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Abstract

The Mississippi River Basin Healthy Watersheds Initiative (MRBI) program launched by the USDA Natural Resources Conservation Service (NRCS) aims to improve the water quality within the Mississippi River Basin. Lake Conway Point Remove (LCPR) watershed, being one of the MRBI watersheds, is a potential candidate for evaluating the effectiveness of MRBI program. Recommended best management practices (BMPs) for LCPR watershed are pond, wetland, pond and wetland, cover crops, vegetative filter strips, grassed waterways, and forage and biomass planting. Before simulating these practices, it is essential to prepare the data needed for model setup to avoid the issue of garbage in, garbage out. This chapter focuses on detailed steps of preparing the data for model setup along with the calibration and validation of the model. The calibration and validation results were within the acceptable bounds. The results from this study provide the data to help simulate the MRBI best management practices effectively and prioritize monitoring needs for collecting watershed response data in LCPR.

Keywords: best management practices, modeling, water quality, SWAT, MRBI

1. Introduction

The Mississippi River Basin Healthy Watersheds Initiative (MRBI) program aims at implementing best management practices (BMPs) to control water quality. Quantifying the impacts of BMPs is important to demonstrate the worth of the MRBI program. Out of various MRBI-selected watersheds, the Lake Conway Point Remove (LCPR) watershed is the one listed in the 2011–2016 priority watershed by the Arkansas Natural Resources Commission (ANRC) [1, 2].
Field studies can be laborious and time-consuming; therefore, watershed modeling technique is generally used for analyzing the effects of BMPs on water quality. The Soil and Water Assessment Tool (SWAT, [3]) model was selected for this study. The SWAT model has been widely applied across the globe to assess the impact of various BMPs [4]. SWAT has also been applied to various watersheds in Arkansas—L’Anguille River Watershed [5, 6], Cache River Watershed [7], and Illinois River Watershed [8]. SWAT allows modifications of various parameters to simulate BMPs [9] and was applied at various spatial and temporal scales [10]. SWAT has been used to simulate impacts of land uses and BMPs [11, 12], develop maximum daily load plans [13, 14], and evaluate impacts on water quality [15, 16]. However, before simulating BMPs, it is essential to acquire and process the data needed for setting up a good model.

The goal of this chapter is to describe the steps in detail for acquiring and processing the data needed to set up, calibrate, and validate the SWAT model for the LCPR watershed.

2. Methodology

2.1. Study area

The Lake Conway Point Remove (LCPR) watershed is a 2950 km$^2$ (1140 miles$^2$) watershed located in central Arkansas within the counties of Conway, Faulkner, Perry, Pope, Pulaski, Van Buren, and Yell (Figure 1). The watershed has mixed land uses of forest, pasture, urban, and...
cropland. An increase in urbanization, in parts of the watershed, has occurred since 1999. The subwatersheds within LCPR along with the area and hydrological unit codes (HUC) can be seen in Table 1.

2.2. Data preparation

The objective of this task was to collect and organize all data needed for the SWAT model setup at a 12-digit hydrological unit code within the LCPR watershed. Geospatial, watershed management,

| Subwatershed | Subwatershed name                                      | Area (km²) | HUC no.     |
|--------------|--------------------------------------------------------|------------|-------------|
| 1            | Trimble creek-west fork point remove creek             | 77.0       | 111102030102|
| 2            | Brock creek                                           | 113.1      | 111102030101|
| 3            | Devils creek-west fork point remove creek              | 88.2       | 111102030107|
| 4            | Barns branch-east fork point remove creek             | 102.7      | 111102030204|
| 5            | Galla creek                                           | 118.0      | 111102030303|
| 6            | Whig creek-Arkansas river                             | 106.3      | 111102030302|
| 7            | Mountain view-east fork point remove creek            | 97.8       | 111102030201|
| 8            | Upper clear creek                                     | 120.4      | 111102030103|
| 9            | Rock creek-west fork point remove creek               | 156.2      | 111102030105|
| 10           | Sunny side creek-east fork point remove creek         | 100.9      | 111102030202|
| 11           | Lower dear creek                                      | 106.5      | 111102030104|
| 12           | Prairie creek-east fork point remove creek            | 106.9      | 111102030203|
| 13           | Gum log creek                                         | 130.4      | 111102030106|
| 14           | Portland bottoms-Arkansas river                       | 90.9       | 111102030503|
| 15           | Headwaters rocky Cypress creek                        | 100.1      | 111102030501|
| 16           | Jim creek-Palarm creek                                | 92.4       | 111102030402|
| 17           | Little creek-Palarm creek                             | 106.8      | 111102030403|
| 18           | Beaverdam creek-Arkansas river                        | 88.0       | 111102030507|
| 19           | Little Palarm creek-Palarm creek                      | 89.9       | 111102030405|
| 20           | Taylor creek-Arkansas river                           | 65.1       | 111102030506|
| 21           | Tupelo bayou                                          | 110.8      | 111102030505|
| 22           | Outlet rocky Cypress creek                            | 70.5       | 111102030502|
| 23           | Pierce creek-Palarm creek                             | 100.0      | 111102030404|
| 24           | Little cypress-Palarm creek                           | 53.4       | 111102030401|
| 25           | Overcup creek                                         | 81.1       | 111102030205|
| 26           | Khun Bayou-Arkansas River                             | 131.1      | 111102030304|
| 27           | Long Lake-Harris creek                                | 148.2      | 111102030301|
| 28           | Point remove creek                                    | 80.2       | 111102030206|
| 29           | Miller Bayou-Arkansas river                           | 116.4      | 111102030504|

Table 1. List of HUC 12 subwatersheds and area in LCPR watershed.
water quantity, and point source data that were available and usable at the time of modeling were collected and reorganized in a consistent format for use in the SWAT model.

2.2.1. Elevation

The elevation dataset was retrieved at a 5 m resolution from GeoStor. This 5 m dataset was resampled to a 10 m resolution to reduce the size of huge files and increase the computation efficiency. The elevation map for LCPR can be seen in Figure 2.

2.2.2. Soils

The soil data were acquired from the Soil Survey Geographic (SSURGO) database for all LCPR counties in Arkansas and combined to make a soil map for the entire watershed. The SSURGO is the most comprehensive and detailed soil dataset available for LCPR. The soil map for LCPR can be seen in Figure 3.

![Figure 2. Lake Conway-Point Remove watershed elevation.](image)
2.2.3. Land use/land cover

Land use and land cover data were acquired for 1999, 2004, and 2006 from GeoStor. Forest area was observed to be the most dominant land use and cover in the LCPR watershed. All land use and land covers were reclassified to make it compatible with the SWAT model. The land use and land cover map for LCPR can be seen in Figure 4.

2.2.4. Climate

Climatic data specifically daily precipitation and maximum and minimum temperature data were obtained from 90 climate stations from the NOAA’s National Climatic Data Center (NCDC). Data are available from 1980 to 2012 for at least one of the climatic parameters. The procedure recommended by USDA-ARS in developing SWAT-formatted climate data were followed. Daily climate data were obtained using an inverse distance-weighted interpolation algorithm. The average data were calculated for each subwatershed using a pseudo-weather

Figure 3. Soil map of Lake Conway Point Remove watershed, Arkansas, showing major soil series.
station. NCDC validation results at each calibration station using leave-one-out cross-validation technique can be seen in Table 2. NEXRAD data were obtained from the Arkansas Basin River Forecasting Center (ABRFC).

2.2.5. Streamflow

The flow data are available for the West Fork Point Remove Creek near the Hattieville monitoring station from the US Geological Survey (USGS). This monitoring station is located in subwatershed 3 and covers approximately 20% of LCPR. The flow data were split between surface and baseflow using the baseflow filter program by [17].

2.2.6. Point sources

Point source data were obtained from the Arkansas Department of Environmental Quality (ADEQ) and was processed in the SWAT-compatible format. Point source data were available for flow, total suspended solids, organic nitrogen, organic and mineral phosphorus, nitrate nitrogen, ammonia nitrogen, and carbonaceous biochemical oxygen demand (CBOD). Locations for active point source facility that was incorporated in the SWAT model can be seen in Table 3.
2.2.7. Cattle grazing, manure deposition, and poultry litter application

The detailed method for estimating pastures that should be receiving litter applications can be seen below.

| Station                          | Parameter | DRAIN | DNO_RAIN | ME | d | PBIAS | R² | NSE | MAE | RMSE |
|---------------------------------|-----------|-------|----------|----|---|-------|----|-----|-----|------|
| Center Ridge, 4.5, AR, USA      | PRCP      | 0.94  | 0.66     | 0.12| 0.95| -0.3  | 0.83| 0.63| 15.48| 45.03|
| Conway, AR, USA                 | PRCP      | 0.91  | 0.79     | -0.64| 0.87| -1.9  | 0.59| 0.58| 23.53| 63.56|
| Dardanelle, AR, USA             | PRCP      | 0.95  | 0.79     | 0.51 | 0.83| 1.5   | 0.54| 0.52| 24.55| 71.4 |
| Hattiesville, AR, USA           | PRCP      | 0.95  | 0.82     | 0.08 | 0.92| 0.2   | 0.74| 0.73| 18.13| 57.15|
| Morrilton, AR, USA              | PRCP      | 0.90  | 0.82     | 0.97 | 0.9  | 2.8   | 0.69| 0.68| 19.84| 59.78|
| North Little Rock Airport, AR, USA | PRCP    | 0.90  | 0.81     | 0.23 | 0.83| 0.7   | 0.56| 0.55| 24.37| 69.37|
| Perry, AR, USA                  | PRCP      | 0.90  | 0.82     | -1.19| 0.89| -3.3  | 0.61| 0.64| 21.71| 64.82|
| Russellville Municipal Airport, AR, USA | PRCP | 0.68  | 0.84     | 1.85 | 0.67| 5.9   | 0.24| 0.03| 34.7 | 99.07|
| Conway, AR, USA                 | TMAX      | 0.45  | 0.99     | 0.2  | 0.95| 0.95  | 14.49| 22.31|
| Dardanelle, AR, USA             | TMAX      | -5.02 | 0.99     | -2.2 | 0.95| 0.94  | 15.14| 22.95|
| Morrilton, AR, USA              | TMAX      | -1.9  | 0.99     | -0.8 | 0.94| 0.94  | 17.39| 23.86|
| North Little Rock Airport, AR, USA | TMAX    | 4.05  | 1        | 1.8  | 0.99| 0.99  | 9.03 | 11.83|
| Russellville Municipal Airport, AR, USA | TMAX | 2.42  | 0.99     | 1    | 0.95| 0.95  | 13.71| 22.57|
| Conway, AR, USA                 | TMIN      | -7.55 | 0.98     | -7.1 | 0.95| 0.94  | 15.59| 22.75|
| Dardanelle, AR, USA             | TMIN      | -7.89 | 0.99     | -7.8 | 0.95| 0.95  | 14.18| 21.36|
| Morrilton, AR, USA              | TMIN      | 5.27  | 0.98     | 5.7  | 0.94| 0.94  | 15.89| 23.35|
| North Little Rock Airport, AR, USA | TMIN    | -9.94 | 0.99     | -8.3 | 0.97| 0.95  | 14.79| 19.68|
| Russellville Municipal Airport, AR, USA | TMIN | 6.76  | 0.99     | 6.9  | 0.96| 0.95  | 13.11| 20.5 |

1NEXRAD detection conditioned on exceeding a given threshold gauge observations (DRAIN).
2NEXRAD detects no rainfall event (DNO_RAIN).
3Mean error (ME).
4Index of agreement (d).
5Percent bias (PBIAS).
6Coefficient of determination (R²).
7Nash-Sutcliffe efficiency (NSE).
8Mean absolute error (MAE).
9Root-mean-square error (RMSE).

Table 2. NCDC precipitation and minimum and maximum temperature validation results at each calibration station using leave-one-out cross-validation.

2.2.7. Cattle grazing, manure deposition, and poultry litter application

The detailed method for estimating pastures that should be receiving litter applications can be seen below.
| No. | Subbasin | Facility                                           | NPDES_ID     | Latitude | Longitude |
|-----|----------|----------------------------------------------------|--------------|----------|-----------|
| 1   | 5        | City of Pottsville                                 | AR0048011    | 35.23    | –93.05    |
| 2   | 6        | City of Dardanelle                                 | AR0033421    | 35.19    | –93.14    |
| 3   | 6        | Dardanelle water treatment plant                   | ARG640149    | 35.21    | –93.15    |
| 4   | 6        | Tyson Foods Inc., Dardanelle                       | AR0036714    | 35.22    | –93.16    |
| 5   | 6        | Russellville Water and Sewer System, City Corporation| AR0021768    | 35.25    | –93.12    |
| 6   | 6        | Freeman Brothers, Inc., d/b/a Bibler Brothers Lumber Company | AR0044474 | 35.25 | –93.13 |
| 7   | 7        | SEECO, Inc., J and R Farms SE1                     | AR0052221    | 35.43    | 92.56     |
| 8   | 7        | Hamilton Aggregates                                 | ARG500026    | 35.44    | –92.54    |
| 9   | 8        | Dover Water Works                                  | ARG640148    | 35.40    | –93.12    |
| 10  | 9        | Quality Rock/Jerusalem Quarry                      | ARG500039    | 35.39    | –92.80    |
| 11  | 10       | KT Rock LLC                                        | ARG500031    | 35.41    | –92.67    |
| 12  | 11       | SEECO, Inc., Campbell Thomas SE1                   | AR0032141    | 35.40    | –92.83    |
| 13  | 12       | City of Atkins                                     | AR0034665    | 35.25    | –92.92    |
| 14  | 13       | Environmental Solutions and Services, Inc.         | AR0051357    | 35.09    | –92.71    |
| 15  | 14       | Green Bay Packaging, Inc., Arkansas Kraft Division | AR0001830    | 35.10    | –92.74    |
| 16  | 15       | Rogers Group, Inc., Beryl Quarry                   | AR0047520    | 35.07    | –92.25    |
| 17  | 16       | Roy Nunn                                           | ARG50322     | 35.07    | –92.37    |
| 18  | 16       | Waste Water Management, Inc. d/b/a Oak Tree Subdivision | AR0050792 | 35.08 | –92.35 |
| 19  | 16       | Fritts Construction, Inc., Hayden’s Place Subdivision | AR0050253 | 35.09 | –92.34 |
| 20  | 16       | BHT Investment Company, Inc.                       | AR0044997    | 35.09    | –92.33    |
| 21  | 16       | Rolling Creek POA                                  | AR0042536    | 35.11    | –92.33    |
| 22  | 16       | Genesis Water Treatment, Inc.                      | AR0051152    | 35.11    | –92.34    |
| 23  | 17       | Faulkner County Public Facility Board, d/b/a Preston Community WW Utility | AR0050571 | 35.03 | –92.41 |
| 24  | 17       | Wilhelmina Cove property owner                     | AR0048682    | 34.93    | –91.11    |
| 25  | 17       | City of Conway, Stone Dam Creek                    | AR0033359    | 35.05    | –92.44    |
| 26  | 17       | Coreslab Structures (ARK), Inc.                    | AR0050474    | 35.06    | –92.43    |
| 27  | 17       | MAPCO Express, Inc. #3059                          | AR0045071    | 35.07    | –92.42    |
| 28  | 17       | Flushing Meadows Water Treatment, Inc.             | AR0048879    | 35.06    | –92.37    |
| 29  | 17       | Jesse Ferrel d/b/a Jesse Ferrel Rental Development | AR0049832    | 35.09    | –92.37    |
| 30  | 18       | City of Mayflower                                  | AR0037206    | 34.95    | –92.45    |
| 31  | 18       | Carla Knight                                       | ARG50430     | 34.97    | –92.48    |
| 32  | 19       | Construction Waste Management, Inc. Class IV Landfill | AR0051764 | 34.93 | –92.44 |
| 33  | 19       | Grassy Lake Apartments                             | AR0050334    | 34.94    | –92.43    |
| 34  | 20       | City of Bigelow                                    | AR0049999    | 35.00    | –92.61    |
| 35  | 20       | City of Conway, Tucker Creek WWTP                  | AR0047279    | 35.07    | –92.50    |
Detailed methods for estimating pastures that received litter application:

1. Create buffer of a random radius around the active poultry houses.
2. Extract pasture areas under the buffer.
3. Assuming a grazing density of 1 cow/0.8 ha of litter amended pasture, calculate the number of cows that can fit the buffer.
4. Compare the calculated number of cows to the number of cows in the subwatershed.
5. Repeat steps 1–4 to obtain the best agreement between estimated numbers of cows.
6. Apply litter to pasture HRUs that fall under the best buffer radius.

The SWAT compatible data for cattle grazing, manure deposition, and poultry litter application can be seen in Table 4.

2.2.8. Urban pasture management

The pasture management schedule relating to specific operation and crop can be seen in Table 5.

2.2.9. Ponds and wetlands

SWAT input parameters relating to ponding were PND_FR, PND_PSA (ha), PND_PVOL (104 m³), PND_ESA, PND_EVOL, and PND_VOL. These ponding parameters can be seen in Table 6. SWAT input parameters relating to wetland were WET_FR, WET_NSA (ha), WET_NVOL 104 (m³), WET_MXSA (ha), WET_MXVOL 104 (m³), and WET_VOL 104(m³). These wetland parameters can be seen in Table 7.
2.3. Model setup

SWAT divides a watershed into subwatersheds and further subwatersheds into hydrological response units. User-defined approach for delineating subwatersheds was used. ArcSWAT

| Subbasin | Cattle grazing rate (kg/day/ha) | Cattle manure deposition rate (kg/day/ha) | Litter application/grazing |
|----------|---------------------------------|-------------------------------------------|---------------------------|
| 1        | 14.38                           | 5.59                                      | Yes                       |
| 2        | 12.59                           | 4.90                                      | Yes                       |
| 3        | 9.16                            | 3.57                                      | Yes                       |
| 4        | 11.46                           | 4.46                                      | Yes                       |
| 5        | 6.11                            | 2.38                                      | Yes                       |
| 6        | 5.83                            | 2.27                                      | Yes                       |
| 7        | 13.18                           | 5.13                                      | Yes                       |
| 8        | 6.27                            | 2.44                                      | Yes                       |
| 9        | 11.43                           | 4.45                                      | Yes                       |
| 10       | 11.46                           | 4.46                                      | Yes                       |
| 11       | 7.34                            | 2.86                                      | Yes                       |
| 12       | 11.46                           | 4.46                                      | Yes                       |
| 13       | 6.11                            | 2.38                                      | Yes                       |
| 14       | 10.51                           | 4.09                                      | Yes                       |
| 15       | 9.05                            | 3.52                                      | Yes                       |
| 16       | 12.03                           | 4.68                                      | No                        |
| 17       | 12.03                           | 4.68                                      | No                        |
| 18       | 11.98                           | 4.66                                      | No                        |
| 19       | 12.44                           | 4.84                                      | No                        |
| 20       | 6.44                            | 2.51                                      | No                        |
| 21       | 12.03                           | 4.68                                      | No                        |
| 22       | 9.24                            | 3.60                                      | Yes                       |
| 23       | 12.03                           | 4.68                                      | No                        |
| 24       | 12.03                           | 4.68                                      | Yes                       |
| 25       | 11.46                           | 4.46                                      | Yes                       |
| 26       | 7.84                            | 3.05                                      | Yes                       |
| 27       | 4.50                            | 1.75                                      | Yes                       |
| 28       | 9.15                            | 3.56                                      | Yes                       |
| 29       | 10.70                           | 4.16                                      | Yes                       |

Table 4. Cattle grazing, manure deposition, and poultry litter application data incorporated into the SWAT model.
| Date       | End       | No. of days | Operation | Comment                                      | Crop     |
|------------|-----------|-------------|-----------|----------------------------------------------|----------|
| 1-Apr      |           |             | Fertilizer| Poultry litter@1 ton/acre of auto-fertilize  | BERM     |
| 1-May      |           |             | Planting  | Warm-season grass (Bermuda)                  | BERM     |
| 15-May     | 31-Oct    | 170         | Grazing   |                                              | BERM     |
| 15-Jun     |           |             | Hay cutting| 85% removal                                  | BERM     |
| 15-Jul     |           |             | Hay cutting| 85% removal                                  | BERM     |
| 15-Aug     |           |             | Hay cutting| 85% removal                                  | BERM     |
| 15-Sept    |           |             | Hay cutting| 85% removal                                  | BERM     |
| 15-Oct     |           |             | Hay cutting| 85% removal                                  | BERM     |
| 1-Mar      |           |             | Fertilizer| Poultry litter@1 ton/acre of auto-fertilize  | BERM     |
| 15-May     | 30-Oct    | 170         | Grazing   |                                              | BERM     |
| 15-Jun     |           |             | Hay cutting| 85% removal                                  | BERM     |
| 15-Jul     |           |             | Hay cutting| 85% removal                                  | BERM     |
| 15-Aug     |           |             | Hay cutting| 85% removal                                  | BERM     |
| 15-Sept    |           |             | Hay cutting| 85% removal                                  | BERM     |
| 15-Oct     |           |             | Hay cutting| 85% removal                                  | BERM     |
| 1-Apr      |           |             | Fertilizer| Poultry litter@1 ton/acre of auto-fertilize  | BERM     |
| 31-Aug     |           |             | Fertilizer| Poultry litter@1 ton/acre of auto-fertilize  | FESC     |
| 1-Sept     |           |             | Planting  | Cool-season grass (fescue)                   | FESC     |
| 15-Mar     | 1-Jun     | 79          | Grazing   |                                              | FESC     |
| 15-May     |           |             | Hay cutting| 85% removal                                  | FESC     |
| 15-Jun     |           |             | Hay cutting| 85% removal                                  | FESC     |
| 1-Sept     |           |             | Fertilizer| Poultry litter@1 ton/acre of auto-fertilize  | FESC     |
| 1-Oct      |           |             | Grazing   |                                              | FESC     |
| 15-Oct     |           |             | Hay cutting| 85% removal                                  | FESC     |
| 21-Feb     |           |             | Fertilizer| Poultry litter@1 ton/acre of auto-fertilize  | FESC     |
| 15-Mar     | 1-Jun     | 79          | Grazing   |                                              | FESC     |
| 15-May     |           |             | Hay cutting| 85% removal                                  | FESC     |
| 15-Jun     |           |             | Hay cutting| 85% removal                                  | FESC     |
| 1-Sept     |           |             | Fertilizer| Poultry litter@1 ton/acre of auto-fertilize  | FESC     |
| 1-Oct      |           |             | Grazing   |                                              | FESC     |
| 1-Oct      | 30-Nov    | 61          | Grazing   |                                              | FESC     |
| 21-Feb     |           |             | Fertilizer| Poultry litter@1 ton/acre of auto-fertilize  | FESC     |

Table 5. Pasture management schedule incorporated into the SWAT model.
was used to develop the SWAT2012 model with a revision number 635. A threshold of 0% for land use, 5% for soil, and 0% for slope was used to delineate HRUs resulting in 3402 HRUs. Some past studies reported the relationship between watershed response and HRU delineation approach [18, 19].

Table 6. Pond input parameters for each subwatershed.
### Table 7. Wetland input parameters for each subwatershed.

| Subwatershed | WET_FR (ha) | WET_NSA (m³) | WET_NVOL 104 (m³) | WET_MXSA (ha) | WET_MXVOL 104 (m³) | WET_VOL 104 (m³) |
|--------------|-------------|--------------|-------------------|---------------|-------------------|-----------------|
| 1            | 0.0000      | 0.00         | 0.00              | 0.00          | 0.00              | 0.00            |
| 2            | 0.0000      | 0.00         | 0.00              | 0.00          | 0.00              | 0.00            |
| 3            | 0.0249      | 65.97        | 32.99             | 219.90        | 109.95            | 6.60            |
| 4            | 0.0151      | 46.43        | 23.22             | 154.78        | 77.39             | 4.64            |
| 5            | 0.0004      | 1.38         | 0.69              | 4.61          | 2.30              | 0.14            |
| 6            | 0.0040      | 12.62        | 6.31              | 42.06         | 21.03             | 1.26            |
| 7            | 0.0001      | 0.15         | 0.08              | 0.50          | 0.25              | 0.02            |
| 8            | 0.0000      | 0.00         | 0.00              | 0.00          | 0.00              | 0.00            |
| 9            | 0.0000      | 0.00         | 0.00              | 0.00          | 0.00              | 0.00            |
| 10           | 0.0000      | 0.00         | 0.00              | 0.00          | 0.00              | 0.00            |
| 11           | 0.0000      | 0.00         | 0.00              | 0.00          | 0.00              | 0.00            |
| 12           | 0.0000      | 0.00         | 0.00              | 0.00          | 0.00              | 0.00            |
| 13           | 0.0018      | 7.18         | 3.59              | 23.92         | 11.96             | 0.72            |
| 14           | 0.0146      | 39.90        | 19.95             | 133.01        | 66.51             | 3.99            |
| 15           | 0.0093      | 27.84        | 13.92             | 92.79         | 46.39             | 2.78            |
| 16           | 0.0003      | 0.96         | 0.48              | 3.20          | 1.60              | 0.10            |
| 17           | 0.0000      | 0.00         | 0.00              | 0.00          | 0.00              | 0.00            |
| 18           | 0.0142      | 37.57        | 18.79             | 125.24        | 62.62             | 3.76            |
| 19           | 0.0058      | 15.53        | 7.77              | 51.78         | 25.89             | 1.55            |
| 20           | 0.0019      | 3.77         | 1.89              | 12.57         | 6.28              | 0.38            |
| 21           | 0.0052      | 17.23        | 8.62              | 57.45         | 28.72             | 1.72            |
| 22           | 0.0331      | 70.06        | 35.03             | 233.53        | 116.76            | 7.01            |
| 23           | 0.0017      | 5.04         | 2.52              | 16.79         | 8.40              | 0.50            |
| 24           | 0.0040      | 6.33         | 3.16              | 21.09         | 10.54             | 0.63            |
| 25           | 0.0000      | 0.00         | 0.00              | 0.00          | 0.00              | 0.00            |
| 26           | 0.0081      | 31.88        | 15.94             | 106.25        | 53.13             | 3.19            |
| 27           | 0.0002      | 0.81         | 0.41              | 2.70          | 1.35              | 0.08            |
| 28           | 0.0060      | 14.39        | 7.20              | 47.97         | 23.99             | 1.44            |
| 29           | 0.0364      | 127.13       | 63.56             | 423.75        | 211.88            | 12.71           |

### 2.4. Calibration and validation

Before calibrating a model, sensitivity analysis is usually performed to reduce the number of parameters. Latin hypercube (LH) one-at-a-time (OAT) method [20] was used to identify the sensitive parameters that might affect the output results. A total of 22 flow parameters were
tested, and the following 12 were found sensitive: SOL_AWC, CN2, ALPHA_BF, SOL_K, CH_N2, CH_K2, CANMX, RCHRG_DP, SURLAG, GW_DELAY, OV_N, and GW_REVAP.

The model calibration period was from 1987 to 2006 and the validation period was from 2007 to 2012. The first 3 years of calibration period were selected as a warm-up period so that the model parameters can be initialized. The calibration started with baseflow followed by surface flow adjusting related parameters affecting baseflow and surface flow. The SWAT Check tool [21] was used before calibration to make sure that the simulated outputs were within the reasonable ranges. The Load Estimator (LOADEST) tool [22] was used on a water quality dataset available from Sept 2011 to Dec. 2012 at Hattieville and Apr. 2012 to Dec. 2012 at Morrilton. The regression coefficients were found to be statistically significant (p < 0.05) at Hattieville and Morrilton for sediment, total phosphorus, and nitrate nitrogen. The performance of the model was determined mainly using the coefficient of determination ($R^2$).

3. Results and discussion

3.1. Calibration and validation results

Various SWAT parameters that were calibrated along with their parameter ranges and final calibrated values can be seen in Table 8. The annual calibrated R2 for the total, surface, and

| File/parameter | Definition | MIN | MAX | Units | Calibrated value | Notes |
|----------------|------------|-----|-----|-------|-----------------|-------|
| .bsn | ESCO Soil evaporation compensation factor | 0 | 1 | 0.95 | Based on water balance |
| | EPCO Plant uptake compensation factor | 0 | 1 | 1 | Based on water balance |
| .gw | GW_DELAY Groundwater delay | 0 | 500 | 2 | Calibrated value |
| | ALPHA_BF Baseflow alpha factor | 0 | 1 | Days | 0.0932 | Baseflow separation factor |
| | GW_REVAP Groundwater “revap” coefficient | 0.02 | 0.2 | | 0.072 | Calibrated value |
| | REVAPMN Threshold depth of water in the shallow aquifer for “revap” to occur | 0 | 1000 | 750 | Calibrated value |
| | RCHRG_DP Deep aquifer percolation fraction | 0 | 1 | 0.06 | Calibrated value |
| | GWQMN Threshold depth of water in the shallow aquifer required for return flow to occur | 0 | 5000 | mm | 800 | Calibrated value |
| .rte | CH_N2 Manning’s “n” value for the main channel | −0.01 | 0.3 | | 0.014 | Calibrated value |
baseflow was 0.83, 0.85, and 0.16. The validated R² was 0.91, 0.93, and 0.60 for the total, surface, and baseflow. The monthly calibrated R² was 0.73, 0.73, and 0.54 and validated R² was 0.84, 0.78, and 0.76 for the total, surface, and baseflow, respectively. The calibration and validation scatter plots for total flow, surface flow, and baseflow can be seen in Figure 5. The validated R² for water quality was 0.5–0.7 at Hattieville and 0.7–0.87 at Morrilton. The results are within acceptable limits of other modeling studies relating to limited data availability [24, 25].

4. Conclusions

Modeling studies are gaining popularity due to rapidness of insight generation before actually performing field experiments. The initiative led by the Mississippi River Basin focused on analyzing the water quality benefits from intended best management practices with the help of modeling studies. However, merely simulating best management practices will not be able to provide reliable results unless the model has been set up correctly and robust. This chapter focused on the detailed discussion for setting up the model to a point where the model setup procedure can be replicated. The model was set up with all relevant information, and each data

| File/parameter | Definition | MIN | MAX  | Units | Calibrated value | Notes |
|----------------|-----------|-----|------|-------|------------------|-------|
| CH_K2 | Effective hydraulic conductivity | -0.01 | 500  | mm/hr | 6  |  |
| .hru |  |  |  |  |  |  |
| CANMX-Forest | Maximum canopy storage | 0 | 100 | mm | 6 | Wu et al., [23] |
| CANMX-Ag | Maximum canopy storage | 0 | 100 | mm | 2.8 |  |
| CANMX-Pasture | Maximum canopy storage | 0 | 100 | mm | 4 |  |
| CANMX-Urban | Maximum canopy storage | 0 | 100 | mm | 0.1 |  |
| SURLAG | Surface runoff lag time | 1 | 24 | Days | 2 | Calibrated value |
| HRU_SLP | Average slope steepness | 0 | 1 | m/m | Reduce by 10% | Based on identified high sediment yield on high-slope agricultural HRUs |
| .mgt |  |  |  |  |  |  |
| CN2 | SCS runoff curve number for moisture condition II | 35 | 98 | CN + 1 | Calibrated value |
| .sol |  |  |  |  |  |  |
| SOL_AWC | Soil available water capacity | 0 | 1 | mm/mm | SOL_AWC × 1.13 | Calibrated value |

Table 8. SWAT model parameter ranges and the final calibrated values.
preparation step has been explained in detail. The model was calibrated and validated for flow at Hattieville. Due to limited water quality data, the model was validated for sediment, total phosphorus, and nitrate nitrogen at Hattieville and Morrilton. The results were satisfactory and within the ranges reported by previous studies. Results from this study can be used to evaluate the relative effectiveness of MRBI-recommended agricultural BMPs for analyzing pollutant load reductions and improving water quality in similar data-limited watersheds.

Conflict of interest

The authors declare no conflict of interest.

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