Project Report

On

Development of a SWAT Model to Investigate the Impact of Climate Change and Land Uses on Water Bodies

Submitted to

Department of Civil Engineering, EWU

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Declaration

We, the below signatories, declare that the project report "Development of a SWAT Model to Investigate the Impact of Climate Change and Land Uses on Water Bodies", is based on our own completion of the project during our study under the supervision of Dr. Shakil Ahmed. We affirm that the claims we have made and the conclusions we have reached are the outcomes of our research.

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Acknowledgment

Working on this project report has been a great working experience for us. We learned about the use of ArcGIS-ArcSWAT software and practically used it. It is now, one of the latest IT skills which will help us in future to secure employment. It will also make us indispensable to any company.

We thank Allah for giving us the patience, guidance, and knowledge to accomplish every task successfully throughout the whole process. Although it is a time of challenge for all as it is the post-pandemic period. We had to make a transition from classes at home to on-campus classes. Allah has provided us with slight assistance regarding our project to come out of our leisure at home and finish this project.

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Finally, we like to thank our parents, relatives, and people with connection, who provided love, support, prayers, and encouragement from the start till the project’s completion.

We are thankful to all contributors listed and unlisted.

Development of a SWAT Model to Investigate the Impact of Climate Change and Land Uses on Water Bodies

Umme Habiba Shanchita (2018-1-22-002); Mahrab Hossain Joy (2017-2-22-023); Sumiya Akhter (2018-1-22-005)

Abstract

A project area of 27,690 acres, known as Lake Fork Reservoir was studied to calculate the surface-overflow runoff and nitrogen load of the selected watershed area. To get the data on present and future surface-overflow load and nitrogen load of the selected watershed area of the project, we used ArcGIS and ArcSWAT modeling software. The spatiotemporal data were processed in ArcGIS-ArcSWAT. The comparison of observed and simulated data from software and graph plotting was done by using MS Excel. Manual calibration was performed by changing curve number. Good calibration (R^2 = 0.68) was found by comparing 2016-2020 simulated surface overflow data with 2016-2020 observed surface overflow data. The validation (R^2 = 0.58) was done by comparing observed data of 2021 and model simulated data of 2021. A comparison chart was created comparing 2020 observed surface overflow with 2050 simulated surface overflow data. We applied vegetative strip as a nature-based solution to reduce nitrogen load for year 2020. After applying the vegetative filter strip, we were able to reduce nitrogen load by almost 65% in the peak farming month of June. The forecast of future surface overflow data also showed that in the future there will be a drastic increase in surface overflow load in winter.

Table of Contents

Contents

List of Abbreviation

- ArcGIS — Aeronautical Reconnaissance Coverage Geographic Information System
- ArcSWAT — Aeronautical Reconnaissance Coverage Soil & Water Assessment Tool
- CN — Curve Number
- DEM — Digital Elevation Model
- GCM — Global climate models
- HRU — Hydrologic Response Units
- IPCC — Intergovernmental Panel on Climate Change
- LARS-WG — Long Ashton Research Station Weather Generator
- MS — Microsoft
- NASA — National Aeronautics and Space Administration
- NEX-GDDP — NASA Earth Exchange Global Daily Downscaled Climate Projections
- USA — United States of America
- RCP — Representative Concentration Pathway
- SDSM — Statistical Downscaling Model
- SWAT — Soil and Water Assessment Tool
- SRTM — Suttle Rader Topography Mission
- USA — United States of America
- USGS — United States Geological Survey
- VFS — Vegetative Filter Strips

1. Introduction

Changes in climate such as precipitation and temperature can have a significant effect on the quantity and quality of surface waters according to data from long-term ecosystem monitoring and research stations worldwide. Water quality can degrade during storms, snowmelt, and periods of elevated air temperature or drought. It can cause water quality conditions that the ecosystem cannot handle. In an ecosystem, the factors controlling water quality are sensitive to climate change. Due to the greenhouse effect, the temperature of Earth is increasing day by day. This is creating changes in the usual climate scenario worldwide and, this continued climate stress will increase the recurrence with which ecosystem thresholds will be exceeded. This will cause a negative impact on water bodies. We can see the example of this even in the present. Droughts are becoming longer and more extreme worldwide. Tropical Storms becoming more severe due to the rise of the temperature of ocean water.

Changes in land use alter chemical, physical, and biological elements in watersheds. This leads to the alteration of the quality of adjacent surface waters. Human caused changes like, the use of chemical fertilizer, pesticides in farming; waste dumping, etc. can complicate the perception of water-quality changes resulting from changes in climate, and can be both mitigated and intensified by climate change.

To investigate these impacts, we need a tool to forecast future scenarios and come up with a solution to mitigate the negative effect of climate change and land use on water bodies. To accurately forecast future scenarios, we built a hydrologic and water quality model. To forecast future climate change impact and land use impact on water bodies we need to know the amount of surface overflow data and chemical yields. For these tasks, SWAT is the latest software to use to get the surface overflow data and chemical yields data.

In this project, SWAT is used to predict and evaluate the agricultural chemical yield which is nitrogen in our case. We also obtained surface overflow data for the present and future. Then, we came up with a nature-based solution which is a provision of the vegetative strip. Nature-based solutions (NBS) are explained as ―actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits (IUCN, International Union for Conservation of Nature, 2016).

1.1. Objectives

The specific objectives of the project are as follows:

1) To develop a hydrologic and water quality model to investigate the effect of climate change and land uses on water quantity (surface overflow runoff) and water quality (nitrogen load) in a waterbody.

2) To design a vegetative filter strip as a nature-based solution to reduce nitrogen load from the watersheds

1.2. Literature Review

Lake Fork Reservoir is located in Texas, USA. It is owned by the Sabine River Authority, a state agency. The communities around Lake Fork are made up of several small towns and communities. It is best known for its fishing. There is also marina's, lake parks, resorts, restaurants, boat ramps, tackle shop, and vacation locations. In this community, wells provide household water and individual wastewater treatment systems are used to manage wastewater. Town wastewater is treated north end of town. However, onsite wastewater treatment systems such as septic systems fail for a variety of reasons. Common soil-type limitations which contribute to failure include seasonally high-water tables, compact glacial till, bedrock, and fragipan. When these septic systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration) there can be adverse effects to surface waters (Horsley and Witten 1996). Septic systems contain all the water discharged from homes and businesses and can be significant sources of pollutants. Moreover, agricultural effluents are also a concerning matter. The annual average surface-overflow data increases most in June as it is the peak farming period. So, to reduce the adverse effect on surface water a nature-based solution is required.

In our project, we used SWAT to come up with the nature-based solution which is the provision of a vegetative filter strip. Hydrologic and water quality modeling using SWAT was done to reach this solution with accuracy.

SWAT is used to evaluate the impact of future climate change on the hydrology and water resources of the Upper Blue Nile River Basin (UBNRB). The inputs of weather data were selected by screening using two well-known downscaling models which are SDSM and LARS-WG. These inputs were screened from large scale output from one GCM or several GCM. The impacts of scenarios are simulated for two future time periods, 2046-2065 and 2081-2100, and compared with model results for the 1970-2000 baseline period. The SWAT model is calibrated and validated on streamflow observed at the Eldiem gauging station (Ethio-Sudan border) during the baseline period. Model performance is evaluated using standard performance parameters. All these statistical quantities indicate a good adjustment of the modeled to the observed streamflow for both the calibration and validation period. The results of the future simulations of flow and other hydrological processes in the UBNRB, using SWAT reveal that, relative to the 20th-century baseline period, the Blue Nile River streamflow declines in both the 2050s and 2090s decade. These reductions range between 10% and 61%, depending mainly due to higher temperatures and lower precipitation, as predicted by the GCM's climate models.

SWAT is also used in predicting hydrologic response to climate change on streamflow in the Luohe River Basin. Here, using SWAT a physically-based distributed hydrological model was calibrated, using daily streamflow records from 1992 to 1996 and validated using daily streamflow records from 1997 to 2000. The calibration and validation results showed that the SWAT model was able to simulate the daily streamflow well, with a coefficient of determination greater than 0.7, for both the calibration and validation periods. Using the average streamflow from 1992 to 2000 as a baseline, the simulated annual average streamflow showed almost no change shortly (around 2020) and increased by approximately 10% by 2050. The predicted seasonal average streamflow showed changes within ±20%. The monthly average streamflow showed changes within ±20% for all months except May, which showed predicted monthly streamflow increases of as much as 60%. Based on model results, the Luohe River basin will likely experience a small change in streamflow by the mid-21st century.

SWAT modeling is used to forecast the variations of temperature and precipitation during the period of 2020-2050 for the northern part of the Thenpennar sub-basin. The simulated data is validated using the base period from 1980 to 2000 which shows the distribution of rainfall and temperature among 38 watersheds. The results from this study show that there is a decrease in rainfall for a maximum of about 20% in the month of December during the predicted period of 2020 and 2050.

The SWAT model is used to simulate and quantify the sediment yield from an Eastern Himalayan River basin. Calibration of 2006–2009 and validation of 2010–2012 of the model showed a reliable and satisfactory estimate of daily streamflow. The critical areas were identified and prioritized at the HRU level. NASA NEX-GDDP dataset is used to simulate future sediment yield. The analysis periods were grouped into 27-year blocks with a baseline of 1979 (1979–2005) and three future time slices, i.e., near-future or the 2030s (2019–2045), mid-future or the 2060s (2046–2072), and far-future of the 2080s (2073–2099). Results indicated a good correlation (R^2 = 0.84) between water yield and sediment yield. Analysis of the spatial distribution of sediment yield showed that a large portion of the study area (73.34%) came under a slight sediment yield class, while a small portion (6.4%) was under a very severe sediment yield class. The temporal variation of sediment yield under various yield classes as well as the average annual sediment yield showed an increasing trend over time. The average total sediment yield for the period (2006–2012) was estimated at 17.92 tons ha per year, which crossed the permissible sediment yield loss limit of 12 tons ha per year by water. Prioritization on the HRU scale revealed that a total of 48 HRUs which aggregated to 53.83 km^2 came under priority class I, while 357 HRUs came under priority class VI representing 74.34% of the watershed area. An increase in the area under slight (2.21%), moderate (1.27%), and severe (0.09%) sediment yield classes and a decrease in area under high (−5.07%), very high (−0.28%), and very severe (1.78%) sediment yield classes was projected under RCP 4.5 scenario. In the case of RCP 8.5 scenario, a decrease in the area under slight (−17.25%), moderate (−5.83%), and high (−3.02%) sediment yield classes and an increase in area under very high (6.0%), severe (11.12%), and very severe (8.98%) sediment yield classes was projected by the end of the twenty-first century. Thus, the sediment yield is projected to increase as a result of climate change, implying the need for basin-wide sediment management measures in the study area to mitigate the detrimental effects of this change.

1.3. Study Area

The study area of our project is Lake Fork Reservoir which is located in Texas, the USA at Latitude 32°49’56” N, longitude 95°36’09” W. Below the study area of our project is marked on the map of USA:

Figure 1: Marked catchment of project area on the USA map

The project area is 27,690 acres. The project area consists of Hunt Hopkins, Lone Oak, Hopkins, and Rains of Texas. It officially serves as a reservoir for Dallas and its suburbs. However, it is best known for its fishing. Here, the study area of the SWAT project is shown with a better view:

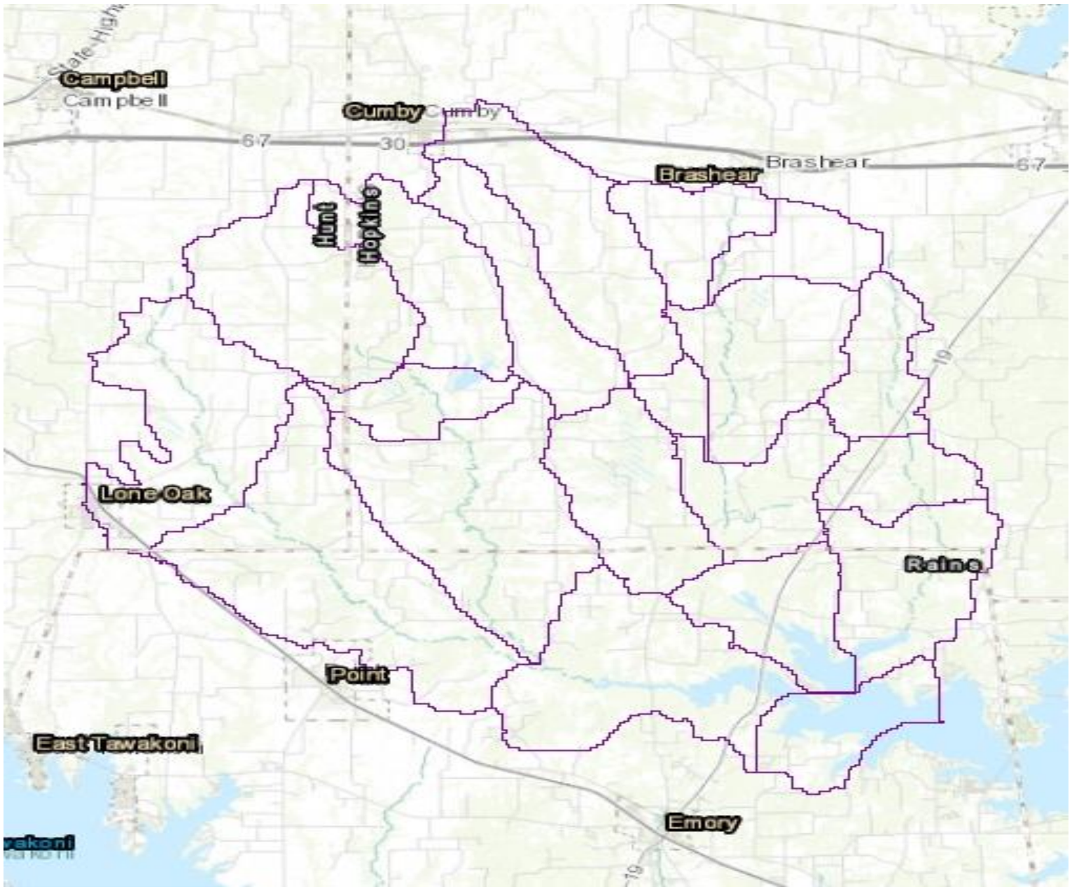

Figure 2: Project catchment area shown in topographic map of USA

1.4. Datasets Used

For the monthly simulation of precipitation and temperature, several parameters were given as input in Arc SWAT. Some of them include the land use/land cover, soil type, slope, and a complete weather database comprising data like – rainfall, temperature, solar radiation, relative humidity, and wind speed. The datasets were both in the form of layers and databases. The source DEM that provides the elevation information was used for delineating the basin. The land use/landcover data was taken from USGS. The corresponding soil cover data was also taken from the SWAT global data. Variables used and climate data required for the study are shown in Table 1.

2. Methodology

The research content is distributed into two main parts corresponding to present and future periods through the SWAT application. Where the first part represents the setting up of the SWAT model, model running, model calibration along with validation. This SWAT model focuses on the simulation of the water flow and climate change. Therefore, the objective of this study is to develop a hydrologic model or water quality model to investigate the effect of climate change and design suitable parameters to reduce the nutrients loads /vegetative load. The second part of this study is to predict the nutrient load based on population growth and urbanization.

2.1. SWAT Model Description

SWAT is a long-term water quality simulation model that predicts the impact of management decisions on water, sediment, and agricultural chemicals in watersheds. The model is specially referenced to a specific watershed. SWAT subdivides a watershed into subbasins linked by a stream network and further delineates HRUs that consist of individual combinations of land cover and soils within each subbasin. The model assumes there is no interaction within HRUs. And these HRUs are virtually located within each subbasin. HRU delineation minimizes the computation cost of simulation by lumping similar soil and land use areas into a single unit. SWAT can simulate surface and subsurface flow, sediment generation and deposit, nutrient fate, and movement through the landscape. As a physically-based distribution model, which uses readily available inputs and enables users to study long-term impacts. SWAT needs many datasets like topography, soil, land use, weather, etc. to support its application.

Table 1. Variables used in the SWAT model and data sources

S. No.	Variables	Data Sources
1	Remote sensing data	SRTM (DEM)
2	Land use/ land cover mapping	Earth Site Explorer -USGS (SWAT Global Data (https://swat.tamu.edu/data/). Digitally LULC map has been prepared by using the image classification tool in ArcGIS
3	-	Observe data was collected from USGS(https://maps.waterdata.usgs.gov/mapper/index.html)
4	Soil	Data have been downloaded from SWAT Global Data((https://swat.tamu.edu/data/)

2.2. Overview of SWAT Model

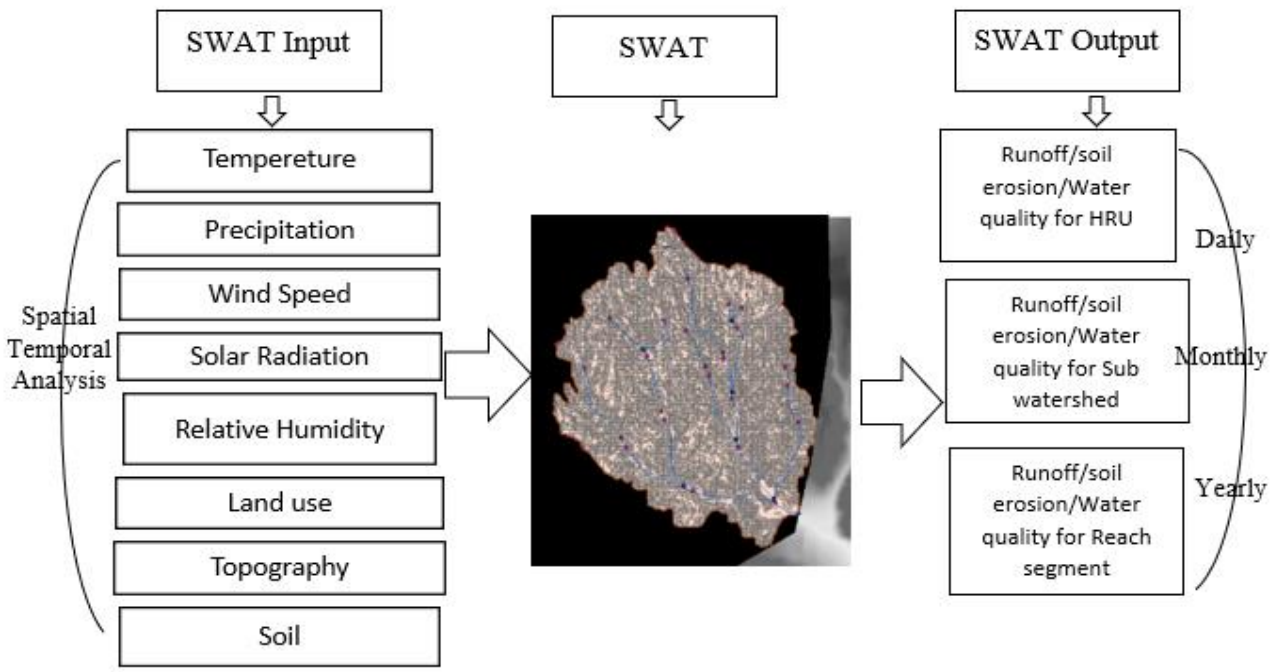

Figure 3: Overview of SWAT model

2.3. Watershed Delineation

Watershed delineation is a process for creating a boundary surrounding a water body or runoff outlet that represents the contributing area for a specific control point or water outlet in order to analyze the portions of the study area. The DEM source was the input to delineate the watershed automatically in Arc SWAT. For the given input DEM, stream outline parameters such as flow direction were calculated. The total area of stream definition was 1000 Ha. The stream outline was followed by the stream network way where the outlets were defined manually by adding a point source to each sub-basin. The sub-basin was then delineated by selecting the watershed outlets. Where Each watershed is first divided into subbasins and then into hydrologic response units based on the land use and soil distributions. In this study, the lake fork watershed was divided into 20 sub-basins. As shown in Figure 3. Each sub basin's respective area covered, length, reach, width, depth, etc. were estimated by calculating the sub-basin parameters.

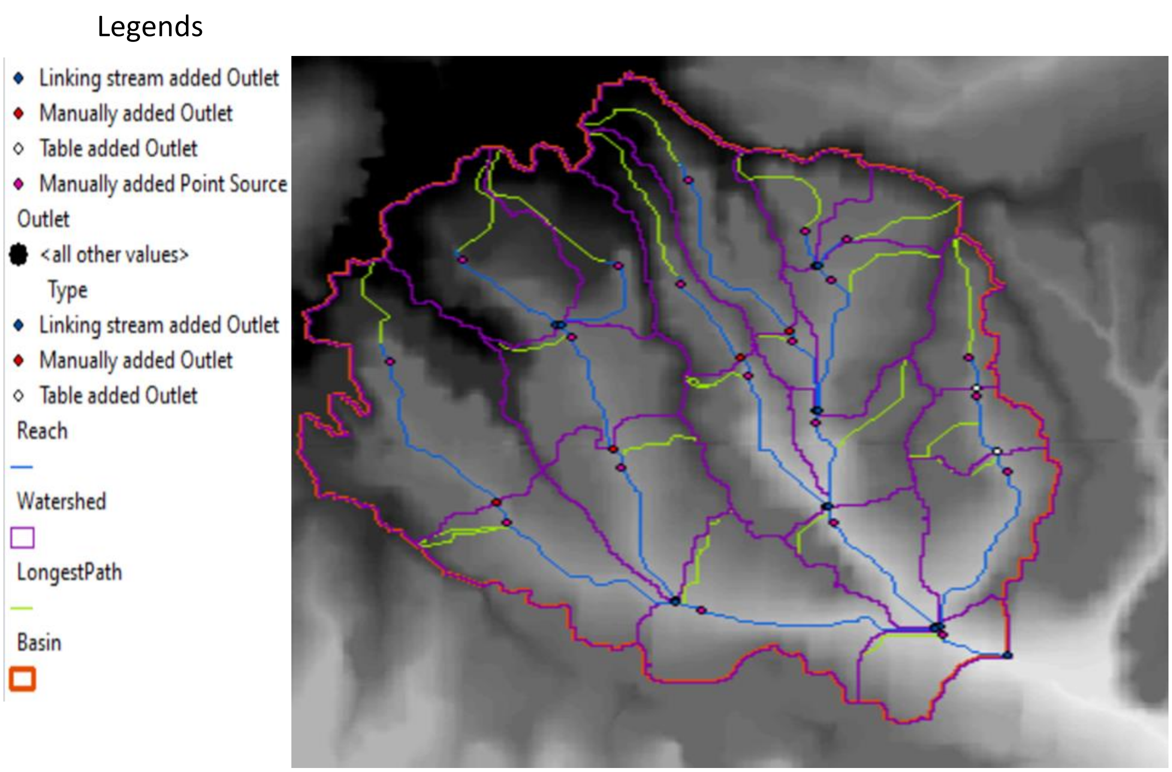

Figure 4: Watershed delineation

2.4. Land Use/Soil/Slope

- Land use/landcover – It generally refers to the classification of human activities and natural elements on the landscape within a specific time frame based on established scientific and statistical methods of appropriate source materials. The physical land type of the study area which defined by importing the Land Use and Land Cover data. where the area was extracted using the sub-basin boundary.

Legends land use classes

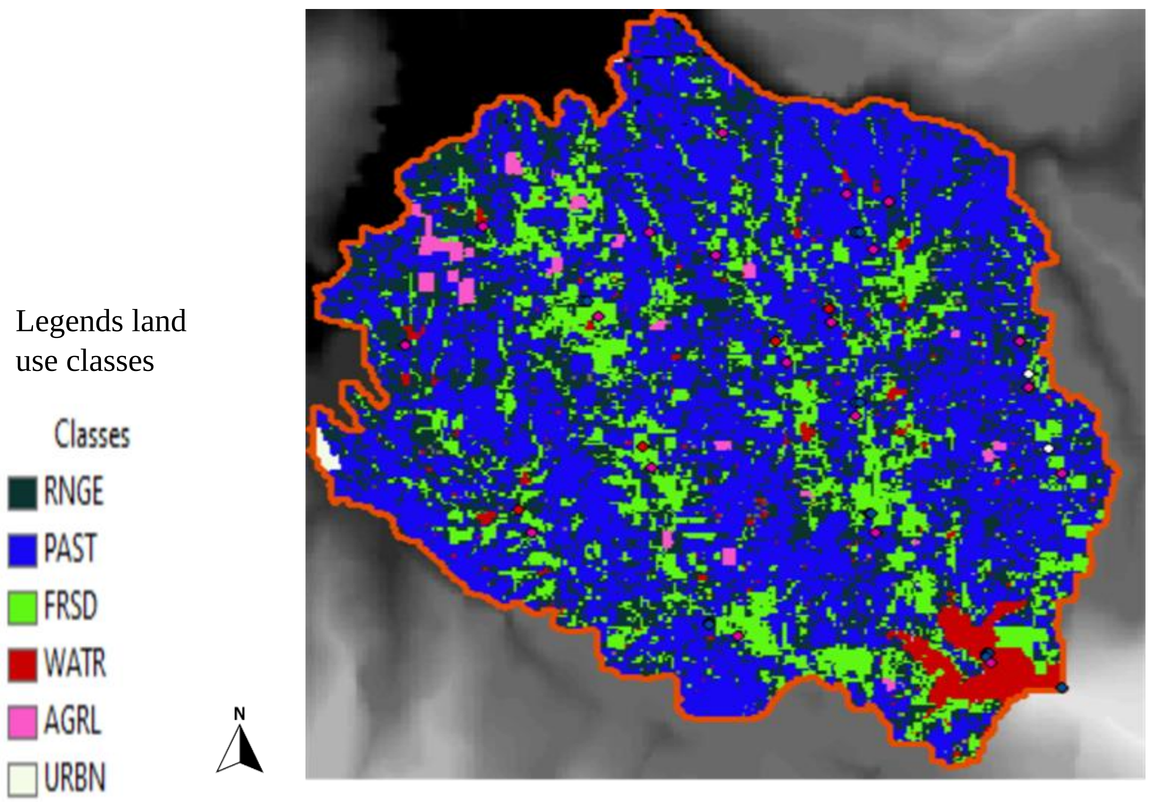

Figure 5: SWAT land use classes

- Soil – The soil type was initially obtained as a layer file and converted to raster format to give input for defining the soil cover later it was reclassified based on user-defined FAO soil type (SWAT- Soil Class).

Legends of
soil classes

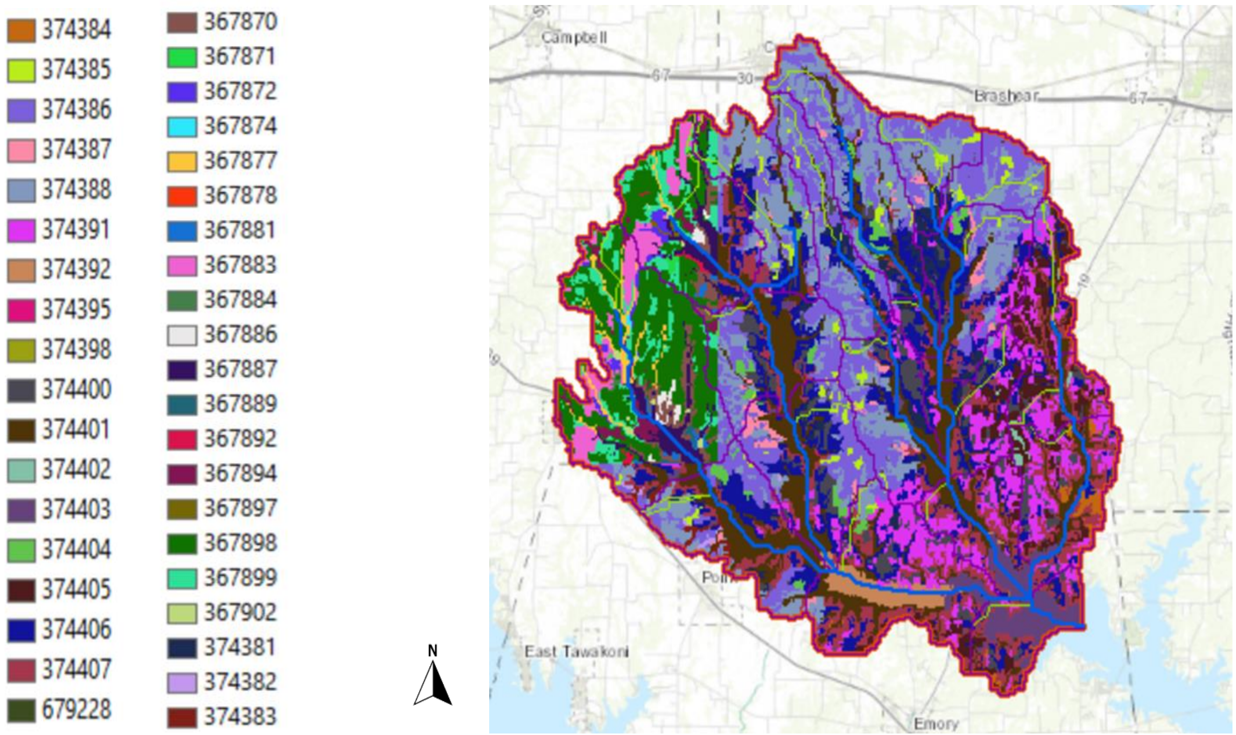

Figure 6: SWAT Soil classes

- Slope – It is an important measure that determines water, nutrients, and sediment movements. The number of slope classes was defined into 2 ranging between 0-1 (lower limit) and 1-9999 (upper limit).

Slope legends

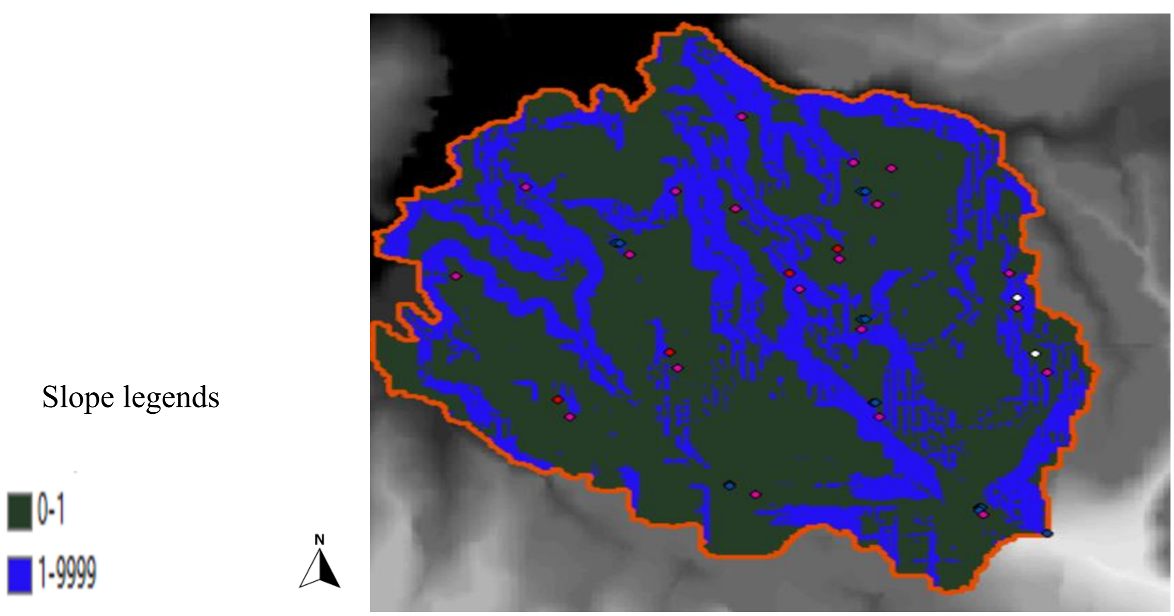

Figure 7: SWAT slope classes

2.5. HRU Analysis

It may be defined as an integration of many soil classes, land cover, and slope classes. The input parameters were overlaid to create the HRU feature classes. A layer is generated showing the HRU for sub-basins for each of the land use/soil/slope. The main source for determining climate factors was obtained from land use/soil/slope defined HRUs in conjunction with the weather database. The outcome of importing the database provides a report in which each HRU is grouped based on the existing land use pattern and soil type. HRU present in the Arc SWAT interface helps in superimposing soil maps and land use maps with corresponding delineated watershed and slope classes creating twenty sub-basins in the Lake fork watershed. Climate change in one way is dependent on the land use, soil, and slope since a whole of measurements are done for each watershed in the sub-basin.

2.6. Weather Database

Weather data consisting of rainfall (mm), maximum and minimum temperature (ºC), wind speed (km/hr), relative humidity (%), and solar radiation (cal/cm^2) obtained from the CFSR world database is imported into the Arc SWAT weather database. These values according to the respective latitude, longitude, and elevation of the study area were analyzed by the software and the input files were written automatically.

2.7. Model Calibration

In initial testing, model calibration is an essential process. Calibration and validation, in general, are done to ensure that the parameters are used to illustrate the study area. The model was calibrated for analyzing the curve number and precipitation using the observed data. Calibration was done to increase the accuracy and efficiency of the model and to obtain good values of the coefficient so that the performance of the model will increase. A warm-up period of one year (2015) was kept for the model to move from the estimated initial condition to an optimal state. Calibration was conducted for five years (2016–2020) on a monthly time step since the daily step didn't give the most appropriate value through changes in the curve number. The higher curve number represents high surface runoff and the lower curve number means the more permeable the soil is. Afterward, calibration values of R^2 were 0.68. After the successful completion of calibration, the model was validated for the years (2021 observed vs. 2021 simulated). Validation was performed to check the accuracy of the results and the performance of the model. The value of R^2 is found to be 0.58 for the validated data. Since values of R^2 are greater than the satisfactory criteria hence the results provided by the model are good.

Figure 8 shows a scatter plot of observed and simulated monthly flow out for the calibration period 2015-2020. The R^2 0.68 value suggests that there was a good agreement between observed and simulated flow during this period. After the calibration of the flow, the SWAT model captured the hydrologic characteristic in the study area well and reproduced acceptable monthly flow simulation. Figure 9 shows the monthly hydrograph for the calibration result which we got through changes in curve number in the SWAT model.

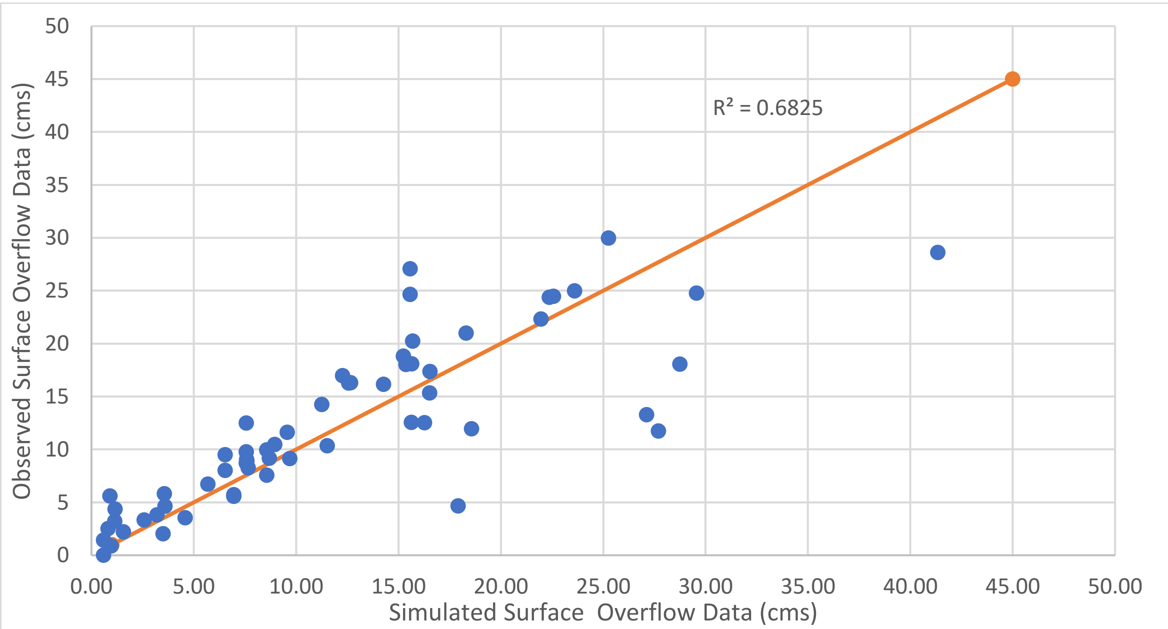

Figure 8: Scatter plot of monthly simulated and observed flow out during the calibration period (2016-2020)

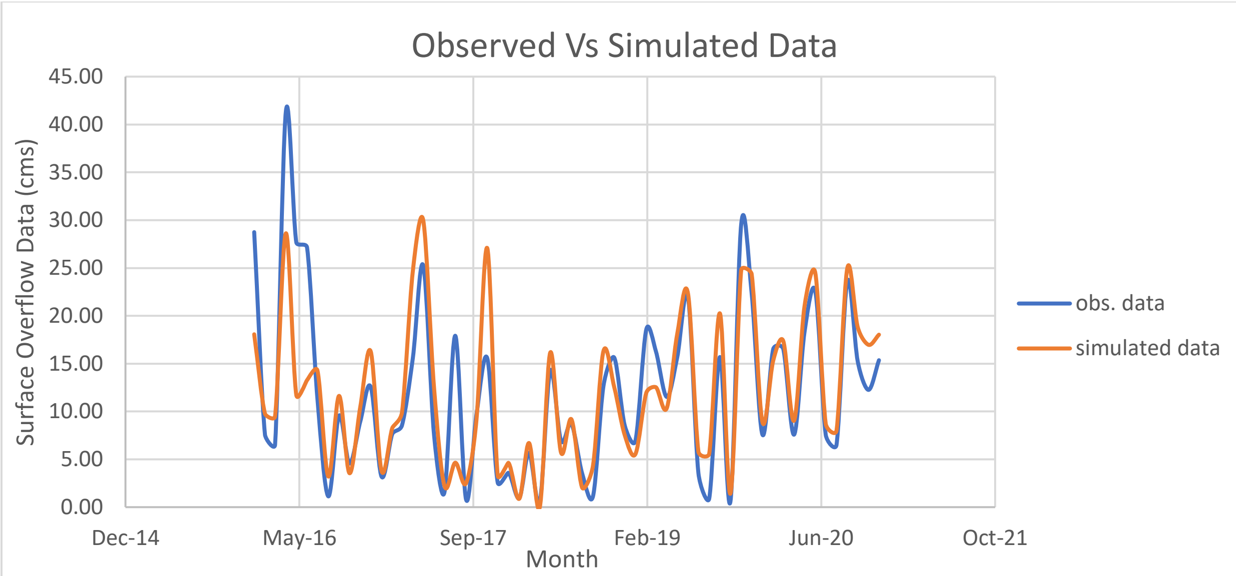

Figure 9: SWAT monthly flow out calibration results (2015-2020)

2.8. Validation of Model

After developing the model, we have to validate the model. We have found out that if the model will work properly for future date simulation.

So, for validation purposes, we compared the simulated and observed data for year 2021.

Table: Surface Overflow Data Comparison of the Year 2021

Month	Observed Data(m^3/s)	Simulated Data(m^3/s)
January	3.32	6.544
February	18.65	21.62
March	19.91	11.77
April	3.31	1.692
May	19.53	13.71
June	5.65	3.54
July	0.93	2.322
August	0.71	5.87
September	0.77	2.601
October	0.70	14.06
November	0.66	2.663
December	29.97	17.13

Here is the comparison chart for year 2021. There are many ways to validate a model. One of the techniques is R square value. When trying to validate a model, if the R square value goes more than 0.5, then we can say that the model is validated. After plotting the data, we found out that our R square value is more than 0.5. As a result, we can say that our model is now validated.

Here is a graphical representation of the model shown below:

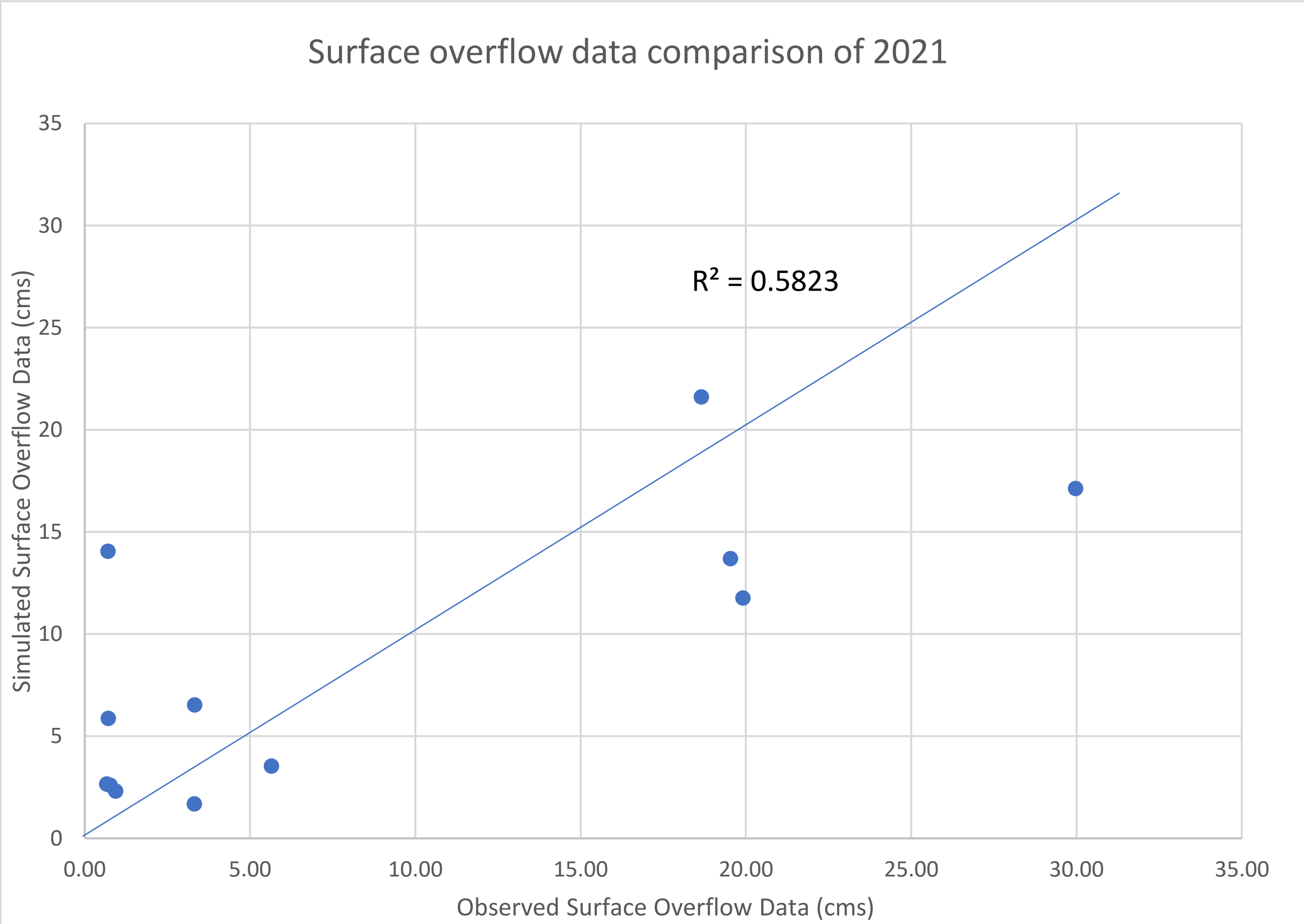

Figure 10: Surface overflow data comparison of 2021

Future Flow Outcome Prediction (2020vs2050)

Based on our model, we tried to simulate the surface overflow data for year 2050. Then we compared it to the observed data for 2020. By comparing both data we get an overall overview of the changes in flow in various months. It gives us a clear picture of how the future flow outcome will change from the present scenario.

Table: Surface Overflow Data Comparison of 2020 and 2050

Month	2020 Observed Data(m^3/s)	2050 Simulated Data(m^3/s)
January	7.59	1.72
February	16.52	13.68
March	16.53	10.34
April	7.58	16.03
May	18.29	15.33
June	22.57	9.20
July	7.57	1.105
August	6.52	15.66
September	23.60	2.634
October	15.23	13.47
November	12.26	8.69
December	15.36	24.78

Here is the comparison data chart of 2020 observed data against 2050 simulated data. This is the graphical representation of this chart

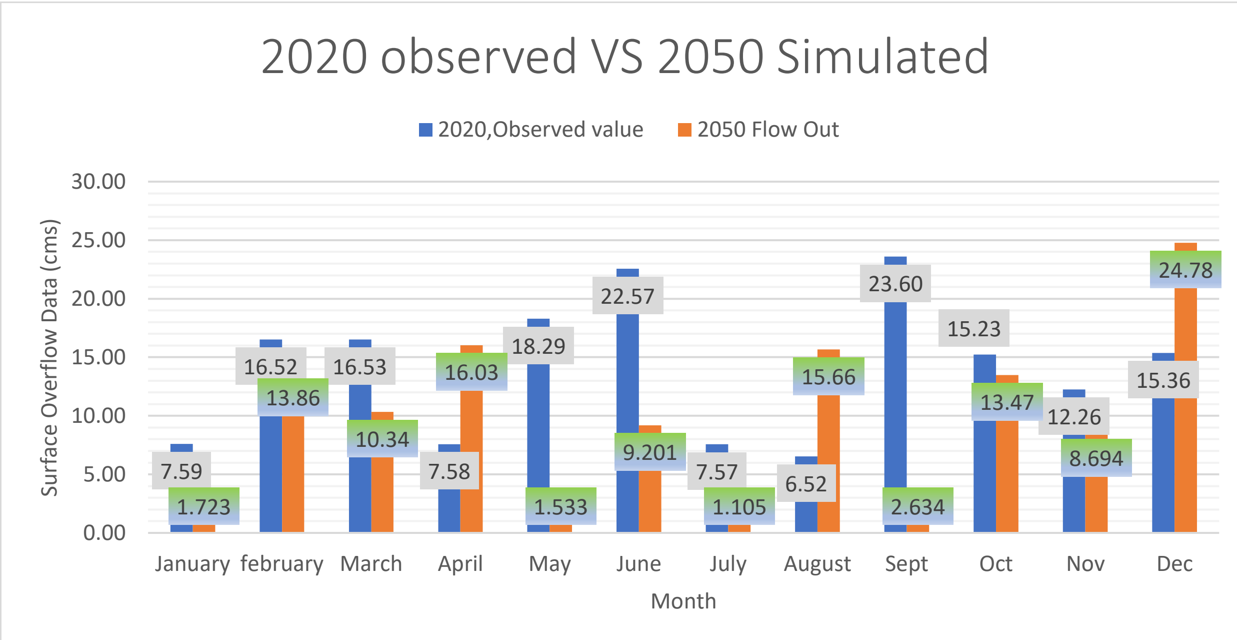

Figure 11: Comparison data chart of 2020 observed surface overflow data against 2050 simulated surface overflow data

May-September Flow

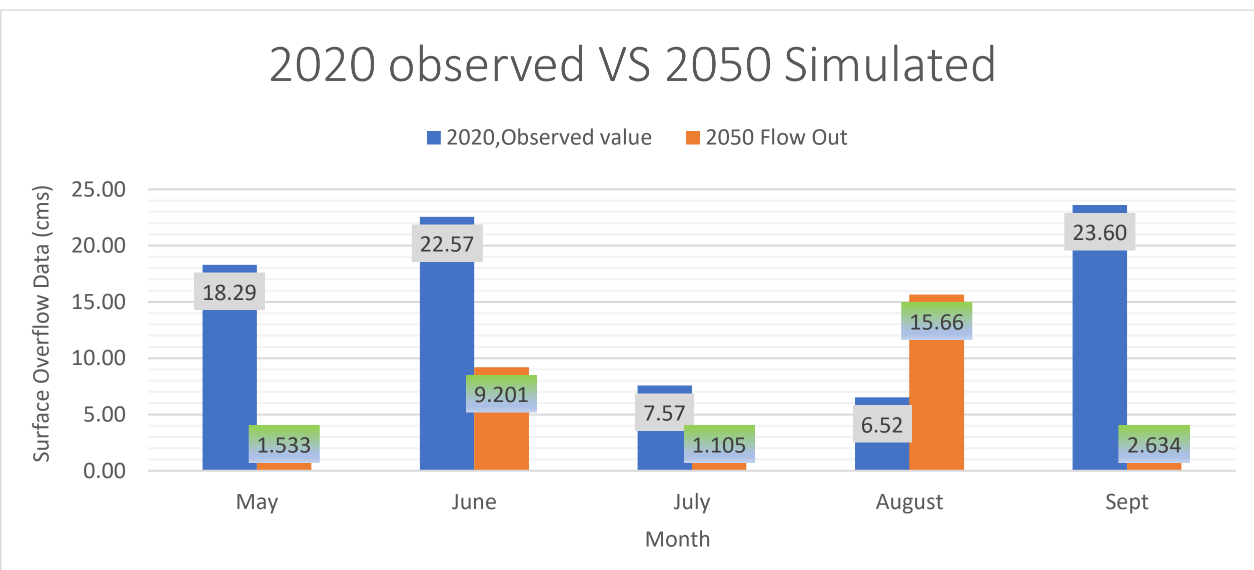

Figure 12: 2020 observed surface overflow data against 2050 simulated surface overflow data (May-Sep)

According to the data we gathered, it shows that in the year 2020 the month of June and September has the highest flow outcome.

But in the future, according to our simulated data, May and July have the highest surface overflow.

October-December Flow

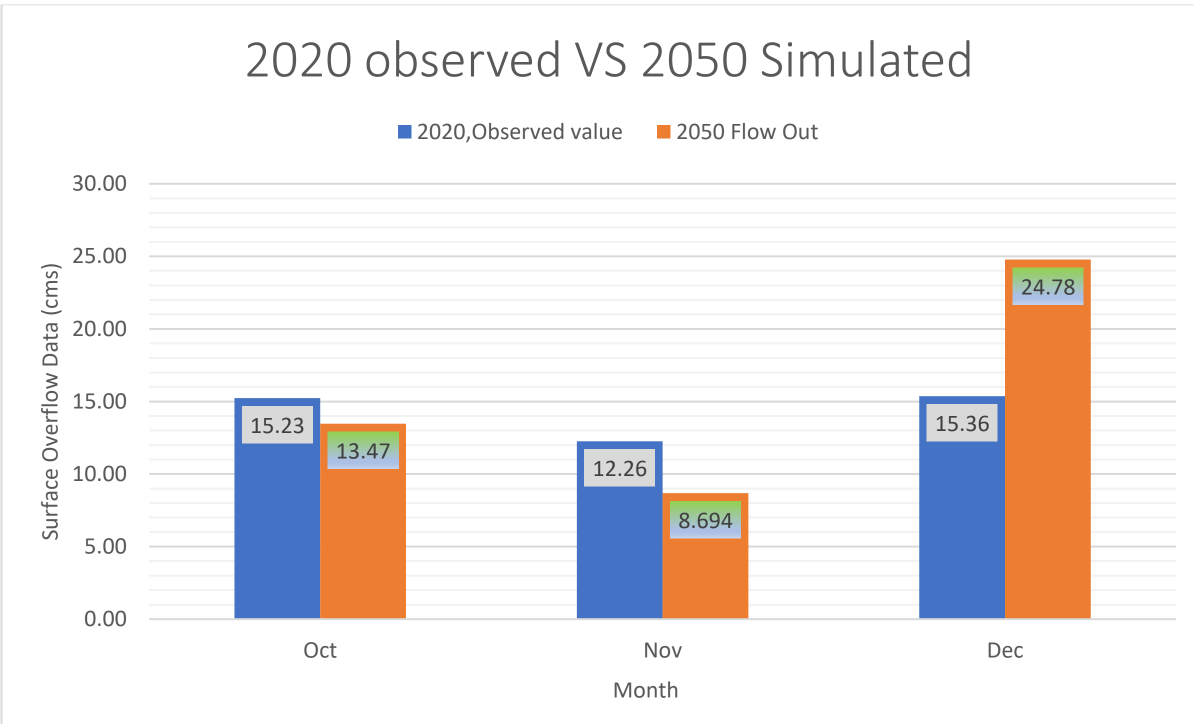

Figure 13: 2020 observed surface overflow data against 2050 simulated surface overflow data (Oct-Dec)

In the year 2050, according to our simulation, the month of December has the highest surface overflow.

Result of Future Flow Outcome

1. According to the Simulation and data analysis, we can say that the flow outcome is way higher than usual in December. December doesn't represent monsoon, but still, the surface flow is higher in this month.

2. Surface overflow has changed drastically in the future. The ongoing climate change is the main reason for this drastic change. December usually represents the month of winter and in this month the flow outcome is rather low. But in this scenario the results are opposite
3. Because of excess surface overflow, in December floods may occur in relevant area
4. Proper infrastructure should be built to control flood water and reduce the damage occurred by flood.

3. Nature-Based Solution

Nature-based solutions (NBS) are explain as ―actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits (IUCN, International Union for Conservation of Nature, 2016). In our project, we want to reduce nutrient load more than 50% (i.e., 65%). We want to design the vegetative filter strip as the nature-based solution to reduce nutrient load by 65%.

3.1. Effect of Vegetative Filter Strips (VFS) for Surface Overflow

Vegetative filter strips are vegetated areas that slow the surface runoff. Slowing the water allows some of the water to infiltrate into the underlying soil which filters out more pollutants. Vegetative filter strips (VFS) are popular conservancy practices placed at the edges of agricultural fields to reduce losses of pollutants from agricultural areas to receiving water bodies. VFS also reduce soil loss in the agricultural fields and protect water bodies. Vegetative filter strips provide an environment to reduce pollutants by reducing sediment carrier energy. In addition, pollutant reduction in the buffer also occurs due to infiltration, adsorption, and plant uptake of nutrients. A wide variability in the VFS effectiveness was to remove sediments and nutrients was noticed in this study.

3.2. Solution for Nitrogen Overflow

Nitrogen is a nutrient that is a natural part of aquatic ecosystems. Nitrogen is also the most abundant element in the air we breathe. Nitrogen and phosphorus support the growth of algae and aquatic plants, which provide food and habitat for fish, shellfish and smaller organisms that live in water.

But when too much nitrogen and phosphorus enter the environment - usually from a wide range of human activities - the air and water can become polluted. Nutrient pollution has impacted many streams, rivers, lakes, bays and coastal waters for the past several decades, resulting in serious environmental and human health issues, and impacting the economy.

Too much nitrogen and phosphorus in the water causes algae to grow faster than ecosystems can handle. Significant increases in algae harm water quality, food resources and habitats, and decrease the oxygen that fish and other aquatic life need to survive. Large growths of algae are called algal blooms and they can severely reduce or eliminate oxygen in the water, leading to illnesses in fish and the death of large numbers of fish. Some algal blooms are harmful to humans because they produce elevated toxins and bacterial growth that can make people sick if they come into contact with polluted water, consume tainted fish or shellfish, or drink contaminated water.

Nutrient pollution in ground water - which millions of people in the United States use as their drinking water source - can be harmful, even at low levels. Infants are vulnerable to a nitrogen-based compound called nitrates in drinking water. Excess nitrogen in the atmosphere can produce pollutants such as ammonia and ozone, which can impair our ability to breathe, limit visibility and alter plant growth. When excess nitrogen comes back to earth from the atmosphere, it can harm the health of forests, soils and waterways. As we can see that nitrogen overflow is a huge concern for environmental perspective.

Why Vegetative Strip is Being Used

Vegetative strip is the most natural and free of cost solution for controlling this type of nutrient pollution. Because,

- Full nature-based solution.

- Preserves biodiversity.
- Reduces erosion, Controls sedimentation.
- High Rate of pollutant filtration
- Improves chemical status of the field
- Prevents Surface water deterioration
- Protects the ecosystem

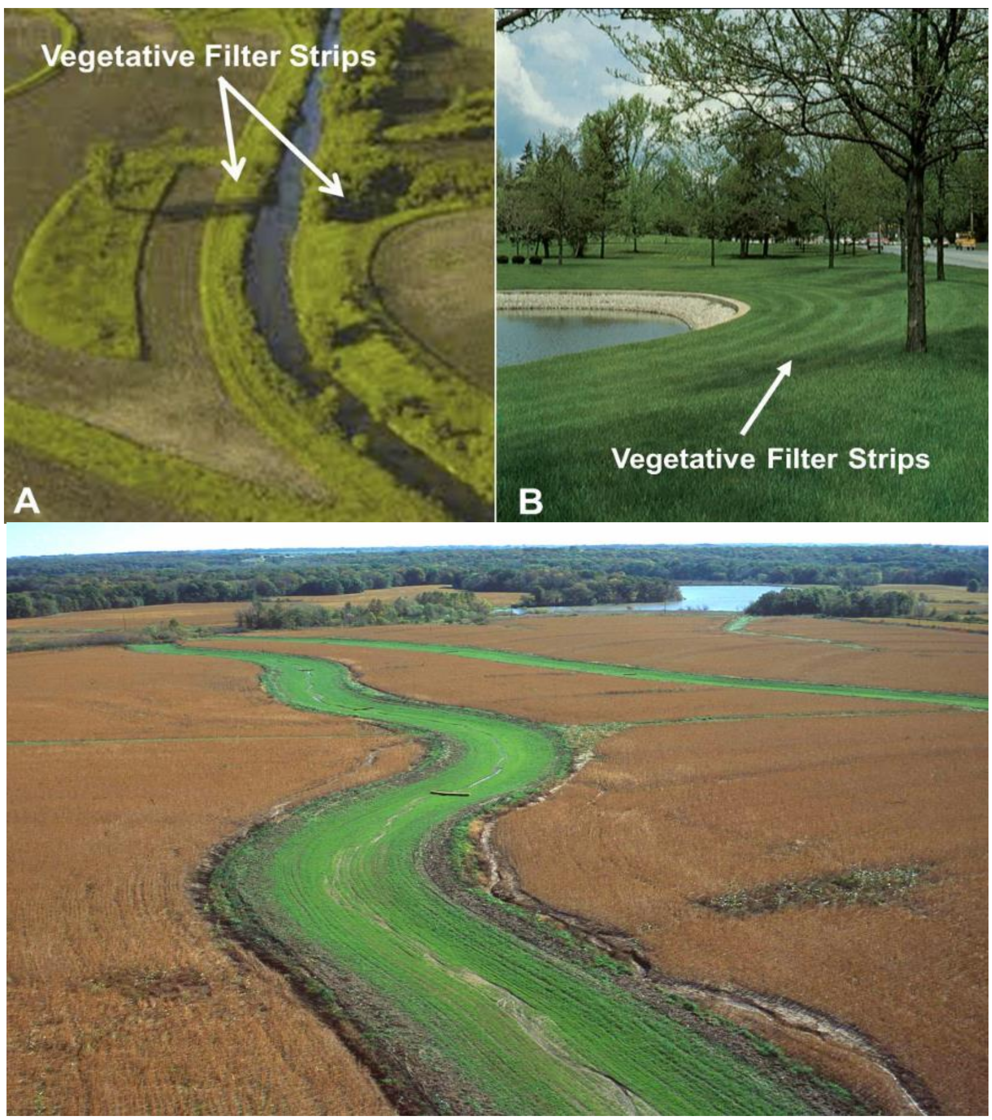

Figure 14: Vegetative Filter Strips

Vegetative fields are designed such a way so that it can work as a barrier for the sub basin to reduce its pollution.

Graphical Representation

June is the month when the farmers cultivate their land mostly. Because of these cultivation farmers usually use different kind of pesticides insecticide and other chemical fertilizer for the maximum growth of their crops. But doing so they increase the amount of nitrogen overflow on land and the surrounding water body.

But through our simulation and analysis we have found out that using vegetative stripe can reduce the overflow of nitrogen by almost 65%.

Here is the comparison data chart of 2020 simulated nitrogen load data before applying vegetative filter strip against 2020 simulated nitrogen load data after applying vegetative filter strip:

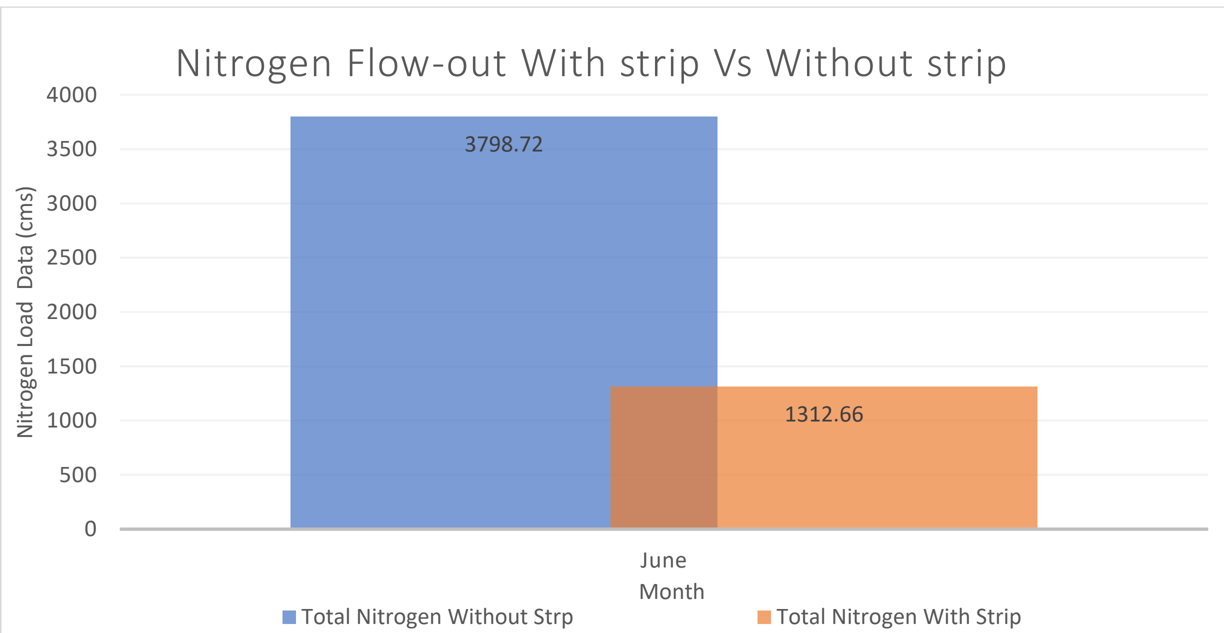

Figure 15: 2020 simulated nitrogen load data before applying vegetative filter strip against 2020 simulated nitrogen load data after applying vegetative filter strip

Our designed vegetative strip has a significant impact on environment because,

- Our strip is fully a nature-based solution. There is no use of any kind of chemical in this strip.
- It consumes less energy, because of that the rate of carbon emission of this strip is very low.
- Its environmentally friendly
- It’s a cost-free solution against nitrogen overflow

4. Project Effect

4.1. Impact/Effect of Climate Change on Water Bodies

Climate change has had marked impacts on natural systems. It also affects hydrology and water resources significantly, including extreme flows. We know that climate change adversely affected food security, land degradation, and land use. Changes in land continue to impact local to global scale weather and climate by altering the flow, water, and greenhouse gases between land and atmosphere. The main climate consequences related to water resources are the increase in temperature, change in precipitation pattern, reduction in water availability which may reduce agricultural productivity, and an increase in flooding. Additional effects of global climate change which have an important implication for water resources include earlier and shorter runoff seasons. This paper attempts to predict the monthly variation of nutrient load from the year 2016 to 2050. In this study, there is no environmental effect since we use a nature-based solution where we develop a SWAT model to investigate the impact of climate change through a vegetative filter strip to reduce the nutrient load.

4.2. Climate Change and Environmental Sustainability

Environmental sustainability is important since it is practiced and implemented for our communities as water resources. There is no doubt that urgent action is needed since temperature changes greatly accelerate other changes in the climate system, such as precipitation patterns, increase evaporation, and extreme temperature. The fact that greenhouse gases influence aspects of the water cycle provide a strong argument for the role of greenhouse gas emissions in climate change. The models simulating changes in precipitation in the oceans are relatively robust, with moist regions becoming wetter and dry regions becoming drier, but not at the same rate. Evidence from high-resolution climate models suggests that the intensity of sub-daily extreme rainfall is likely to increase in the future, making them theoretically estimated decadence most likely in many regions. The representation of extreme precipitation has generally improved and confidence in model-based projections has increased. Sustainability in responding to climate change should not be an overarching strategy that affects people's actions and responsibilities. The good news about climate change is that we know what is causing it and how to stop it, but we must not lose sight of other deeper environmental sustainability problems, which also require action. There are forms of environmental degradation about which we need to learn more and take measures to reduce them. Even moderate changes in the climate are likely to have dramatic and damaging consequences, which will almost certainly affect every corner of the world. We must face the unavoidable effects of climate change to minimize the negative effects on human health and the environment. These kinds of predictions will help the government agencies, rulers, and decision-makers in policy making and implementing the adaptation strategies for the changing climatic conditions.

4.3. Effect of Vegetative Filter Strips (VFS) on Environment and Sustainability

This study is aimed to improve the physical representation of VFS in the Soil and Water Assessment Tool to improve the hydrologic processes. The improvements are implemented in SWAT by modifying input files by changing the SWAT subbasins parameter. VFS can be very effective in reducing runoff and nutrients from surface flow. The model improvements are tested with VFS and without VFS on the watershed. The improved model estimated a 65% nitrate reduction with VFS in the cultivation period. The improved model was able to represent increased infiltration, and soil moisture in the VFS area. Overall, the results indicate improved physical representation of VFS in SWAT. Moreover, it benefits people and the environment. Since they control erosion, stabilize stream banks, and improve water quality and wildlife habitats. They also give economic benefits that include the sale of hay grown on them. Other revenue opportunities include programs like the Environmental Quality Incentive Program.

4.4. Project Effect on Society

Climate change and land use can hugely affect the society. Example: Chaco canyon is situated almost 150 miles way to the north-east direction from Albuquerque, New Mexico. Here, civilization was formed 1000 years ago. The civilized race was very developed in technology. They were the first to build two story buildings. The civilization was built by river. They were hunter gatherer race. In present the race no longer exists. This is because of climate change effect on waterbody. There was no rain for about 50 years when the race existed. So, lack of water and drinking water caused migration of animals. Crops were not growing also, due to the lack of water. Thus, caused the extinction of the civilized race.

Change of land use can also affect the society. Example: In 2015, the thousand years flood event in South Carolina, USA happened. This this was because of the construction of road at high rate which reduces the permeability and the percolation rate of water and leads to flood. The other reasons are there is less open space then before and more population. Urbanization was planned for a limited amount of people but then, the population increased which also increased the construction of home. The draining system was also inadequate for the larger population. So, the flood happened which caused many difficulties in the urban life of South Carolina USA. the lesson that we learn here is that, it will develop to various disaster when one change land use without any effective plan.

Same thing can happen if farmers of a community start to use chemical fertilizer instead of organic fertilizer without any treatment plan. It can lead to excessive nitrogen load in waterbodies which can hamper one's health and also biodiversity. Thus, it will lead to extinction of the community due to lack of water for using and drinking.

The nature-based solution vegetative filter strip from our project can mitigate the load of chemical yields in these situations, it can also trap nutrition and moisture thus helping to protect environment and biodiversity without causing any chemical yields from the solution itself.

4.5. Project Effect on Health and Safety

Climate change will affect the farming season drastically as, there can be both drought and flood in any season. Thus, it will reduce crop yields due to this unpredicted climate change. It will compel the farmers to use chemical fertilizer to increase the crop yields. However, excess nitrogen can also hamper plants by decreasing growth of crop yields. It can also harm the soils and waterways. Thus, it can create shortage of food and drinking water which will affect our health and safety eventually.

Change of land use by using chemical yields in agriculture, chemicals like nitrogen, chlorin can also get into atmosphere by evaporation and get into waterbodies by surface runoff from watersheds due to rainfall. Excess nitrogen in atmosphere can produce pollutants as ozone, ammonia which can impair our visibility and ability to breath. Excess nitrogen in water causes algae to grow faster than ecosystem can handle. This will lead to downfall of water quality, food, habitat, oxygen level which adversely effects the survival of aquatic life. Thus, it can create shortage of aquatic food and potable water which will also affect our health and safety. Moreover, upon inducing nitrogen polluted water, or breathing in nitrogen polluted air, it can cause liver-kidney damage and skin rashes.

Nitrogen can displace oxygen from enclosed place which can cause oxygen deprivation Thus, hampering our health and safety. So, it must be handles in well-ventilated area.

The nature-based solution vegetative filter strip from our project can mitigate the load of chemical yields in waterbodies, which will also save our health and ensure safety from adverse effect of excess nitrogen load in waterbodies.

4.6. Project Effect on Legal and Cultural Issues

Climate change and changes in land use can also affect legal and cultural issues. Example: Lake Fork is best known for fishing culture. It is one of the premier trophy bass fishing lakes in the world. There is also marina's, lake parks, resorts, restaurants, boat ramps, tackle shop and vacation locations. So, the tourism business is also taking active part in the country's economic growth.

If there is excess nitrogen in the waterbodies of Lake Fork, the fish will not survive in the water of the Lake. The supply of water in households which is done by well system will also not be possible as, the water will no longer remain potable water. Thus, there will be extinction of aquatic life and lifesaving water. The bass fishing culture will also be abolished.

Then tourism will also be at halt and legal permit for tourism business in the area of Lake Fork will also be nullified. Thus, it will create a huge loss for the business persons who were in tourism business in Lake Fork.

Thus, an area of 27,690 acres will be useless. It will also increase illegal fishing business which will affect people's health. Societal misconducts will also increase by those who lost everything in the tourism business.

The nature-based solution vegetative filter strip from our project can mitigate the load of chemical yields in waterbodies, which can prevent these situations from happening. Thus, continuing the culture of fishing and ensuring legal stability of a society

5. Timeline of Project Activity

Task Name	Start Date (MM-DD-YYYY)	End Date (MM-DD-YYYY)	Duration (Days)
Introduction to Project Topic	6/21/2021	6/30/2021	9
Provision of Course Outline	7/1/2021	7/5/2021	4
Guidelines on ArcGIS and SWAT Software Use	7/6/2021	8/7/2021	32
Downloading and Installing ArcGIS and SWAT	8/8/2021	8/24/2021	16
Necessary SWAT Input File Collection	8/25/2021	9/20/2021	26
Building Hydrologic and Water Quality Model Using SWAT	9/21/2021	10/22/2021	31
Running Analysis of Model and Saving Outputs of Surface Overflow and Nitrogen Load	10/23/2021	10/31/2021	8
Collection of Observed Surface Overflow Data	11/1/2021	11/15/2021	14
Analyzing Model Surface Overflow Data with Observed by Calibration for 2016-2020	11/16/2021	11/21/2021	5
Analyzing Model Surface Overflow Data for 2021 with Observed for 2021 by Validation and then, comparing observed 2020 vs simulated 2050 surface overflow data	11/22/2021	11/30/2021	8
Checking of Calibration and Validation Results	12/1/2021	12/6/2021	5
Finalizing Calibration and Validation Result	12/7/2021	12/8/2021	1
Guidelines on How to apply Vegetative Filter Strip in SWAT	12/9/2021	12/22/2021	13
Applying Vegetative Filter Strip in Model as a Nature-based Solution	12/23/2021	1/12/2022	20
Running Analysis of Model and Saving Outputs of Nitrogen Load After Application of Vegetative Filter Strip for 2020	1/13/2022	1/21/2022	8
Comparing Model Nitrogen load of Before and After Application	1/22/2022	1/27/2022	5

Task Name	Start Date (MM-DD-YYYY)	End Date (MM-DD-YYYY)	Duration (Days)
Guidelines on Project Report Writing	1/28/2022	2/4/2022	7
Research Paper Reading and Collection of Data for Report Writing	2/5/2022	2/20/2022	15
Completing First Draft of Project Report	2/21/2022	3/10/2022	17
Checking and Revising Project Report	3/11/2022	3/16/2022	5
Guidelines on Project Presentation Making	3/17/2022	3/22/2022	5
Completing First Draft of Project Presentation	3/23/2022	4/11/2022	19
Checking and Revising Project Presentation	4/12/2022	4/30/2022	18
Finalizing Project Presentation	5/1/2022	5/7/2022	6
Presenting Project Presentation	5/7/2022	5/8/2022	1
Revising Project Report based on Suggestions made During Project Presentation by Other's Project Supervisor	5/9/2022	5/12/2022	3
Checking and Revising Project Report	5/13/2022	5/16/2022	3
Finalizing Project Report	5/17/2022	5/18/2022	1

6. Cost Estimation

Filter strips are one of the least expensive stormwater runoff control measures one can implement. Seeding costs can range from $20 to $100 per 1,000 square feet with superoxide dismutase (SOD) costing $125 per 1,000 square feet ($0.40 to $6.25 per linear foot for a 20- to 50-foot-wide strip) depending on site conditions. The average cost of labor to install vegetative filter strip is around $2 to $8 (average $4) per square foot. Maintenance costs average $350 per acre per year or, $0.009 per square feet

Estimated Area to provide vegetative filter strip = 29800000 ft^2

Cost per unit area = $125 per 1000 square feet = $0.125 per square feet

Cost of labor = $4 per square feet

Total cost per square feet = ($0.125 + $4) = $4.125

Total cost of the vegetative filter strip construction = (29800000 × $4.125) = $122925000

Maintenance costs = $0.009 per square feet

Maintenance cost per year = (29800000 × $0.009) = $268200

7. Recommendations

Our project is focused on nature-based solution. We tried to develop our model in way so that anyone can use it without any cost. In future, if anyone want to predict the stream flow, calculate the nutrient pollution rate or want to prevent the harmful effects of nutrient over flow then our model is the perfect equipment to do that. Our project gives the proper natural solution for Nutrient overflow.

8. Conclusion

The prediction of Surface overflow and Nutrient overflow is very important to make necessary strategies and take proper steps to reduce the impacts of climate change. Our model predicts future surface overflow and nutrient overflow based on various data simulation. By doing this we can properly find out the changes in flow outcome over the years. Also, it can warn us about any kind of future flooding or droughts. Our model also gives opportunity to evaluate and choose nature-based solution for the nutrient overflow problem. Based on all the simulation and data analysis, authorities can take necessary steps against any kind of environmental anomalies.

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