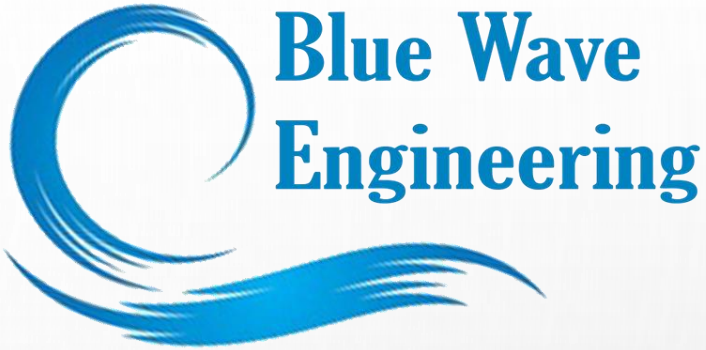


Blue Wave Engineering

Flagstaff Weighted Curve Number Research

CENE 486 Capstone Presentation

December 6th, 2019

Grace Garwin, Ethan Crane, Abdullah Alenezi, Chad Murphy

Purpose

- Analyze the effectiveness of TR-55 curve numbers for residential district by the lot size.
- Attempt to pinpoint the cause of unforeseen localized flooding within some urbanized areas in the City of Flagstaff.

Figure 1: Overland Flow [1]

Client

City of Flagstaff Stormwater Division

Ed Schenk

Jim Janesek

Figure 2: City of Flagstaff Badge [2]

Scope Change

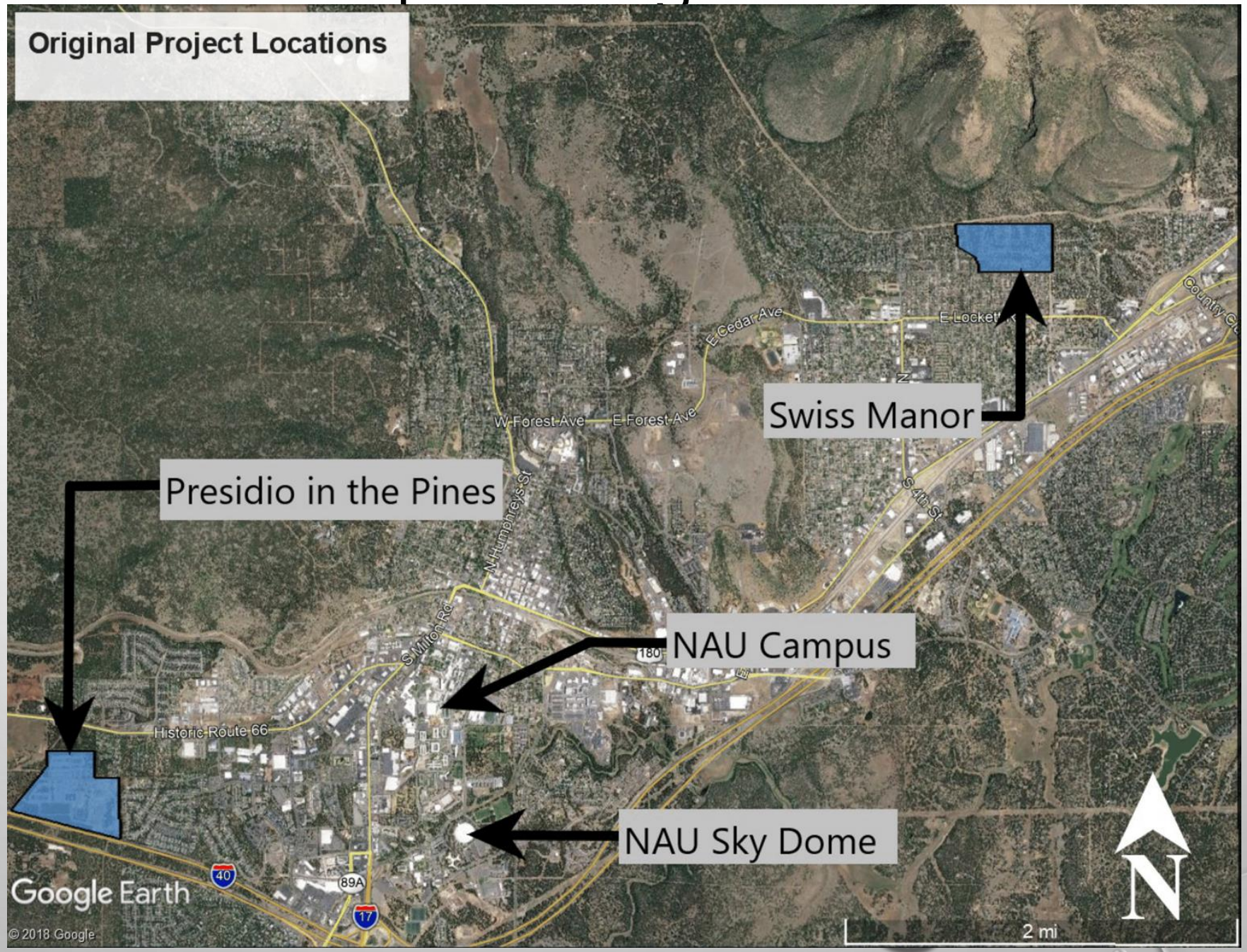


Figure 3: Scope Change Map [3]

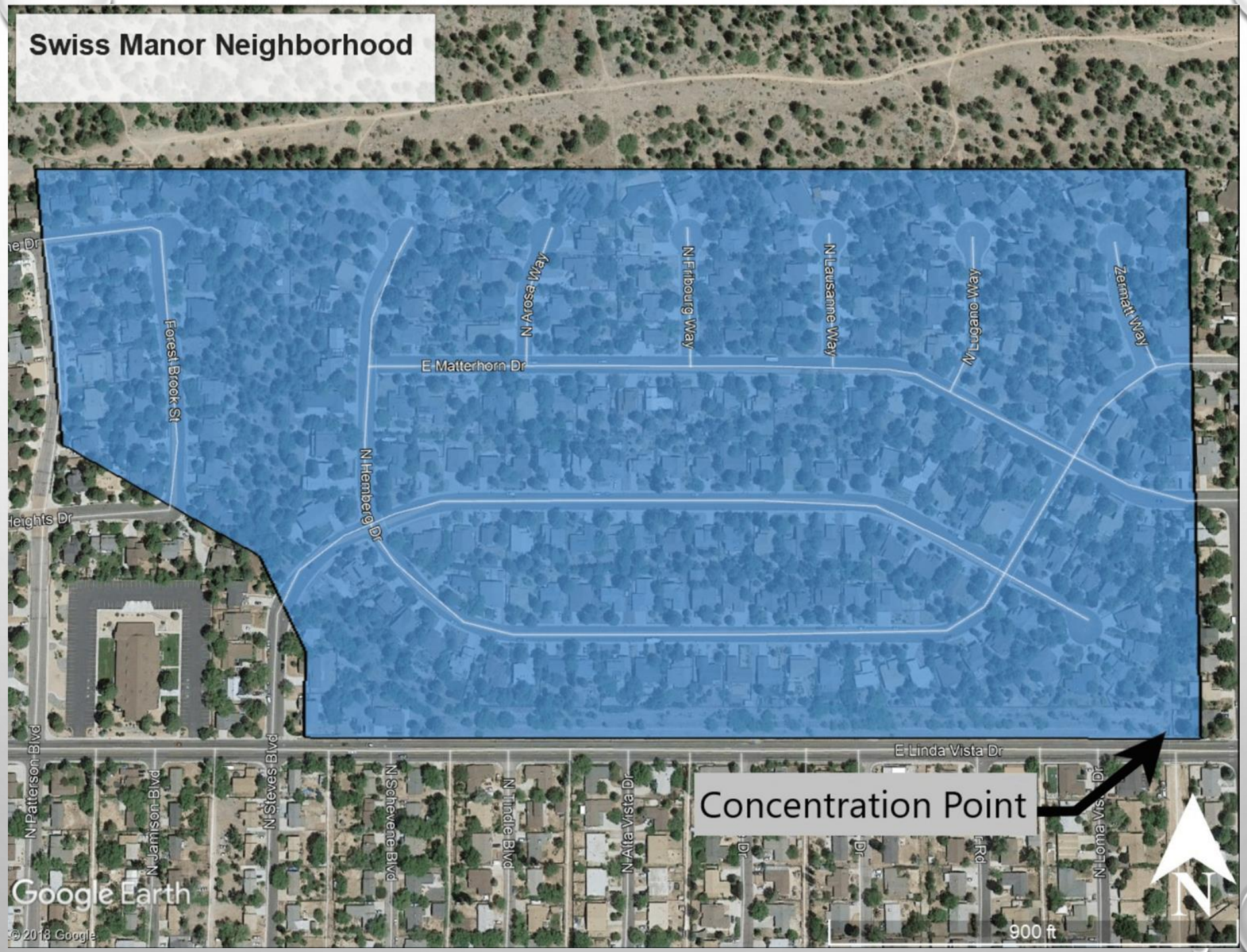


Figure 4: Swiss Manor Urban Residential Area [3]

Site Investigation

Table 1: Web Soil Survey Legend

Map Unit Symbol	Map Unit Name	Percent of Area of Interest
3	Baldy stony loam, 2 to 8 percent slopes	34.6
3A	Baldy stony loam, 8 to 15 percent slopes	1.4
4	Baldy rock outcrop association, 15 to 60 percent	10.2
8	Paymaster family fine sandy loam, 0 to 3 percent slopes	3.4
13	Lynx loam, 0 to 2 percent	0.1
14	Daze fine sandy loam, 0 to 8 percent slopes	0
NOTCOM	No digital data available	50.3

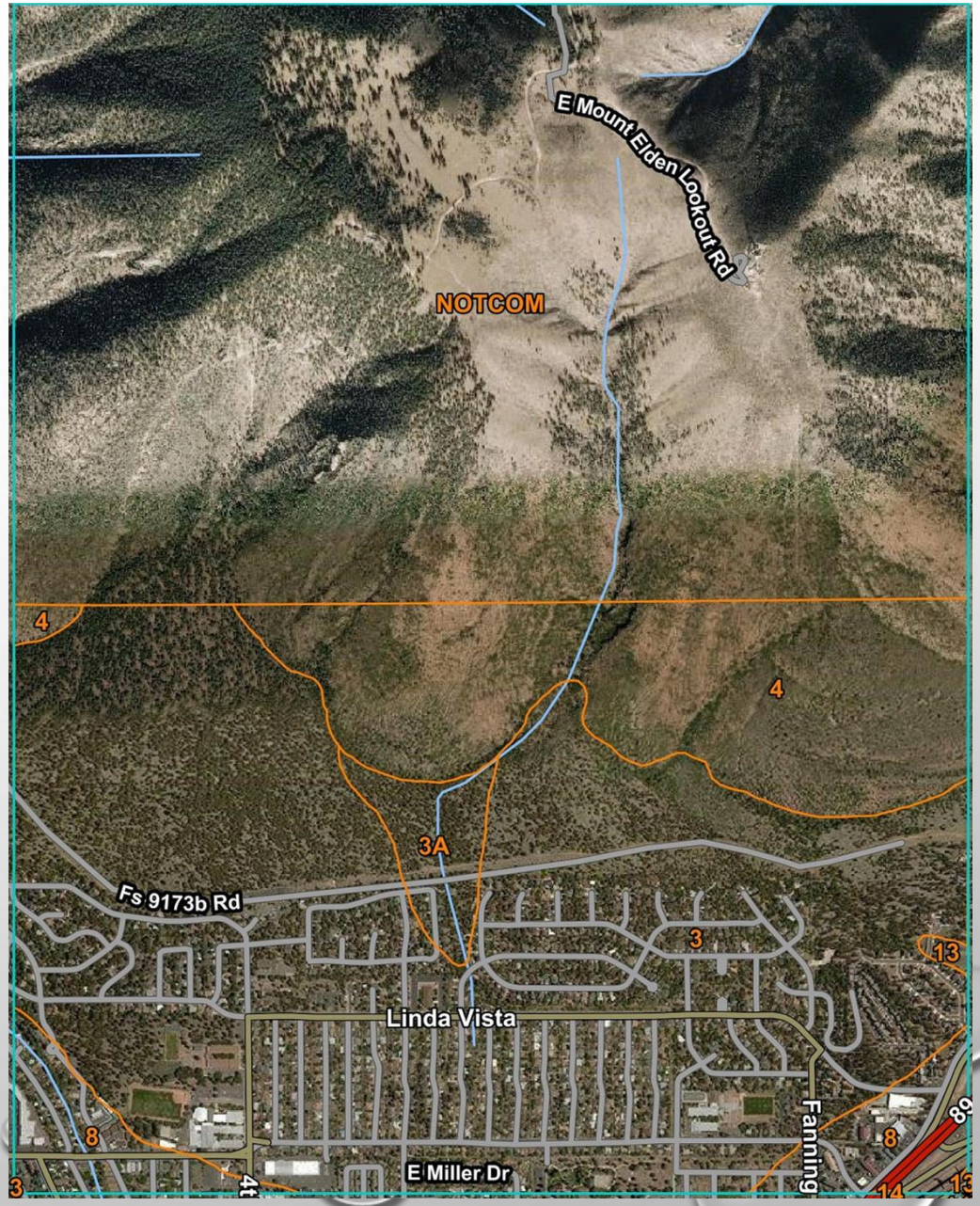


Figure 5: Web Soil Survey Map [4]

Precipitation Data

Table 6: City of Flagstaff Precipitation

Date	Time	Cumulative Depth (in)
8/28/2019	13:28:30	0.98
8/28/2019	13:30:47	1.02
8/28/2019	13:34:04	1.06
8/28/2019	13:35:02	1.1
8/28/2019	13:37:01	1.18
8/28/2019	13:38:01	1.22
8/28/2019	13:39:01	1.26
8/28/2019	13:40:18	1.3
8/28/2019	13:45:07	1.34
8/28/2019	13:55:11	1.42
8/28/2019	13:58:03	1.46
8/28/2019	13:59:03	1.5

Date	Time	Cumulative Depth (in)
8/28/2019	13:59:49	1.57
8/28/2019	14:00:49	1.61
8/28/2019	14:03:45	1.77
8/28/2019	14:04:45	1.81
8/28/2019	14:06:38	1.93
8/28/2019	14:07:38	1.97
8/28/2019	14:09:38	2.05
8/28/2019	14:11:38	2.13
8/28/2019	14:17:47	2.2
8/28/2019	14:20:27	2.24
8/28/2019	14:21:25	2.28
8/28/2019	14:22:18	2.36
8/28/2019	14:25:56	2.44

Basin Delineation and Runoff Routing

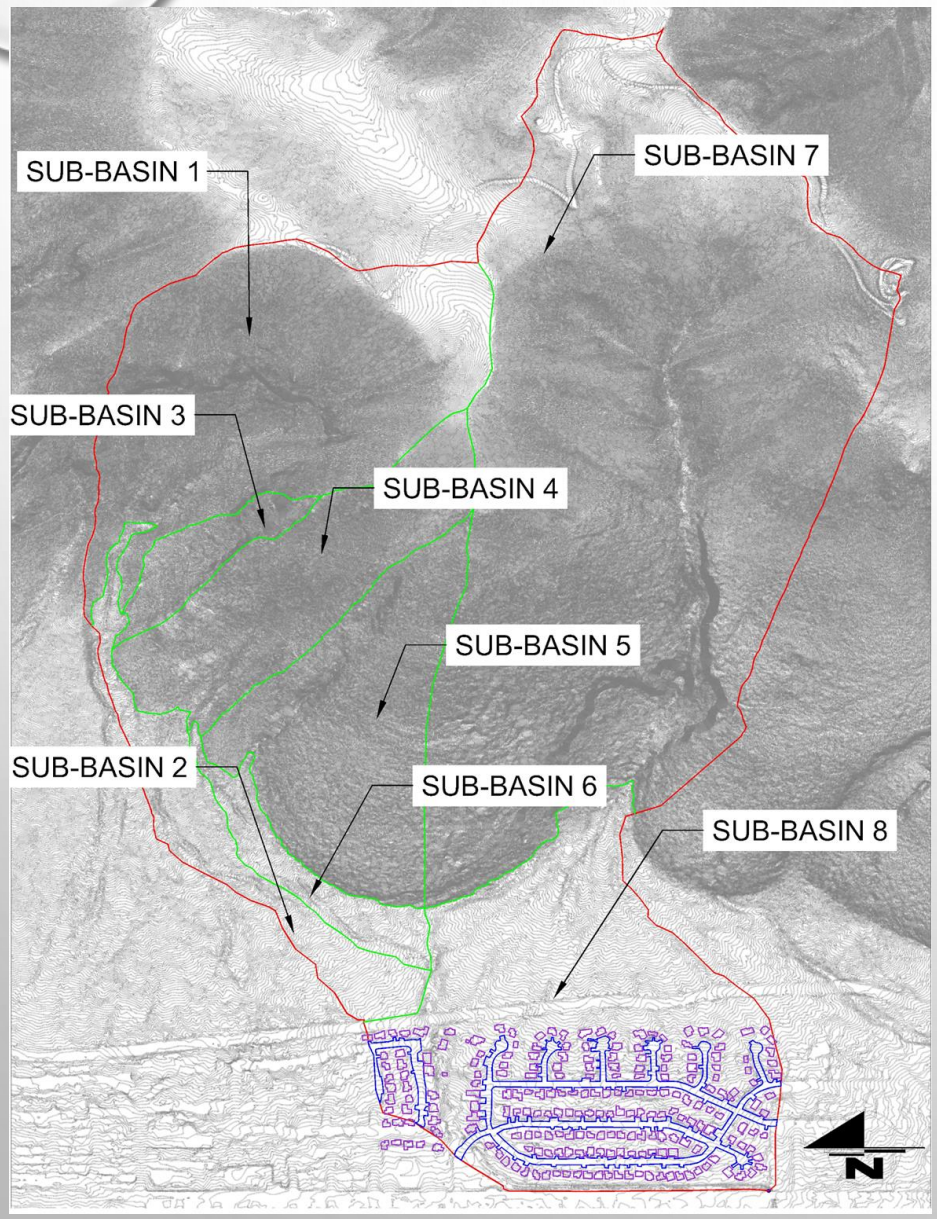


Figure 6: Delineation of Major Basin and Sub-Basins on Final Map

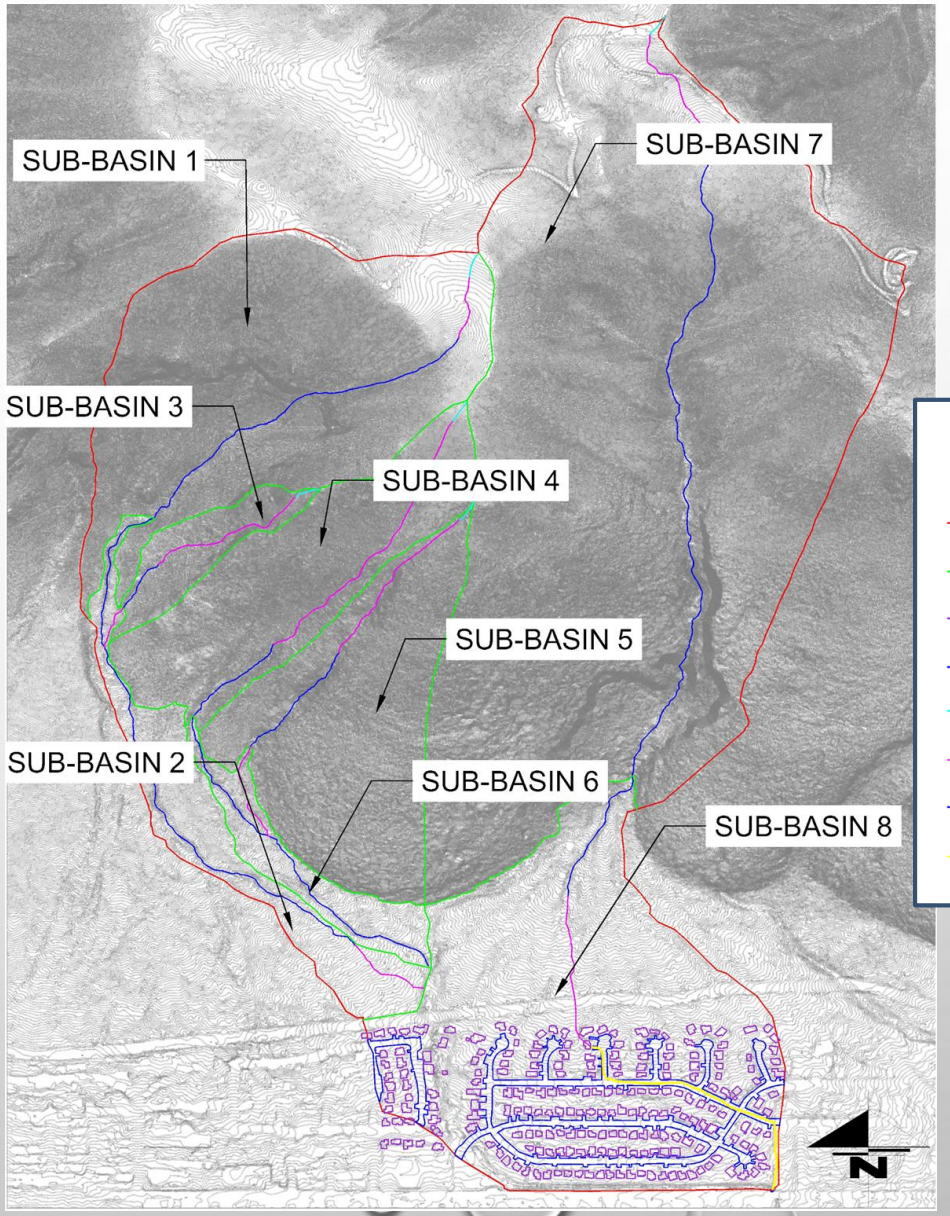


Figure 7: Time of Concentration Runoff Routing

Time of Concentration

Table 2: Time of Concentration for Each Sub-Basin

Time of Concentration and Lag Time Summary		
Sub-Basin	Time of Concentration (min)	Lag Time (min)
Sub-Basin 1	25	45
Sub-Basin 2	24	44
Sub-Basin 3	11	37
Sub-Basin 4	43	56
Sub-Basin 5	14	39
Sub-Basin 6	9	35
Sub-Basin 7	32	49
Sub-Basin 8	33	50

Detailed Curve Number

Table 3: Example Land Use Weighted Curve Number Calculation

Parcel ID	Parcel Area (Acres)	House Area (Acres)	Percent of Area	Curve Number	Landscape Area (Acres)	Percent of Area	Landscape Type (Soil Type B)	Curve Number	Weighted Curve Number
2655	0.21	0.044922	0.214	98	0.165078	0.786	Grass Cover < 50%	79	83
3799	0.34	0.079582	0.234	98	0.260418	0.766	Grass Cover 50% to 75%	69	76

Table 4: Percent Impervious for Urban Area

Percent Impervious Calculation	
Total Streets (ac)	28.9
Area of houses (ac)	9.0
Impervious Area (ac)	38.0
Basin Area (ac)	304.4
Percent Impervious	12.49%

Table 5: Sub-Basin 8 Curve Numbers for Weighted Curve Number

Curve Number Generation Summary		
Sub Basin	Area (acres)	Curve Number
8-Natural	223.3	53
8-Parcel	52.1	78
8- Road	28.992	98

Curve Numbers

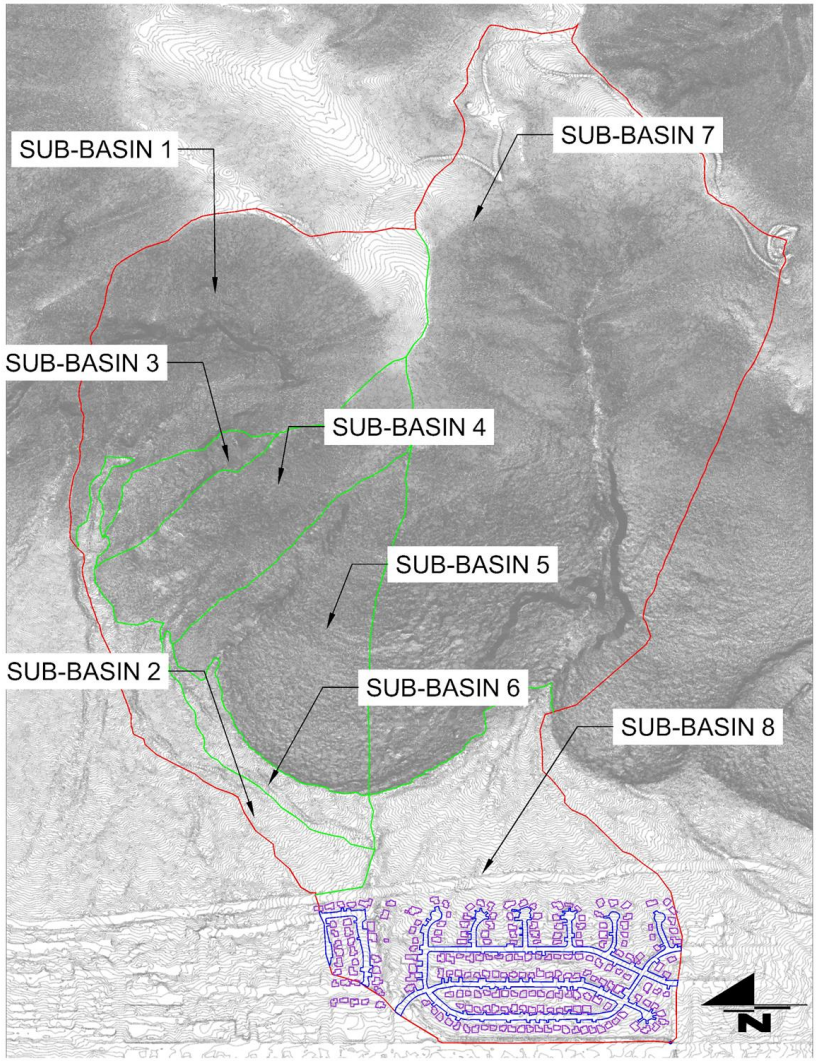
Table 6: TR-55 Approach Curve Numbers

Curve Numbers for TR-55 Approach			
Sub Basin	Area (acres)	Curve Number	Description
1	251.3	71	B, Mixed Conifer, Poor
2	69.6	53	B, Mixed Conifer, Fair
3	28.7	71	B, Mixed Conifer, Poor
4	119.5	71	B, Mixed Conifer, Poor
5	149.0	71	B, Mixed Conifer, Poor
6	34.9	53	B, Mixed Conifer, Fair
7	715.4	71	B, Mixed Conifer, Poor
8-Natural	223.3	53	B, Mixed Conifer, Fair
8-Urban	81.1	75	B, 1/4 Acre Lots
8- Total	304.4	59	Basin 8 total weighted CN

Table 7: Land Use Approach Curve Numbers

Curve Numbers for Land Use Approach			
Sub Basin	Area (acres)	Curve Number	Description
1	251.3	71	B, Mixed Conifer, Poor
2	69.6	53	B, Mixed Conifer, Fair
3	28.7	71	B, Mixed Conifer, Poor
4	119.5	71	B, Mixed Conifer, Poor
5	149.0	71	B, Mixed Conifer, Poor
6	34.9	53	B, Mixed Conifer, Fair
7	715.4	71	B, Mixed Conifer, Poor
8-Natural	223.3	53	B, Mixed Conifer, Fair
8-Parcel	52.1	78	B, Based on Detailed Analysis
8- Road	29.0	98	B, Based on Detailed Analysis
8- Total	304.4	62	Basin 8 total weighted CN

Basin Model



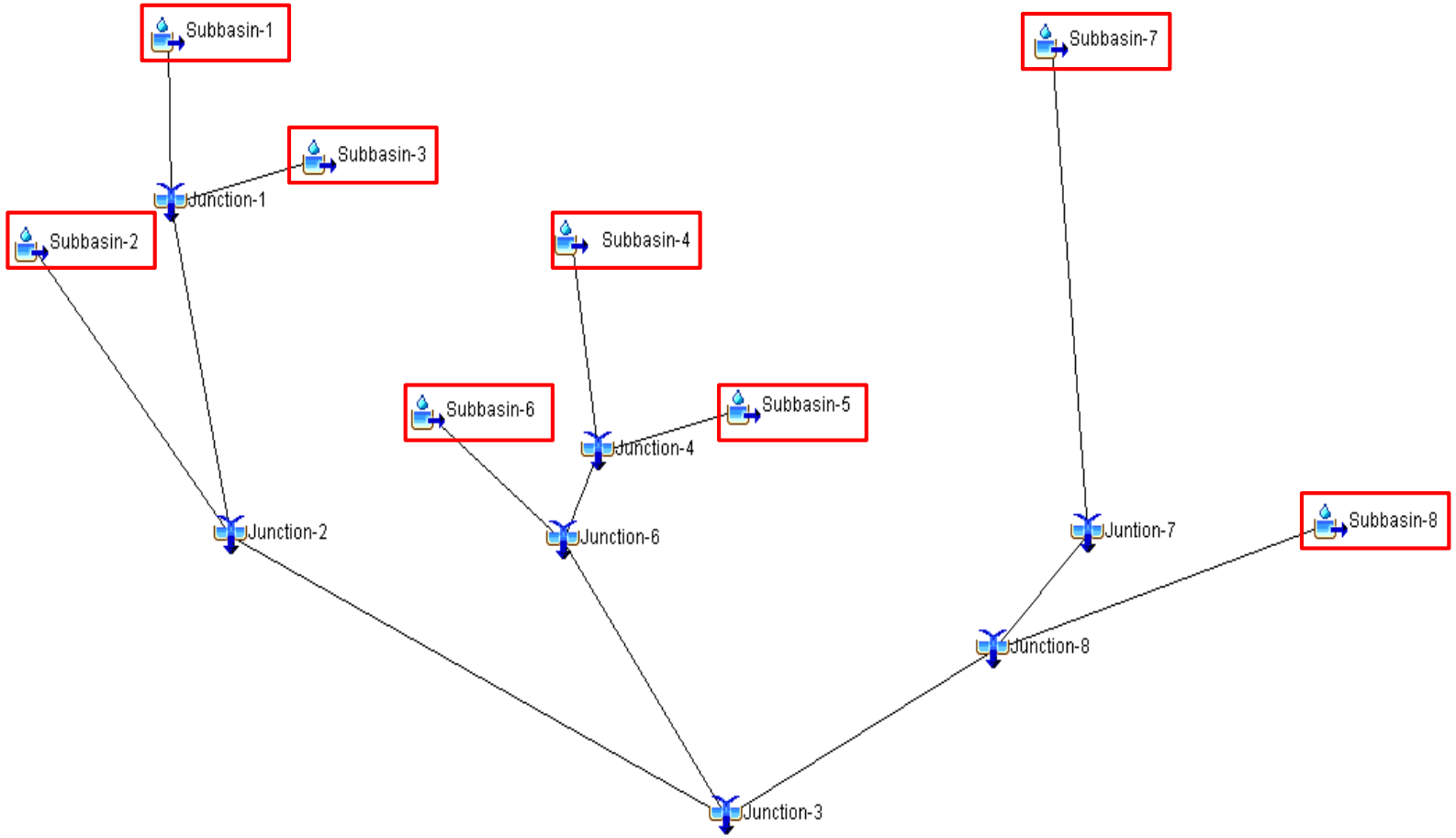


Figure 8: Sub-Basin Layout from HEC-HMS Model

Hydrograph Results

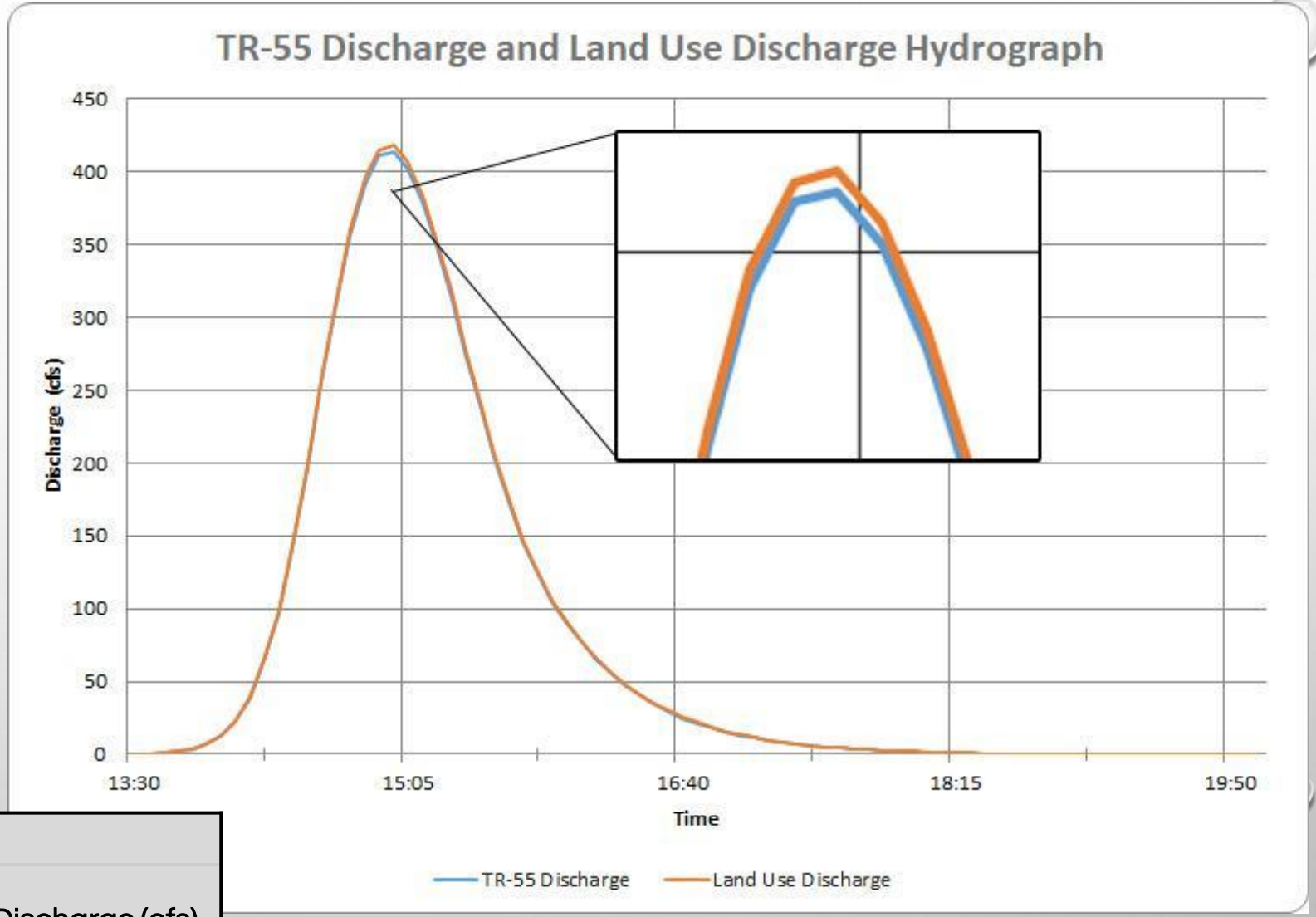


Figure 9: Hydrograph Result of TR-55 and Land Use Discharge

Table 8: HEC-HMS Model Discharge

HEC-HMS Discharge Results	
TR-55 Peak Discharge (cfs)	Land Use Peak Discharge (cfs)
413.2	417.9

Results

Table 9: TR-55 Increased Development Area Curve Numbers

TR-55 Increased Development Area Altered Curve Numbers			
Sub Basin	Area (acres)	Curve Number	Description
8-Nat	104.448	53	B, Mixed Conifer, Fair
8-Urban	200	75	B, 1/4 Acre Lots
8- Total	**304.448**	**67**	**Basin 8 total weighted CN**

Table 10: Land Use Increase Development Area Curve Numbers

Land Use Increased Development Area Altered Curve Numbers			
Sub Basin	Area (acres)	Curve Number	Description
8-Natural	104.4483	53	B, Mixed Conifer, Fair
8-Parcel	128.531	78	B, Based on Detailed Analysis
8- Road	71.4687	98	B, Based on Detailed Analysis
8- Total	**304.448**	**74**	**Basin 8 total weighted CN**

Table 11: Increased Development Peak Discharges

Increased Development Area Simulation	
TR-55 Peak Discharge (cfs)	Land USe Peak Discharge (cfs)
426.9	443.4

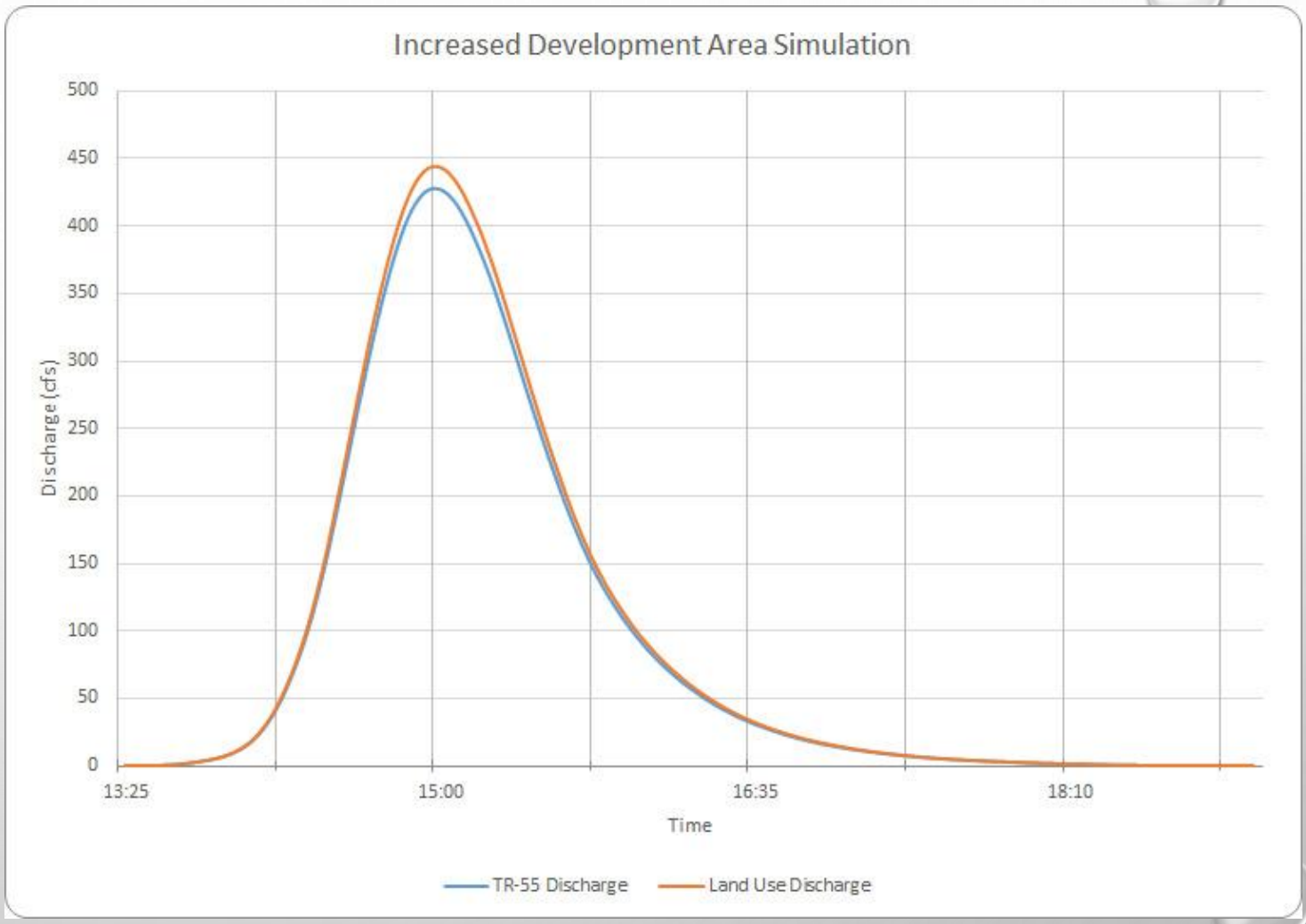


Figure 10: Increased Development Model Discharge Results

Results

Table 9: TR-55 Increased Development Area Curve Numbers

TR-55 Increased Development Area and Home Size Altered Curve Numbers			
Sub Basin	Area (acres)	Curve Number	Description
8-Nat	104.448	53	B, Mixed Conifer, Fair
8-Urban	200	75	B, 1/4 Acre Lots
8- Total	**304.448**	**67**	**Basin 8 total weighted CN**

Table 12: Increased Development and Home Size Curve Numbers

Land Use Increased Development Area and Home Size Altered Curve Numbers			
Sub Basin	Area (acres)	Curve Number	Description
8-Natural	104.4483	53	B, Mixed Conifer, Fair
8-Parcel	128.531	81	B, Based on Altered Detailed Analysis
8- Road	71.4687	98	B, Based on Detailed Analysis
8- Total	**304.448**	**75**	**Basin 8 total weighted CN**

Table 13: Increased Development and Home Discharges

Increased Development and Home Size Area Simulation	
TR-55 Peak Discharge (cfs)	Land Use Peak Discharge (cfs)
430.5	449.5

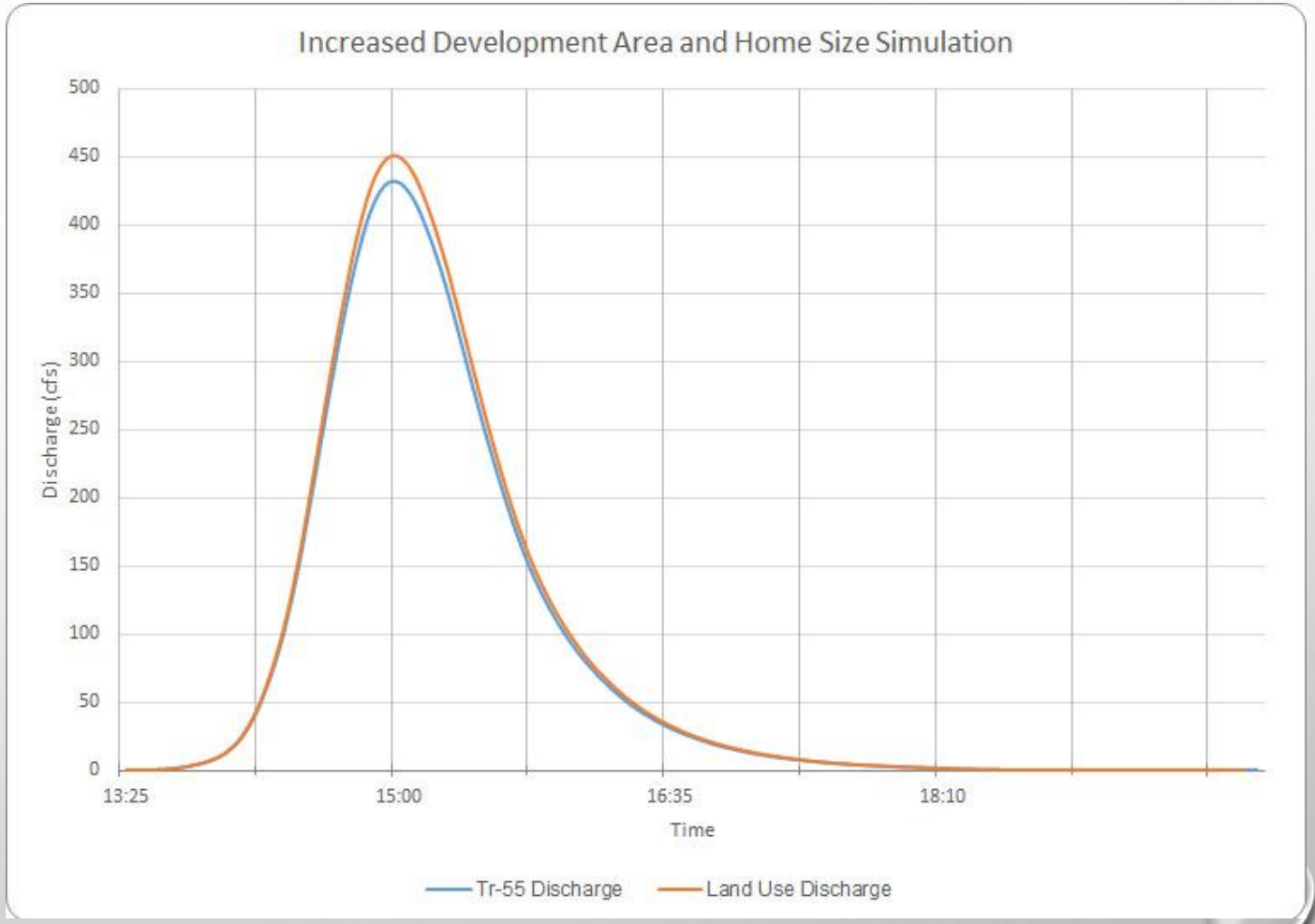


Figure 11: Increased Home Size Model Discharge Results

Economic Impacts

- New development regulation changes
- Flooding may still occur because curve numbers are not the source
- Property damage
- Future simulations will be an additional cost to citizens

Environmental Impacts

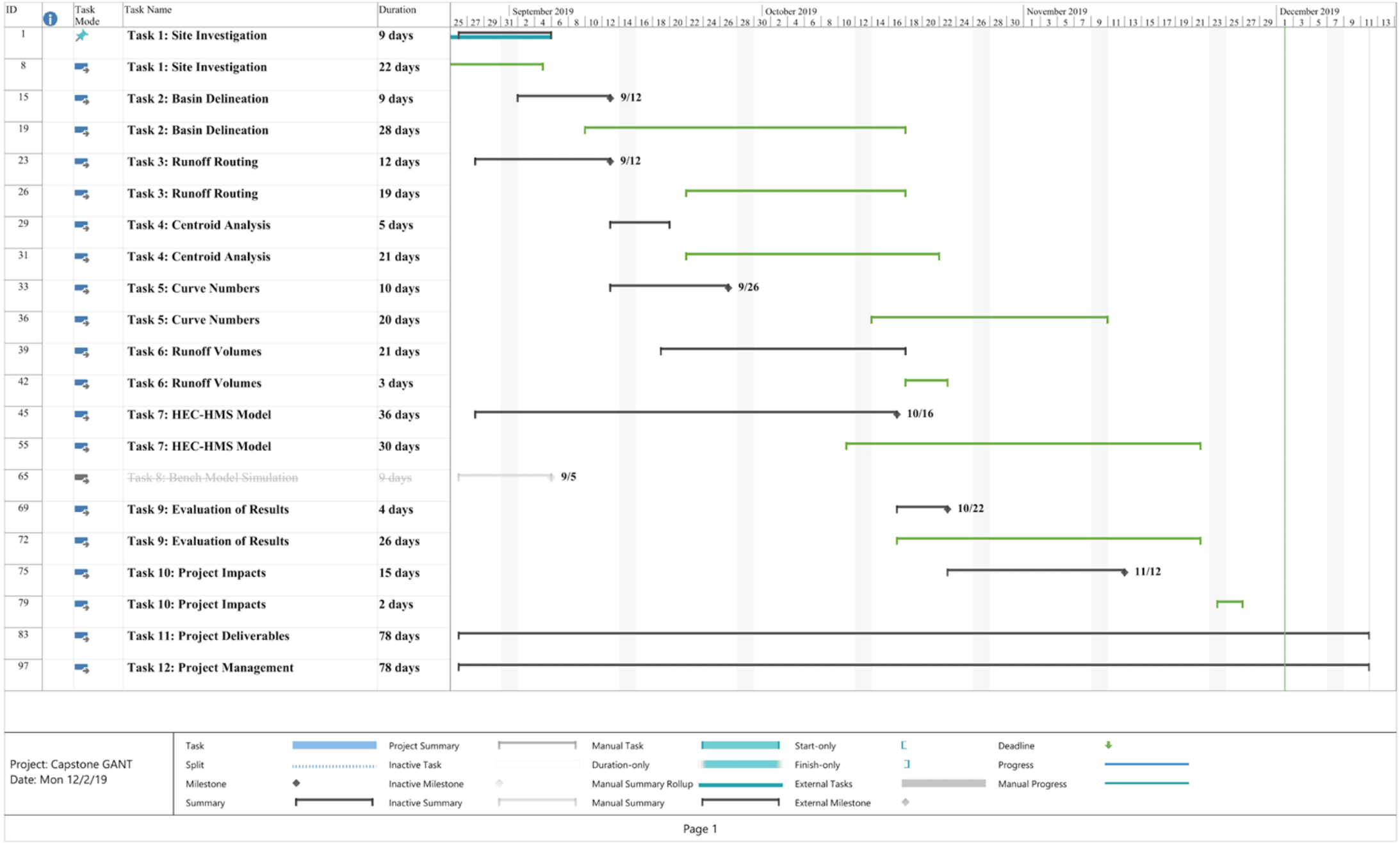
- Flooding
- Erosion and carrying contaminated water
- Wildlife displacement and harm from contaminated waters
- Use of extra material to protect or repair houses

Social Impacts

- Higher cost of developments mean higher cost of homes
- No desire to move into a flooding hazard area

Recommendations for Future Simulations

- Select a location with a smaller contributing watershed.
- Select a location with a majority of developed Area.
- Perform a soil survey of Mt. Elden to accurately determine soil type.
- The location should have stage data available above and below the urbanized area to allow for comparison against real world conditions.
- Several large storm events with accurate and better resolution of data.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Task Mode
Task Name
Duration
September 2019
October 2019
November 2019
December 2019
1 Task 1: Site Investigation 9 days
8 Task 1: Site Investigation 22 days
15 Task 2: Basin Delineation 9 days
9/12
19 Task 2: Basin Delineation 28 days
23 Task 3: Runoff Routing 12 days
9/12
26 Task 3: Runoff Routing 19 days
29 Task 4: Centroid Analysis 5 days
31 Task 4: Centroid Analysis 21 days
33 Task 5: Curve Numbers 10 days
9/26
36 Task 5: Curve Numbers 20 days
39 Task 6: Runoff Volumes 21 days
42 Task 6: Runoff Volumes 3 days
45 Task 7: HEC-HMS Model 36 days
10/16
55 Task 7: HEC-HMS Model 30 days
65 Task 8: Bench Model Simulation 9 days
9/5
69 Task 9: Evaluation of Results 4 days
10/22
72 Task 9: Evaluation of Results 26 days
75 Task 10: Project Impacts 15 days
11/12
79 Task 10: Project Impacts 2 days
83 Task 11: Project Deliverables 78 days
97 Task 12: Project Management 78 days
Project: Capstone GANT
Date: Mon 12/2/19
Task
Split
Milestone
Summary
Project Summary
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
External Tasks
External Milestone
Deadline
Progress
Manual Progress
Page 1

Summary of Engineering Cost

Table 14: Comparison of Staffing Hours

	Proposed					Actual				
Tasks	SENG	ENG	EIT	AA	Total	SENG	ENG	EIT	AA	Total
Task 1: Site Investigation	1	8	35	0	**44**	2	0	31.5	0	**33.5**
Task 2: Basin Delineation	0	7	21	0	**28**	2	10	51.5	0	**63.5**
Task 3: Runoff Routing	0	14	13	0	**27**	3	10	24	0	**37**
Task 4: Centroid Analysis	0	2	6	0	**8**	0	3	4	0	**7**
Task 5: Curve Numbers	2	6	22	0	**30**	7	9	30.5	0	**46.5**
Task 6: Runoff Volumes	2	11	48	0	**61**	0	0	0	0	**0**
Task 7: HEC-HMS Model	1	7	21	0	**29**	3	10	17.5	0	**30.5**
Task 8: Bench Model Simulation	1	10	26	0	**37**	0	0	0	0	**0**
Task 9: Evaluation of Results	8	16	24	0	**48**	0	8	9	0	**17**
Task 10: Project Impacts	6	30	0	0	**36**	0	4	0	0	**4**
Task 11: Project Deliverables	30	33	91	11	**165**	6	11	68	2	**87**
Task 12: Project Management	118	179	0	26	**323**	8.5	6.5	62.5	7	**84.5**
Total Hours	**169**	**323**	**307**	**37**	**836**	**31.5**	**71.5**	**298.5**	**9**	**410.5**

Summary of Engineering Cost

Table 15: Estimated Cost of Engineering Services

Description	Unit	Quantity	Unit Cost	Cost
SENG	HR	169	$160	$27,040
ENG	HR	323	$110	$35,530
EIT	HR	307	$60	$18,420
AA	HR	37	$50	$1,850
Bench Model Supplies	LS	1	$1,000	$1,000
TOTAL				$83,840

Table 16: Actual Cost of Engineering Services

Description	Unit	Quantity	Unit Cost	Cost
SENG	HR	31.5	$160	$5,040
ENG	HR	71.5	$110	$7,865
EIT	HR	298.5	$60	$17,910
AA	HR	9	$50	$450
Bench Model Supplies	LS	0	$1,000	$0
TOTAL				$31,265

References

[1]“Catching Storm Runoff Could Ease Droughts, But It's No Quick Fix,” KQED, 17-Mar-2016. [Online]. Available: https://www.kqed.org/science/573382/catching-storm-runoff-could-ease-droughts-but-it-wont-come-cheap. [Accessed: 24-Apr-2019].

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[3] “Overview – Google Earth,” *Google Earth*. [Online]. Available: https://www.google.com/earth/. [Accessed: 25-Apr-2019].

[4] ”Web Soil Survey - Home,” Websoilsurvey.sc.egov.usda.gov, 2019. [Online]. Available: https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm. [Accessed: 24- Sep- 2019].

Questions?