Comparison of HEC-HMS hydrologic model for estimation of runoff computation techniques as a design input: case of Middle Awash multi-purpose dam, Ethiopia

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Abstract
Rainfall-runoff modeling requires a selection of a suitable hydrologic model for the determination of an accurate quantity from a given process. For this study, the HEC-HMS event-based hydrologic model of the Initial and constant, the Green and Ampt, and the SCS CN loss methods were selected as a modeling tool for estimation of the amount of runoff at the middle awash multi-purpose dam on the Awash River basin. The HEC-HMS model calibration of this study was done by using the meteorological and hydrological data for the years from 2004 to 2008. The model was validated by using the daily data for the years from 2009 to 2013. The results with the comparison of the observed and simulated hydrographs and the model performance showed that the initial and constant (Nash-Sutcliff NSE = 0.73, Correlation coefficient $R^2 = 0.75$, and RMSE = 0.5) model is appropriate for hydrological simulations in the Middle Awash Catchment.

Keywords Awash River Basin · HEC-HMS · SCS-CN · Streamflow

Introduction
Hydrology, a science that treats different phases of earth’s water (precipitation, evaporation, snowmelt, infiltration, runoff, and other processes in the hydrologic cycle) is important in water resources planning, development, and operation of various schemes, rainfall-runoff relationship study, an accurate estimation of hydrologic response of the basin and main concern for any infrastructural development and causes for uncertainty, the source for over and under-estimation of each design component. Water resources for water supply, hydropower plants, irrigation and drainage, transport, and recreation are the main purpose that humans practice all over the world (Nega 2019).

Hydrological and meteorological data measurement and collection is the scratch point for any hydrological investigation such as rainfall-runoff estimation, which is the very first step in the design of water-related scientific research and projects. But, similar to other developing countries the quality and quantity of the gauging stations available in the country are not sufficient, and according to the information from experts, some of the available stations are not functioning properly because of the lack of well-experienced technicians to operate and maintain the existing instruments (Mulugera 2013) and need an alternative hydrological model which helps in a reasonable estimate of the necessary input data.

The use of the hydrologic model needs different parameters, assumptions, and considerations and takes place in the watershed which has a variable nature, and the limitation of scientific knowledge of the researcher in the area becomes the major cause for uncertainty and inaccuracy in the proposed infrastructure developmental works and leads to un-necessary quantification and financial losses in each component, in worse cases leads to the damage of life and property in the vicinity.

Several models develop at different times all over the world to better understand the earth’s hydrology and its
response to various effects. These models came into use in the 1960s and 1970s when demand for numerical forecasting of water quality and quantity is derived from environmental legislations in the USA and the United Kingdom (Lemma 2018). Generally, hydrologic models are the simplified simulation of the complex hydrologic system (Behailu Shimeles 2004) and can classify in different ways, but the major classification is as a Physical model which represents the scaled-down representation of the real-world system in the laboratory for example simulation of open channel flow. The Analog model a simulated process that is used to represent the natural process as the usage of electric current in the circuit to represent the flow of water the input is controlled by adjusting the amperage, and the output is measured with a voltmeter, historically the analog models have been used to calculate subsurface flow (Arlen D. Feldman 2000). A mathematical model is a clear chronological set of relations between numerical and logical steps that change the numerical input into numerical output (Sivapalan et al. 2003).

Based on the assumption used and the complex nature of the watershed each method of computation of runoff has limitations and requires calibration of parameters and validation of its models. Under this study, the mathematical model developed by the Us Army Corps of Engineers Hydrologic Engineering Center-Hydrologic Modeling system (HEC-HMS) computer package models of Initial and constant loss, Soil Conservation Service Curve Number method (SCS CN), and Green and Ampt infiltration methods are evaluated by considering the Middle Awash catchment under the Awash River basin at the outlet of Middle Awash Multi-Purpose Dam.

**Methodology**

**Study area**

Middle Awash Multi-purpose Project (MAMPP) is located in the middle part of the Awash Basin. The altitude range in the Basin varies between 830 and 2500 m, and the total area of MAMPP is about 20,658.76 km² at the proposed dam location. The Middle Awash dam site and command area are administratively located in Oromia regional state, West Shao, East Shao, and Arisi zone. The project area (dam, catchment, and reservoir area) is located in the Universal Transmitters Meter (UTM) coordinate 629786 m E and 990686 m N (Fig. 1). MAMPP was initiated primarily to control floods and protect the downstream community and
infrastructure and also serve to harness the water resources of the Awash River for irrigation (Corporation, n.d).

**Data collection**

Meteorological data of nine stations within the project area and nearby such as rainfall, maximum and minimum temperature, wind speed, relative humidity, and sunshine hour are collected from the Ethiopian Meteorological Agency (EMA) shown in Table 1. For the comparison of the model output with the observed flow, the daily stream flow data of the Awash 7kilo gauge station recorded period from 2004 to 2013 was collected from the Ministry of Water, Irrigation, and Energy. Figure 2 exhibited the spatial location of collected meteorological and hydrological data.

The computation of model parameters such as initial abstractions, curve number, and lag time requires the knowledge of the land use land cover (2013), land treatment condition, as well as the soil type of the watershed, was collected from the Awash Basin Authority.

**Table 1** Selected Meteorological Stations Information

| No | Station Name       | Elevation | Longitude | Latitude | Start | End |
|----|--------------------|-----------|-----------|----------|-------|-----|
| 1  | Addis Ababa Observatory | 2386      | 9.019     | 38.75    | 1979  | 2017|
| 2  | Addis Ababa Bole     | 2354      | 9.033     | 38.75    | 1979  | 2018|
| 3  | Awash Melka          | 916       | 8.983     | 40.15    | 1987  | 2017|
| 4  | Debrezeit            | 1900      | 8.733     | 38.95    | 1979  | 2012|
| 5  | Koka Dam             | 1618      | 8.469     | 39.15    | 1981  | 2017|
| 6  | Mojo                | 944       | 8.859     | 39.92    | 1984  | 2017|
| 7  | Methara              | 944       | 8.859     | 39.92    | 1984  | 2017|
| 8  | Natherath            | 1622      | 8.550     | 39.28    | 1993  | 2013|
| 9  | Welencheti           | 1458      | 8.670     | 39.43    | 1993  | 2013|

Fig. 2 Hydrological and meteorological stations in and out of the project area
Due to its length and crossing of different areas which is suitable for irrigation and electric power development the basin highly utilized from early time till now. The water schemes that abstract water from the river and their abstraction are identified by the field survey, literature review, and design documents obtained from Ethiopian Construction Design and Supervision Works Corporation, Oromia Water Works Design and Supervision Enterprise, and Awash Basin Authority libraries (see Table 2).

The physiographic data (Elevation) was extracted using the digital elevation model (DEM) cell size 20 m*20 m to determine the topographic map of the area, terrain processing for further use in the estimation of initial model parameters, stream networks definition and to determine stream length, to evaluate the river bed slope, to identify stream order and sub-basin areas of the catchment, and to fix the dam location which is used as an outlet for the watershed delineation on the proposed river basin.

**HEC–HMS model**

The Hydrologic Engineering Center’s Hydrologic Modeling System (HEC-HMS) is a computer program designed to simulate the Precipitation-runoff of dendritic watershed (US Army corps of Engineers 2013). HEC-HMS version 4.3 in a combination of Arc-GIS with HEC-GeoHMS for watershed development was used in this study.

**Basin model**

A basin model contains a schematic consisting of any combination of the seven objects; sub-basin, reach, junction, source, sink, and reservoir, and stores information about the properties and connectivity of the objects in the schematic. This model was created using the HEC-GeoHMS Arc-GIS extension (see Fig. 3).

**Meteorology model**

Mean areal precipitation was computed by the Thiessen polygon method in Arc-GIS. For each sub-basin contributed gauge, their areal coverage, and weightage are shown in tabular form in Table 3.

**Loss model**

The loss models in HEC-HMS normally calculate the runoff volume by computing the volume of water that is intercepted, infiltrated, stored, evaporated, or transpired and subtracting it from the precipitation (Al-Mukhtar and Al-Yaseen 2019). In this study, three methods were selected to estimate direct runoff from a design rainfall.

- **Soil conservation service curve number loss method** The SCS–CN method has been established in 1954 by the United States Department of Agriculture Soil Conservation Service (SCS) by the National Engineering Handbook (NEH–4) Section of Hydrology (Satheeshkumar et al. 2017). Curve number (CN) is an index developed by the Soil Conservation Service (SCS) now called the Natural Resource Conservation Service (NRCS), developed to estimate the amount of rainfall that infiltrates into the soil and the amount of surface runoff. It is firstly developed for agricultural watersheds, and then it was consequently used in urban areas (Shukur 2017).

  SCS–CN technique is one of the first and simplest methods for rainfall-runoff modeling (Shukur 2017) which provides an empirical relationship for estimating initial abstraction and runoff by considering four major runoff-producing watershed characteristics soil type, land use, surface condition, and antecedent moisture condition and the model computes the direct runoff volume for a given rainfall event and estimating the volumes and peak rates of surface runoff in agricultural, forest, and urban watersheds (Iliaffe Khaddor 2015).

  This method is based on the actual retention and the initial abstraction. Therefore, these data were extracted from LULC and Soil data of the study area. The Curve Number (CN) for a watershed can be estimated as a function of land use, soil type, and antecedent watershed moisture. For the watershed that consists of different soil types and land use, composite or weighted CN was calculated. Generally, for this study area, the initial parameters for the SCS CN method are shown in Table 4.

- **Green and Ampt loss method** The Green–Ampt infiltration model is a simplified version of the physically-based full hydrodynamic model, known as the Richards equation (Sahoo 2011). Being a physically-based model, the Green–Ampt infiltration model has been widely investigated for its applicability to various scenarios inhomogenous.

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**Table 2** Existing and planned project

| Project name               | Type of abstraction | Annual abstraction (MCM) |
|----------------------------|---------------------|--------------------------|
| Wonji state                | Pump                | 62.87                    |
| Welenchti                  | Canal intake        | 30.85                    |
| Dodoma                     | Pump                | 26.24                    |
| Wake tio                   | Pump                | 9.64                     |
| Tibila diversion           | Diversion weir      | 29.92                    |
| Nura era and merti jeju    | Diversion weir      | 122.74                   |
| Fentalie diversion         | Diversion weir      | 241.25                   |
| Abadir diversion           | Diversion weir      | 233.36                   |
| Abadir canal intake        | Canal intake        | 103.022                  |
| Lake Beseka                | Inflow to awash     | 54.55                    |
geneous soils but less extensively for layered soils in simulating rainfall and runoff (Liu 2014). Parameters of this method are initial loss, Conductivity, Wetting Front Suction head $\Psi$, hydraulic conductivity of the soil $K$, the porosity $\eta$, saturated moisture content, and imperviousness($\%$), and all these parameters are dependent on the type of soil on the catchment (land cover (2013) shown in Table 5.

Initial and Uniform loss model The initial loss is similar to the SCS CN model due to the similarity in the LULC condition, terrain characteristic, and cover condition, and the resulting constant loss rate is determined using the maximum soil infiltration capacity which depends on the soil type (see Table 6).

Transform model

In HEC-HMS, different models are used to simulate the development of direct runoff from the excess precipitation on a catchment as alteration of precipitation excess into point runoff. So, for this study, the following method was selected for the analysis.

SCS unit hydrograph method In the SCS CN rainfall-runoff method, the excess precipitation transforms to point runoff by the SCS unit hydrograph method which develops by the soil conservation service based upon the average of UH derived from gauged rainfall and runoff from a large number of small agricultural watersheds throughout the US (Arlen D. Feldman 2000). In the HEC-HMS SCS UH method, the peak discharge of the basin is determined based on the lag time of the drainage area (see Table 4).

Snyder UH For the transformation of the excess precipitation to the point runoff using Snyder UH the initial model parameters are the peaking coefficient and the standard lag (see Table 7).

Clark UH initial model This transformation method uses the time of concentration ($T_c$) and the storage coefficient ($R$) as...
input parameters. The storage coefficient represents the temporal storage of water and its value can be found through calibration it ranges from 0 to 150 h and the time of concentration represents the transformation of the excess to reach the linear reservoir near the outlet and it is a function of a geomorphological characteristic of the watershed (Table 8).

### Model calibration and validation

The time series of discharge at the outlet of the watershed was used as data for calibration which is a systematic process of adjusting model parameter values is needed until simulation results match acceptably the observed data and

### Table 3 Sub-basins and rainfall stations with their gauge weights

| Sub-basin name | Contributing gages | Area coverage | Gauge weight |
|----------------|--------------------|---------------|--------------|
| W710 Methara   | 1376               | 0.813         |
| W710 Welenchiti| 256                | 0.152         |
| W710 Awash Melka| 60              | 0.035         |
| W800 Methara   | 970                | 0.535         |
| W800 Awash Melka| 36               | 0.020         |
| W800 Welenchiti| 808                | 0.445         |
| W820 Debrthit  | 391                | 0.086         |
| W820 Addis Ababa Bole | 53 | 0.012 |
| W820 Addis Ababa Observatory | 4099 | 0.902 |
| W900 Methara   | 1047               | 0.410         |
| W900 Nathrith  | 242                | 0.095         |
| W900 Welenchiti| 1264               | 0.495         |
| W1150 Nathrith | 827                | 0.452         |
| W1150 Koka Dam | 760                | 0.416         |
| W1150 Welenchiti| 241              | 0.132         |
| W1420 Nathrith | 481                | 0.238         |
| W1420 Mojo     | 115                | 0.057         |
| W1420 Koka Dam | 1393               | 0.690         |
| W1420 Welenchiti| 30               | 0.015         |
| W1440 Debrthit | 1597               | 0.459         |
| W1440 Mojo     | 5                  | 0.001         |
| W1440 Koka Dam | 427                | 0.123         |
| W1440 Addis Ababa Bole | 854 | 0.245 |
| W1440 Addis Ababa Observatory | 597 | 0.172 |
| W1450 Debrthit | 1237               | 0.566         |
| W1450 Nathrith | 6                  | 0.003         |
| W1450 Mojo     | 674                | 0.308         |
| W1450 Koka Dam | 131                | 0.060         |
| W1450 Addis Ababa Bole | 45 | 0.021 |
| W1450 Welenchiti| 93               | 0.043         |

### Table 4 SCS CN Method Initial Parameters

| Sub-basin | Area (km²) | Weighted CN | Potential Retention S (mm/hr.) | Initial Abstraction Iₐ (mm) | Lag time |
|-----------|------------|-------------|--------------------------------|---------------------------|----------|
| W820      | 4543.36    | 77.23       | 74.89                          | 14.978                    | 700.48   |
| W1440     | 3480.43    | 77.19       | 75.06                          | 15.012                    | 935.17   |
| W1450     | 2186.05    | 77.72       | 72.82                          | 14.564                    | 747.75   |
| W1420     | 2018.69    | 72.52       | 96.25                          | 19.250                    | 920.53   |
| W1150     | 1828.95    | 73.52       | 91.48                          | 18.297                    | 619.13   |
| W900      | 2553.18    | 64.82       | 137.85                         | 27.571                    | 1164.3   |
| W800      | 1814.26    | 68.68       | 115.84                         | 23.168                    | 1053.6   |
| W710      | 2233.76    | 62.74       | 150.85                         | 30.169                    | 797.71   |

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the calibration process finds the optimal parameter values that minimize the gap between recorded data and model result (Winarata 2019). The model was calibrated using the measured stream flow data from January 1, 2004, to December 31, 2008, and the parameters were first optimized using calibrating tool both manually and automatically until the simulated and observed values showed good agreement.

After calibration, to utilize the calibrated model for estimating the effectiveness of future potential, the model was tested against an independent set of measured data, and this testing is called model validation and is used under different scenarios (Asalf 2018). For this study, the data from January 1, 2009, to December 31, 2013, at awash 7kilo were used for model validation.

### Statistical evaluation

After the model was run for the different scenarios, the result checked for their effectiveness using model evaluation criteria. The objective of this section is to analyze the sensitivity of three models toward the values of the parameters implied in the simulations. To evaluate the flexibility of the rainfall-runoff model in this study case, Nash–Sutcliffe coefficient of efficiency (NSE), root mean square error (RMSE), and correlation coefficient ($R^2$) is used.

Furthermore, the choice of the model does not only depend on the performance evaluation criteria but it also depends on the statistical relation between the outputs of different models in this study case, the Analysis of variance (ANOVA) use to check the statistical relationship between each model. The single-factorial or one-way ANOVA principle was implemented with the help of the Statistical Package for Social Science (SPSS). One-way ANOVAs are useful for gaining an understanding of interactions where more than one variable may influence the result. To start the analysis

| Table 5 Green Ampt Initial Model Parameters |
|---------------------------------------------|
| Sub-basin | Saturate content | Hydraulic conductivity, $\theta$ saturated (cm/hr.) | Wetting front suction (cm) | Initial water content |
| W820 | 0.47 | 5.21 | 580.66 | 0.2 |
| W710 | 0.47 | 11.11 | 471.08 | 0.2 |
| W800 | 0.47 | 7.98 | 488.47 | 0.2 |
| W900 | 0.46 | 12.58 | 150.32 | 0.2 |
| W1150 | 0.47 | 9.65 | 512.63 | 0.2 |
| W1420 | 0.45 | 15.88 | 312.25 | 0.2 |
| W1440 | 0.46 | 3.32 | 627.47 | 0.2 |
| W1450 | 0.47 | 7.01 | 544.10 | 0.2 |

| Table 6 Initial and constant loss model initial parameters |
|---------------------------------------------|
| Sub-basin | Initial loss (mm) | Constant rate (mm/hr.) |
| W820 | 14.98 | 1.74 |
| W710 | 15.01 | 2.36 |
| W800 | 14.56 | 2.71 |
| W900 | 19.25 | 2.56 |
| W1150 | 18.30 | 2.21 |
| W1440 | 27.57 | 1.95 |
| W1420 | 23.17 | 2.94 |
| W1450 | 30.17 | 1.58 |

| Table 7 Snyder UH initial parameters |
|---------------------------------------------|
| Sub-basin | $L$—flow path (km) | Centroid longest flow path (km) | $C$ | $C_t$ | Standard lag $t_l = C_t C (LL_{c})^{0.3}$ (hr) | Peaking coefficient |
| W710 | 134.471 | 61.415 | 0.75 | 2.1 | 23.570 | 0.5 |
| W800 | 146.444 | 72.784 | 0.75 | 2.1 | 25.444 | 0.5 |
| W820 | 138.275 | 61.366 | 0.75 | 2 | 22.630 | 0.6 |
| W900 | 147.76 | 68.418 | 0.75 | 1.8 | 21.467 | 0.8 |
| W1150 | 105.691 | 56.136 | 0.75 | 1.9 | 19.311 | 0.7 |
| W1420 | 135.853 | 39.726 | 0.75 | 1.9 | 18.770 | 0.7 |
| W1440 | 198.304 | 82.955 | 0.75 | 1.8 | 24.842 | 0.8 |
| W1450 | 134.724 | 62.186 | 0.75 | 2 | 22.544 | 0.8 |
both the dependent and independent variables (the factors) are identified. The dependent variable is the discharge generated or the runoff volume and the Green and Ampt, Initial and Constant, and the SCS CN loss rate methods are selected as independent variables. Then simulation for the significance of each variable is identified based on the $p$-value which determines whether the variables are statically significant to the mean or not. When the value of $p$ is significantly less than the confidence level $\alpha = 0.05$ that shows the comparison is significant if the reverse happens the relationship is not statically significant.

**Result and discussion**

**Calibration**

**Initial and constant loss rate**

For the initial and constant loss rate method, the sensitivity analysis is done by changing the initial value of the initial loss and constant rate value in the loss method and storage coefficient and time of concentration in the Clark UH transform method for each sub-basin. But, according to the result, the constant loss rate, the time of concentration, and the storage coefficient show a high sensitivity while changing and creating visible variation in the model output and are identified as sensitive parameters for the initial and constant loss rate model, and calibration done by changing their value.

After running the model using the initial value, calibration, and optimization are done to get a better result based on those parameters identified as more sensitive parameters in the sensitivity analysis. And the process was performed until the value in the simulated and observed meets the criteria on the model performance evaluations and has a good relationship (see Tables 9, 10, and Fig. 4). As shown in Table 11, performance of the model is acceptable.

**SCS curve number method**

In the SCS CN method, the curve number, initial abstractions, and the lag time in the SCS UH transform method are identified as sensitive parameters, and calibration is done based on changing the values. The result is summarized in Tables 12, 13, 14, and Fig. 5.

**Green and ampt loss method**

In this model the hydraulic conductivity which is a factor resulting from the soil texture class being highly sensitive, and the suction head, saturate content and initial water contents show less sensitivity to the changing the initial value. Additionally, in the Snyder transform method, the peaking coefficient is more sensitive and, the lag time is less sensitive. The result is summarized in Tables 15, 16, 17, and Fig. 6.

**Validation**

The verification of the model is performed to check the validity of the model and its parameters for the use of the outputs for the entire period on this catchment. For this study, model validation was performed by taking five years from 2009 to 2013 for the meteorological and hydrological data and the model parameters found after calibration from the individual methods feed to the model and simulation run

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**Table 8 Clark UH initial model parameters**

| Sub-basin | Longest flow path L (km) | Lag time (min) | $T_c$ (hr) | Storage coefficient (hr.) |
|-----------|--------------------------|----------------|------------|--------------------------|
| W820      | 138.28                   | 700.48         | 19.46      | 21                       |
| W710      | 133.53                   | 935.17         | 25.98      | 23                       |
| W800      | 137.53                   | 747.75         | 20.77      | 12                       |
| W900      | 140.79                   | 920.53         | 25.57      | 12                       |
| W1150     | 98.96                    | 619.13         | 17.20      | 15                       |
| W1420     | 110.00                   | 1164.3         | 32.34      | 10                       |
| W1450     | 206.72                   | 1053.6         | 29.27      | 14                       |
| W1440     | 194.91                   | 797.71         | 22.16      | 14                       |

**Table 9 Calibration result for initial and constant loss method**

| Measure               | Simulated | Observed | Percent difference |
|-----------------------|-----------|----------|--------------------|
| Total volume (MM)     | 474.02    | 482.89   | 0.981              |
| Peak flow (m3/s)      | 272.3     | 291      | 3.23               |
| Time of peak          | September 18, 2007 | August 30, 2006 |

**Table 10 Calibrated model parameters initial and constant loss rate method**

| Sub-basin | $T_c$ (hr) | Constant rate (mm/hr) |
|-----------|------------|------------------------|
| W820      | 20         | 2                      |
| W710      | 25         | 4                      |
| W800      | 25         | 10                     |
| W900      | 10         | 8                      |
| W1150     | 30         | 0.232                  |
| W1440     | 10         | 3                      |
| W1420     | 15         | 2                      |
| W1450     | 30         | 8                      |
processed. The result in the initial and constant loss methods are 0.5, 0.7, and 0.47 for Nash-Sutcliff, RMSE and Correlation coefficient ($R^2$), respectively. On the other hand, the Nash-Sutcliff was 0.51, 0.7 RMSE, and Correlation coefficient ($R^2$) 0.46 for the Green and Ampt method. Similarly, the data is also validated for the SCS CN method and the result shows 0.52 for Nash-Sutcliff, 0.7 for RMSE, and 0.55 for Correlation coefficient ($R^2$) and presents graphically in Fig. 7.

**Discussion**

For the comparison of the model outputs from the performance evaluation criteria, the value of the Nash-Sutcliff, coefficient of determination $R^2$, and RMSE were used. In the Initial and Constant loss rate according to the information found from the result of calibration the Nash–Sutcliffe value is more sensitive to the constant loss rate value and less sensitive to other parameters. In contrast, the RMSE value highly responds to the change in the value of storage coefficient and time of concentration than the constant loss rate. Additionally, the result of calibration in the SCS CN method shows that the Nash–Sutcliffe value is more sensitive to the curve number and initial abstraction value and less sensitive to other parameters. In contrast, the RMSE value highly responds to the change in the value of lag time than the curve number and initial abstraction. And the Green Ampt method the Nash-Sutcliff value was more sensitive to the hydraulic conductivity of the soil and less sensitive to...
the suction head and the RMSE was sensitive to the peaking coefficient.

Arekhi Saleh (2011) performed three models of runoff losses using HEC-HMS; Green and Ampt, Initial and constant loss rate, and Deficit and Constant loss rate by considering objective functions of the difference between the percent of observed and simulated volume and peak and the result showed that Initial and constant loss rate method among six events, in four events by fitting with percent error in peak and five events by fitting with percent error in volume had better results rather than Green and Ampt method which in three events by fitting with the objective function of percent error in peak and one event by fitting with percent error in volume had less variation coefficient of observed discharges compared to simulated discharges. Additionally, King et al., 1999 compared two methods on the Goodwin Creek watershed, and the observed and simulated stream flow at the outlet were evaluated and the monthly model efficiency was 0.84 for SCS-CN and 0.69 for Green and Ampt models.

Finally, the Initial and Constant loss rate, the Green Ampt, and, the SCS CN method of the HEC-HMS hydrologic model compared based on their statistical relationship by the single-factorial ANOVA using SPSS was done.
and show the significant relationship between the model performance evaluation criteria with \( p \)-value highly less than \( \alpha = 0.05 \) and the analysis result present in Table 18. Overall, the Initial and Constant loss rate method is relatively better than the other method based on these evaluation criteria (Fig. 8).

![Observed Vs Simulated](image1)

**Fig. 6** Simulated versus observed flow data for green and Ampt after calibration

![Observed Vs Simulated](image2)

**Fig. 7** Model validation result

![Validation](image3)

**Validation**

![Table 18](image4)

**Table 18** Statistical evaluation between the observed and simulated discharges

| Summary | Count | Sum | Average | Variance |
|---------|-------|-----|---------|----------|
| Method Code | 12 | 30 | 2.5 | 1.363636 |
| Discharge | 12 | 5780.7 | 481.725 | 88.28523 |

**ANOVA**

| Source of Variation | SS | \( df \) | MS | \( F \) | \( p \)-value | \( F \)_{critical} |
|---------------------|----|------|----|------|----------|----------|
| Between Groups      | 1,377,940 | 1 | 1,377,940 | 30,740.82 | 4.2E-36 | 4.30095 |
| Within Groups       | 986,1375 | 22 | 44,82443 |        |          |           |
| Total               | 1,378,926 | 23 |        |        |          |           |
**Conclusion**

An objective of the study is to assess the appropriate hydrologic model for estimation of runoff in the Awash River Basin at the middle awash multi-purpose dam and estimation of its volume by considering the Initial and Constant loss, Green and Ampt, and SCS CN methods from the HEC-HMS hydrologic model software package and evaluate their performance numerically, graphically and statically.

The data which is an essential aspect of the rainfall-runoff modeling is the focal point in this study various sources are identified to get the real-world data and intensive efforts are put into data collection and processing. And the major data identified as important for this study are the daily meteorological and hydrological data, the DEM, LULC, and Soil map of the watershed, and the existing water abstractions. The simulation of the model began by selecting the initial parameters and estimating from the collected data and inputted to the HEC-HMS schematic which was developed with the help of Arc-GIS in conjunction with HEC-GeoHMS extension software. The model was calibrated by taking five-year stream flow data from 1 January 2004 to 31 December 2008 until the simulated and observed discharges were equal. After calibration, the model validates using five-year data from 1 January 2009 to 31 December 2013 and parameters found during calibration. And the performance of each model was evaluated using the Nash-Sutcliff, Correlation coefficient $R^2$, and RMSE.

According to the result after the calibration and validation of each model, the initial and constant loss method shows a good fit between the observed and the simulated value with 0.73, 0.75, and 0.5 for Nash-Sutcliff, correlation coefficient $R^2$, and RMSE values, respectively. Finally, the statistical relation between each model was checked by the ANOVA and showed a significant relationship between the three models.

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**Data availability** All essential data generated during the manuscript analysis are included within the article. Furthermore, datasets are available from the corresponding author upon request.

**Declarations**

**Conflict of interest** We (Authors) wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

**Ethical approval** We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

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