software/s		
SWAT-CUP	SWAT parameter campration	wat-cup/		
SWAT_SWATCUP.exe	SWAT-CUP input file generator	Installed with SDMProjectBuilder		
Input_SWAT.in	Default input file of "SWAT_SWATCUP.exe"	Installed with SDMProjectBuilder		
Lindate nar inflexe	Updating "par_inf.txt" with new parameter	Installed with SDMProjectBuilder		
	ranges after each SWAT-CUP iteration			
	Library package for executing	https://software.intel.com/en-		
EOPTRANLibrary	SWAT SWATCHD avo and	us/articles/redistributable-		
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		fortran-compiler-for-windows		

 Table 1. Summary of SWAT-related Software (after Kim et al., 2016a)

DOWNLOADING FLOW, SEDIMENT, AND NUTRIENT OBSERVATION TIME SERIES

This section describes how to obtain flow, sediment, and nutrient observations for the calibration process. Kim et al. (2016b) describe how flow observations at USGS gage stations can be downloaded and exported through BASINS, although the example used is with the HSPF watershed model. For SWAT simulation and calibration, sediment and nutrient observations must be directly downloaded through the Internet. Here, a process is outlined that gathers data from sources which may differ slightly due to browser choice and its plug-in capabilities. The objective is to produce CSV-formatted files for use in SWAT-CUP. This may require steps to save the data in native formats, perform ancillary processes (e.g., un-zip), import the data into a spreadsheet (e.g., Excel), and save the data in a CSV format.

Daily Discharge Data

1. To download flow data at USGS Salt River ab Reservoir nr Etna WY gage station (13027500), click the following link to reach a USGS webpage:

http://waterdata.usgs.gov/	/nwis/inventory/?site	no=13027500&agency	cd=USGS

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S 13027500 SALT RIVER AB RESERVOIR NR ETNA WY				
Available data for this site SUMMARY OF ALL AVAILABLE DATA	✓ GO			
am Site				
ESCRIPTION:				
Latitude 43°04'47", Longitude 111°02'14" NAD83				
Lincoln County, Wyoming, Hydrologic Unit 17040105				
Drainage area: 857 square miles				
Datum of gage. 5,070 feet above inGVD29.				
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	Dogin Date	End Data		
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Daily discharge data from 1953/10/01 to 2016/01/20 are available, including the simulation period specified in Kim et al. (2016a), which is the precursor to this tutorial. Click "Daily Data" in the "AVAILABLE DATA" table. The data at USGS gages are continuously updated, so more data may be available when users access this site.

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Drainage area: 857 square miles				
Datum of gage: 5,676 feet above NGVD29.				
VAILABLE DATA:				
Data Type	Begin Date	End Date	Count	
Current / Historical Observations (availability statement)	2007-10-01	2016-01-21		
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3. The following page will appear.



Ensure that "Discharge(Mean)" is checked and other variables are unchecked. Select "Tabseparated" for "Output format", and set "Begin date" and "End date" as "1990-01-01" and "2000-12-31", respectively. "Begin date" and "End date" can be outside the simulation period as long as they include it (1990-01-01 – 2000-12-31). Click "GO".

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			15 TO A		
Station operated in c	ooperation with]	Idaho Water Distri	ct No.1.		
Realtime Gage Heigh	t data is provideo	l by <u>U.S. Bureau of</u>	FReclamation (USBR) teleme	etry .	
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6. Right-click on the webpage, and select "Export to Microsoft Excel".

waterdata.usgs.gov/nwis/ D + O atta.usgs.gov				<u>пх </u>
<u>_</u>				
R		Back	-	
±		Back		
# The data you have obtained from this automated U.S. Geological Survey database		Forward		
# have not received Director's approval and as such are provisional and subject to		Go to copied address Ctrl+S	Shift+L	
# revision. The data are released on the condition that neither the USGS nor the				
a oniced states government may be need insite for any damages resulting from its use. Additional info: http://blp.waterdata.usgs.gov/policies/provisional-data-statement		Save background as		
		Set as background		
# File-format description: http://help.waterdata.usgs.gov/faq/about-tab-delimited-output				
# Automated-retrieval info: http://help.waterdata.usgs.gov/faq/automated-retrievals +		Copy background		
# Contact: gs-w support nwisweb@usgs.gov		Select all		
# retrieved: 2016-01-21 15:20:22 EST (caww01)		Select all		
# 		Paste		
# Jata for the following 1 site(3) are contained in this file # USGS 13027500 SALT RIVER AB RESERVOIR ME FINA WY	_	-		
		E-mail with Windows Live		
÷	5	Translate with Bing		
# Data provided for site 13027500		All Accelerators	•	
D) parameter statistic Description 2 00060 00003 Discharge, cubic feet per second (Mean)		All Accelerators		
÷		Create shortcut		
# Data-value gualification codes included in this output:				
A Approved for publication Processing and review completed.		Add to lavorites		
		View source		
agency_cd site_no datetime 02_00060_00003 02_00060_00003_cd		Inspect element		
5s 15s 20d 14n 10s				
USGS 13027500 1990-01-01 415 A USGS 13027500 1990-01-02 420 A		Encoding	•	
USGS 13027500 1990-01-03 410 A				
USGS 13027500 1990-01-04 412 A		Print		
USGS 13027500 1990-01-05 417 A		Print preview		
USGS 13027500 1990-01-07 401 A		Defeash		
USGS 13027500 1990-01-08 452 A		Kerresh		
USGS 13027500 1990-01-09 427 A		Former than Million of the Former's		
USGS 13027500 1990-01-10 416 A		Export to Microsoft Excel		
USGS 13027500 1990-01-11 415 A		Send to OneNote		
USGS 13027500 1990-01-13 420 A				
USGS 13027500 1990-01-14 422 A		Properties		
USGS 13027500 1990-01-15 426 A				
USG5 13027500 1990-01-16 420 A USG5 13027500 1990-01-17 413 A				
USGS 13027500 1990-01-18 408 A				
USGS 13027500 1990-01-19 397 A				\sim
				₫ 100% ▼
				10070

7. The following window will appear. Click "Import".

New Web Query
Address: http://waterdata.usgs.gov/nwis/dv?cb_00060=on&format=rdb 🔽 😡 🕲 🖄 🖄 🖳 Options
Click 💿 next to the tables you want to select, then click Import.
<pre>WARNING</pre>
<pre># File-format description: http://help.waterdata.usgs.gov/faq/about-tab # Automated-retrieval info: http://help.waterdata.usgs.gov/faq/automated #</pre>
<pre># Contact: gs-w_support_nwisweb@usgs.gov # retrieved: 2016-01-21 11:33:38 EST (vaww02) #</pre>
<pre># Data for the following 1 site(s) are contained in this file # USGS 13027500 SALT RIVER AB RESERVOIR NR ETNA WY #</pre>
Data provided for site 13027500
Import Cancel
Done

8. On the following window, click "OK".

Import Data		? X
Where do you	want to put the data?	
Existin	g worksheet:	
=\$A\$	1	1
© <u>N</u> ew v	vorksheet	
P <u>r</u> operties.	. ОК	Cancel

9. These data must be imported into an Excel spreadsheet. If the "Export to Microsoft Excel" menu is not available in the browser, data must be manually copied from the webpage and pasted to the spreadsheet. Now save the Excel file. In this example, the file is saved as "C:\Temp\SDMProject\SaltBiverID\HUC8\Scenarios\17040105\Elow 13027500 csv". The file can be file and the spreadsheet.

"C: $Temp\SDMProject\SaltRiverID\HUC8\Scenarios\17040105\Flow_13027500.csv"$. The file can be saved in any other folder with a different name.

🛣 Save As					X
📀 🕞 🗕 📜 « SDMPi	roject 🕨 SaltRiverID 🕨 HUC8 🕨 S	cenarios 🕨 17040105 🕨	▼ 🐓 Search 17	7040105	Q
Organize 🔹 New fo	lder			•	0
👢 HSPF	Name	Date modified	Туре	Size	
HSPF-PES	🗼 Scen 🐌 TablesIn	1/12/2016 11:59 A 1/12/2016 11:59 A	File folder File folder		
LocalData	👢 TablesOut	1/12/2016 11:59 A	File folder		
 MHC NHDPlus NLCD pcs Scenarios 1704010 	👢 TxtInOut	1/12/2016 11:59 A	File folder		
1 14/	▼	III			•
File name: Flo	ow_13027500.csv				_
Save as type: CS	V (MS-DOS) (*.csv)				_
Authors: Kee	ewook Kim	Tags: Add a tag			
Hide Folders		Tools	✓ Save	Cancel	

Sediment Data

10. To download sediment data at USGS Salt River ab Reservoir nr Etna WY gage station (13027500), click on http://cida.usgs.gov/sediment/#, which results in the following USGS webpage.



11. Within the "Boundary Filters" section, type the USGS gage station ID "13027500" for the "Basin Boundary", then click "Apply Filter".



12. A purple circle (highlighted with a red open circle in the picture below) will appear at the gage station's location. Click "Download Data".



13. The following prompt window appears in the browser.



14. Select "csv" for "File Format", check "Direct Download", and include your Email address in the text box for "Email Address". Click "Download Data".



15. A download prompt will appear in the browser, asking if you want to open or save a zip file.



16. Click , to the rig	sht of "s	Save", then select "Sav	e as".		
	,	Ay Lanu USe (%). Detween			
and and an dimension of all an		and			
s of 01-21-2016. Point size	Fore	Forest Land Use (%): between			
o years of available data.		and			
Site Legend					
		Save			
		Save as	- H-		
Open Save	• •	Save and open	-		
		N 100	70		

17. Here, the file is saved as

"C:\Temp\SDMProject\SaltRiverID\HUC8\Scenarios\17040105\Sediment.zip". The file can be saved with a different name in any other folder.

🐏 Save As						X
🚱 💮 🗕 📗 « OS (C:) 🕨	Temp > SDMProject > SaltRiverID > HUC8 >	Scenarios 🕨 1704010	05 🕨 👻	Search 17	7040105	Q
Organize 🔻 New folder					•	0
📙 Manitowoc_S 🔦	Name	Date modified	Туре	Size		
📙 SaltRiverID	Scen	1/12/2016 11:59 A	File folder			
L HUC8	Tablesin	1/12/2016 11·59 Δ	File folder			
👢 HSPF	TablesOut	1/12/2016 11:59 A	File folder			
HSPF-PES'	TublesOut	1/12/2010 11:55 A	File folder			
👢 huc12	 Txulout 	1/12/2010 11.35 A	File folder			
🐌 LocalData						
👢 met						
📙 NHDPlus						
👢 NLCD 🗮						
📙 pcs						
Scenarios						
1704010						
👢 Watershee						
📙 HUC8_0km 👻						
Filo namo: Sedime	ent zin					
The name. Second						
Save as type: zip Arc	hive (*.zip)					•
Hide Folders				Save	Cance	el

18. Once the ZIP file is extracted, two CSV files will appear in the folder.

📀 🕞 🗕 📗 « Temp 🕨 SDMF	Project 🕨 SaltRiverID 🕨 HU	IC8 🕨 Scenarios 🕨 170	40105 🕨 🔍	Search 17040105	Q
Organize 🔻 🔀 Open S	hare with 👻 Print Bi	urn New folder			• 🗌 🔞
L SaltRiverID	 Name 	<u>^</u>	Date modified	Туре	Size
L HUC8	👢 Scen		1/12/2016 11:59 A	File folder	
L HSPF-PEST	LablesIn		1/12/2016 11:59 A 1/12/2016 11:59 A	File folder File folder	
LocalData	👢 TxtInOut		1/12/2016 11:59 A	File folder	
👢 met	discrete_da	(a) discrete_data.csv	1/21/2016 11:31 A	Microsoft Excel Co	18 KB
NHDPlus	Flow_13027	/500.xlsx	1/21/2016 9:41 AM	Microsoft Excel W	32 KB
) pcs	≝ 📕 Sediment.zi	ip	1/21/2016 10:35 A	zip Archive	6 KB
L Scenarios					
Uatershed					
HUC8_0km	-				
2 items selected D	Date modified: 1/21/2016 11: Size: 20.9 KB	31 AM Date created	d: 1/21/2016 10:35 AM		

Nutrient Data

19. To download nutrient data at the USGS Salt River ab Reservoir nr Etna WY gage station (13027500), click <u>http://nwis.waterdata.usgs.gov/usa/nwis/qwdata</u>, and the following USGS webpage will appear.

nttp://nwis.waterdata.us	sgs.gov/t 🔎 👻 USGS Water Quali	ty Sampl ×		* ★
			USG Cont Seat	S Home tact USGS rch USGS
National Water Information	System: Web Interface			
ISGS Water Resources			Data Category: Geographic Area: Water Quality United States	✓ GO
 Click to hide News Bulletins August 8, 2013 Try our new <u>Mobile-friendly wat</u> New improved user interface. Full News 	ter data site from your mobile device!			
Nater Quality So ome complex retrievals may Choose Site Selection There are 404,868 sites wit	amples for the Na take a few minutes. n Criteria th water-quality data. Choose at	ation least one of the following criteri	a to constrain the number of site:	s
Nater Quality S ome complex retrievals may Choose Site Selection There are 404,868 sites wit selected.	amples for the Na take a few minutes. n Criteria th water-quality data. Choose at site	ation least one of the following criteri Site	a to constrain the number of site	s
Nater Quality S tome complex retrievals may Choose Site Selection There are 404,868 sites wit selected.	amples for the Na take a few minutes. n Criteria th water-quality data. Choose at Site Identifier	least one of the following criteri Site Attribute	a to constrain the number of site: Data Attribute *	s
Nater Quality S ome complex retrievals may Choose Site Selection There are 404,868 sites wit selected. Site Location © State/Territory © Hydrologic Region © Lat-Long box	Amples for the Na take a few minutes. In Criteria th water-quality data. Choose at Site vality data. Choose at Site Name Site Name Site Name Agency Code File of Site Numbers	least one of the following criteri Site - Attribute © Site type © Drainage area © Well depth © Hole depth © National aquifer (by code) © National aquifer (by name)	Data Attribute * Image: Number of observations Image: Period of record Image: Sample medium type Image: Parameter Codes Image: Pille of Parameter Codes Image: Parameter Codes<	5

20. Check "Site Number" under "Site Identifier" and "Parameter Codes" under "Data Attribute", and click "Submit".



21. The following screen will appear.



22. Place the USGS gage station ID (i.e., 13027500) in the blank for "Site Number"; place parameter codes "00060" for discharge, "00061" for instantaneous discharge, "00600" for total nitrogen, and "00665" for total phosphorus in the text box for "Parameter Codes"; and select "Sites must have at least one parameter code listed".



23. Scroll down, and select "Tab-separated data", then click "Submit". Ensure that pull-down menus are selected, as shown below.

	_ D X
(←) → 📓 http://nwis.waterdata.usgs.gov/ı 🔎 マ 🖒 📓 USGS Water Quality Sampl ×	☆★ ☆
*	
Retrieve samples for specified parameter values: (Parameter Code) Greater than (Numeric Value Samples and parameters to include: Samples that include only above parameter selection criteria (Count: 0) Samples that include above selection criteria and all associated parameters Samples that include above selection criteria plus one or more of these parameter codes separated by a comma (Limit: 20	e) 🔨
Samples that include above selection criteria plus one or more of these parameters in a file Enter the full pathname of a file containing parameter codes. (Limit: 200 codes) Browse	
Table of data <u>Leavur</u> attributes Yerry-MM-DD Save to file Save compressed files with a .gz file extension.	
Submit Reset Help	
Questions about sites/data? Dat Feedback on this web site Exx Automated retrievals Sut Help New	<u>a Tips</u> Janation of terms Jscribe for system changes <u>VS</u>
Accessibility Plug-Ins FOIA Privacy Policies and Notices <u>U.S. Department of the Interior U.S. Geological Survey</u> Title: Water Quality Samples for USA: Sample Data URL: http://nwis.waterdata.usgs.gov/nwis/qwdata?	USA.gov.
Page Contact Information: USGS Water Data Support Team	×
	₹ 100% ×

24. A download prompt will appear in the browser.

C SGS Water Quality Sampl ×	★★
*	
 Retrieve samples for specified parameter values: (Parameter Code) Greater than (Numeric Value) Samples and parameters to include: Samples that include only above parameter selection criteria (Count: 0) Samples that include above selection criteria and la associated parameters Samples that include above selection criteria plus one or more of these parameter codes separated by a comma (Limit: 2 Samples that include above selection criteria plus one or more of these parameters in a file Enter the full pathname of a file containing parameter codes. (Limit: 200 codes) 	ie)
O @ Table of data Default attributes	⊻ *
Submit Reset Help	
Questions about sites/data? Date Feedback on this web site Estimated Automated retrievals St Help Na	<u>ata Tips</u> «planation of term <u>s</u> "bscribe for system changes ews
Accessibility Plug-Ins FOIA Privacy Policies and Notices U.S. Department of the Interior U.S. Geological Survey Title: Water Quality Samples for USA: Sample Data URL: http://nwis.waterdata.usgs.gov/nwis/qwdata?	USA.gov.
Page Contact Do you want to open or save qwdata from nwis.waterdata.usgs.gov ? Open Save	▼ Cancel × >

25. Click , to the right of "Save", then select "Save as".



26. In this example, the file is saved as

"C:\Temp\SDMProject\SaltRiverID\HUC8\Scenarios\17040105\Nutrient_13027500.txt". The file can be saved with a different name in any other folder.

Save As					l	
	Temp SDMProject SaltRiverID HUC8	Scenarios + 1704010	05 🕨 👻 🗸	Search 170	040105	Q
Organize 🔹 New folder					•	0
🗼 Manitowoc_S 🔦	Name	Date modified	Туре	Size		
SaltRiverID HUC8 HSPF HSPF-PES huc12 LocalData met NHDPlus NLCD pcs Scenarios 1704010 Scen	 Scen TablesIn TablesOut TxtInOut discrete_data.csv discrete_sites.csv Flow_13027500.xlsx Sediment.zip 	1/12/2016 11:59 A 1/12/2016 11:59 A 1/12/2016 11:59 A 1/12/2016 11:59 A 1/21/2016 11:31 A 1/21/2016 11:31 A 1/21/2016 9:41 AM 1/21/2016 10:35 A	File folder File folder File folder Microsoft Excel Co Microsoft Excel W Zip Archive	18 KB 4 KB 32 KB 6 KB		
File name: Nutrier	nt_13027500.txt					-
Save as type: All Files	5 (*.*)					•
) Hide Folders				Save	Cance	el

27. Open "Nutrient_13027500.txt" in Excel, and save it as "Nutrient_13027500.csv".

PREPARING SWAT-CUP INPUT FILES FOR SWAT PARAMETER CALIBRATION

28. Parameter calibration will be performed using daily observations. For this, create a new folder (".\SWAT\"); in this case, it was created under "C:\Temp\SDMProject\SaltRiverID\HUC8\".

Computer •	US (C:) I emp SDMProject SaitRiverid	HUC8 Search HUC8	
Organize 🔻 [Open	Include in library Share with Burn	New folder	•
👢 SaltRiverID	Name	Date modified Type	Size
L HUC8	L HSPF	1/12/2016 9:59 AM File folder	
L HSPF	↓ HSPF-PEST	1/12/2016 8:26 AM File folder	
L HSPF-PEST	kuc12	1/12/2016 8:26 AM File folder	
huc12	👃 LocalData	1/12/2016 12:00 PM File folder	
LocalData	👢 met	1/12/2016 8:40 AM File folder	
	👢 NHDPlus	1/12/2016 8:32 AM File folder	
	🔲 👢 NLCD	1/12/2016 8:33 AM File folder	
	🗉 🗼 pcs	1/12/2016 8:31 AM File folder	
Scenarios	Scenarios	1/12/2016 11:59 A File folder	
SWAT	👢 SWAT	1/21/2016 1:42 PM File folder	
Watershed	👢 Watershed	1/12/2016 11:59 A File folder	
HUC8 0km	🐴 17040105.mdb	1/12/2016 11:59 A Microsoft Access	7,684 KB
	▼ (III	•
SWAT Date mo	dified: 1/21/2016 1:42 PM		

29. Move the following files, including observations, to

"C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT\". If you saved these files under different names, you should move them with your naming convention.

🚱 🕞 – 🖡 🕨 Computer 🕨 OS	(C:) ► T	emp + SDMProject + SaltRiverID + HUC8 + 1	SWAT 👻	Search SWAT	م م
Organize 👻 🔀 Open Sha	ire with 🔻	Print Burn New folder			• 🔳 🔞
👢 SaltRiverID	•	Name	Date modified	Туре	Size
HUC8		discrete_data.csv	1/21/2016 11:31 A	Microsoft Excel Co	18 KB
		discrete_sites.csv	1/21/2016 11:31 A	Microsoft Excel Co	4 KB
		Elow_13027500.csv	1/21/2016 1:23 PM	Microsoft Excel Co	124 KB
		Nutrient_13027500.csv	1/21/2016 1:29 PM	Microsoft Excel Co	623 KB
net					
NHDPlus					
NLCD	-				
👢 pcs					
👢 Scenarios					
17040105					
👢 SWAT					
👢 Watershed	-				
4 items selected Dat	e modifie Si	ed: 1/21/2016 11:31 AM Date created: 1/21/2 ize: 767 KB	2016 1:44 PM		

Generate a New SWAT-CUP Project

30. A new SWAT-CUP project must be generated, so open SWAT-CUP by double-clicking (left) on the icon. If the icon cannot be found on the Desktop screen, locate SwatCup.exe on the hard drive, typically in C:\SWAT\SWAT-CUP\.



31. The following SWAT-CUP window will appear.

mm 凹 つ CP 後 =	SWAT-CUP	×
Home Parallel Processing Utili Accut Undo Find Find Find Find Clear Paste Copy Select All Clear Edit Project Explorer	SWAT-CUP	- • ×
Rch 🕪 HRU 🕪 Sub		
Parallel Processing License Status: Limited		



32. At the top-left of the window, select " >New".

33. The "New Project Wizard" window will appear. Click "Next".



34. The screen below appears. SWAT input files are located at "TxtInOut Location"; this location must be specified, so click "Browse...".

New Project Wizard			×
Import a swat TxtInOut directory Please Browse a swat TxtInOut directory as d	ata source of your	project to import	Ś
TxtInOut Location:			Browse
	< Back	Next >	Cancel

35. A window like the following will appear.

TxtInOut Folder		X
Please choose a TxtInOut Folder		
Desktop Computer S Col: B De RE Drive (D:) Coll Disk (E:) Removable Disk (C:) Removable Disk (I:) Removable Disk (I:) Control Panel KKim KKim Network Recycle Bin Control Panel Network Recycle Bin Flow		
	Open Ca	incel

36. In this example, browse to

"C:\Temp\SDMProject\SaltRiverID\HUC8\Scenarios\17040105\TxtInOut\", then click "Open". Alternatively, browse to the location of previously created SWAT TxtInOut directory.

TxtInOut Folder	X
Please choose a TxtInOut Folder	
SDMProject BoiseRiverID Manitowoc_MET Manitowoc_NLDAS Manitowoc_SWAT SalRiverID SalRiverID HUC8 HSFF	*
HSPF-PEST huc12 LocalData met NLCD pcs Scenarios Scenarios Scen	III
TableSin TableSut IXTINOUT WAT Watershed IVAL Watershed IVAL HUC8_10km IVAL HUC8_15km IVAL HUC8_15km	Ţ
Open C	ancel

37. The SDMProjectBuilder was originally designed to prepare input files for SWAT 2005, but SWAT 2005 is also compatible with SWAT 2009; therefore, select "2009" for "SWAT Version" and "64-bit" for "Processor Architecture". "32-bit" can be selected, if using a 32-bit Operating System (OS). Click "Next". Note that SWAT input files generated by the SDMProjectBuilder are not compatible with SWAT2012.

New Project Wizard			X
SWAT Version Please choose the SWAT Version.			
SWAT Version: 2009 Processor Architecture: 64-bit			
	< Back	Next >	Cancel

38. The following window appears. There are different calibration algorithms that can be used within SWAT-CUP; for the purpose of this tutorial, we will only use Sufi2 for calibration of SWAT. Select "Sufi2" for "Project type". Details of project types in SWAT-CUP can be found in Abbaspour (2014). Click "Next".

New Project Wizard			X
Project Type Choose the calibration method for project			S G P M
Project type:		•	Help ?
	< Back Ne	ext > Ca	ncel

39. The following screen appears. Define "Project Name" (in this case, "SaltRiverHUC8"), and browse to the "Project Location" of "C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT\. SWAT-CUP generates a new folder with the "Project Name" in the "Project Location". Here, the project will be generated in "C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT\SaltRiverHUC8.Sufi2.SwatCup\". Click "Finish".

New Project Wizard			X
Project Name and Location Please choose the project name and location	n to create in		***
Project Name: SaltRiverHUC8 .Sufi2.Sw	ratCup		
C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT			Browse
	< Back	Finish	Cancel

40. SWAT-CUP will copy SWAT input files from the "TxtInOut" folder to the project folder. Depending on the size of the project, this could take minutes to hours. This example took only a few minutes.



41. After files have been copied, the project will appear in the SWAT-CUP window.



Prepare SWAT-CUP Input Files

42. SWAT-CUP input files need additional preparation, but must be copied from

"C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT-SWATCUP\" to

"C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT\"

- "SWAT_SWATCUP.exe"
- "Input_SWAT.in"
- "Update_par_inf.exe"

Descriptions of these and related files are provided in Table 2.

					_ D X
Computer OS (C:)	▶ Te	mp SDMProject SaltRiverID HUC8 SV	NAT 🕨 👻 🗸	Search SWAT	Q
Organize 🔹 🧳 Open Share w	/ith ▼	Burn New folder			
SaltRiverID	•	Name	Date modified	Туре	Size
		👢 SaltRiverHUC8.Sufi2.SwatCup	2/23/2016 4:15 PM	File folder	
		🔊 discrete_data.csv	1/21/2016 11:31 A	Microsoft Excel Co	18 KB
hus12		discrete_sites.csv	1/21/2016 11:31 A	Microsoft Excel Co	4 KB
		🐴 Flow_13027500.csv	1/21/2016 1:23 PM	Microsoft Excel Co	124 KB
met		Input_SWAT.in	3/8/2016 10:49 AM	IN File	4 KB
NHDDhue	=	Nutrient_13027500.csv	2/1/2016 11:21 AM	Microsoft Excel Co	32 KB
		SWAT_SWATCUP.exe	4/11/2016 3:14 PM	Application	61 KB
Dec.		Update_par_inf.exe	4/11/2016 3:23 PM	Application	20 KB
Scenarios					
SWAT					
Watershed					
	Ŧ	•	III		•
3 items selected Date m	odifie Siz	d: 3/8/2016 10:49 AM - 4/ Date created: 2/3/20: e: 83.4 KB	16 2:38 PM - 4/11/2016	3:32 PM	

Table 2.	Descriptions	of Selected Files
----------	--------------	-------------------

FILE	DESCRIPTION
	is the file used in the calibration process and contains ranges in
par_inf.txt	parameter values that are within acceptable minimum and maximum
	values
	contains suggested updated ranges in parameter values computed by
new_pars.txt	SWAT-CUP without considering whether the values are outside of the
	minimums and maximums defined in "Absolute_SWAT_Values.txt"
Absoluto SMAT Values tyt	identifies acceptable minimum and maximum value ranges for all SWAT
Absolute_SWAT_values.txt	parameters and is a part of SWAT-CUP
SWAT_SWATCUP.exe	prepares SWAT-CUP input files
	is a default input file of "SWAT_SWATCUP.exe", includes acceptable
Input_SWAT.in	ranges for calibration parameters (i.e., subset of
	"Absolute_SWAT_Values.txt"), and are the same as those included in
	"Absolute_SWAT_Values.txt"

Update_par_inf.exe	reads suggested parameter ranges, compares them to acceptable minimums and maximums, modifies suggested parameter ranges within acceptable bounds, and stores updated ranges in "par_inf.txt" for the next iteration
par_inf_init.txt	Is created by "Update_par_inf.exe", and stores the original acceptable ranges defined in "Input_SWAT.in" for use after the first calibration iteration

43. Save a copy of "Input_SWAT.in" to another folder for future use. Open "Input_SWAT.in" with a text editor, since it needs to be reviewed and updated. In this example, parameters for flow, sediment, and total phosphorus will be calibrated.

File Edit Format View Help1990!Simulation start year1995!Simulation end year1!# of years for model warm up1000!# of parameter setsFlow!Parameter group25!# of parametersCN2mgtrelativeCN2mgtrelativeSURLAGbsnreplaceALPHA_BFgwreplaceGW_REVAPgwreplaceGW_REVAPgwreplaceGWAREVAPgwreplaceGWAREVAPgwreplaceGWAREVAPgwreplaceGWAREVAPgwreplaceGUNNXhrureplaceO100GWAREVAPgwreplace0SUL_XC()solrelative-0.80.8BIOMIXmgtreplace0SUSUBSNhrureplace0SUL_X()solrelative-0.80.8REVAPNNgwreplace0STFMPbsnreplace0SWFMNbsnreplace0SWFMNbsnreplace0SWFMNbsnreplace0SWTMPbsnreplace0SWTMPbsnreplace0SWTMPbsnreplace0SWTMPbsnreplace0SWTMPbsn </th <th>📗 Input_SWAT.ir</th> <th>n - Notepad</th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th>X</th>	📗 Input_SWAT.ir	n - Notepad							X
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REVAPMNgwreplace0500EPCObsnreplace01SFTMPbsnreplace-2020SMFMNbsnreplace020SMFMXbsnreplace020SMTMPbsnreplace-2020	SOL_K()	sol	relative	-0.8	0.8				
EPCObsnreplace01SFTMPbsnreplace-2020SMFMNbsnreplace020SMFMXbsnreplace020SMTMPbsnreplace-2020	REVAPMN	gw	replace	0	500				
SFTMPbsnreplace-2020SMEMNbsnreplace020SMEMXbsnreplace020SMTMPbsnreplace-2020	EPC0	bsn	replace	0	1				
SMFMNbsnreplace020SMFMXbsnreplace020SMTMPbsnreplace-2020	SFTMP	bsn	replace	-20	20				
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ITMP DSN replace U I	TIMP	bsn	replace	U	1				~
	•								•
Ln 20, Col 39								Ln 20, Col 39	

44. Under the "Nutrient" parameter group,

- change "TNTP" in line 50 to "TP"
- remove parameters for nitrogen
- update the "# of parameters" to "13".

Save and close "Input_SWAT.in". Parameter definitions can be found in the SWAT Input/Output Documentation (Arnold et al., 2012) or in the "Absolute_SWAT_Values.txt" file, generated in the SWAT-CUP project folder.

🧾 Input_SWAT.in - N	otepad					X
File Edit Format	View Help					
LAT_SED RSDIN ADJ_PKR PRF_BSN USLE_C{1-121} USLE_P USLE_K() SPCON SPEXP CH_COV1	hru hru bsn plant.dat mgt sol bsn bsn rte	replace replace replace relative replace replace replace replace replace	0 0.5 0 -0.5 0 -0.8 0.0001 1 0.05	$5000 \\ 10000 \\ 2 \\ 0.5 \\ 1 \\ 0.8 \\ 0.01 \\ 1.5 \\ 0.6$		•
CH_COV2 Nutrient TP 13 PPERCO RSDCO PHOSKD P_UPDIS PSP BC4 ERORGP SOL_LABP() SOL_ORGP() SOL_CBN() BC1 BC2 RS3	rte !Param !TN or !# of bsn bsn bsn bsn bsn swq hru chm chm sol swq swq swq swq	replace TP TP replace replace replace replace replace replace replace replace replace replace replace replace replace replace replace replace replace	$\begin{array}{c} 0.001 \\ 10 \\ 0.02 \\ 100 \\ 0 \\ 0.01 \\ 0 \\ 0 \\ 0 \\ -0.5 \\ 0.1 \\ 0.2 \\ 0 \end{array}$	$ \begin{array}{c} 1\\ 17.5\\ 0.1\\ 200\\ 100\\ 0.7\\ 5\\ 100\\ 100\\ 0.5\\ 1\\ 2\\ 1\end{array} $		 ▲
					Ln 1, Col 1	444 444

SWAT-CUP input files are prepared by executing "SWAT_SWATCUP.exe" with its input file "Input_SWAT.in". "SWAT_SWATCUP.exe" prepares:

- A. A SWAT input file
 - Master watershed file (file.cio): Beginning year of SWAT simulation, number of years simulated, and number of years to skip output printing (model warm up period) are modified, as defined in "Input_SWAT.in". A description of "Input_SWAT.in" is provided in Appendix A. "Input_SWAT.in", the default input file of "SWAT_SWATCUP.exe", contains details for preparing SWAT-CUP input files, including:
 - i. Simulation start and end year
 - ii. Number of years for model warm up
 - iii. Number of parameter sets in each iteration for the parameter calibration process
 - iv. Parameter group name (i.e., Flow, Sediment, or Nutrient), number of parameters to be calibrated in each group, names of parameters to be calibrated in each group, and ranges.
- B. Seven SWAT-CUP input files
 - a. "SUFI2_swEdit.def": A file including starting and ending simulation numbers.
 - b. "SUFI2_extract_rch.def": A file defining how to extract modeling results for estimating the objective function (e.g., Nash-Sutcliffe statistic).
 - c. "par_inf.txt": A file defining the number and names of parameters to be calibrated and their ranges, and number of model runs for calibration.

- d. "observed.txt": A file including the objective function of the calibration, observed data, etc.
- e. "observed_rch.txt": A file including the number of observations and observed data in reaches.
- f. "var_file_name.txt": A file including all variable names in the estimation of the objective function.
- g. "var_file_rch.txt": A file including all variable names in reaches that should be included in estimation of the objective function.
- C. Input file for "Update_par_inf.exe"
 - a. "projectfolder.txt": Includes a name of the SWAT-CUP project folder.
- D. An extra output file
 - a. "observed_data.txt": Includes all observed data in the parameter calibration. This can be used for drawing graphs and parameter validation with another period.
- 45. In "C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT\", execute "SWAT_SWATCUP.exe" by doubleclicking on the icon. The Command window shown below will appear.
 - a. Type in the SWAT-CUP project folder name, where the SWAT-CUP project was generated: "SaltRiverHUC8.Sufi2.SwatCup". Press enter.
 - b. Type in "Flow_13027500.csv" for the flow observation file name. Press enter.
 - c. Type in "discrete_data.csv" and "Nutrient_13027500.csv" for sediment and nutrient observation file names, and press enter, respectively.

C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT\SWAT_SWATCUP.exe	x
SWAT-CUP project folder name? SaltRiverHUC8.Sufi2.Swatcup	
Flow observation file name? Flow_13027500.csv	1
Sediment observation file name? discrete_data.csv	
Nutrient observation file name? Nutrient_13027500.csv	
	-

46. The following screen will appear, but the "Reach number for the observed data" must first be determined for the observed data where the USGS gage is located, which will be determined by executing BASINS.



47. Without exiting the current screen, start BASINS from the BASINS 4.1 icon on the desktop:



48. At the "Welcome" window, choose "Open Existing Project".

Welcome to BASINS 4.1		×
	Build New Project View Documentation Open Existing Project 02060006	
Show this dialog at startup		

49. Navigate to the project folder (e.g., "C:\Temp\SDMProject\SaltRiverID\HUC8\), with the MapWindow project file (*.mwpj), and select "SaltRiver.mwprj". Click "Open".



50. The following screen will appear.

51. In the "Legend" section, highlight "Simplified Flowline".



52. From the Tool bar, click Identify, and select the stream line directly upstream from the USGS gaging station, as illustrated in the screen capture below.

0

BASINS 4.1 - SaltRiver				
File 👹 Watershed Delineation 👹 Com	pute 💐 Models 💐 Launch 💐 Analysis	Layer View Bookmarks	Plug-ins Shapefile Editor	Converters Help
New Open Save Print Settings	Add Remove Clear Symbology	Categories Query Properties	Table Select Desel	ect Measure Identify Label Mover
↔ Pan In Out Extent Selected Previou		• 🛃 🚵 🚓 ship s New Insert Add Ren	nove Copy Paste Merge Er	ase Erase beneath Move
Legend # ×			\wedge	
Layers Toolbox			and	
Land Use Index 📎 🌷		Section of	J J	
□ Managed Area Database		R Com		
C State Soil		Shing	12ml	
Simplified Flowline		7.		
Simplified Catchment		ods !!!	1 - h	
PV Area of Interest		Mr & /	Summer	
		n VIT	The second	
🗹 🗁 Observed Data Stations				
Hydrology		1 3F	-tomal	
Soil, Land Use/Cover			2) 2	
🗹 🗁 Hydrology-NHDPlus		13 12		
Political 👻		- All		
Preview Map 📮 🗙		and P	" in the second se	
		(Alle	All	
		1	NY J	
		Charlot I		
💟 unnamed 🔻 X: -1,213,209.977 Y: 2,325,80	51.314 Meters Lat: 43.062 Long: -111.038	(1:620223	.:

53. In the "Identify" window, read the value for "SWATSUB"; this is the reach number for the observed data.

Identify	[×
Shape Index	▼ 1 ▼]
Field Name	Field Value 🔺	
WID2	130.84658748346	
DEP2	2.8274296797312	
MINEL	1730	
MAXEL	1742	
SLO2	0.1104870638062	
SNAME	Salt River	
SWATSUB	2	
	v	

54. "SWAT_SWATCUP.exe" only works for a single outlet. If the user wants to include multiple outlets for parameter calibration, the user needs to manually modify SWAT-CUP input files (i.e., SUFI2_extract_rch.def, observed.txt, observed_rch.txt, var_file_name.txt, var_file_rch.txt). Close BASINS, then type in "2" in the Command window for the "Reach number for the observed data". Press enter.



55. Press ENTER to close the Command window.



Inspect SWAT-CUP Input Files

56. To inspect the SWAT-CUP input files prepared by "SWAT_SWATCUP.exe", activate reaches in SWAT-CUP window by clicking ^{SRCh} in the "Project Explorer" section.



57. Expand "Calibration Inputs" by clicking "+" at the left of "Calibration Inputs".



58. Sub-items of "Calibration Inputs" will be shown.



59. Among the sub-items within "Calibration Inputs", expand "Observation", "Extraction", and "Objective Function" by clicking the corresponding "+" signs.



60. Open "Par_inf.txt", "SUFI2_swEdit.def", "File.Cio", "Observed_rch.txt", "Var_file_rch.txt", "SUFI2_extract_rch.def", "Observed.txt", and "Var_file_name.txt" by double-clicking on the file names. The files will be shown in the main section of the SWAT-CUP window. They can be directly modified in the SWAT-CUP window, if desired. Details of the files can be found in the SWAT-CUP user manual (Abbaspour, 2014).

🚥 🖽 여 🛞 📼			Pai	rameterizatio	on SaltRi	verHUC8.Sufi	2 - SWAT-C	UP						_ = ×
Home Parallel Processing Utility	Program	ns	Layout Pa	rameterizatio	n									^ Ø
Paste X Cut Select All Clar Bookn K Delete Select All Clar Bookn Fdit	okmark s Bookma narks	ark 1	Save All Save All Add par	a new Inser ameter para	tanew I ameter F	mport New Parameters								
Paris et Fardance	D D:	er inf	tyt x			File Cie	Obconvod re	h ht	- Nar	file, reh bet		CUED ovtract	ch dof	
Project Explorer		Pa c	r_inf.txt	ameters to be	optimized.	After a comple	te iteration, re	eview the	suggested	new param	eters in	the "Calibration O	utputs \ new	_pars.bd",
Par_inf.bt SUFI2_swEdit.def File.Clo	Numb	er Of F 49 (neters:	Parameters Numb	per Of Simulat 100	ions: 0 ‡									
Absolute_SWAT_Values.txt			Pasic Info	rmation		Nalue			Filter	Conditions	(option	al)		
🙀 Observed_rch.txt		#	Par Name	File Name	File Ext.	Method	Min	Max	Hydro Grp	Soil Text	Land	Subbasins	Slope	Condition
🔂 Observed_hru.bd	•	1	CN2		.mgt	1 Relative	-0.2	0.2				(All)		
Observed_sub.bt		2	ESCO		.bsn	V Replace	0	1				(All)		
Extraction		3	SURLAG		.bsn	V Replace	0.05	24				(All)		
🙀 Var_file_rch.txt		4	ALPHA_BF		.gw	V Replace	0	1				(All)		
🙀 Var_file_hru.bt		5	GW_REVAP		.gw	V Replace	0.02	0.2				(All)		
		6	CH_N2		.rte	V Replace	0	0.3				(All)		
🖓 SUFI2_extract_rch.def		7	CH_K2		.rte	V Replace	0	500				(All)		
		8	CANMX		.hru	V Replace	0	100				(All)		
Var_file_name.txt		9	GWQMN		.gw	V Replace	0	5000				(All)		
This file contains the names of all the variables that should be included in the in the objective function. These names are similar to the names in the	1 Tex	10 dt View	SOL AWC		.sol	I Relative	-0.8	0.8				(AII)		· · · · · · · · · · · · · · · · · · ·
Parallel Processing License Status: Limited SWAT Ver	rsion: 20	09, Pro	ocessor Architectu	ure: 64-bit								100%	Э ()

CALIBRATING SWAT PARAMETERS WITH SWAT-CUP

Calibration, Iteration 1

61. Go to the "Home" tab in the SWAT-CUP window, and click the "Calibrate" button.

eur 💾	500	ā, -				Parameterization	SaltRiver	HUC8.Sufi2	- SWAT-C	UP					_ - ×
	Home	Paralle	Processing	Utility Programs	Layout	Parameterization	7								∧ Ø
(m)	X Cut	🔊 Undo	🧇 Find	Rext Bookmark	💾 Save					-	1			4	
	🖷 Сору	🌈 Redo	ab Hac Replace	Revious Bookmark	哈 Save A	н 🏾 🍑	9	W	(FC		V			2	
Paste	🗱 Delete	Select All		Clear Bookmarks		Calibrate Sa	ive Iteration	Validate	Print Preview	Advanced Writing	All	Help	About	License and Activation •	
			Edit			Calibrat	ion - Valida	tion	Print	Tools	Window		He	р	

62. The following "Execute Calibration" window will appear. Click "Execute all".



63. A command window will appear. Type "y", then press enter.



64. When the following prompt windows appear in sequence, click "OK".



65. Execution of SWAT-CUP will begin, and it will run SWAT with multiple parameter sets in the following window.



66. This execution may take hours to days depending on the project (e.g., number of HRUs, subbasins, years for simulation, etc.). Once complete, the following prompt window will appear. Click "OK".



67. On the next prompt window, click "OK".



68. SWAT-CUP will perform post processing, including calculating the objective function (i.e., Nash-Sutcliffe statistic), parameter range for the next iteration, etc.

SUFI2	_post.ba	t		x
255	NS=	-10.424198		
256	NS=	-0.841008		
257	NS=	-0.839705		
258	NS=	-0.791637		
259	NS=	-0.832170		
260	NS=	-0.823107		
261	NS=	-0.745404		
262	NS=	-0.869770		
263	NS=	-0.772260		
264	NS=	-0.852318		
265	NS=	-0.799210		
266	NS=	-0.853272		
267	NS=	-0.835671		
268	NS=	-1.221882		
269	NS=	-0.893478		
270	NS=	-0.750147		
271	NS=	-0.826394		
272	NS=	-0.780345		
273	NS=	-0.845186		
274	NS=	-0.851770		
275	NS=	-0.858618		
276	NS=	-0.859746		
277	NS=	-0.946346		=
278	NS=	-0.807311		
279	NS=	-0.756194		
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69. Upon completion, the following prompt window will appear. Click "OK".



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70. The main SWAT-CUP window appears with a prompt window. Click "Yes".

71. The following window appears. In this example, "Iteration Name" is "Calibration_01". Click "Ok", and save.

Save New Iteration
Iteration Name: Calibration_01
Ok Cancel

72. The first iteration of the parameter calibration is complete. To view results, open "Iteration History>Calibration Outputs>Summary_Stat.txt" in the "Project Explorer" section by double-clicking on "Summary_Stat.txt".



73. The file will open to the SWAT-CUP window. In the "Summary_Stat.txt", results of the best objective function for the SWAT simulation are shown for each variable. Other goodness-of-fit statistics are also indicated in the file.



74. Results of the goodness-of-fit statistics do not indicate good performance of the SWAT model: -0.52, -0.03, and 0.04 of Nash-Sutcliffe for flow, sediment, and total phosphorus, respectively. Because Iteration 1 may not be acceptable, additional calibrations iterations may be required.

A summary of key folder locations associated with the example calibration is presented in Table 3.

FILE	FOLDER LOCATION
par_inf.txt	C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT\SaltRiverHUC8.Sufi2.SwatCup\SUFI2.IN\
New_pars.txt	C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT\SaltRiverHUC8.Sufi2.SwatCup\SUFI2.OUT\
Absoluto SWAT Values tyt	C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT\SaltRiverHUC8.Sufi2.SwatCup\
Absolute_SWAT_Values.txt	[Note that this file is a part of SWAT-CUP.]
	C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT\
SWAT SWATCHE ave	[Note that this file is included with the SDMPB install and copied to
SWAT_SWATCOP.exe	C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT-SWATCUP\
	when a new SDMPB project is generated.]
	C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT\
Input SMAT in	[Note that this file is included with the SDMPB install and copied to
input_SWAT.in	C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT-SWATCUP\
	when a new SDMPB project is generated.]
	C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT\
Lindata par inflova	[Note that this file is included with the SDMPB install and copied to
opuate_par_ini.exe	C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT-SWATCUP\
	when a new SDMPB project is generated.]
	C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT\SaltRiverHUC8.Sufi2.SwatCup\SUFI2.IN\
par_inf_init.txt	[Note that this file is generated by "Update_par_inf.txt", when it is executed after the first
	iteration.]

Table 3. Folder Locations of Key Files for this Example Calibration

Additional Calibration Iterations

75. To improve performance statistics, additional calibration iterations can be implemented by repeating steps outlined previously for calibration Iteration 1. With new iterations, parameter ranges, which can be supplied by SWAT-CUP, must be updated. To view, open "Iteration History>Calibration_01>Calibration Outputs>New_pars.txt" in the "Project Explorer" section by double-clicking the name.



76. The file will open to the SWAT-CUP window.

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Utility Programs	This file shows the suggested values of the new parameters to be used in the next iteration. These values can be copied and pasted in the Property par_no · · · · par_name · · · · new_min · · · · new_max	ar_inf.bxt file for
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	r_SOLAWC().sol -0.881258 0.239658 v_BIOMIX.mgt -0.344785 0.551785 r_SLSUBBSN.hru -1.202858 0.132458	
Summary_Stat.	v GW DELAY.gw 46.894535 315.652466 v SOL_K().sol -0.330058 0.610058 v REVAPMN.gw 231.857285 695.642700	
New_pars.txt This file shows the suggested va	v EPCO.bsn -0.016517 0.661207 v SFTMP.bsn -0.151419 39.551414 v SMFMN.bsn 0.904300 13.635700	
next iteration. These values can copied and pasted in the Par_inf	v SMFMX.bsn 1.804294 13.935705 bt file v SMTMP.bsn -4.111421 27.671419	•
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Because SWAT-CUP does not consider acceptable minimum and maximum values identified in par_inf_init.txt (which contains the same ranges as in "Absolute_SWAT_Values.txt") when it suggests ranges in "New_pars.txt", those ranges must be reviewed and revised, then copied to "par_inf.txt" for use in the calibration. For example, in the above window, the new range for "ALPHA_BF" is calculated as -0.43 - 0.52, and the acceptable range is 0 - 1. In this case, the new range needs to be revised to 0 - 0.52. Although these ranges can be modified manually by copying the revised ranges to "par_inf.txt" (located in "C:\Temp\SDMProject\SaltRiverID\HUC8\SWAT\SaltRiverHUC8.Sufi2.SwatCup\SUFI2.IN\"), a module ("Update_par_inf.exe") has been developed to automatically check and revise ranges and copy them to "par_inf.txt" for use in the calibration process.

77. Execute "Update_par_inf.exe". The Command window below appears. Press "Enter" to exit.



78. Updated parameter ranges in "Par_inf.txt" can be checked by opening the file in the SWAT-CUP window.

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- 79. For additional iterations, repeat steps outlined in "Calibration, Iteration 1" until the desired objective function (e.g., Nash-Sutcliffe statistic) is obtained. A summary of calibration steps is presented in Table 4. For this example, flow, sediment, and nutrient have been calibrated simultaneously, so there is only one calibration with 10 iterations.
- 80. This example performed 10 iterations, and a summary of the results for the 10th iteration can be found in "Iteration History>Calibration_10>Calibration Outputs>Summary_Stat.txt"



Table 4. Summary of Calibration Steps

CALIBRATION 1

- 1. Manually update "Input_SWAT.in" with a text editor
- 2. Execute "SWAT SWATCUP.exe"

First iteration of calibration 1

- 3. Go to the "Home" tab in the SWAT-CUP window and click "Calibrate" button.
- 4. Click the "Execute all" button.
- 5. Answer command line questions and prompt windows
- 6. Save first iteration of calibration 1
 - When the iteration is saved, it copies files (file.cio, SUFI2_extract_rch.def, etc.) from the SWAT-CUP project folder and subfolders (".\SUFI2.IN\" and ".\SUFI2.OUT\") to the ".\Iterations\(*Iteration Name*)\" folder. Saved files for the first and subsequent iterations are different. For example, parameter ranges in "par_inf.txt" are different, and resulting files in .\SUFI2.OUT\ are different.
- 7. Execute "Update_par_inf.exe", where the first iteration is based on the original "par_inf.txt" (i.e., prior to modification), and the following automated steps (i.e., invisible to the user) occur:
 - reads "new_pars.txt"

- reads the original "par_inf.txt" file [For the first iteration, parameter ranges are the same as those in "Input_SWAT.in".]
 saves the "par_inf.txt" ranges to "par_inf_init.txt". [This only happens after the first iteration, so "par_inf_init.txt" records possible parameter ranges throughout the iterations for this calibration cycle.]
- compares new ranges with acceptable ranges
- updates new ranges in "par_inf.txt"

Second iteration of calibration 1

- 8. Go to the "Home" tab in the SWAT-CUP window and click the "Calibrate" button.
- 9. Click the "Execute all" button.
- 10. Answer command line questions and prompt windows
- 11. Save second iteration of calibration 1
- 12. Execute the "Update_par_inf.exe"; the following automated steps (i.e., invisible to the user) occur:
 - reads "new_pars.txt"
 - reads "par_inf_init.txt" to obtain the possible ranges. [Note that ranges in "par_inf_init.txt" and "Input_SWAT.in" are the same].
 - compares new ranges with acceptable ranges
 - updates the new ranges in "par_inf.txt"

Third iteration of calibration 1

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Tenth iteration of calibration 1

etc.

[Note: The total number of iterations depends on goodness-of-fit statistics]

CALIBRATION 2

- 13. Update "Input_SWAT.in" manually with a text editor
- 14. Execute "SWAT_SWATCUP.exe"

First iteration of calibration 2

- 15. Go to the "Home" tab in the SWAT-CUP window and click "Calibrate" button.
- 16. Click "Execute all" button.
- 17. Answer command line questions and prompt windows
- 18. Save the first iteration of calibration 2
- 19. Execute "Update_par_inf.exe" (see Step 7)

Second iteration of calibration 2

- 20. Go to the "Home" tab in the SWAT-CUP window and click "Calibrate" button.
- 21. Click the "Execute all" button.
- 22. Answer command line questions and prompt windows
- 23. Save the second iteration of calibration 2
- 24. Execute "Update_par_inf.exe"(see Step 12)

Third iteration of calibration 2

- •
- •
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- 81. After the 10th iteration, Nash-Sutcliffe statistics have improved to 0.38, 0.46, and 0.53 for flow, sediment, and total phosphorus, respectively. This example calibrates the three parameters simultaneously to illustrate the calibration process. It is strongly recommended to calibrate parameters for flow, sediment, and nutrients separately when performing SWAT parameter calibrations. Appendix B provides example "Input_SWAT.in" files for independent calibrations of flow, sediment, and nutrients. One can modify "Input_SWAT.in" and repeat steps outlined in "Calibration, Iteration 1" and "Additional Calibration Iterations". Additional calibration steps are summarized in Table 4, including steps for Calibrations 2 and 3.
- 82. The parameters sets with the best Nash-Sutcliffe statistic can be found in "Iteration History>Calibration_10>Calibration Outputs>Best_Par.txt".

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83. A comparison of observations and simulations can be found in History>Calibration_10>Calibration Outputs>Best_Sim.txt". No specific software can generate plots for SWAT modeling results. One may import the results to BASINS and generate plots, similarly to those reported by Kim et al. (2016c), or use spreadsheet software such as Microsoft Excel.

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DISCLAIMER

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APPENDIX A Details of "SWAT_SWATCUP.exe" and "Input_SWAT.in"

The purpose is to provide details of the FORTRAN code for preparing SWAT parameter calibration with SWAT-CUP (i.e., SWAT_SWATCUP.exe). "SWAT_SWATCUP.exe" is designed to

- consume data from observation files downloaded by the user and the user input file "Input_SWAT.in"
- modify the SWAT input file "file.cio"
- prepare SWAT-CUP input files (i.e., SUFI2_swEdit.def, SUFI2_extract_rch.def, par_inf.txt, observed.txt, observed_rch.txt, var_file_name.txt, var_file_rch.txt) and an extra file including observed data with missing values (i.e., observed_data.txt).

Input files include:

- Observed data for flow, sediment, or nutrient for the parameter calibration, downloaded by user. The user must download data as instructed in this document. The time series in this file can include missing data.
- A User input file ("Input_SWAT.in") containing information for generating SWAT-CUP input files

change	lower	upper
change	lower	upper
	change change	change lower change lower

Figure A.1. Construction of user input file ("Input_SWAT.in")

Figure A.1 presents the format of the "Input_SWAT.in". Descriptions of input data are:

- startyear: simulation start year including model warm-up period
- endyear: simulation end year
- *ny_warm*: number of years for model warm-up from start of the simulation (i.e., *startyear*)
- *nparaset*: number of parameter sets to be generated by SWAT-CUP for parameter calibration
- paragroup: name of parameter group, which needs to be defined as "Flow", "Sediment", or "Nutrient"

- *(TNTP)*: names of nutrient to be calibrated ("TN", "TP", or "TNTP" for total nitrogen, total phosphorus, or both, respectively). This variable is only needed when the *paragroup* is "Nutrient". With another *paragroup* (Flow or Sediment), the line including *TNTP* must be removed.
- *npara*: number of parameters to be calibrated in the corresponding *paragroup*
- *para*: name of each parameter. Names can be identified from the SWAT input/output documentation (Arnold et al., 2012) or "Absolute_SWAT_Values.txt", generated in the SWAT-CUP project folder.
- *parafile*: extension of SWAT input file where the corresponding parameter will be located. The file extension can be identified from SWAT input/output documentation (Arnold et al., 2012) or "Absolute_SWAT_Values.txt".
- *change*: a variable that defines how parameter values should be changed. SWAT-CUP supports three change types: replace, relative, and additive. Among these, "SWAT_SWATCUP.exe" only supports two types: replace and relative, excluding additive change type; therefore, one of the following variables must be selected:
 - replace: parameter value is replaced
 - relative: parameter value is changed proportionally to the original value in the SWAT input file. This is generally done if the parameter is defined differently by landuses, soils, subbasins, etc.
- *lower* and *upper*: minimum and maximum values of each parameter used in the calibration process. Parameter ranges can be identified from "Absolute_SWAT_Values.txt".

Figure A.2 illustrates an example user input file "Input_SWAT.in". It defines three parameter groups for simultaneously calibrating flow, sediment, and nutrients (TN and TP for total nitrogen and total phosphorus, respectively). The following assumptions apply when constructing the file:

- A daily time step is assumed for calibrating parameters with observed data.
- Instantaneous observations of constituent concentrations are assumed to represent daily values.
- Instantaneous flow observation are used to estimate daily constituent loadings from concentrations. Daily flow observations always have to be prepared even when flow parameters are not calibrated. For example, when only sediment or nutrient parameters are calibrated, "SWAT_SWATCUP.exe" always asks for the flow observation file.
- To obtain total number of reaches in the SWAT project, software reads "fig.fig". The SWAT input file "fig.fig" defines channel connectivity and provides the total number of reaches.
- The objective function for parameter calibration uses the Nash-Sutcliffe Modeling Efficiency. The objective function can be modified through the "observed.txt" file.

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GW REVAI	e gw	replace	0.02	0.2
CH N2	rte	replace	0	0.3
CH K2	rte	replace	0	500
CANMX	hru	replace	0	100
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SPCON	bsn	replace	0.00	0.0
SPEXP	bsn	replace	1	1.5
CH_COV1	rte	replace	0.05	0.6
CH_COV2	rte	replace	0.001	1
	ID			
Nutrient	!Parame	ter group		
TNTP	!TN or	TP		
7	!# of pa	arameters		
CMN	bsn	replace 0.	001	0.003
CDN	bsn	replace 0		3
NPERCO	bsn	replace 0		1
PPERCO	bsn	replace 10		17.5
SDNCO	bsn	replace 0		1
RSDCO	bsn	replace 0	.02	0.1
PHOSKD	bsn	replace 10	00	200

Figure A.2. Example user input file ("Input_SWAT.in"), which defines the three parameter groups for calibrating flow, sediment, and nutrient (TN and TP) parameters simultaneously

APPENDIX B

Example "Input_SWAT.in" Files for Independen	t Calibrations of Flow, Sediment, and Nutrients
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🧾 Input_SWAT.in - N	lotepad	_ D X
File Edit Format	View Help	
1990 1995 1	!Simulation start year !Simulation end year !# of years for model warm up	^
1000	!# of parameter sets	
Flow 25 CN2 ESCO SURLAG ALPHA_BF GW_REVAP CH_N2 CH_K2 CANMX GWQMN SOL_AWC() BIOMIX SU_SUBBSN GW_DELAY SOL_K() REVAPMN EPCO SFTMP SMFMN SMFMN SMFMN SMFMN SMFMN SMFMN SMFMN SMFMN SMFMN SMFMN SMFMN SMFMN SMFMN SMFMN SMFMN SMFMN SMFMN SMFMN SMFMN SMFMD TIMP TLAPS SLSOIL SOL_ALB() RCHRG_DP	!Parameter group !# of parameters mgt relative -0.2 0.2 bsn replace 0.01 1 bsn replace 0 1 gw replace 0 1 gw replace 0 24 gw replace 0 1 gw replace 0.02 0.2 rte replace 0 0.3 rte replace 0 500 hru replace 0 500 sol relative -0.8 0.8 gw replace 1 450 sol relative -0.8 0.8 gw replace 0 500 bsn replace 0.01 1 bsn replace 0 20 bsn replace 0 20 bsn replace 0 1 sub replace 1 10 hru replace 0 150	
4		
		Ln 1, Col 1

Figure B.1. Example user input file ("Input_SWAT.in"), which defines the setup of Flow for calibration

🗾 Input_SWAT.in - Notepad	
File Edit Format View Help	
1990 !Simulation start year 1995 !Simulation end year 1 !# of years for model warm up	^
1000 !# of parameter sets	
Sediment IParameter group 11 I# Of parameters LAT_SED hru replace 0 5000 RSDIN hru replace 0 10000 ADJ_PKR bsn replace 0 2 USLE_C{1-108} crop.dat relative -0.5 0.5 USLE_P mgt replace 0 1 USLE_K() sol relative -0.8 0.8 SPCON bsn replace 1 1.5 CH_COV1 rte replace 0.05 0.6 CH_COV2 rte replace 0.001 1	*
•	4
	Ln 1, Col 1

Figure B.2. Example user input file ("Input_SWAT.in"), which defines the setup of Sediment for calibration

Input_SWAT.in - N	Notepad							x
File Edit Format	View Help							
1	1# 0	f voars for m	odol warm	up				
1	:# 0	i years for m	ouer warm	up				^
1000	!# o	f parameter s	ets					
Nutrient TNTP 26 CMN CDN NPERCO PPERCO PPERCO SDNCO RSDCO PHOSKD N_UPDIS P_UPDIS P_UPDIS P_UPDIS P_UPDIS PSP BC3 RS4 BC4 ERORGN ERORGN ERORGN ERORGP SOL_ORGN() SOL_ORGP() SOL_ORGP() SOL_CBN() BC1 BC2 RS3 CH_ONCO LAT_ORGN HLIFE_NGW	<pre>!Par: !TN !# of bsn bsn bsn bsn bsn bsn bsn bsn bsn bsn</pre>	ameter group or TP f parameters replace	$\begin{array}{c} 0.001\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\$	$\begin{array}{c} 0.003\\ 3\\ 1\\ 17.5\\ 1\\ 0.1\\ 200\\ 100\\ 100\\ 100\\ 0.7\\ 0.4\\ 0.1\\ 0.7\\ 5\\ 5\\ 100\\ 100\\ 100\\ 100\\ 100\\ 100\\ 10$				
								~
•								•
						Ln 1,	Col 1	.41

Figure B.3. Example user input file ("Input_SWAT.in"), which defines the setup of Nutrients for calibration