*Abstract: This laboratory familiarizes students with SWAT modeling in ArcGIS 10.2. Students are to import data and run the SWAT model under different changed parameters. This helps students compare the predicted outflow to the observed outflow and calibrate the model to better represent the observed outflow. Sensitivity Analysis will be performed to lay the ground for model calibration. After calibration, validation is performed and set as a “default” parameter for future SWAT runs.*

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BSEN 5520 SWAT LAB 3

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**INTRODUCTION**

The Soil and Water Assessment Tool (SWAT) is a small watershed to river basin model that simulates the quality and quantity of surface and ground water and predicts the environmental impacts of land use, land management practices and climate change. Swat modeling is also used to assess soil erosion prevention and control, non-point source pollution control and regional management in watersheds.

The study area used is the Greensboro Watershed on the border of Maryland and Delaware that drains into the Chesapeake Bay. Due to high load of nutrients from surrounding watersheds, the Chesapeake Bay is listed as impaired waters. In this lab, SWAT is used to predict the impacts of land use change on water quality in the study area.

In the previous lab, the sensitivity analysis performed was based on “condition numbers” and did not consider the effect of observed streamflow. Another way of performing sensitivity analysis is by assessing the model performance with respect to the observed data. If a change in a model parameter does not cause any appreciable change in the model performance then the model is not sensitive to that parameter under the given conditions. This type of sensitivity analysis is usually performed simultaneously with the model calibration.

These values are then analyzed based on three statistic values: Nash-Sutcliffe efficiency (NSE), Pearson’s correlation coefficient of determination (R-Squared or R2), and Percent Bias (PBIAS). The NSE value is a normalized statistic that determines the relative magnitude of the residual variance (“noise”) compared to the measured data variance (“information”). Pearson’s correlation coefficient of determination (R2) describes the degree of linear relationship between the simulated data and the measured data. PBIAS measures the average tendency of the simulated data to be greater than or less than their observed counterparts.

**PROCEDURE**

1. Import the previous lab data into ArcMap. Use the observed daily stream flow data in the excel file from the previous lab.
2. Break up your observed data into calibration and validation periods.
3. Use roughly 60 to 70% of your streamflow data for the calibration and then the remainder for validation. Use the 1984 and 1985 as warm-up periods.
4. Calibrate the surface runoff. Start modifying the model parameters that will effect the surface runoff and run the model after each modification. Compare your simulated and observed surface runoff using the coefficient of determination (R squared), percent bias (PBIAS) and Nash-Sutcliffe efficiency (NSE).
5. Repeat the previous step for base flow. Once you are satisfied with the calibration for surface runoff, move to base flow calibration. At the end of this step, your simulated total discharge should match your observed flow data fairly well.
6. Validate your model by using the independent validation data set from part 2. Note that you can save the calibrated model parameters (save simulation option) and later bring it in as the “default” for further model runs for validation.

**RESULTS**

**Table 1. Calibration Simulation Runs for Total Flow**

|  |
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| **Total Flow** |
| **Sim #** | **Calibrated Parameter** | **R2** | **ENS** | **PBIAS** | **Change** |
| **R2** | **ENS** | **PBIAS** |
| 1 | default simulation | 0.63 | 0.51 | 29% | - | - | - |
| 2 | added 5 to CN2 | 0.68 | 0.60 | 28% | Improved↑ | Improved↑ | Improved↑ |
| 3 | biomix multiply by 1.2 (+20%) | 0.68 | 0.60 | 28% | No change↔ | No change↔ | No change↔ |
| 4 | esco multiply by 0.9 (-10%) | 0.69 | 0.67 | 16% | Improved↑ | Improved↑ | Improved↑ |
| 5 | esco multiply by 0.85 (-15% -25%total) | 0.71 | 0.71 | 5% | Improved↑ | Improved↑ | Improved↑ |
| 6 | GW Revap multiply by 0.9 (-10%) | 0.71 | 0.71 | -11% | No change↔ | No change↔ | Deteriorated↓ |
| 7 | GW\_Revap multiply by 1.21 (+21% +10% total) | 0.71 | 0.71 | 4% | No change↔ | No change↔ | Improved↑ |
| 8 | Slope multiply by 1.3 (+30%) | 0.71 | 0.71 | 4% | No change↔ | No change↔ | No change↔ |
| 9 | epco multiply 1.2 (+20%) | 0.71 | 0.71 | 4% | No change↔ | No change↔ | No change↔ |
| 10 | Recharge\_dp multiply by 1.2 (+20%) | 0.71 | 0.71 | 4% | No change↔ | No change↔ | No change↔ |
| 11 | Recharge\_dp multiply by 0.634 (-40% -20% total) | 0.71 | 0.71 | 4% | No change↔ | No change↔ | No change↔ |
| 12 | surlag multiply by 0.8 (-20%) | 0.71 | 0.71 | 4% | No change↔ | No change↔ | No change↔ |
| 13 | canmx multiply by 0.7 (-30%) | 0.71 | 0.71 | 4% | No change↔ | No change↔ | No change↔ |
| 14 | subtracted 2 from cn | 0.71 | 0.71 | 4% | No change↔ | No change↔ | No change↔ |
| 15 | subtracted 4 from cn | 0.69 | 0.69 | 4% | Deteriorated↓ | Deteriorated↓ | No change↔ |
| 16 | esco multiply by 0.8 (-20% -45 total) | 0.71 | 0.70 | -6% | Improved↑ | Improved↑ | Deteriorated↓ |
| 17 | revap\_mn multiplied by 0.8 (-20%) | 0.71 | 0.70 | -6% | No change↔ | No change↔ | No change↔ |
| 18 | slope subbasin multiply by 1.2 (+20%) | 0.70 | 0.70 | -6% | Deteriorated↓ | No change↔ | No change↔ |
| 19 | sol\_z multiplied by 1.45 (+45%) | 0.74 | 0.71 | -13% | Improved↑ | Improved↑ | Deteriorated↓ |
| 20 | decrease mannings coefficient by 0.05 | 0.74 | 0.71 | -13% | No change↔ | No change↔ | No change↔ |
| 21 | surlag added 5 | 0.74 | 0.71 | -13% | No change↔ | No change↔ | No change↔ |
| 22 | esco multiplied by 0.9 (-10% -35 total) | 0.74 | 0.70 | -15% | No change↔ | Deteriorated↓ | Deteriorated↓ |
| 23 | gwqmn multiplied by 0.4 (-60%) | 0.74 | 0.71 | -11% | No change↔ | Improved↑ | Improved↑ |
| 24 | sol\_awc multiplied by 0.90 (-10%) | 0.74 | 0.72 | -9% | No change↔ | Improved↑ | Improved↑ |
| 25 | increase CN by 3 | 0.75 | 0.73 | -9% | Improved↑ | Improved↑ | No change↔ |

Table 1 above shows twenty-five simulations that were run with altered parameters to improve the R-squared (R2), ENS and PBIAS values. Model simulation can be considered satisfactory if the NSE value is greater than 0.50, if the R-squared value is less than or equal to 0.70, and if the PBIAS value is approximately 25%. The optimal values would be the R-squared value of negative or positive 1, the NSE value of positive 1 and the PBIAS value of 0.

Table 1 indicates the total flow R2 value of 0.75 is a high linear correlation with less error variance. Values above 0.5 are considered acceptable, indicating that this model is calibrated to be greater than acceptable. This means that the model accurately predicts the observed values with the simulated values. The NSE value of 0.73 indicates the plot of observed verses simulated data fits the 1:1 line well. The PBIAS value of negative 9% indicates the models overestimation bias, meaning the model is prone to overestimate the simulated data compared to the observed data.

**Table 2. Final Calibration Data**

|  |
| --- |
| **Last Calibration Data** |
|  | **Total** | **Surface** | **Base** |
| **R2** | **0.75** | **0.48** | **0.71** |
| **Ens** | **0.73** | **0.40** | **0.66** |
| **Bias** | **-9%** | **5%** | **-17%** |
| **Table 3. Validation Data** |
| **Validation Data** |
|  | **Total** | **Surface** | **Base** |
| **R2** | **0.69** | **0.48** | **0.67** |
| **Ens** | **0.69** | **0.29** | **0.63** |
| **Bias** | **-6%** | **7%** | **-13%** |
| **Table 4. Original Default Data** |
| **Original Default Data** |
|  | **Total** | **Surface** | **Base** |
| **R2** | **0.63** | **0.42** | **0.62** |
| **Ens** | **0.51** | **0.41** | **0.34** |
| **Bias** | **29%** | **15%** | **37%** |

The original data in table 4 compared to the calibration data In table 2 and the validation data in table 3 shows the improvement in all statistical measurements for the model. The validation data shows that the calibration was satisfactory in the total flow and base flow, with an improvement in the surface runoff. By validating the data, the model is now able to be used for future watersheds.

**Figure 1. Simulated Total Flow versus Observed Total Flow in cms**

**Figure 2. Simulated Base Flow versus Observed Base Flow in cms**

**Figure 3. Simulated Surface Runoff versus Observed Surface Runoff in cms**

The final hydrographs for the total flow, base flow and surface runoff were recorded that compared the simulated flows to the observed flows after calibration and validation. The total flow and the base flow observed hydrograph and simulated hydrograph were almost identical. The surface runoff observed hydrograph and simulated hydrograph were similar but not as identical, with a few simulated peaks missing in the observed data.

**CONCLUSION**

Since the validation statistics for the surface runoff were not as successful as the total flow and the base flow, there could be error if this model is used as a default model for future watersheds. There were many trial and error operations that occurred between the recorded simulations. For example, the available water capacity affecting percolation (sol\_awc) parameter was changed in various ways before realizing that it was not affecting the model. Therefore, it was taken out and the model was set back to the previous step. The maximum potential rooting depth (sol\_z) was then decreased, which had negative impacts on the model. The same parameter was then increased, which had positive results.

The total flow R2 value of 0.75 is a high linear correlation with less error variance, indicating that this model is calibrated to be greater than satisfactory. This means that the model accurately predicts the observed values with the simulated values. The total flow NSE value of 0.73 is considered a very good value and indicates the plot of observed verses simulated data fits the 1:1 line well. The PBIAS value of negative 9% is considered very good and indicates the models overestimation bias, meaning the model is prone to overestimate the simulated data compared to the observed data.

Overall, the performance of the calibration was successful with higher than satisfactory statistic values for R2, NSE and PBIAS. After performing the calibration and validation processes, I feel confident about using SWAT modeling in a similar watershed.