CENE Capstone
Flagstaff Weighted Curve Numbers
Blue Wave Engineering

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1.0 Project Understanding

1.1 Project Purpose

This project aims to investigate how different methods of weighted curve number estimation can more accurately represent the real-world runoff values for discontinuous impervious surfaces during 2-yr, 10-yr and 100-yr storm events. Current estimation of runoff values for Flagstaff have led to frequent localized flooding during storm events. Weighted curve numbers are needed to accurately predict runoff volumes on both pervious and impervious surfaces. These weighted curve numbers are used to design retention and detention facilities within the city that are capable of withstanding 2-yr, 10-yr and 100-yr storm events.

1.2 Project Background

In June of 2016 a major storm event dropped an estimated 2 inches of rain over 2 hours in the Sunnyside neighborhood. During this storm event, the Sheriff's office reported water up to a car door in town. Major storm events should produce little to no flooding in urbanized areas. This unexpected flooding prompted the City to investigate potential reasons for this occurrence [1], [2].

Weighted curve numbers can be used as a surrogate measure of runoff volumes. As weighted curve numbers increase the predicted runoff volume increases. The method by which a curve number is determined for a heterogeneous area has a large effect on predicted runoff. However, transitions between pervious and impervious surfaces are not accounted for in the current weighted curve number calculations.

Presidio in the Pines and the Swiss Manor neighborhoods have been selected as locations that reflect common characteristics of urban areas in Flagstaff. Both of these neighborhoods also experience frequent flooding during storm events. These traits make the two locations an ideal area to test the alternate weighted curve number estimation methods and study the effects of these weighted curve numbers on theoretical storm events.

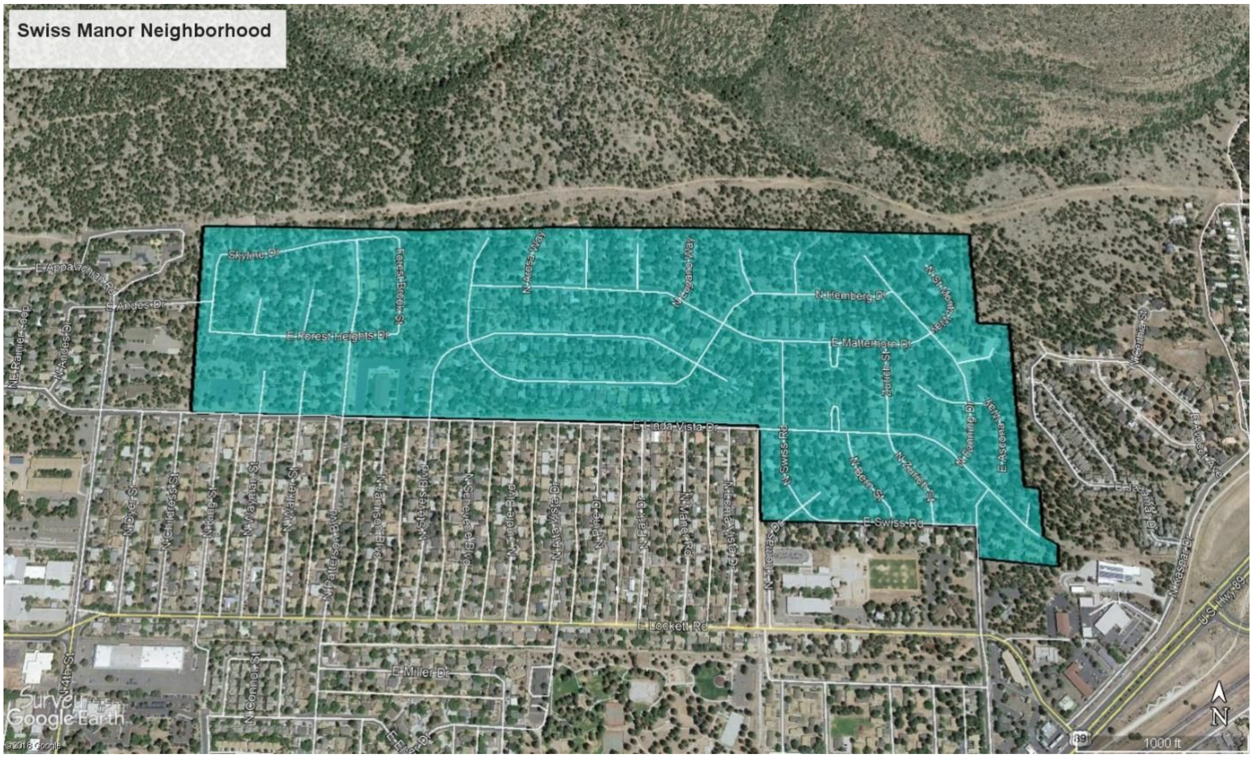

Figure 1: Swiss Manor Neighborhood [3]

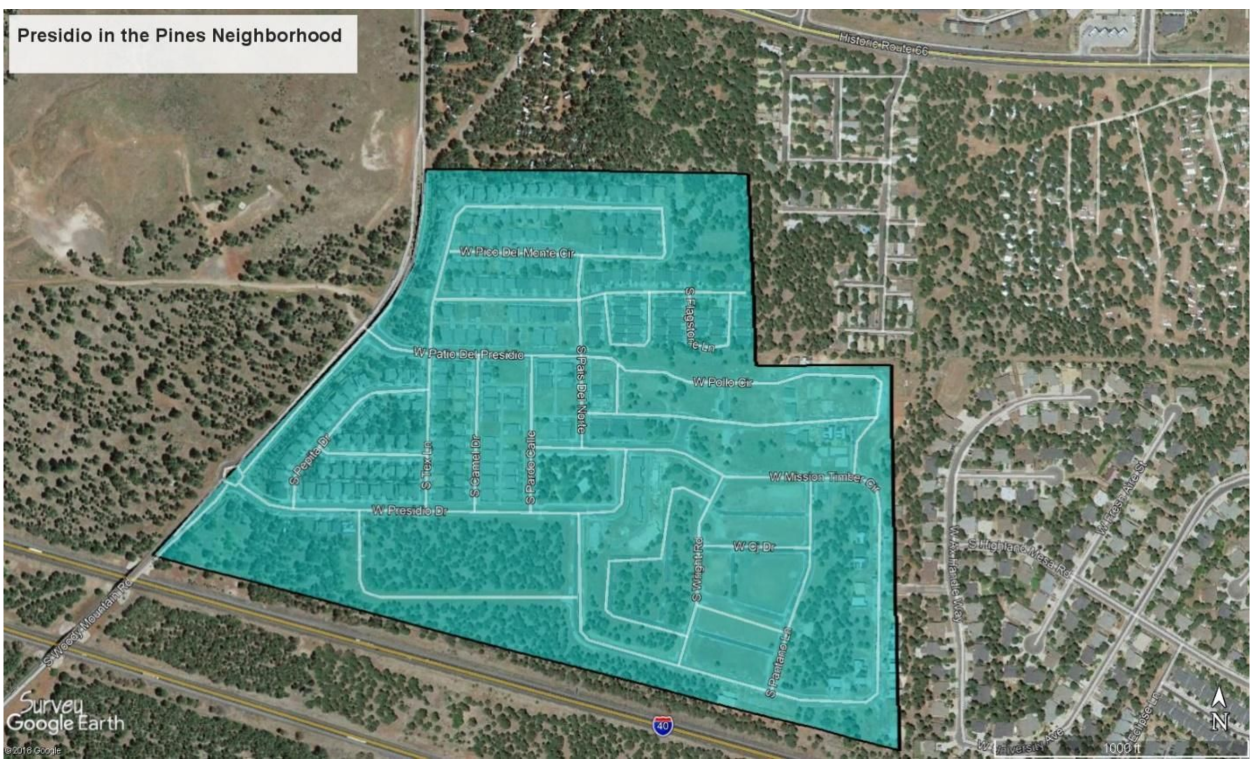

Figure 2: Presidio in the Pines Neighborhood [3]

1.3 Technical Considerations

This project is comprised of two main technical aspects that are needed to complete the project: comparison of known storm event runoff volumes to HEC-HMS runoff volumes, and comparison of a physical model and testing runoff volumes to theoretical runoff volumes. Known storm runoffs will be collected throughout the summer during monsoon season. These will be used as the comparison to runoff volumes computed through HEC-HMS modeling of our watershed. As a second method of analysis a physical model of a watershed will be built. Then a controlled storm event will be tested on this model and the runoff volumes compared to the runoff volumes calculated through the two methods of weighted curve numbers.

1.4 Potential Challenges

1.4.1 HEC-HMS

The team will be using HEC-HMS to do hydrologic analysis of the watersheds. While this software has been used by all members before, it was in a limited capacity. Before HEC-HMS can be used, team members must research and review the best ways to use the software in order to produce the desired results. The technical advisor will also be consulted for knowledge on how HEC-HMS can be utilized in the best way.

1.4.2 Physical Model

A physical model of a watershed will be made in order to compare theoretical calculations to real world results. This physical model will be created from scratch as well as the testing procedure used. This presents a challenge as the members of the team have not created a model in this way before, as well, this type of modeling has not been done in recent years in the department. This is a new method of analysis for both the team and the technical advisor.

To overcome the potential challenges in lab testing, the team will utilize the available resources within Northern Arizona University (NAU). The team will consult with their technical advisor in addition, with the lab manager for the Civil Engineering department to ensure lab procedures align with professional practice and will provide the desired data.

1.4.3 Equipment Acquisition

Flow data will need to be collected for the project using specialized flow equipment. This will be a challenge as new equipment will need to be ordered through Northern Arizona University (NAU) before collection can begin. This equipment will be ordered well in advance in order to collect flow data during the rainy season in Flagstaff.

1.4.4 Data Collection

The flow data will be needed to be collected by a team member during storm events throughout monsoon season. This will require field visits to each site in order to collect the data. Data collection will not be done on a schedule as storm events are difficult to predict ahead of time. The flexibility of team members in Flagstaff throughout monsoon season will be vital to collect substantial data to use in the project.

1.5 Stakeholders

The project impacts several stakeholders: City of Flagstaff, Coconino County, Flagstaff Area Developers, and the communities in flash flooding areas. However, the groups with the largest stake in the outcome of the project are Flagstaff developers and the communities that are near flash flooding areas.

1.5.1 City of Flagstaff

The City of Flagstaff, in coordination with Coconino County, provides regulations to developers outlining specific methods to design stormwater mitigation. Based on the results of the project, the City may need to update their published standards to better reflect the actual runoff conditions within Flagstaff and provide these new regulations to developers. Updated regulations will result in the City being able to better manage stormwater runoff during large storm events and ensure the safety of Flagstaff residents.

1.5.2 Coconino County

Coconino County has policies and standards that outline how to design stormwater mitigation. Based on the results of the project, Coconino County may choose to adjust their published policies and standards related to stormwater mitigation to more accurately reflect conditions within the City of Flagstaff.

1.5.3 Flagstaff Area Developers

Developers would be directly affected by any change in regulation as designs are based upon established code. If additional runoff must be captured through stormwater mitigation, the cost of design would be directly affected. This cost increase could affect the viability of developers business as clients might stray from increased costs.

1.5.4 Communities in Localized Flooding Areas

Communities in or nearby localized flooding areas are largely affected by changing environmental conditions. Communities are the most affected when design regulations fail. During minor storm events these communities often see significant flooding. These communities have a vested interest in seeing a change in methods to predict runoff as it will reduce the threat of flooding to their homes and infrastructure.

2.0 Scope of Services

Task 1: Site Investigation

Task 1.1: Field Visit and Preliminary Assessment - Time spent in the field at the selected sites for an initial visit to observe the overall site characteristics and to determine any special considerations for each site.

Task 1.1.1: Topographic Maps - Collect topographic maps from digital elevation data to help create flow lines and delineate basins. This task is crucial to the project as it provides data needed for the breakdown of basins and delineation of time of concentration lines used for curve number analysis.

Task 1.1.2: Aerial Maps - Maps will be collected from municipalities and public domain to assist in the visualization of topography as well as the identification and delineation of site locations. The implementation of aerial maps into Arc-Maps will provide an easily referenced geospatial database that will assist in highlighting vital topographic features as well as act as a method for communicating information to stakeholders.

Task 1.1.3: Precipitation Data - Precipitation data will be sourced from the City of Flagstaff and The National Oceanic and Atmospheric Administration. This data is vital to the project as it is needed for the creation of hydrographs. This data will be used to analyze the effective precipitation data created by each modeling method.

Task 1.2: Soil Assessment - Performance of one soil assessment at each selected site to verify the soil conditions within Flagstaff are consistent with information available on Web Soil Survey. This data will be used to accurately determine the runoff coefficients for each micro-basin in order to model each site in HEC-HMS.

Task 1.3: Flow Measurement – Flow data will be collected during monsoon season at each site. Equipment from NAU will be used to collect this data. This data will be used to create hydrographs to calibrate the HEC-HMS model.

Task 2: Basin Delineation

Task 2.1: Major Basin - Use of AutoCAD to identify the sub-basin boundaries for each site. The sub-basin will be delineated to drain the entire area of each neighborhood. The sub-basin delineation allows for accurate flow lines and time of concentration paths to be produced. This is vital to the project as the TR-55 method uses these paths to calculate weighted curve numbers.

Task 2.2: Sub-Basins for Weighted Curve Number - The major basin will be broken up into sub-basins based on topography, land use, and hydraulic infrastructure. Sub-basins will allow for a more detailed approach to assigning runoff coefficients. These will be constructed based upon land features and predicted flow tendencies.

Task 2.3: Micro-Basins Based on Surface Type - Creation of micro-basins within the sub-basins based upon single surface type while keeping standards of practice for basin delineation and topography. Allowing for the individual calculation of runoff volumes from each micro basins.

Task 3: Runoff Routing

Task 3.1: Time of Concentration Path Delineation - Time of concentration lines will be drawn for the sub-basins and each micro-basin at each site. This will be done using AutoCAD, by drawing lines that represent the water flow path based on the contour lines from digital elevation data. The path of the flow line will run from the highest elevation in each area to the concentration points of each area. These flow lines will be used to calculate the time of concentration for each site.

Task 3.2: Time of Concentration - Using City of Flagstaff standards and provided methods to calculate the time for water to move to the concentration point of the sub-basin and the micro-basins. This needs to be done based on different flow conditions in accordance with the Coconino County Drainage Design Manual, which can mainly be computed based on the surface type. The computation of the time of concentration can be either done by hand or using developed software like Microsoft Excel.

Task 4: Centroid Analysis

Centroid analysis will be performed in AutoCAD. The distance between the centroid and the time of concentration path will be measured in the Cartesian coordinate system to determine the shape of the watershed. This will help get a general idea of the shape and uniformity of the watershed without looking at a map or topography.

Task 5: Curve Numbers

Task 5.1: Weighted Curve Number Calculation for Sub-Basins - Calculation of the weighted curve number for each sub-basin. The weighted curve numbers allow analysis of stormwater runoff and comparison between methods of estimation. Using the area-weighted method in TR-55 as outlined by the City of Flagstaff to calculate the weighted curve number of the sub-basin for each site. This will be used to calculate the runoff volumes for the basin.

Task 5.2: Curve Numbers for Micro-Basins - Curve numbers for single surface type will be collected from TR-55. These will be used to calculate the runoff of the micro-basins. This is important to the project as micro-basins are being evaluated as to whether this method of estimation will produce more accurate volumes.

Task 6: Runoff Volumes

Task 6.1: Runoff Volumes Using Weighted Curve Numbers - The runoff volume from a known storm will be calculated for the sub-basins using the weighted curve number calculated. The TR-55 method in conjunction with the City of Flagstaff Stormwater Management Design Manual will be used to calculate these runoff volumes for each site and sub-basin.

Task 6.2: Runoff Calculations Using Micro-Basin Curve Numbers - The runoff volume for each micro-basin will be calculated using methods developed by the team. This runoff volume will be added for each micro-basin to get a total volume for the sub-basin, which can be compared to the runoff volume calculated from TR-55. The results from this method will help highlight the shortcomings introduced by the TR-55 area weighted method.

Task 7: HEC-HMS Model

Task 7.1: Data Input - Inputting data from the soil survey, runoff routing and topographic maps into HEC-HMS for analysis. This must be done to complete the analysis of results and to compare all the results among the different methods used to conclude the precision and the accuracy of each analysis. Inputting data could be done by identifying all the gathered data from the previous tasks and run the data.

Task 7.1.1: Soil Assessment Input - This will be conducted by assessing the soil type at the site locations to determine what the type of soil and its manning's roughness coefficient values that will affect the runoff speed and volume.

Task 7.1.2: Runoff Routing - ARC-GIS will be used for the purpose of defining the water runoff path based on the contour lines and the surface type on the map.

Task 7.1.3: Topographic Maps - Provided topographic maps will be analyzed in Civil-3D to visualize the elevations of the site locations.

Task 7.2: Running HEC-HMS Model - After data input is complete, the HEC-HMS model will be run to create an alternative runoff scenario. This will be done to compare the calculated runoff volumes from a storm to known storm runoff volumes.

Task 7.3: Create Hydrographs -Creation of hydrographs for each site based on data collected from NOAA Atlas 14, USGS, and City of Flagstaff. HEC-HMS will be used to show the soil response to the gathered 2-yr, 10-yr, and 100-yr storm event data. Hydrographs allow results of flow due to storm events.

Task 7.3.1: 2-yr Storm Hydrograph - Using previously collected precipitation data from a single storm, a hydrograph will be created in HEC-HMS. This will be used as a baseline estimate to assess the validity of the HEC-HMS model of each site.

Task 7.3.2: 10-yr Storm Hydrograph - Using previously collected precipitation data from a single storm, a hydrograph will be created in HEC-HMS. This will be used as a baseline estimate to assess the validity of the HEC-HMS model of each site.

Task 7.3.3: 100-yr Storm Hydrograph- Using previously collected precipitation data from a single storm, a hydrograph will be created in HEC-HMS. This will be used as a baseline estimate to assess the validity of the HEC-HMS model of each site.

Task 8: Bench Model Simulation

Task 8.1: Creation of Physical Model - Creation of a bench model will be done at the NAU lab facilities. This is a scaled down model that will consist of similar surfaces to that of the neighborhoods. This will allow small scale comparison of what happens in the field to the theoretical calculated runoff volumes.

Task 8.2: Physical Model Storm Testing - A known quantity of water will be sprinkled over the physical model to simulate a storm. The runoff will be collected and measured to produce comparable results to the theoretical runoff volume calculated for the physical model. The results will consist of data that will be runoff and infiltration values.

Task 8.3: Generate Hydrographs from Results - Creation of a hydrograph showing the results of the physical model storm simulation. This will be used to compare the runoff volumes to the theoretical volumes in the final report. This is integral to the project as it will validate or invalidate the methods used to determine runoff using weighted curve numbers.

Task 9: Evaluation of Results

Task 9.1: Compare HEC-HMS Results to Known Storm Events - The HEC-HMS hydrograph of each site will be compared to the hydrographs produced from known storm events. This will evaluate how accurate modeling watershed response and runoff volumes in HEC-HMS compares to the response of the watershed during a storm event.

Task 9.2: Compare Simulation to Runoff Volume Results- The results produced from the runoff volume calculation and volumes from the bench model simulation will be compared. This will evaluate how accurate the developed methods of weighted curve number and runoff volume calculation are to real world results.

Task 10: Project Impacts

Task 10.1: Economic Impacts - Research the economic impact of the alterations to development code. Identify changes in municipality spending due to an increase in flood response, mitigation and damages.

Task 10.2: Social Impacts - Report examining how the research conducted will have long term impacts on the rate of development around Flagstaff, how demographics will change in the researched neighborhoods and the rate of migration into Flagstaff for families.

Task 10.3: Environmental Impacts - Research the effect that uncontrolled storm water poses to city infrastructure. Identify the impacts to local ecosystems caused by uncontrolled runoff. Identify possible causes for infrastructure failure and impact it poses to local ecosystems.

Task 11: Project Deliverables

Task 11.1: 30% Submittal - Preparation of 30% submittal documents including writing, editing, and printing. Submittal will include the collected data.

Task 10.1.1: 30% Report - A write up highlighting the initial collection of data. This will include data from the Site Investigation, Basin Delineation, Runoff Routing, and Centroid Analysis. This report provides an opportunity to share project progress with stakeholders.

Task 10.1.2: 30% Presentation - The presentation will highlight findings from the initial collection of data. Information from the report will be compressed and delivered in a manner that is easily followed.

Task 11.2: 60% Submittal - Preparation of 60% submittal documents including writing, editing, and printing. Submittal will include the collected data and results from each method of generating a weighted curve number.

Task 11.2.1: 60% Report - In this report, the collected data and the results from Curve Numbers, Runoff Volumes, HEC-HMS Model and Bench Model Simulation will be compiled into one report. It will incorporate revisions from the previous report.

Task 11.2.2: 60% Presentation - This will be a continuation of the 30% presentation and consist of edits as well as new data collected and reported in the 60% report.

Task 11.3: 90% Submittal - Preparation of 90% submittal documents including writing, editing, and printing. Submittal will include the data collected, results of weighted curve number methods and analysis of results. This task will also include all time spent making the project website.

Task 11.3.1: 90% Report - This report will include information compiled from the 30% and 60% submittals as well as the evaluation of the results from the different modeling techniques. All milestones will be accomplished and recorded within this report along with a study of possible impacts.

Task 11.3.2: 90% Website - This will consist of a relatively complete website that will include information on the team members as well as the general information on the curve number project. The website provides an opportunity for the general public to view and follow the progress of the project.

Task 11.4: Final Submittal - Preparation of final submittal documents including writing, editing, and printing. This submittal will not include new information, this submittal will only be used for fine tuning and editing of the previous submittal. This task will also include any additional time spent revising the project website.

Task 11.4.1: Final Report - A complete and polished record of the findings of the curve number project. This document will include all information compiled from the 90% report along with an intense editing process. The client will be presented with the completed final report.

Task 11.4.2: Final Presentation - This will showcase the culmination of the analysis completed over the course of the project. The final presentation will summarize the information encased within the final report and present it in an easily digestible format.

Task 11.4.3: Final Website - A completed summary of the project that will include revised information from the 90% website.

Task 12: Project Management

Task 12.1: Meetings - Set up meetings, meeting times, and keeping records of all meetings including minutes and memo binder.

Task 12.1.1: Client Meetings- These meetings are to update the client on the progress of the project and address question. These meeting will be held on a monthly basis.

Task 12.1.2: Technical Advisor Meetings- Meet before every deliverable, to receive feedback on project progress and technical tasks.

Task 12.1.3: Grading Instructor Meetings- Meet upon request for questions or concerns. These meetings will be used to improve future deliverables and help guide the course of project.

Task 12.1.4: Team Meetings - These meetings will be used to complete scope tasks as well as coordination, scheduling and resource management. The team will meet at least once a week.

Task 12.2: Coordination - This task will include email correspondence and delivery of documents. These tool are necessary for scope task completion and schedule management.

Task 12.3: Schedule Management - Time used to make any necessary updates to the project schedule. This is a vital tool used to keep the project meeting deliverable dates and milestones. The schedule will assist in the coordination of meetings with stakeholders.

Task 12.4: Resource Management - Time used for hour tracking for each task. This task will include tracking the project budget and the use of equipment.

2.1 Exclusions

2.1.1: Topographic Surveying - Topographic surveying will not be included within the project. When topography is necessary to the project, readily available topographic maps from the U.S. Geological Survey will be used.

2.1.2: Curve Numbers - Existing curve numbers for surface type will not be evaluated or tested.

3.0 Schedule

The project schedule shown in *Figure 3* shows the time duration, dates, and predecessor for each task and its accompanying subtasks. The project has a total duration of 78 working days starting on August 26, 2019 and concluding on December 11, 2019. Ten major tasks compose the majority of the work for the project, these tasks are: Site Investigation, Basin Delineation, Runoff Routing, Centroid Analysis, Curve Numbers, Runoff Volumes, HEC-HMS Model, Bench Model Simulation, Evaluation of Results, and Project Impacts.

REMOVE AND REPLACE SCHEDULE

Figure 3: Project Schedule

3.1 Critical Path

The critical path for this project is as follows: Task 1.2, Task 3.2, Task 5.2, Task 6.2, Task 9.2, Task 10, and Task 11.4. This is the critical path because it starts with the soil assessment, which is used in several different tasks throughout the project. It goes to the time of concentration, which is then used in the calculation of runoff from the micro-basins, which is a main component to the analysis of the weighted curve numbers. This is compared to the simulation results and the results provided in the final report. The team plans to keep the critical path on track through open communication and keeping each other accountable.

4.0 Staffing Plan

4.1 Positions

Four different positions will be utilized throughout the project. These four positions are: Senior Civil Engineer (SENG), Civil Engineer (ENG), Civil Engineer in Training (EIT), and Administrative Assistant (AA).

4.2 Qualifications

Senior Civil Engineer: This person must have at least 6 years of experience as a Civil Engineer, hold a Bachelor of Science in Civil or Environmental Engineering and hold a PE in Civil or Environmental Engineering. The person must be a strong self-motivator, and have the ability to motivate those that work under them. This person must have experience with project billing and managing others.

Civil Engineer: This person must have at least 4 years of experience as a Civil Engineer, hold a Bachelor of Science in Civil or Environmental Engineering and hold a PE in Civil or Environmental Engineering. The person must be a strong self-motivator, and have the ability to motivate those that work under them. Experience managing others is not necessary.

Civil Engineer in Training: No previous experience necessary. This person must hold their EIT certificate in Civil Engineering and Bachelor of Science in Civil or Environmental Engineering. This person must be able to independently complete assigned tasks and create thorough reports for Engineers and Senior Engineers.

Administrative Assistant: At least 1 year in an administrative position at an engineering or construction firm. This person must be organized and able to effectively communicate with project managers about the status of a project. This person must have experience with project billing.

4.3 Staffing

Table 1 shows the hourly breakdown for each task and each position. This was based on the estimated days in the schedule along with the description of each task and sub-task. Each subtask total hours is the sum of the sub-sub tasks. Each major task total hours is the sum of each subtask hours.

Table 1: Staffing

Tasks	SENG	ENG	EIT	AA	Total
Task 1: Site Investigation	1	8	35	0	44
Task 1.1: Field Visit and Preliminary Assessment	0	7	17	0	24
Task 1.1.1: Topographic Maps	0	2	4	0	6
Task 1.1.2: Aerial Maps	0	2	5	0	7
Task 1.1.3: Precipitation Data	0	3	8	0	11
Task 1.2: Soil Assessment	1	1	6	0	8
Task 1.3: Flow Measurement	0	0	12	0	12
Task 2: Basin Delineation	0	7	21	0	28
Task 2.1: Major Basin	0	3	3	0	6
Task 2.2: Sub-Basins for Weighted Curve Number	0	1	4	0	5
Task 2.3: Micro-Basins Based on Surface Type	0	3	14	0	17
Task 3: Runoff Routing	0	14	13	0	27
Task 3.1: Time of Concentration Path Delineation	0	6	5	0	11
Task 3.2: Time of Concentration	0	8	8	0	16
Task 4: Centroid Analysis	0	2	6	0	8
	0	2	6	0	8
Task 5: Curve Numbers	2	6	22	0	30
Task 5.1: Weighted Curve Number Calculation for Sub-Basin	1	4	18	0	23
Task 5.2: Curve Numbers for Micro-Basins	1	2	4	0	7
Task 6: Runoff Volumes	2	11	48	0	61

Task: 6.1: Runoff Calculations Using Weighted Curve Numbers	1	3	12	0	16
Task: 6.2: Runoff Calculations Using Micro-Basin Curve Numbers	1	8	36	0	45
Task 7: HEC-HMS Model	1	7	21	0	29
Task 7.1: Data Input	0	3	11	0	14
Task 7.1.1: Soil Assessment Input	0	1	3	0	4
Task 7.1.2: Runoff Routing	0	1	4	0	5
Task 7.1.3: Topographic Map	0	1	4	0	5
Task 7.2: Running HEC-HMS Model	1	1	4	0	6
Task 7.3: Create Hydrographs	0	3	6	0	9
Task 7.3.1: 2-yr Storm Hydrograph	0	1	2	0	3
Task 7.3.2: 10-yr Storm Hydrograph	0	1	2	0	3
Task 7.3.3: 100-yr Storm Hydrograph	0	1	2	0	3
Task 8: Bench Model Simulation	1	10	26	0	37
Task 8.1: Creation of Physical Model	0	4	10	0	14
Task 8.2: Physical Model Storm Simulation	0	4	10	0	14
Task 8.3: Generate Hydrographs from Results	1	2	6	0	9
Task 9: Evaluation of Results	8	16	24	0	48
Task 9.3: Compare HEC-HMS Results to Known Storm Events	4	8	12	0	24
Task 9.2: Compare Simulation to Runoff Volume Results	4	8	12	0	24
Task 10: Project Impacts	6	30	0	0	36
Task 10.1: Economic Impacts	2	10	0	0	12
Task 10.2: Social Impacts	2	10	0	0	12
Task 10.3: Environmental Impacts	2	10	0	0	12
Task 11: Project Deliverables	30	33	91	11	165
Task 11.1 30% Submittal	5	6	22	3	36
Task 11.1.1: 30% Report	3	4	15	2	24

Task 11.1.2: 30% Presentation	2	2	7	1	12
Task 11.2: 60% Submittal	5	6	22	3	36
Task 11.2.1: 60% Report	3	4	15	2	24
Task 11.2.2: 60% Presentation	2	2	7	1	12
Task 11.3: 90% Submittal	7	6	39	3	55
Task 11.3.1: 90% Report	5	4	15	2	26
Task 11.3.2: 90% Website	2	2	24	1	29
Task 11.4: Final Submittal	13	15	8	2	38
Task 11.4.1: Final Report	8	8	1	1	18
Task 11.4.2: Final Presentation	4	4	0	1	9
Task 11.4.3: Final Website	1	3	7	1	12
Task 12: Project Management	118	179	0	26	323
Task 12.1: Meetings	58	174	0	26	258
Task 12.1.1: Client Meetings	2	6	0	2	10
Task 12.1.2: Technical Advisor Meetings	4	12	0	4	20
Task 12.1.3: Grading Instructor Meetings	4	12	0	4	20
Task 12.1.4: Team Meetings	48	144	0	16	208
Task 12.2: Coordination	20	5	0	0	25
Task 12.3: Schedule Management	20	0	0	0	20
Task 12.4: Resource Management	20	0	0	0	20

Table 2: Summary of Staffing Hours

	SENG	ENG	EIT	AA	Total
Total Hours	**169**	**323**	**307**	**37**	**836**

The hour distribution for each position is shown in *Table 2*. The engineer has the highest number of hours, this is because the engineer does a significant part of the technical work as well as attends all meetings. The EIT does most of the technical work, however there is no hours allotted for meetings with the client, grading instructor, or technical advisor. The senior engineer has less hours than the engineer or EIT because the senior engineer does very little technical work and mostly coordinates the project and reviews items as they are completed. The administrative assistant has the lowest amount of hours as they do not do any technical work and only help review submittals and presentations as well as write meeting minutes.

5.0 Cost of Engineering Services

Cost of engineering services are calculated in order to give the client an estimate of how much the project will cost. *Table 3* below shows the personnel base pay, how much the employee will be paid, the billing rate, how much the client will be charged to cover office expenses, and the multiplier calculated from the ratio of billing rate to base pay. Base pay was estimated on the average pay for civil engineers in Phoenix, Arizona. Personnel costs were computed based upon the billing rate ($/hr), shown in *Table 4*, and the total working hours for each classified position as computed in *Table 2*. A supply fee of $1000 is used for the creation of the physical bench model. Subcontract fees are not applicable for this project. The total cast was computed by summing the total personnel cost and the travel cost, which summed to a total of $82,620.

Table 3: Base Pay Rate and Multiplier

Classification	Base Pay $/hr	Billing Rate $/hr	Multiplier
SENG	75	160	2.13
ENG	55	110	2
EIT	35	60	1.71
AA	20	50	2.5

Table 4: Cost of Engineering Services

Description	Unit	Quantity	Unit Cost	Cost
SENG	HR	159	$160	$25,440
ENG	HR	333	$110	$36,630
EIT	HR	295	$60	$17,700
AA	HR	37	$50	$1,850
Bench Model Supplies	LS	1	$1,000	$1,000
TOTAL				**$82,620**

6.0 References

[1]"Storm Events Database - Event Details | National Centers for Environmental Information", *Ncdc.noaa.gov*, 2019. [Online]. Available: https://www.ncdc.noaa.gov/stormevents/eventdetails.jsp?id=642832. [Accessed: 28- Feb- 2019].

[2]"PF Map: Contiguous US", *Hdsc.nws.noaa.gov*, 2019. [Online]. Available: https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html. [Accessed: 28- Feb- 2019].

[3]"Google Earth", *Earth.google.com*, 2019. [Online]. Available: https://earth.google.com/web/. [Accessed: 06- May- 2019]