Enhanced Automatic Calibration Toolbox for SWMM5

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Abstract

Numerical modelling has become the go-to approach for stormwater management because it allows to investigate various scenarios at a fraction of the cost of a full-scale physical monitoring, which requires a large amount of equipment, personnel, and funds. Although the models are approximations of the physical world, they must be calibrated and validated using on-site measurements. This paper aims to contribute to the calibration side of modelling by reducing the time required for it. Calibration of a stormwater model (in our case, SWMM) typically necessitates the user to create and read an input file multiple times, which is a tedious and time-consuming task. The Excel-based automatic calibration module improves calibration significantly by eliminating the need to create and read input files after every single parameter change, reducing the time spent by the researcher on the creation and verification of new input files. SWMM5 was linked to Excel via a newly created dynamic link library, and the programming of the calibration module was done in Visual Basic programming language.

Keywords: calibration, groundwater, swmm, stormwater modelling, automatic calibration.

1 Introduction

Climate change is having a significant impact on precipitation intensity [1, 2]. This necessitates an investigation into the impact on the current drainage system as well as

the identification of areas at risk of overflow. The EPA SWMM5 model can be used to estimate the risk. Before using this model for this task, it must be calibrated.

Unfortunately, the dynamic link library for this model contains a relatively small number of functions that allow changing parameters. Currently the process of adjusting parameters is done through creating and reading new input files and this is very time consuming. To tackle this issue, some authors have proposed changing parameters in an input file and reading it in automatically, but this is not as efficient or convenient as changing the parameters directly within SWMM5 [3]. The purpose of this article is to explain in greater detail the problems that may arise when using this dynamic link library for SWMM (version 5.1.015 (July 2020)).

2   Methods

US EPA SWMM5 [4] was used to create a new dynamic link library. The new DLL was developed with the purpose of improving the functionality of the existing SWMM5 DLL. This was achieved by adding the possibility to adjust parameters without having to read in a new input file for each iteration. This is not the first attempt on creating such capability, as formerly Open Water Analytics (OWA) had also created a toolkit which allowed to adjust various parameters, but the toolkit was primarily used for viewing the parameters built into SWMM and it provided the functionality to change only a few of them [5].

The authors of this paper modified the OWA SWMM toolkit to test additional parameters in the SWMM model calibration. These changes were integrated into the existing SMWM5 code [3]. To test the functional compatibility of the new DLL with Excel, some examples prepared by US EPA [4] were used. For automatic calibration, the Gradient Method was implemented, this utilized the Minpack package developed by Argonne National Laboratory (University of Chicago) [6]. This package was rewritten from FORTRAN to Visual Basic (to allow easier control over Excel program), however, with minor modifications to allow the user to change the minimal step along the parameters. Changing the step was necessary to reduce the influence of random oscillations of the objective function surface. The Gradient Method was selected as it is much more computationally efficient (faster) compared to other popular optimization methods, e.g., Genetic Algorithm [7].

It is worth noting that as of this year (2022) a new version of US EPA SWMM5 (v5.2.0) has been released If the user wishes to use the tool developed by the authors the user should use the input files based on the former release of SWMM (v5.1.015).

3   Results

As MS Excel provides a plethora of options for analysing results and graphically representing results, such as built-in formulas for calculations, tables, and alternatives for creating charts, a workbook was created for calibration of SWMM models. The two alternatives for calibration were coded in MS Excel Visual Basic language. These alternatives are as follows: Variant (A) was created for testing simultaneously one or two parameters (up to 21 parameter values in one calibration calculation) within user defined limits and Variant B) that calibrates up to five parameters simultaneously. The

first variant (A) allows the user to investigate the model's sensitivity to various parameters, but the user can also fix a parameter and test different variants to find the second one. The second variant (B) is useful for the users who know the set of parameters that need calibration. The Workbook also contains a number of Worksheets, where measured data may be added, such as flow and other calibration parameters. The Figure 1 below contains results obtained by running the second variant (B). Three parameters were used for this simulation simultaneously.

Figure 1: Example of SWMM calibration results obtained by variant B presented in MS Excel Workbook

The user should also be aware that when running automatic calibration, the SWMM has some peculiarities related to the way it was coded. A significant discovery was one relating to the manner in which data is extracted from input files – some of the parameters are only read in once. This would be insignificant if the user only ran the SWMM program once, but this is critical when using tools like automatic calibration, which uses the values obtained from previous iterations on rerun of the program. When conducting several cycles of calibration SWMM internally restores the built-in settings for some values, while updating others. This may be incorrect for calibration purposes, and thus the user of the calibration module must manually adjust the parameters which did not get updated on their own. Some of these parameters that must be updated by the user are related to precipitation.

Another aspect that the user should be aware of is the choice of a proper step for calibration – this is a parameter typically unknown during the start of calibration and it is typically determined through manually testing different variants. The toolbox developed by the author gives the user the possibility to alter this calibration step

within an easy-to-use manner in MS Excel (by changing the size of the step within a pre-determined cell).

4   Conclusions and Contributions

The authors' contribution is the development of a new Dynamic Link Library for SWMM5 (v5.1.015) that can be used in MS Excel and in other programs. The decision to connect SWMM5 and MS Excel was made because the software is relatively simple to use, it has a large user base, and it has many built in functions for analysis. The created DLL allows you to change 22 SWMM5 parameters and calculate the objective function (sum of squared deviations) within MS Excel without having to constantly create and read new input files. The program also allows you to find the smallest objective function by changing five parameters during the model calibration at the same time. The authors are distributing the MS Excel based program for calibration and its DLL free of charge.

Acknowledgements

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