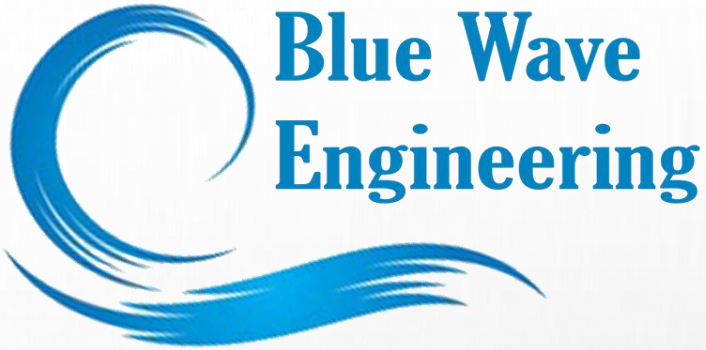


Blue Wave Engineering

Flagstaff Weighted Curve Numbers

CENE 476 Capstone Presentation

April 25th, 2019

Grace Garwin, Ethan Crane, Abdullah Alenezi, Chad Murphy

Purpose

- Curve numbers are a coefficient used to estimate runoff volumes from a storm event
- Flagstaff experiences localized flooding during storm events
- Current estimations do not consider flows over discontinuous surface types
- Comparison between area-weighted method and micro-basins based on surface type.

Figure 1: Overland Flow [1]

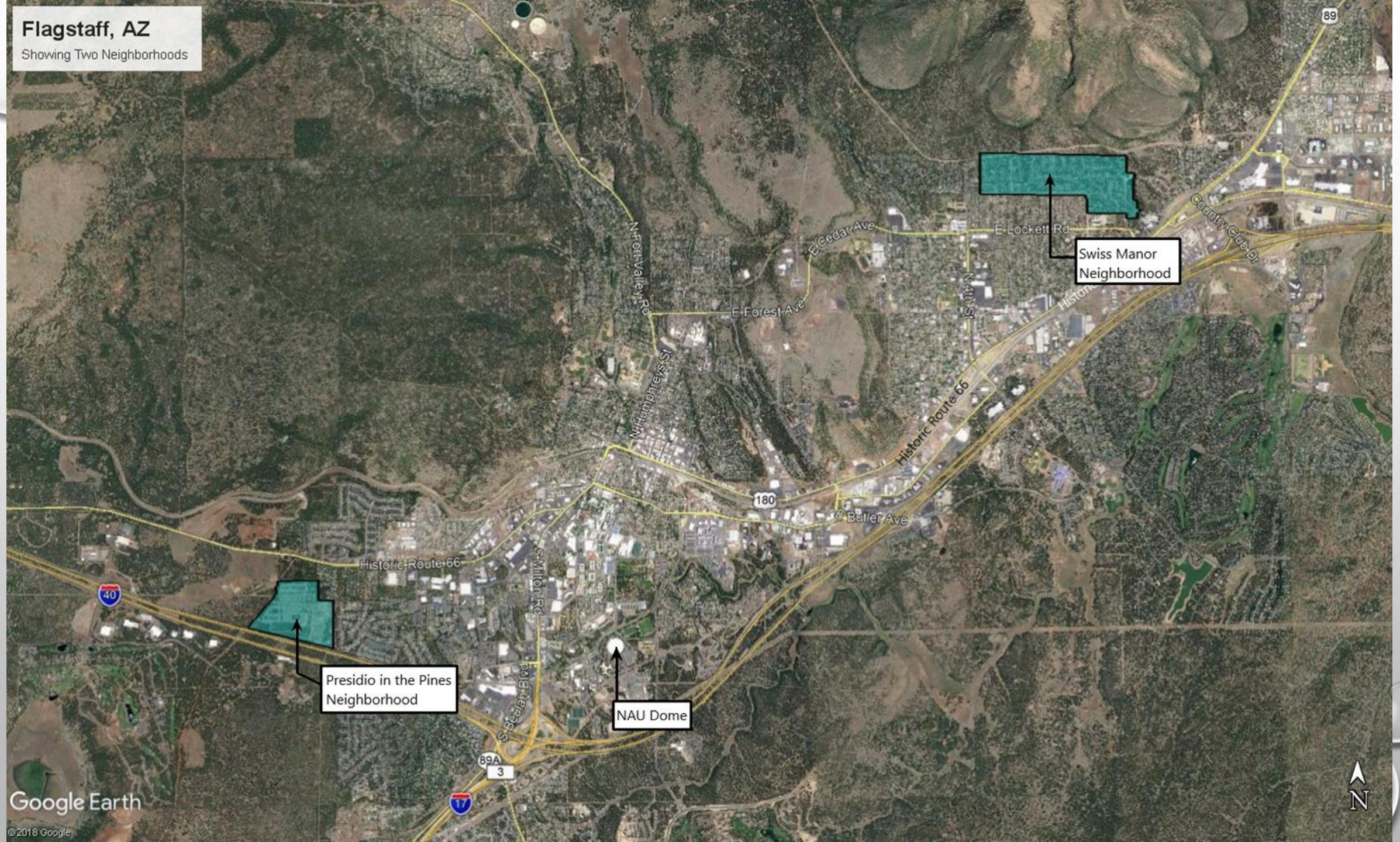
Client

City of Flagstaff Stormwater Division

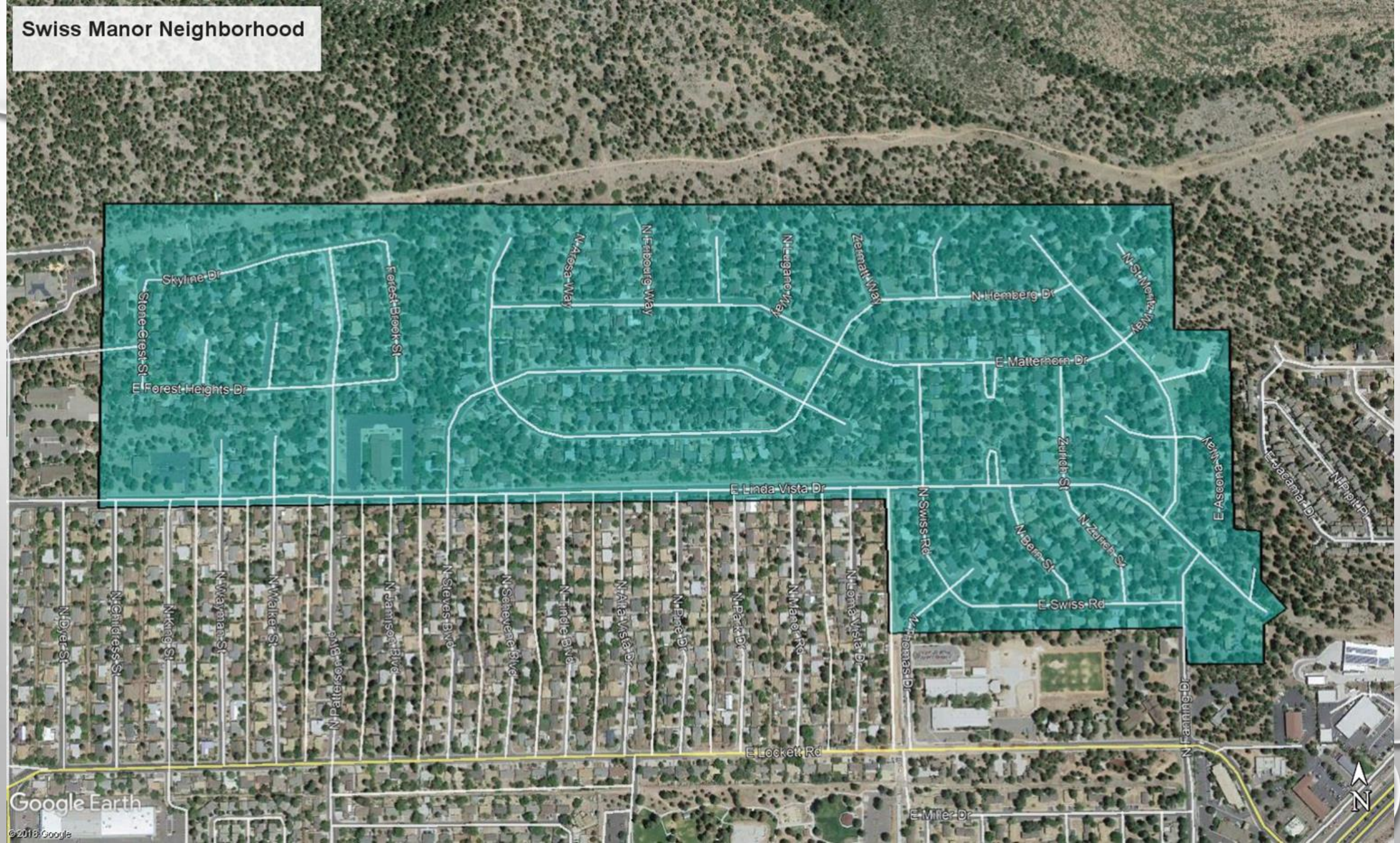
Ed Schenk

Jim Janesek

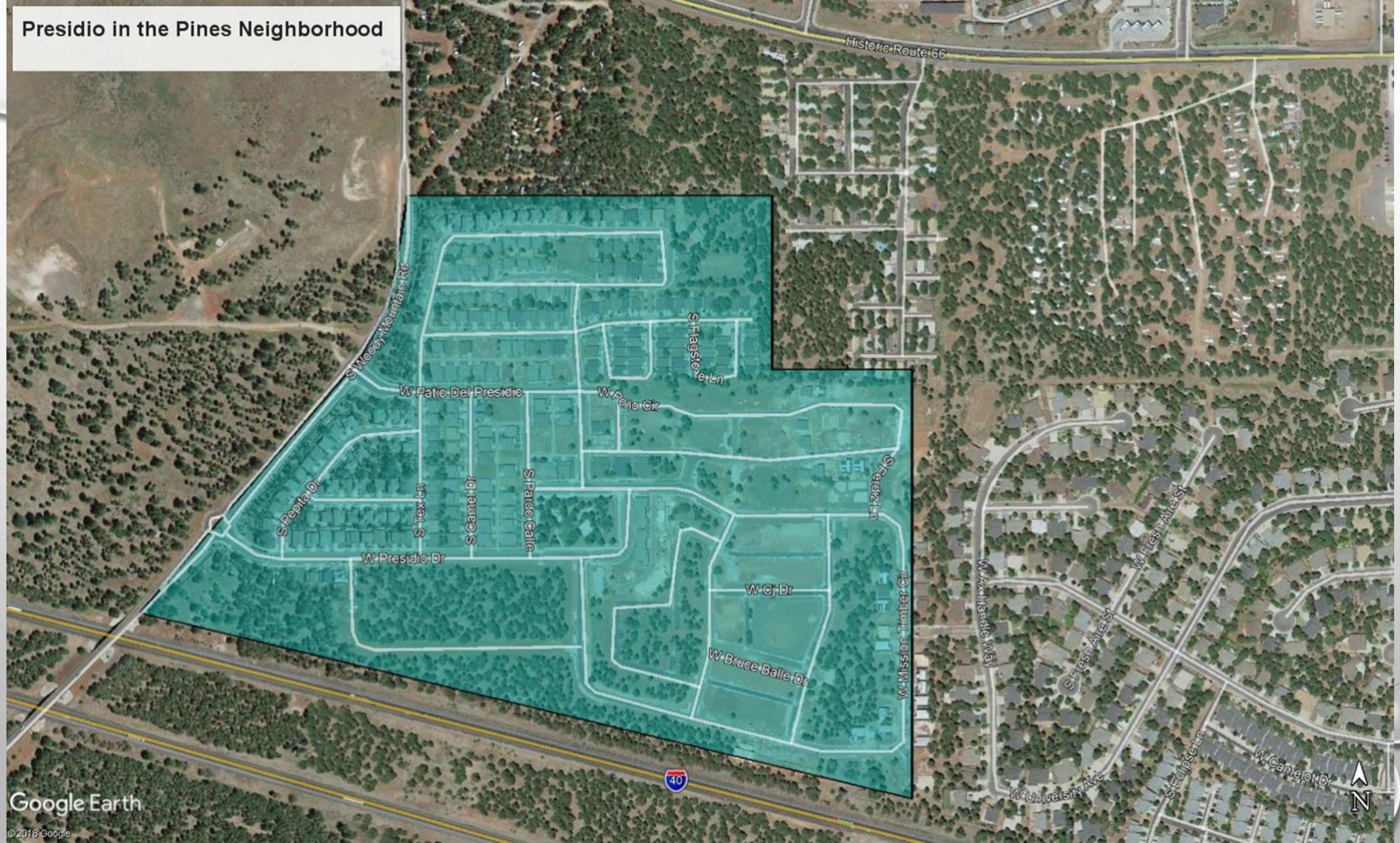
Figure 2: City of Flagstaff Badge [2]


Flagstaff, AZ
Showing Two Neighborhoods
Swiss Manor Neighborhood
Presidio in the Pines Neighborhood
NAU Dome
E Cedar Ave
E Lockett Rd
E Forest Ave
N Fort Valley Rd
N Humphreys St
N 4th St
Historic Route 66
E Butler Ave
S Milton Rd
S Beaver St
Country Club Dr
180
89
89A
3
40
17
Google Earth
©2018 Google
N

[3]


Swiss Manor Neighborhood
Skyline Dr
Stone Crest St
E Forest Heights Dr
Forest Brook St
N Arosa Way
N Fribourg Way
N Lugano Way
Zermatt Way
N Hemberg Dr
N St Moritz Way
E Matterhorn Dr
E Linda Vista Dr
N Swiss Rd
Zurich St
N Bern St
N Zermatt St
E Ascona Way
E Lugano Dr
N Pontiac Dr
E Swiss Rd
N Dover St
N Chateau St
N King St
N Wayland St
N Walker St
N Patterson Ave
N Jamison Blvd
N Steves Blvd
N Stevenson Blvd
N Linda Vista Blvd
N Park Dr
N Manor Rd
N Loma Vista Dr
N Thomas Dr
E Lockett Rd
E Miller Dr
Google Earth
©2018 Google
N

[3]


Presidio in the Pines Neighborhood
Historic Route 66
S Woody Mountain Rd
W Patio Del Presidio
W Polo Cir
S Flagstone Ln
S Pepita Dr
S Tex Ln
S Camel Dr
S Patio Calle
S Pizarro Ln
W Presidio Dr
W Cj Dr
W Bruce Balle Dr
W Mission Timber Cir
W Axminster Way
W Fresno Ave St
S Fresno Ave St
S Eclipse Ln
W Camelot Dr
W University Ave
40
Google Earth
©2018 Google
N

[3]

Task 1: Site Investigation

- Task 1.1: Field Visit and Preliminary Assessment
  - Task 1.1.1: Topographic Maps
  - Task 1.1.2: Aerial Maps
  - Task 1.1.3: Precipitation Data
- Task 1.2: Soil Survey

Task 2: Basin Delineation

- Task 2.1: Major Basin
- Task 2.2: Sub-Basins
  - Task 2.2.1: Sub-Basins for Weighted Curve Number
  - Task 2.2.2: Micro-Basins Based on Surface Type

Task 3: Runoff Routing

- Task 3.1: Time of Concentration Path Delineation
- Task 3.2: Time of Concentration

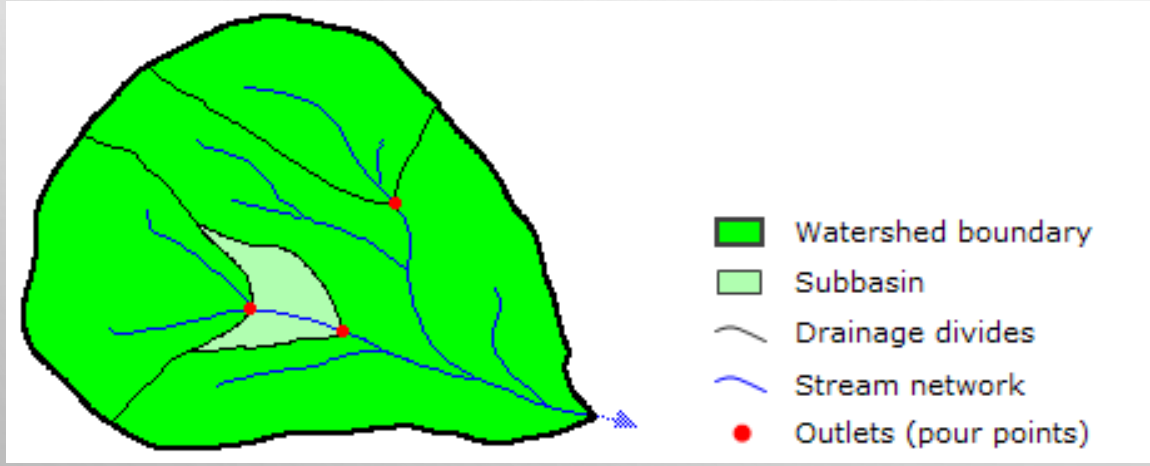


Figure 3: Example Runoff Path [4]

Task 4: Centroid Analysis

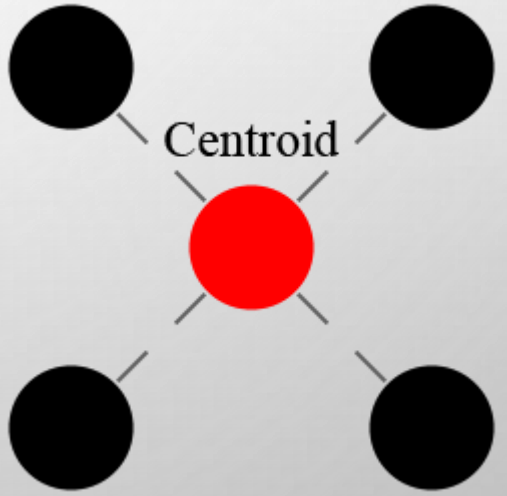


Figure 4: Example Centroid [5]

Task 5: Curve Numbers

- Task 5.1: Weighted Curve Number Calculation for Sub-Basins
- Task 5.2: Curve Numbers for Micro-Basins

Land Use	Slope (%)	Hydrologic Class A	B	C	D	Drainage Length (m)
Agricultural land	< 3	62	72	79	82	10
	3-8	64	76	84	88	
	> 8	70	80	87	90	
Pasture	< 3	32	51	72	79	25
	3-8	44	65	77	82	
	> 8	59	74	83	87	
Forest	< 3	24	54	68	76	20
	3-8	33	59	73	79	
	> 8	44	66	78	83	
Urban	Dense	73	83	88	90	5

Figure 5: Curve Number Chart [6]

Task 6: Runoff Volumes

- Task 6.1: Runoff Calculations Using Weighted Curve Numbers
- Task 6.2: Runoff Calculations Using Micro-Basin Curve Numbers

$$I_a = 0.2\,S$$

$$Q = \frac{(P - 0.2\,S)^2}{(P + 0.8\,S)}$$

$$S = \frac{1000}{CN} - 10$$

Figure 6: SCS Method Runoff Equation [7]

Task 7: HEC-HMS Model

- Task 7.1: Data Input
  - Task 7.1.1: Soil Survey Input
  - Task 7.1.2: Runoff Routing
  - Task 7.1.3: Topographic Maps
- Task 7.2: Running HEC-HMS Model

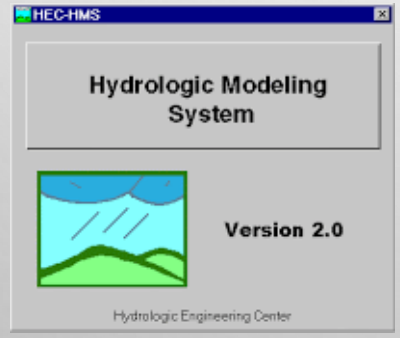


Figure 7: HEC-HMS Badge [8]

Task 8: Bench Model Simulation

- Task 8.1: Creation of Physical Model
- Task 8.2: Physical Model Storm Simulation
- Task 8.3: Generate Hydrographs from Results

Task 9: Evaluation of Results

- Task 9.1: Create Hydrographs
  - Task 9.1.1: 2-yr Storm Hydrograph
  - Task 9.1.2: 10-yr Storm Analysis
  - Task 9.1.3: 100-yr Storm Analysis
- Task 9.2: Compare Simulation to Runoff Volume Results
- Task 9.3: Compare HEC-HMS Results to Known Storm Events

Task 10: Project Impacts

- Task 10.1: Economic Impacts
- Task 10.2: Social Impacts
- Task 10.3: Environmental Impact

Figure 8: Environmental Impact Representation [9]

Task 11: Project Deliverables

- Task 11.1: 30% Submittal
  - Task 10.1.1: 30% Report
  - Task 10.1.2: 30% Presentation
- Task 11.2: 60% Submittal
  - Task 11.2.1: 60% Report
  - Task 11.2.2: 60% Presentation
- Task 11.3: 90% Submittal
  - Task 11.3.1: 90% Report
  - Task 11.3.2: 90% Website
- Task 11.4: Final Submittal
  - Task 11.4.1: Final Report
  - Task 11.4.2: Final Presentation
  - Task 11.4.3: Final Website

Task 12: Project Management

- Task 12.1: Meetings
  - Task 12.1.1: Client Meetings
  - Task 12.1.2: Technical Advisor Meetings
  - Task 12.1.3: Grading Instructor Meetings
  - Task 12.1.4: Team Meetings
- Task 12.2: Coordination
- Task 12.3: Schedule Management
- Task 12.4: Resource Management

Exclusions

- Topographic Surveying
- Evaluating Curve Numbers
- Developing Curve Numbers

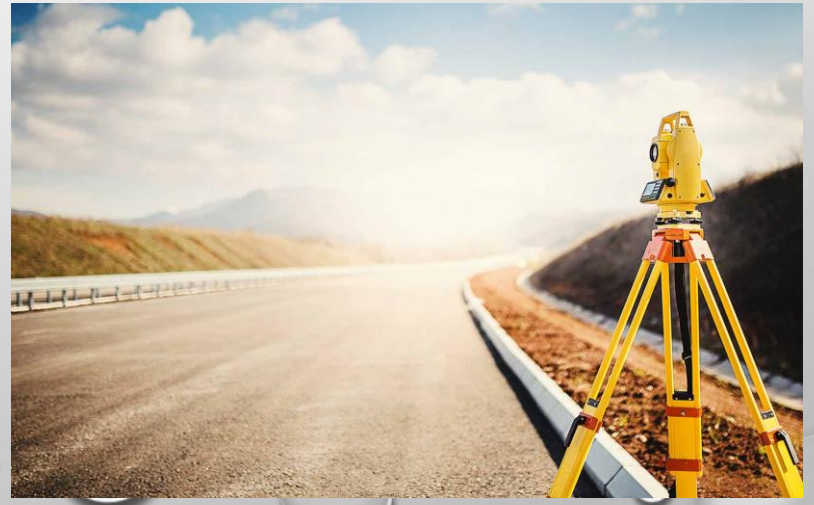
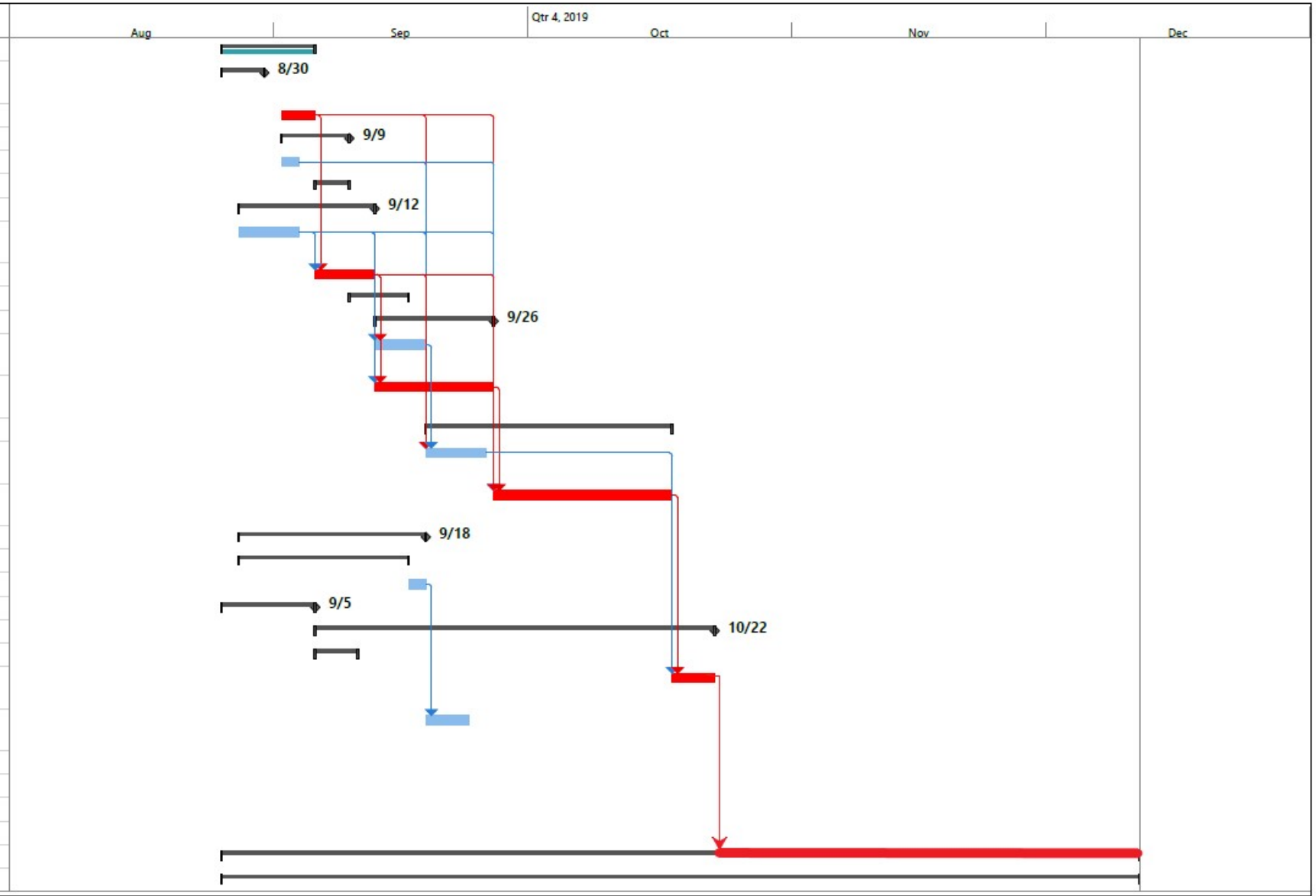


Figure 9: Surveying Equipment [10]

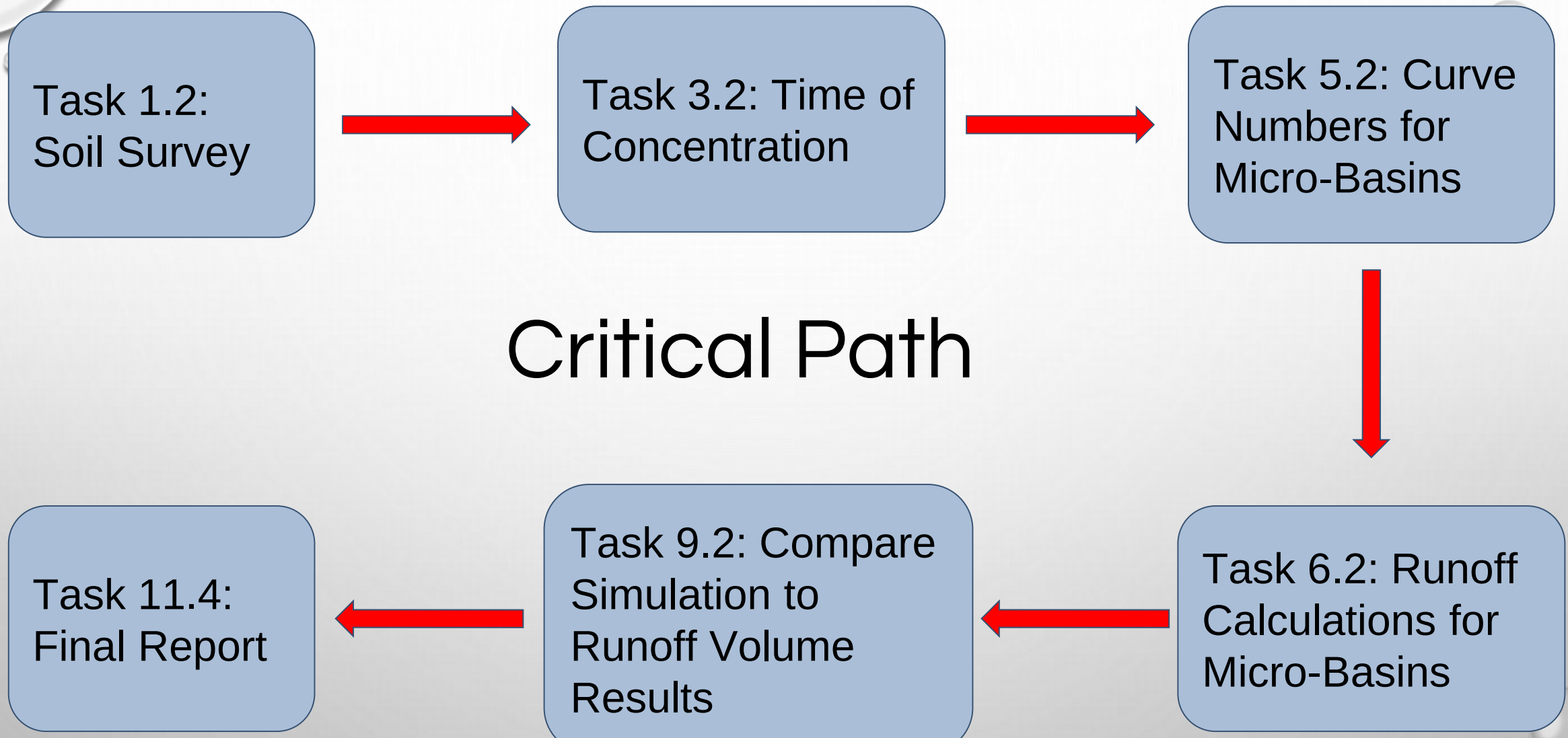
ID	Task Name	Duration
1	**Task 1: Site Investigation**	9 days
2	**Task 1.1: Field Visit and Preliminary Assessment**	5 days
6	Task 1.2: Soil Survey	4 days
7	**Task 2: Basin Delineation**	6 days
8	Task 2.1: Major Basin	2 days
9	**Task 2.2: Sub-Basins**	2 days
12	**Task 3: Runoff Routing**	12 days
13	Task 3.1: Time of Concentration Path Delineation	5 days
14	Task 3.2 Time of Concentration	5 days
15	**Task 4: Centroid Analysis**	5 days
17	**Task 5: Curve Numbers**	10 days
18	Task 5.1: Weighted Curve Number Calculation for Sub-Basins	4 days
19	Task 5.2: Curve Numbers for Micro-Basins	10 days
20	**Task 6: Runoff Values**	21 days
21	Task 6.1: Runoff Calculations Using Weighted Curve Numbers	5 days
22	Task 6.2: Runoff Calculations Using Micro-Basin Curve Numbers	15 days
23	**Task 7: HEC-HMS Model**	16 days
24	**Task 7.1: Data Input**	14 days
28	Task 7.2: Running HEC-HMS Model	2 days
29	**Task 8: Bench Model Simulation**	9 days
33	**Task 9: Evaluation of Results**	33 days
34	**Task 9.1: Create Hydrographs**	3 days
38	Task 9.2: Compare Simulation to Runoff Volume Results	3 days
39	Task 9.3: Compare HEC-HMS Results to Known Storm Events	3 days
40	**Task 10: Project Impacts**	15 days
41	Task 10.1: Economic Impacts	15 days
42	Task 10.2: Social Impacts	15 days
43	Task 10.3: Environmental Impacts	15 days
44	**Task 11: Project Deliverables**	78 days
58	**Task 12: Project Management**	78 days



Project: Capstone GANT
Date: Wed 4/24/19

Task	Project Summary	Manual Task	Start-only	Deadline	
Split	Inactive Task	Duration-only	Finish-only	Progress	
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress	
Summary	Inactive Summary	Manual Summary	External Milestone		

Critical Path



Staffing Plan

Tasks	SENG	ENG	EIT	AA	Total
Task 1: Site Investigation	1	8	23	0	32
Task 1.1: Field Visit and Preliminary Assessment		7	17		24
Task 1.1.1: Topographic Maps		2	4		6
Task 1.1.2: Aerial Maps		2	5		7
Task 1.1.3: Precipitation Data		3	8		11
Task 1.2: Soil Survey	1	1	6		8
Task 2: Basin Delineation	0	7	21	0	28
Task 2.1: Major Basin		3	3		6
Task 2.2: Sub-Basins		4	18		22
Task 2.2.1: Sub-Basins for Weighted Curve Number		1	4		5
Task 2.2.2: Micro-Basins Based on Surface Type		3	14		17
Task 3: Runoff Routing	0	14	13	0	27
Task 3.1: Time of Concentration Path Delineation		6	5		11
Task 3.2: Time of Concentration		8	8		16
Task 4: Centroid Analysis	0	2	6		8
		2	6		8

Tasks	SENG	ENG	EIT	AA	Total
Task 5: Weighted Curve Numbers for Sub-Basins	2	6	22	0	30
Task 5.1: Weighted Curve Number Calculations for Sub-Basins	1	4	18		23
Task 5.2: Curve Numbers for Micro-Basins	1	2	4		7
Task 6: Weighted Curve Numbers Sub-Basins Based on Surface Type	2	11	48		61
Task: 6.1: Runoff Calculations Using Weighted Curve Numbers	1	3	12		16
Task: 6.2: Runoff Calculations Using Micro-Basin Curve Numbers	1	8	36		45
Task 7: Software	1	4	15	0	20
Task 7.1: Data Input		3	11		14
Task 7.1.1: Soil Survey Input		1	3		4
Task 7.1.2: Runoff Routing		1	4		5
Task 7.1.3: Topographic Map		1	4		5
Task 7.2: Running HEC-HMS Model	1	1	4		6
Task 8: Bench Model Simulation	1	10	26	0	37
Task 8.1: Creation of Physical Model		4	10		14
Task 8.2: Physical Model Storm Simulation		4	10		14
Task 8.3: Generate Hydrographs from Results	1	2	6		9

Staffing Plan

Tasks	SENG	ENG	EIT	AA	Total
Task 9: Evaluation of Results	8	19	30	0	57
Task 9.1: Create Hydrographs		3	6		9
Task 9.1.1: 2-yr Storm Analysis		1	2		3
Task 9.1.2: 10-yr Storm Analysis		1	2		3
Task 9.1.3: 100-yr Storm Analysis		1	2		3
Task 9.2: Compare Simulation to Runoff Volume Results	4	8	12		24
Task 9.3: Compare HEC-HMS Results to Known Storm Events	4	8	12		24
Task 10: Project Impacts	6	30	0	0	36
Task 10.1: Economic Impacts	2	10			12
Task 10.2: Social Impacts	2	10			12
Task 10.3: Environmental Impacts	2	10			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

Tasks	SENG	ENG	EIT	AA	Total
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		1	9
Task 11.4.3: Final Website	1	3	7	1	12
Task 12: Project Management	108	189	0	26	323
Task 12.1: Meetings	48	184	0	26	258
Task 12.1.1: Client Meetings		8		2	10
Task 12.1.2: Technical Advisor Meetings		16		4	20
Task 12.1.3: Grading Instructor Meetings		16		4	20
Task 12.1.4: Team Meetings	48	144		16	208
Task 12.2: Coordination	20	5			25
Task 12.3: Schedule Management	20				20
Task 12.4: Resource Management	20				20
Total Hours	**159**	**333**	**295**	**37**	**824**

Cost of Engineering Services

Cost Estimate 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**

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].

[2]Government | City of Flagstaff Official Website. [Online]. Available: https://www.flagstaff.az.gov/979/Government. [Accessed: 24-Apr-2019].

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

[4]"How Watershed Works", ArcGIS, 24-April-2019. [Online]. Available: http://desktop.arcgis.com/en/arcmap/latest/tools/spatial-analyst-toolbox/how-watershed-works.htm

[5]Cs.cornell.edu. (2019). *CS 1110: Assignment 5*. [online] Available at: http://www.cs.cornell.edu/courses/cs1110/2013fa/assignments/assignment5/index.php [Accessed 25 Apr. 2019].

[6]Research Gate. (2019). [online] Available at: https://www.researchgate.net/figure/Runoff-Curve-Number-CN-after-Monfet-1979-and-drainage-length_tbl1_230819102 [Accessed 25 Apr. 2019].

[7]SCS Curve Number Method. [Online]. Available: https://engineering.purdue.edu/mapserve/LTHIA7/documentation/scs.htm. [Accessed: 25-Apr-2019].

8]"HEC-HMS ," *HEC-HMS*. [Online]. Available: https://sites.google.com/a/aquacloud.net/15he02/hydrological-analysis/hec-hms. [Accessed: 25-Apr-2019].

[9]O.Nieburg,"Whatis chocolate's biggest environmental impact?," confectionerynews.com, 15-Mar-2018. [Online]. Available: https://www.confectionerynews.com/Article/2018/03/15/What-is-chocolate-s-biggest-environmental-impact. [Accessed: 25-Apr-2019].

[10]E. Creative, "Land Surveying," *Barghausen Consulting Engineers, Inc.* -. [Online]. Available: https://www.barghausen.com/services/land-surveying. [Accessed: 25-Apr-2019].

Questions?