A Computer Model for Precipitation, Stream Discharge, and Phosphorus Levels in the Mettawee River Watershed

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Introduction

The Mettawee and Poultney Rivers are included in the southern part of the Lake Champlain Watershed. The Mettawee River is approximately 66 kilometers (41 miles) in length , flows northeast and empties into the southern portion of Lake Champlain. The Mettawee River drains 355 km^2 (137square miles) of land in Vermont. Over the past several years, significant storm events (TS Irene and TS Sandy) have had dramatic impacts on the mobilization of nutrients from the watershed areas into Lake Champlain. Therefore, creating a computer model which accounts for the watershed hydro-geologic properties (soil saturation, infiltration, soil porosity, and runoff) is an important first step in predicting the impact of future storm events on nutrient loading in Lake Champlain.

Scope of Project

The overall goal of this project was to develop a computer model which could be used to predict the movement of water and nutrients through the Mettawee River watershed following storm events.

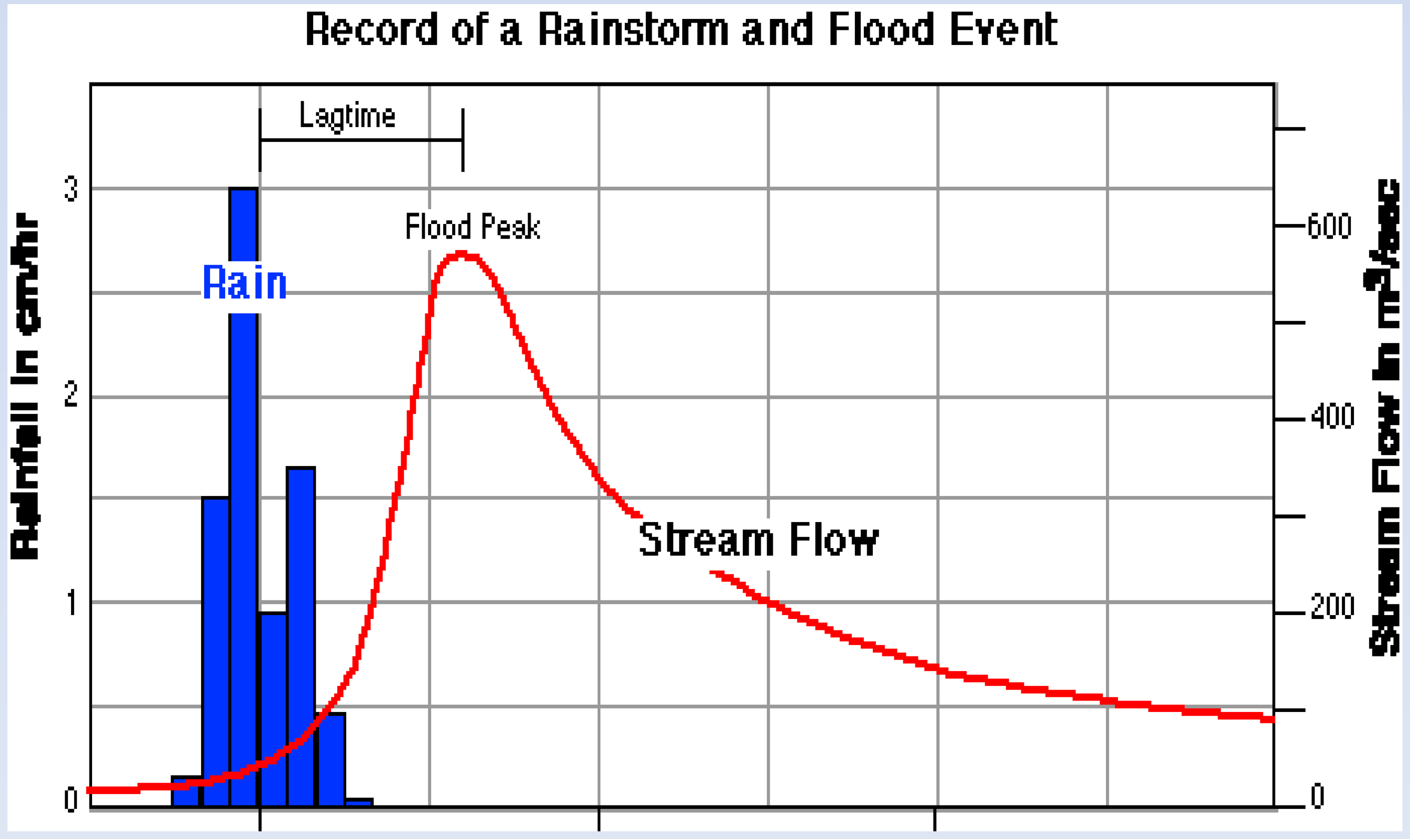
The specific goals include:

1) The development of a model which follows the predicted reference behavior pattern for rainfall, stream discharge, and nutrient concentrations in published hydrographs.

2) Create a model which produces results which agree with data collected from the Mettawee River watershed in terms of stream discharge and nutrient concentrations following major storm events.

Methods

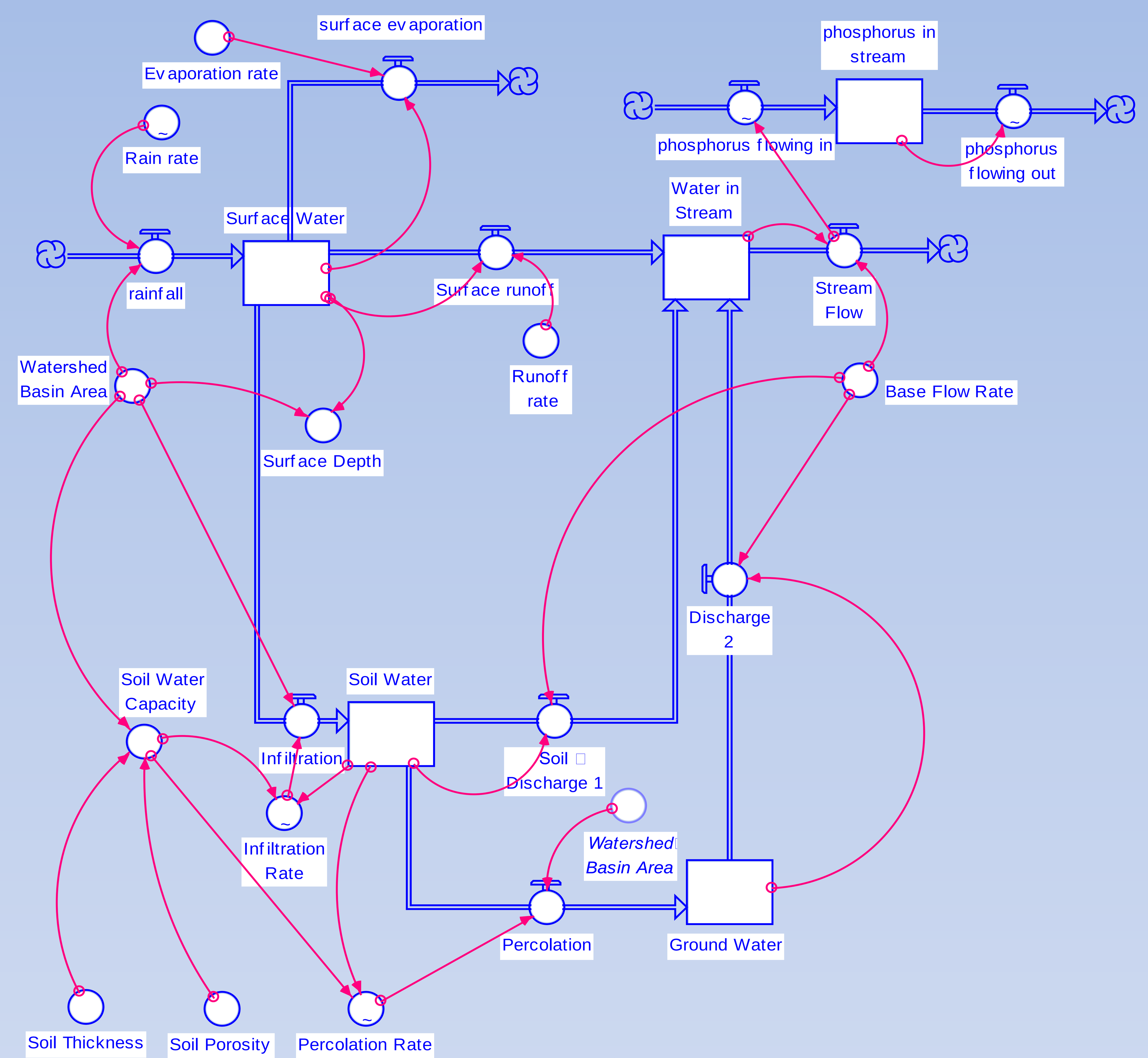
In this project, a dynamic model for rainfall, stream discharge, and nutrient concentrations was developed using STELLA© modeling software. The specific inputs into the computer model (watershed area, base stream discharge, soil composition, slope of stream, and relationship between phosphorus concentration and stream discharge) were obtained from data collected over the last six (6) years of research on the Mettawee River (VT EPSCoR). In order to complete the model, we made several assumptions for the size of the of ground water reservoir and the amount of water in the soil.



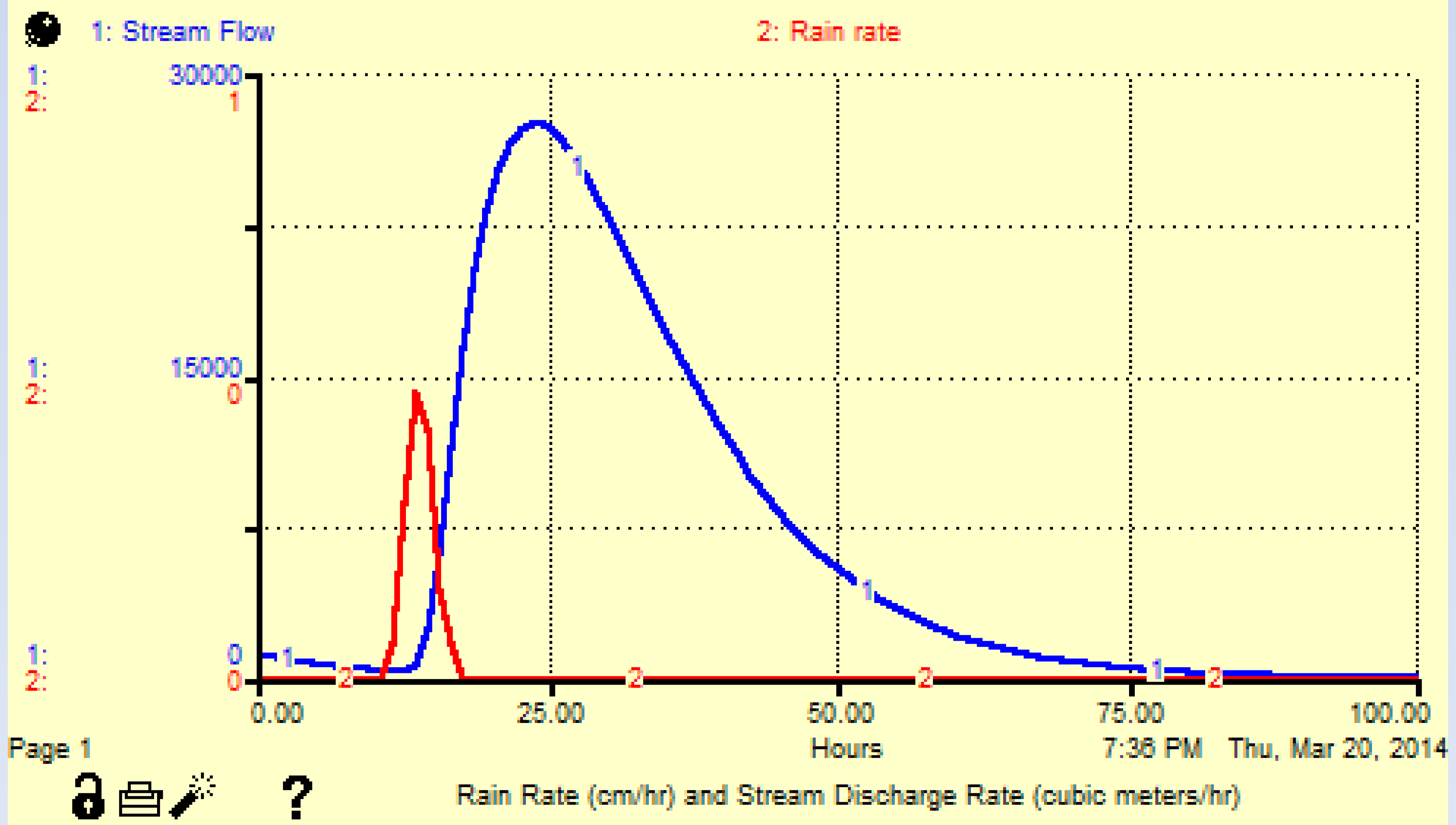
Reference Behavior Pattern – Hydrograph

From: alevelgeography.com

STELLA Model



Graph generated from computer model



Inputs and Equations

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Ground_Water(t) = Ground_Water(t - dt) + (Percolation - Discharge_2) * dt
INIT Ground_Water = 1000
INFLOWS:
Percolation = Watershed_Basin_Area*(Percolation_Rate*.01)
OUTFLOWS:
Discharge_2 = Base_Flow_Rate*.95*(Ground_Water/INIT(Ground_Water))
phosphorus_in_stream(t) = phosphorus_in_stream(t - dt) + (phosphorus__flowing_in -
phosphorus__flowing_out) * dt
INIT phosphorus_in_stream = 5
INFLOWS:
phosphorus__flowing_in = GRAPH(Stream_Flow)
(0.00, 0.00), (8000, 14.0), (16000, 19.8), (24000, 20.6), (32000, 21.6), (40000, 22.1),
(48000, 23.6), (56000, 25.8), (64000, 28.9), (72000, 32.4), (80000, 38.1)
OUTFLOWS:
phosphorus__flowing_out = GRAPH(phosphorus_in_stream)
(0.00, 0.00), (10.0, 0.137), (20.0, 0.275), (30.0, 0.275), (40.0, 0.619), (50.0, 1.62), (60.0,
3.06), (70.0, 6.08), (80.0, 7.15), (90.0, 8.08), (100, 8.32)
Soil_Water(t) = Soil_Water(t - dt) + (Infiltration - Soil__Discharge_1 - Percolation) * dt
INIT Soil_Water = 500
INFLOWS:
Infiltration = Watershed_Basin_Area*(Infiltration_Rate*0.01)
OUTFLOWS:
Soil__Discharge_1 = Base_Flow_Rate*.05*(Soil_Water/INIT(Soil_Water))
Percolation = Watershed_Basin_Area*(Percolation_Rate*.01)
Surface_Water(t) = Surface_Water(t - dt) + (rainfall - Surface_runoff - Infiltration -
surface_evaporation) * dt
INIT Surface_Water = 0
INFLOWS:
rainfall = Watershed_Basin_Area*(Rain_rate*.01)
OUTFLOWS:
Surface_runoff = Surface_Water*Runoff__rate
Infiltration = Watershed_Basin_Area*(Infiltration_Rate*0.01)
surface_evaporation = Surface_Water*Evaporation_rate
Water_in_Stream(t) = Water_in_Stream(t - dt) + (Surface_runoff + Soil__Discharge_1
+ Discharge_2 - Stream_Flow) * dt
INIT Water_in_Stream = 10000
INFLOWS:
Surface_runoff = Surface_Water*Runoff__rate
Soil__Discharge_1 = Base_Flow_Rate*.05*(Soil_Water/INIT(Soil_Water))
Discharge_2 = Base_Flow_Rate*.95*(Ground_Water/INIT(Ground_Water))
OUTFLOWS:
Stream_Flow = Water_in_Stream*(Base_Flow_Rate/INIT(Water_in_Stream))
Base_Flow_Rate = 1080
Evaporation_rate = 0.1
Infiltration_Rate = GRAPH(Soil_Water/Soil_Water_Capacity)
(0.00, 4.98), (0.1, 4.90), (0.2, 4.67), (0.3, 4.31), (0.4, 3.88), (0.5, 3.44), (0.6, 3.08), (0.7,
2.41), (0.8, 1.60), (0.9, 1.03), (1.00, 0.00)
Percolation_Rate = GRAPH(Soil_Water/Soil_Water_Capacity)
(0.00, 0.00), (0.1, 0.00), (0.2, 0.000687), (0.3, 0.00275), (0.4, 0.0067), (0.5, 0.0124),
(0.6, 0.0201), (0.7, 0.0301), (0.8, 0.0385), (0.9, 0.0455), (1.00, 0.0497)
Rain_rate = GRAPH(TIME)
(10.0, 0.00), (10.8, 0.0137), (11.7, 0.172), (12.5, 0.323), (13.3, 0.419), (14.2, 0.309),
(15.0, 0.117), (15.8, 0.0619), (16.7, 0.00), (17.5, 0.00), (18.3, 0.00), (19.2, 0.00), (20.0,
0.00)
Runoff__rate = 0.4
Soil_Porosity = 0.1
Soil_Thickness = 2
Soil_Water_Capacity = Watershed_Basin_Area*Soil_Thickness*Soil_Porosity
Surface_Depth = Surface_Water/Watershed_Basin_Area
Watershed_Basin_Area = 57300000
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Conclusions

This project, which was a collaborative effort between students and their teacher, shows that a storm/hydrologic model for a watershed can be easily constructed to simulate different storm event scenarios. Furthermore, the data needed to construct a watershed model was readily available on the ESPCoR Streams Research website. Our results show that this model was able to recreate historical stream measurements with a high degree of accuracy. After inputting TS Irene rain data, our model generated stream discharge measurements and phosphorus levels which closely matched data obtained from actual stream measurements. Finally, our model is useful for highlighting the important factors that have the greatest impact on stream discharge and nutrient fluxes in a watershed.

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