FLAGSTAFF-SHADOW MOUNTAIN DRAINAGE DESIGN

Sydney Wilson, Carleigh Jones, Shanya Whitehorse

CENE 486C

April 28, 2023

AB Stormwater Management Co.

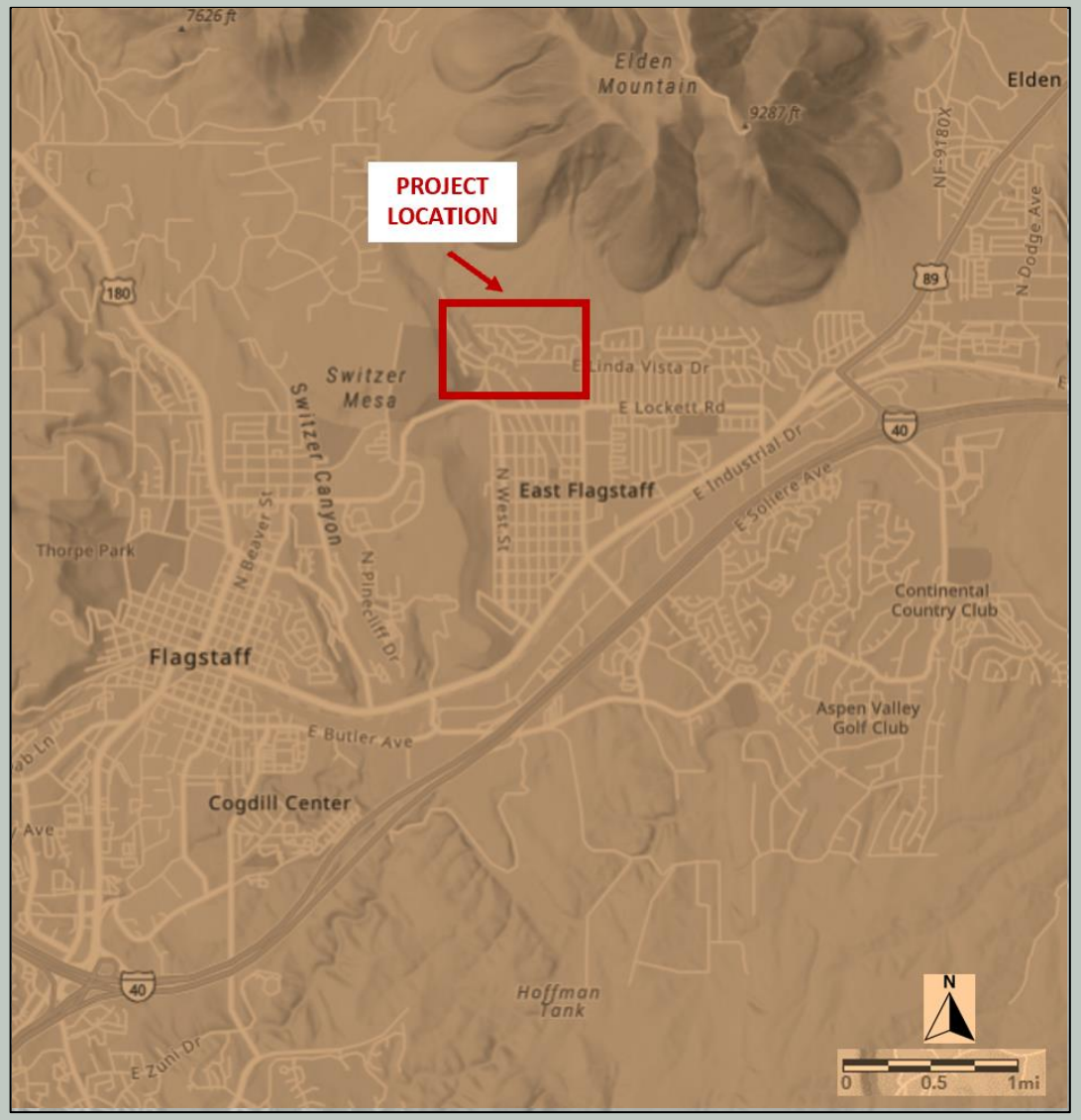


Figure 1 – Map of the City of Flagstaff

INTRODUCTION

Purpose: Alter the terrain to reduce the impact of flooding

Client: Chase McLeod - Flagstaff Stormwater Department

Background:

- Built in the late 1970's
- Minimal existing stormwater infrastructure
- Annual floods, sediment deposits, and destruction to property

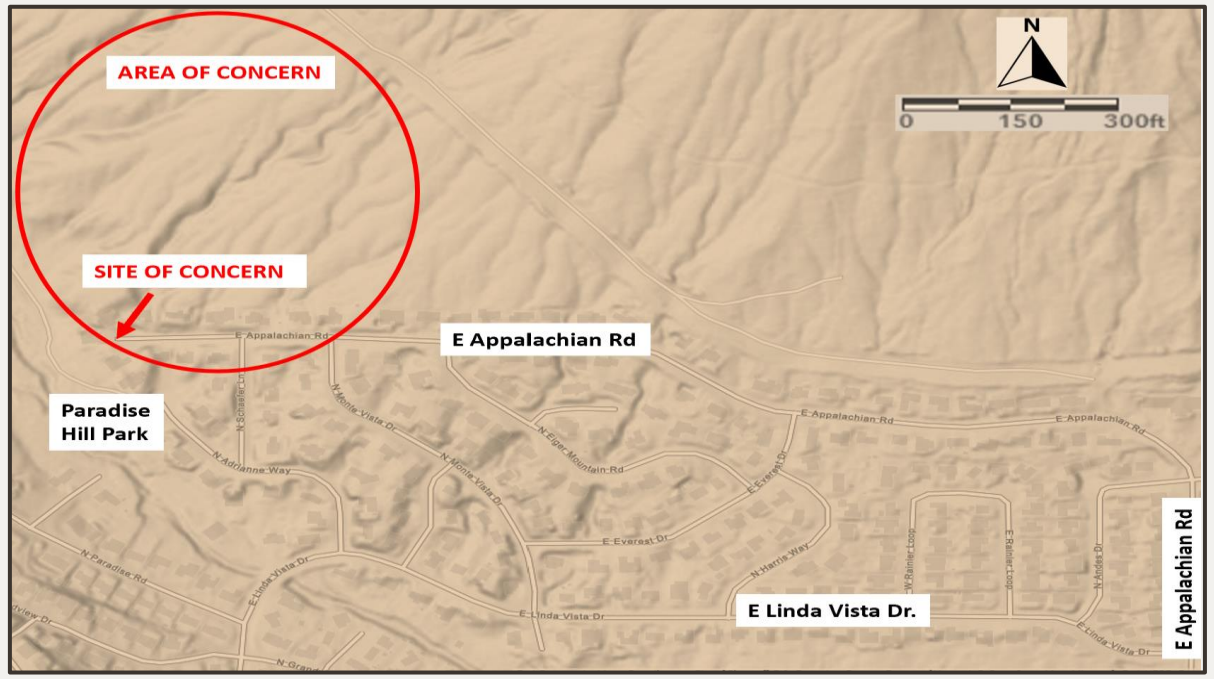


Figure 2 – Map of the Shadow Mountain Community

Figure 3– Sandbags


Figure 4 – Site flooding in Summer 2022

RESEARCH FEMA FLOODPLAIN

- Shadow Mountain community is categorized as an AE flood zone
- Project area is categorized as Zone X

Figure 5 – FEMA Floodplain Map of Shadow Mountain Community

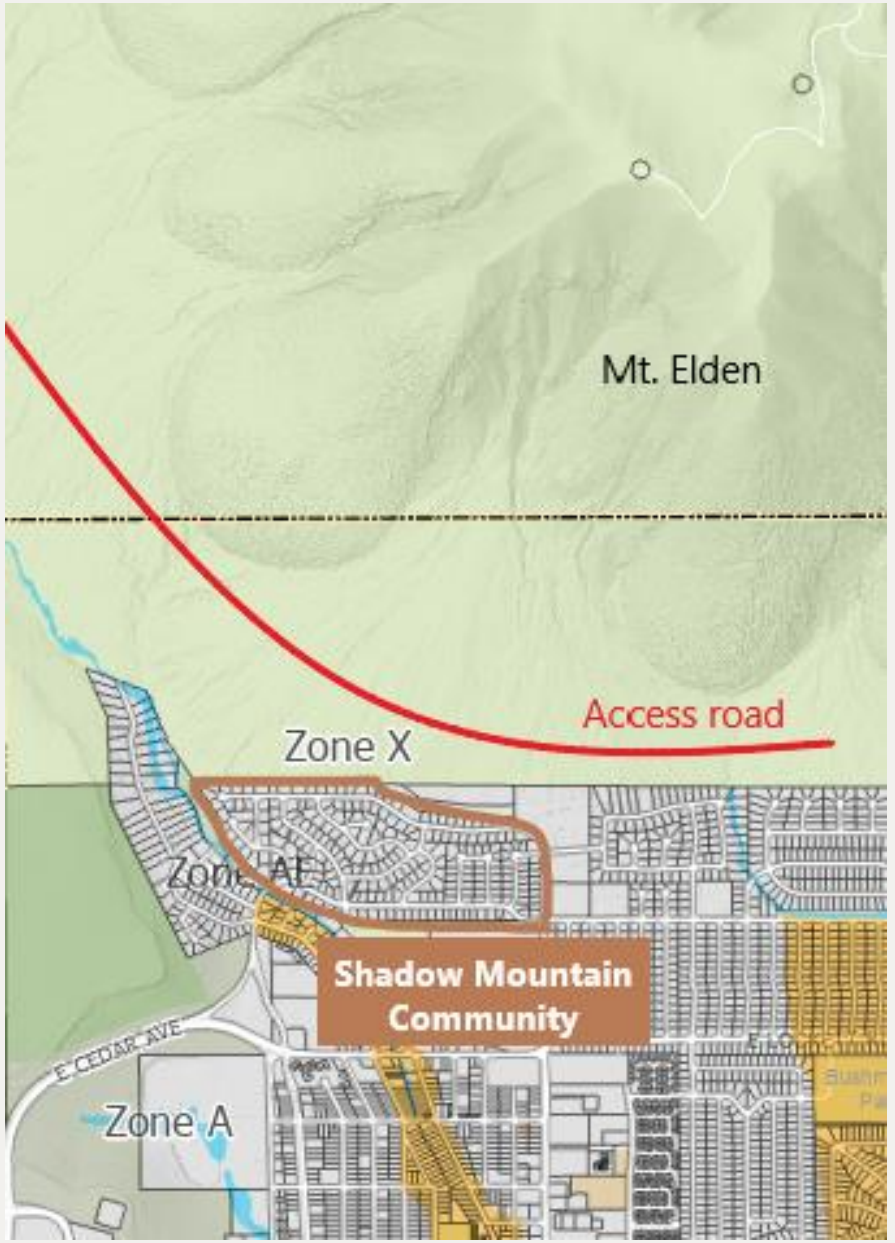


Figure 6 – FEMA Floodplain Map of Flagstaff

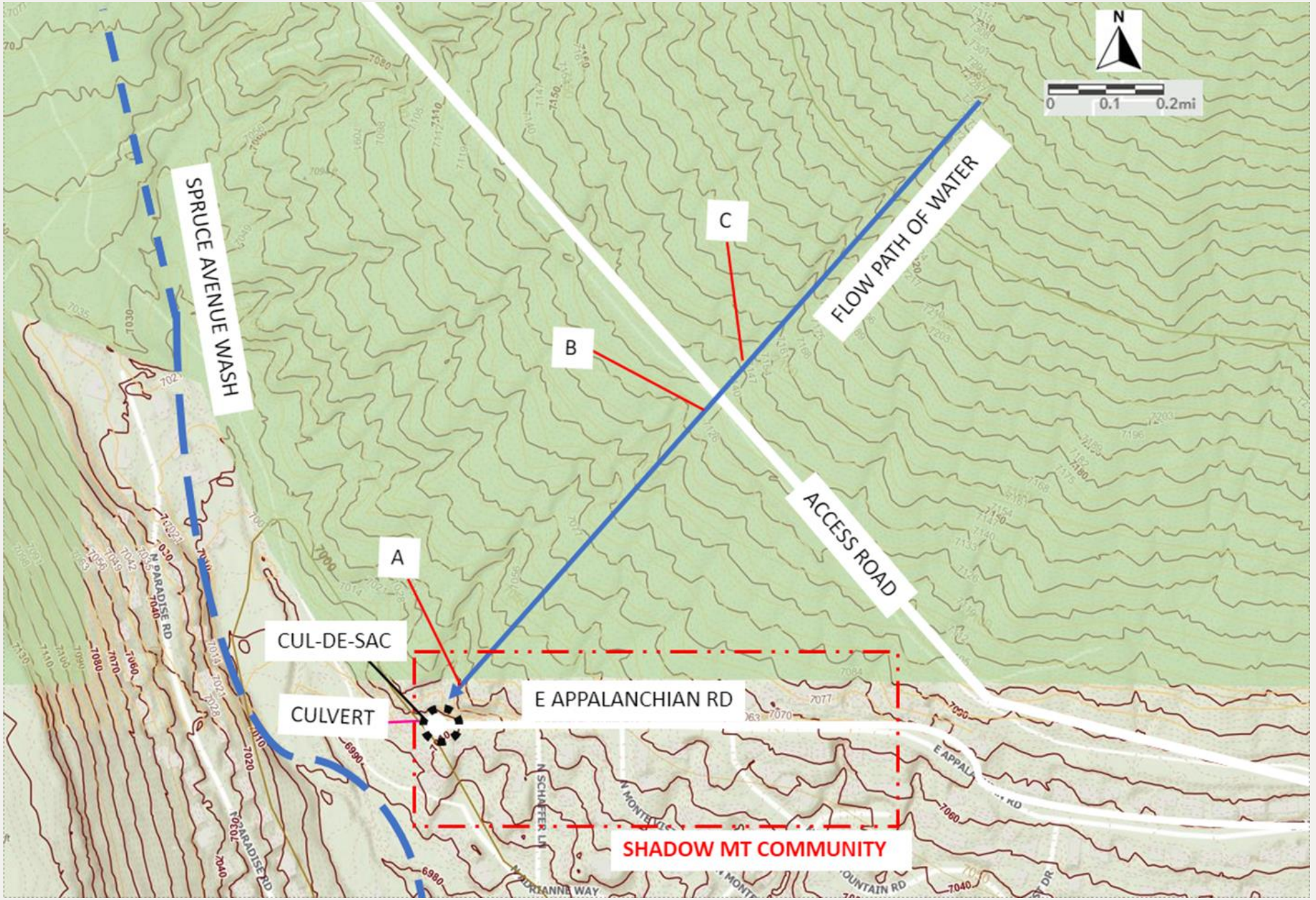
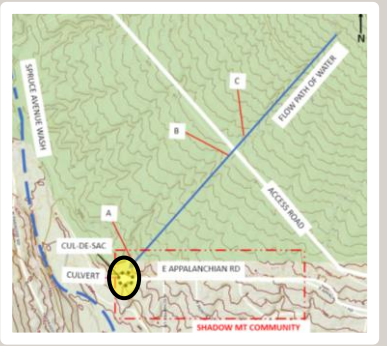


Figure 7 – Annotate Shadow Mountain site map

FIELD SITE INVESTIGATION:

Conditions in the Community



Site Identifier

- Natural stormwater runoff channel above community
- Shallow terrain slope North of community up to the access road
- Steep terrain sloped above access road
- Access road is owned by gas company
- National Forest manages land


Figure 8– View of Access Point where Mt. Elden runoff enters Shadow Mountain


Figure 9– Image of Natural Channel's path


Figure 10 – Consistent ground of the Channel

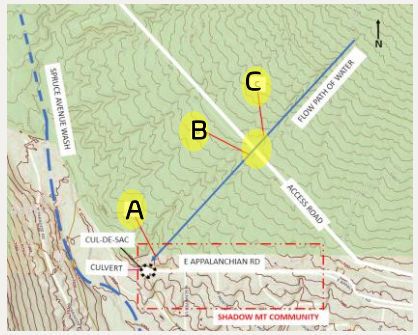
FIELD SITE INVESTIGATION:
Potential Design Locations

Figure 11 – Location A, directly North of Community

Figure 12 – Location B, southwest of pipeline access road

Figure 13 – Location C, area northeast of access road

Figure 14 –Access road, dirt road covered in snow



Site Identifier

HYDROLOGIC ANALYSIS

Table 1 – Watershed inputs

WATERSHED INPUTS	
Landform Type:	Mountain, with rough rock and boulder cover
Flow Type:	Overland Flow
Watershed Resistance Coefficient:	0.25
Longest Flow Path Length (miles):	1.643
Watershed Slope (ft/mile):	1253.8

Table 2 – Watershed and subarea inputs

SUB-AREA INPUTS		
Sub-Area	Area (acres)	Subbasin Type
1	121.747	Mountain Ponderosa Pine
2	141.88	Mountain Ponderosa Pine
3	76.6	Mountain Juniper Grass

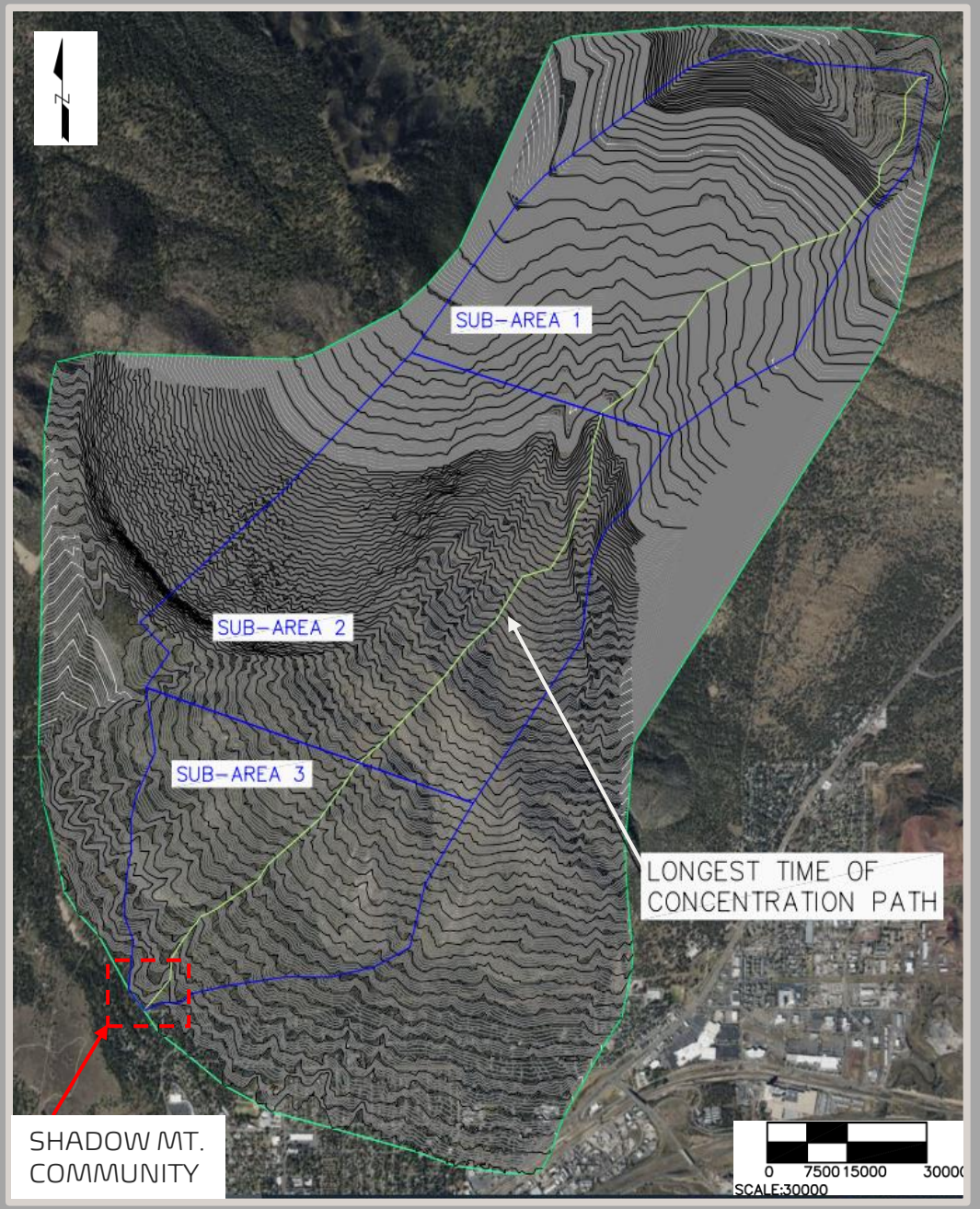


Figure 15 – Subareas of watershed

HYDROLOGIC ANALYSIS

Table 3 – ADOT Rational Method Tool Results

ADOT RATIONAL METHOD TOOL RESULTS	
Parameter:	100-Year
Discharge, Q (cfs):	308.7
Rational Coefficient, C (unitless):	0.20
Rainfall Intensity, i (in/hr):	4.54
Subbasin Total Area, A (acres):	340.23
Time of Concentration, Tc (min):	26.4

HYDRAULIC ANALYSIS

Existing structures composed of a combined catch basin

- Two 24-inch steel corrugated pipes
- Discharging into Spruce Ave. Wash

Table 4 – Hydraulic Analysis

Under Inlet Control	
Discharge, Q (cfs)	58
Under Outlet Control	
Discharge, Q (cfs)	44

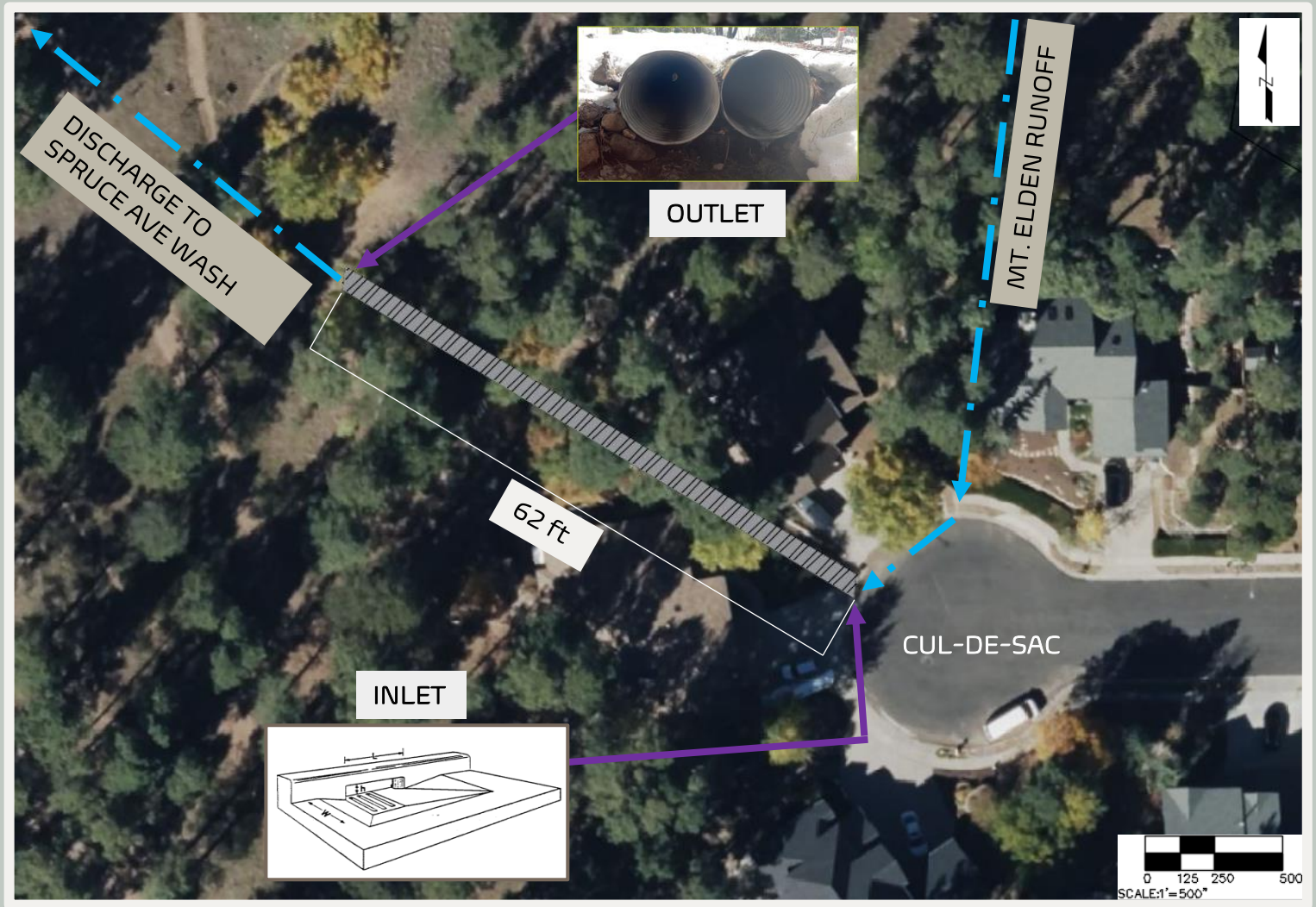


Figure 16 – Map of annotations of existing culvert

ANALYSIS OF ALTERNATIVES:

Design Criteria Standards

Table 5 – Scoring criteria

Scoring (1-3)	
1	Poor performance
2	Average performance
3	Excellent performance

Table 6 – Category standards

Alternative Design Standards	
DESIGNING CRITERIA	STANDARD
CONSTRUCTION COST	Under $100,000
TIME OF CONSTRUCTION	9 - 12 MONTHS
DESIGN EFFECTIVENESS	• Decrease velocity • Prevent flooding • Improve water quality
ANNUAL MAINTENANCE	Low maintenance under $1,500

ALTERNATIVE DESIGN 1:

Retention Basin

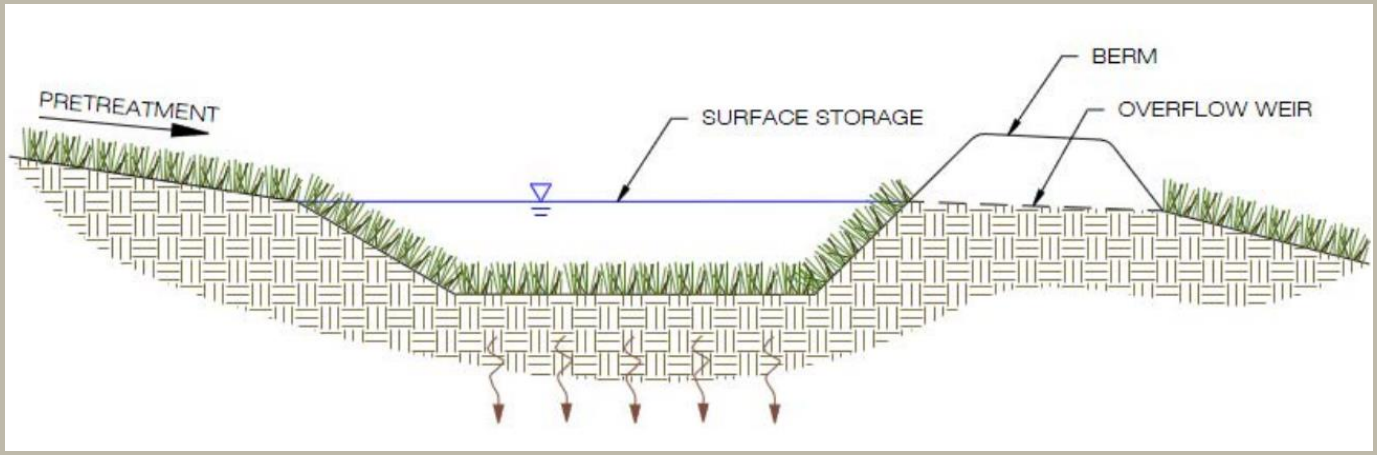


Figure 17 – Retention basin

Construction Cost :

$105,000

Time of Construction:

12 months

Design Effectiveness:

- Hold and distribute rain runoff
- Improve water quality
- Prevent flooding

Maintenance:

- Starts at $150 - $1,000
- Semi-annual inspection

ALTERNATIVE DESIGN 2:

Bioswale

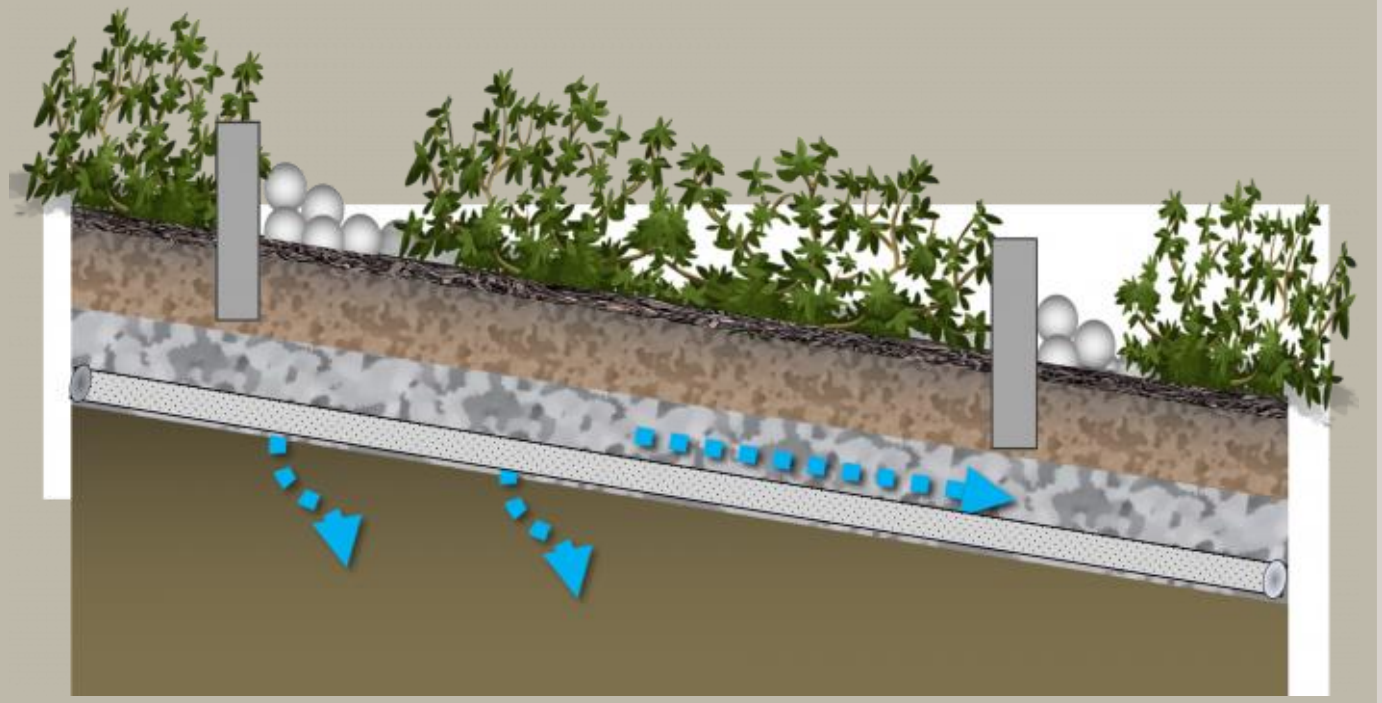


Figure 18 - Bioswales

Construction Cost :

$36,000

Time of Construction:

9 months

Design Effectiveness:

- Slowing runoff velocity
- Improves the quality of surface water
- Helps recharge the groundwater

Maintenance:

- Semi-annual (Spring and Fall)
- About $4.31 per linear ft

ALTERNATIVE DESIGN 3:

Retention Basin+ Bioswale

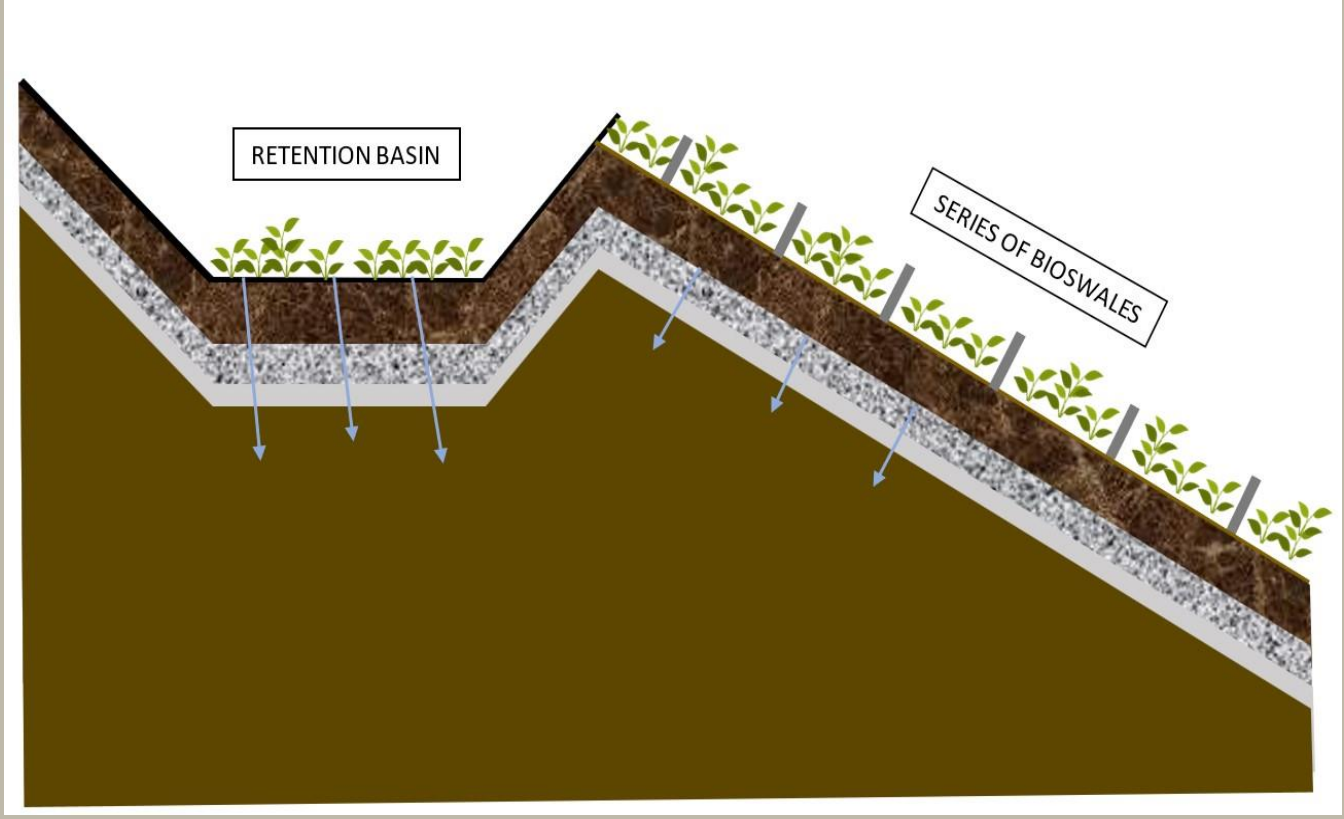


Figure 19 – Retention basin + bioswales

Construction Cost :

$141,000

Time of Construction:

15 months

Design Effectiveness:

- Successful reduced runoff
- Reduced pollutants
- Improved energy efficiency

Maintenance:

Quarterly-annual inspection

ALTERNATIVE DESIGN 3:

Rip Rap + Retention Basin

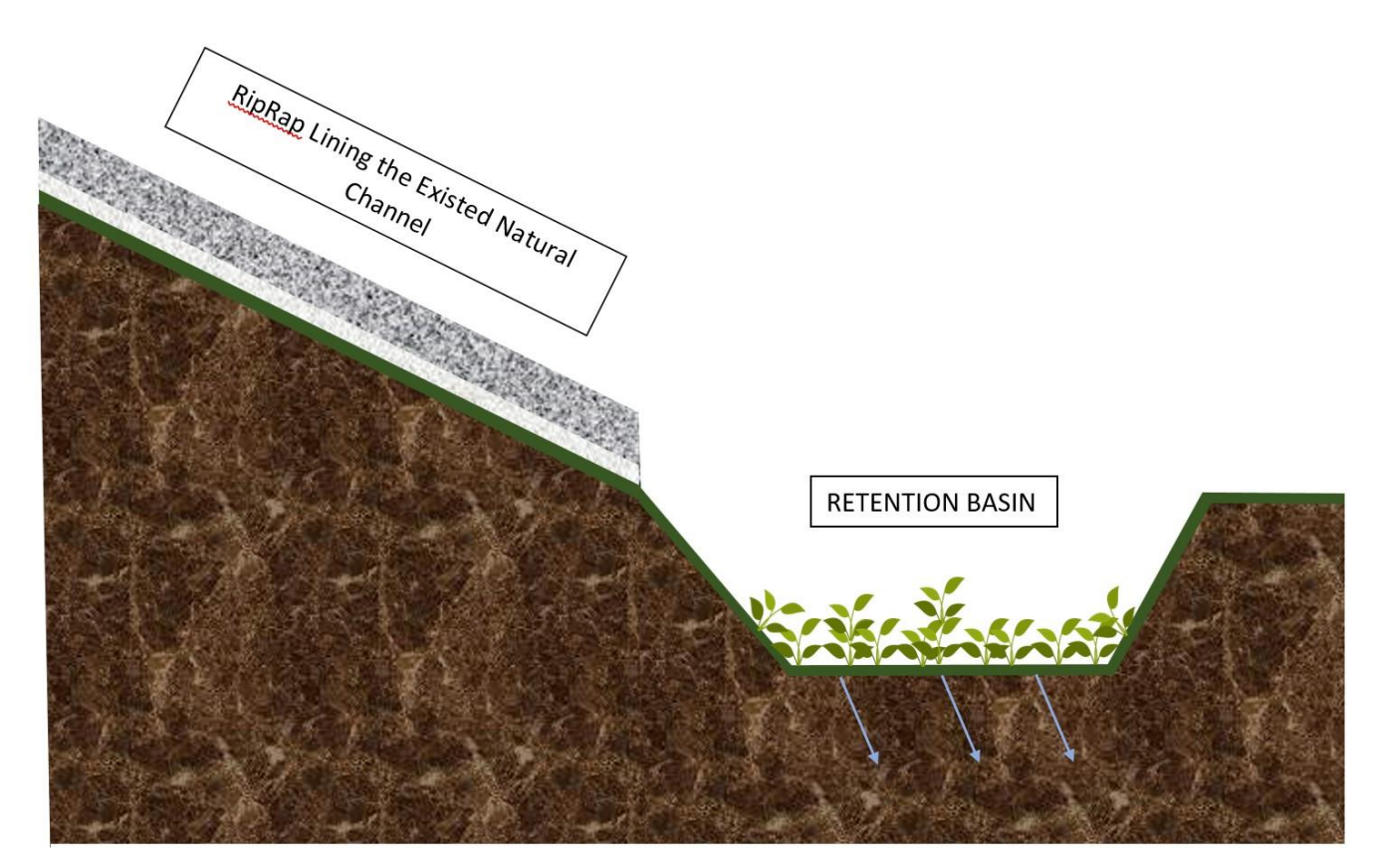


Figure 20 – Riprap + retention basin

Construction Cost :

$130,000

Time of Construction:

13 months

Design Effectiveness:

- Protecting slopes from erosion
- Increasing roughness and decreasing velocity
- Easy to install and maintain

Maintenance:

- Annual, after every major storm
- High maintenance cost

ANALYSIS OF ALTERNATIVES:

Design Selection

Table 7– Design decision matrix

Final Score design				
Design Criteria	Retention Basin	Bioswale	Retention Basin + Bioswale	Rip Rap + Retention Basin
Construction Cost (35%)	2	3	1	1
Design Effectiveness (28%)	2.7	1.3	2.3	2
Time of Construction (22%)	2.7	3	2	2
Annual Maintenance (15%)	2	3	1.3	1.7
TOTAL WEIGHTED SCORES	**2.3**	**2.5**	**1.7**	**1.6**

FINAL DESIGN:

Parameters

Table 8 – Summary of final design parameters

Final Design Parameters		
Parameter	**Value**	**Units**
Determined Q for Design Storm Q_{100}	309	cfs
Manning's coefficient, n	0.240	unitless
Bottom Width, B	2	ft
Length of Bioswale,L	341	ft
Longitudinal slope minimum, S_m	0.025	ft/ft
Depth, y		ft
Cross Sectional Area, A	3	ft^2
Wetter Perimeter of Trapezoid, P	9.416	ft
Velocity, v	103	ft/s
Hydraulic Retention Time, HRT	3.31	s

FINAL DESIGN:

Design Details

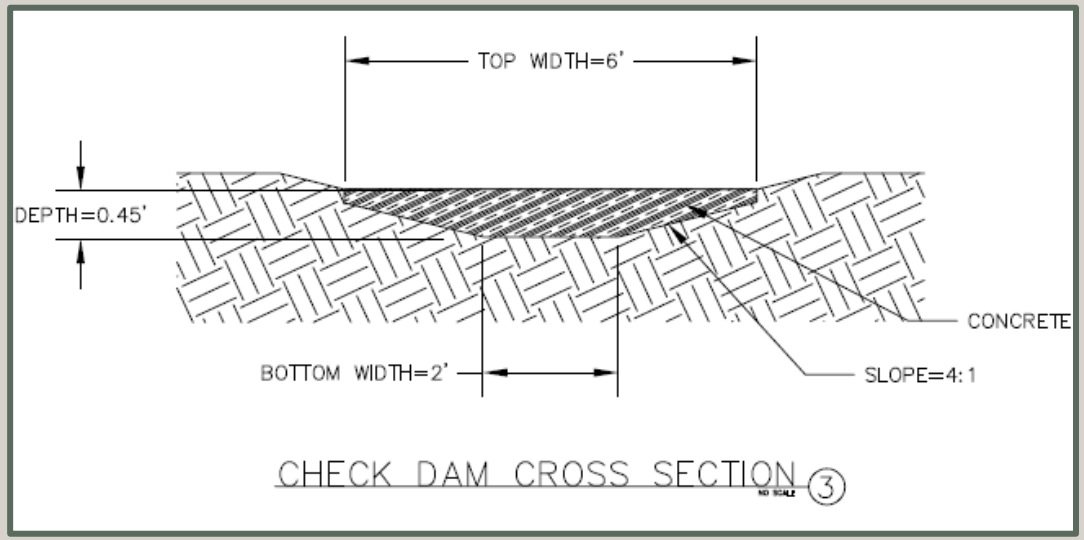


Figure 21 – Cross section of check dam

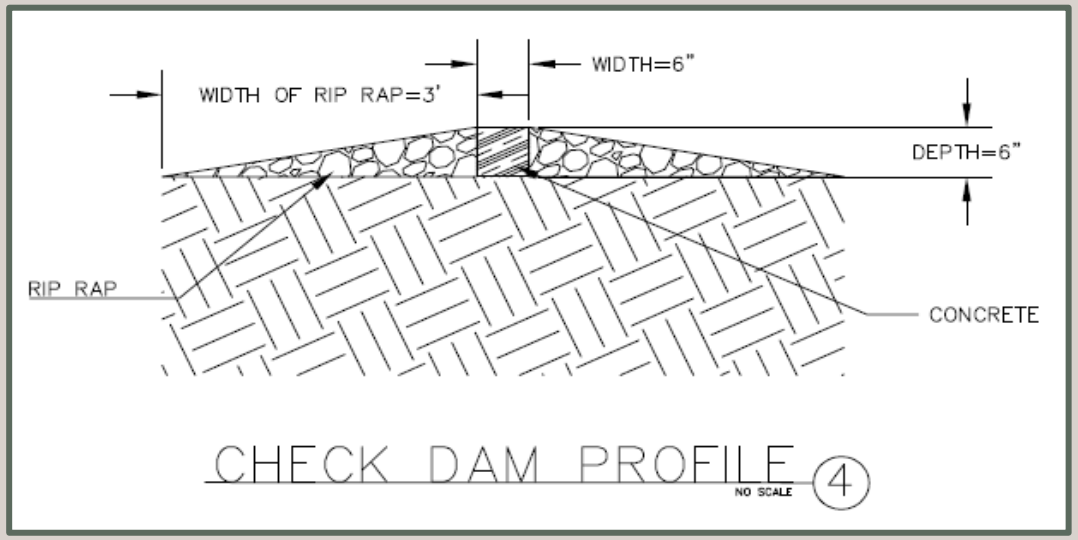


Figure 22 – check dam profile

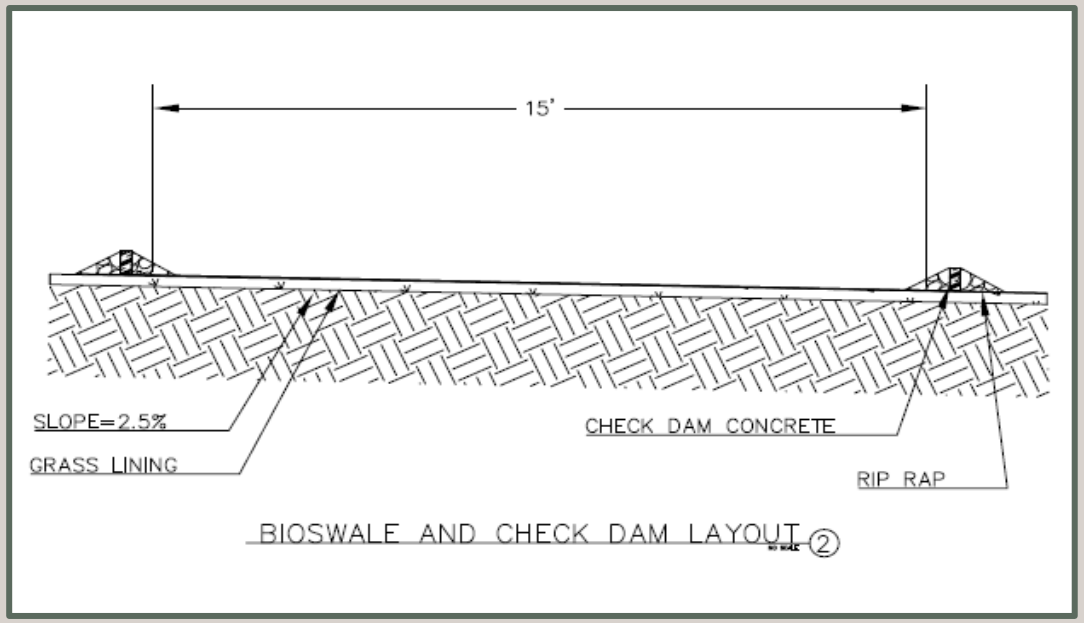


Figure 23 – Profile of check dam placement in bioswale

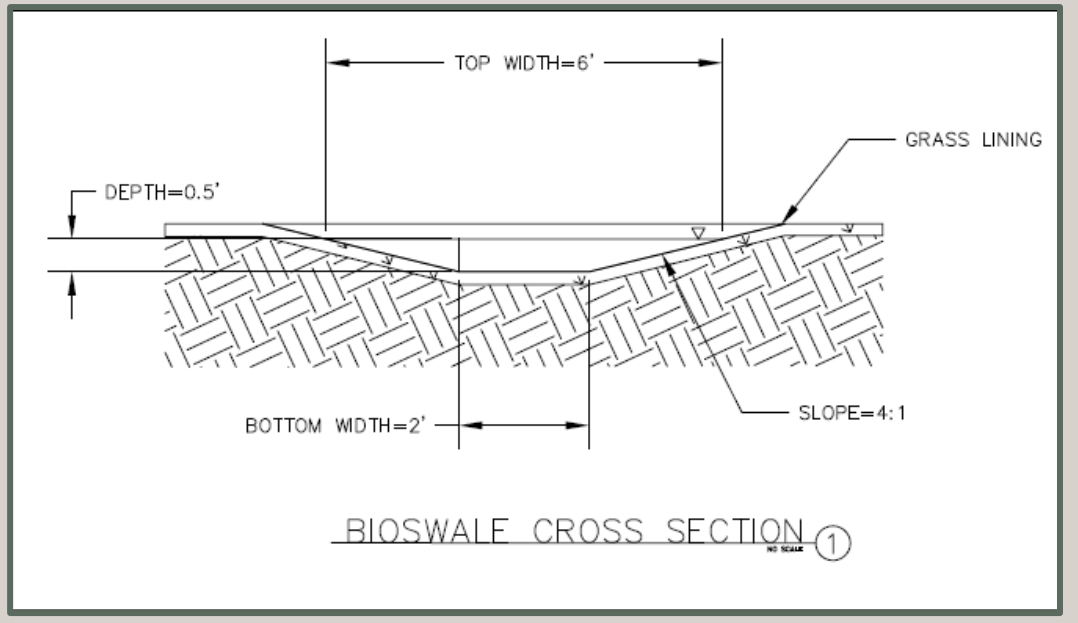


Figure 24 – Cross section bioswale

FINAL DESIGN:

Complete Design Plan View

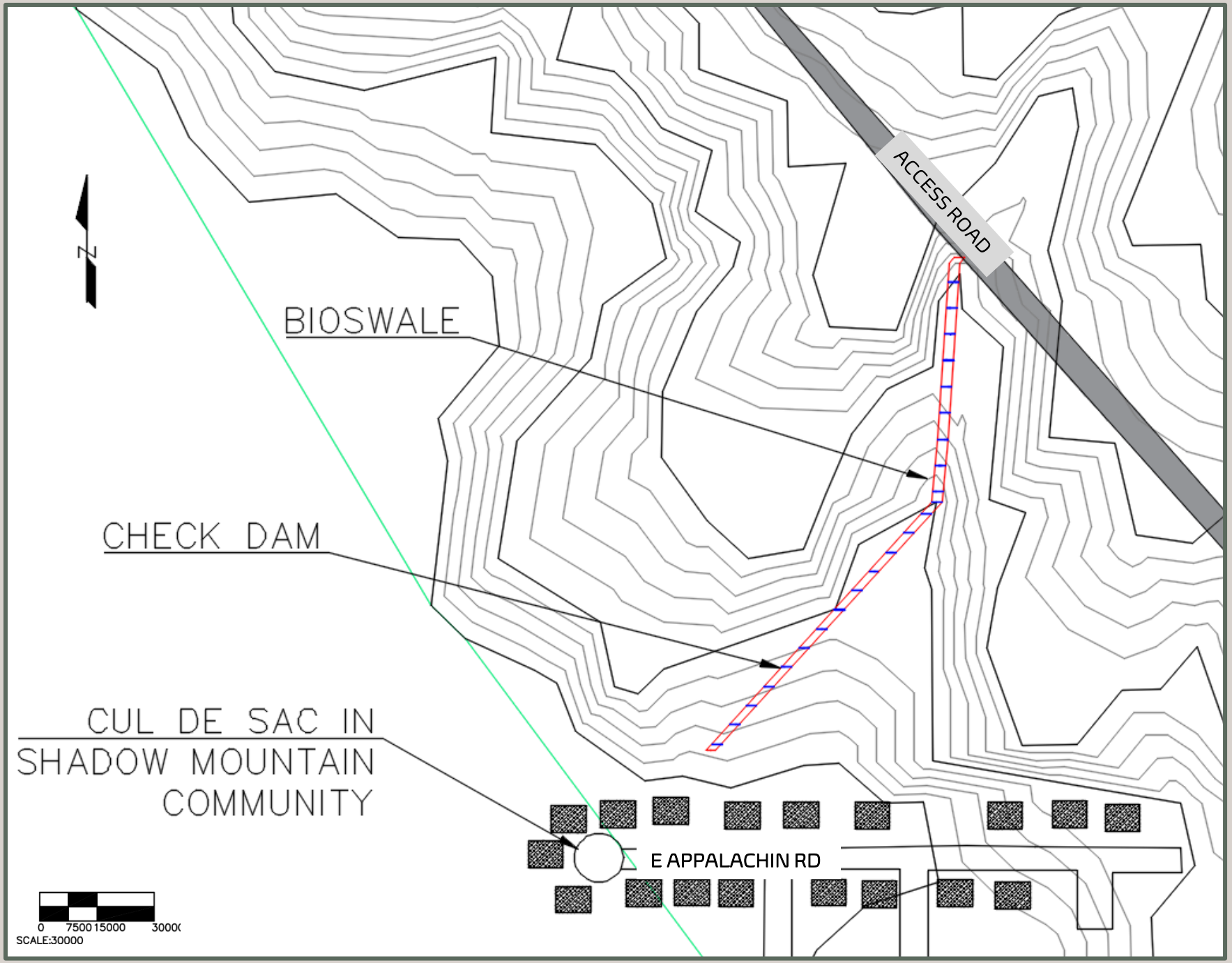


Figure 25 – Plan view of bioswale design

CONSTRUCTION COST

Table 9 – Excavate cost

Stage	Cost	Quantity	Total Cost
Excavate	$600/$yd^3$	7 yd3	$4,200

Table 10 – Installation cost

Type of Infrastructure	Installation costs	Quantity	Total installation costs
Bioswales	$20 per ft^2	345 ft2	$20,010
Check dams	$162 per dam	23 dams	$3,726

Table 11 – Total cost

Materials	Cost	Quantity	Total
Riprap stone	$55/ton	22 tons	$1,184
Woven geotextile	$6/$ft^2$	345 ft^2	$2,070
Bioswale mix	$37/$yd^3$	10 yd^3	$367
Mulch	$130/$yd^3$	10 yd^3	$1,290
Top soil	$32/$yd^3$	10 yd^3	$317
TOTAL			**$33,165**

Design Impacts

ECONOMIC

Figure 26 – Economic Cost

Cost of Implementation

Figure 27 – Construction Time

Time of Construction

SOCIAL

Figure 28 – Noise Pollution

Noise Pollution

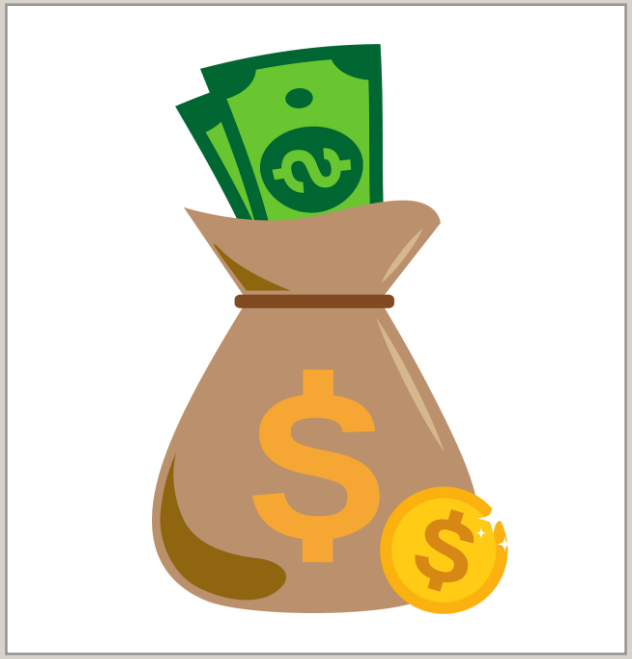


Figure 29 – Taxpayer Cost

Taxpayer Cost

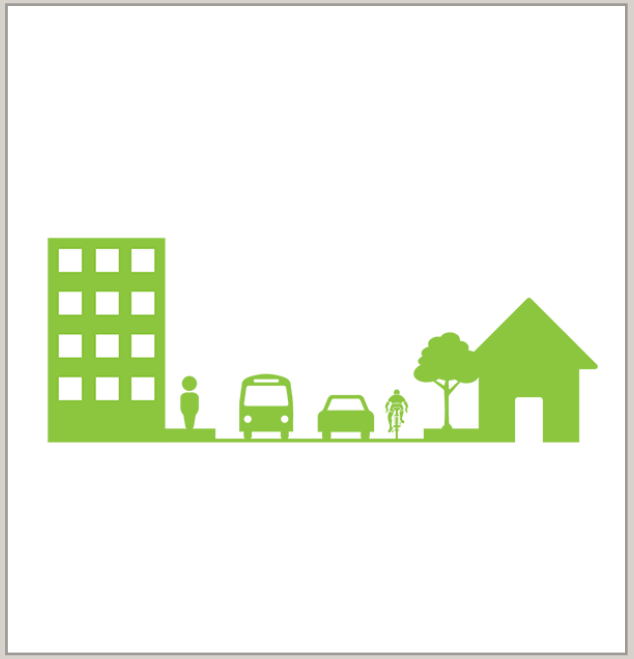


Figure 30 – Land Use

Land Use

ENVIRONMENTAL

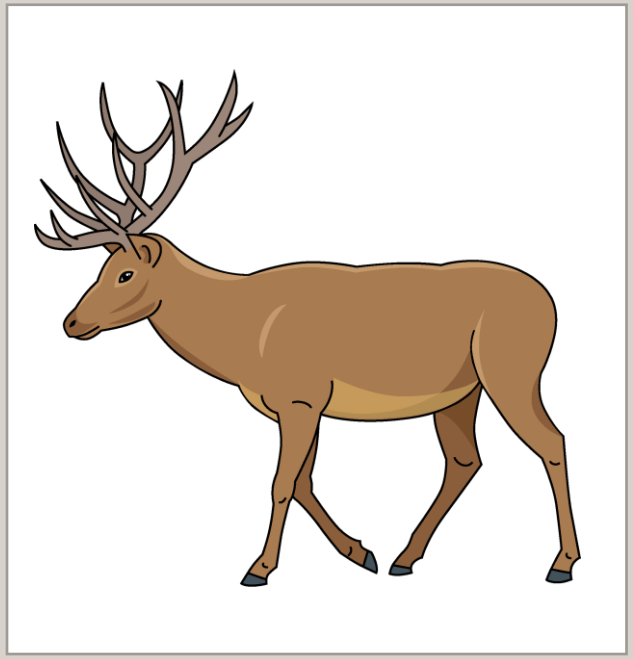


Figure 31 - Wildlife

Disruption of Local Wildlife

Figure 32 - Erosion

Erosion Potential

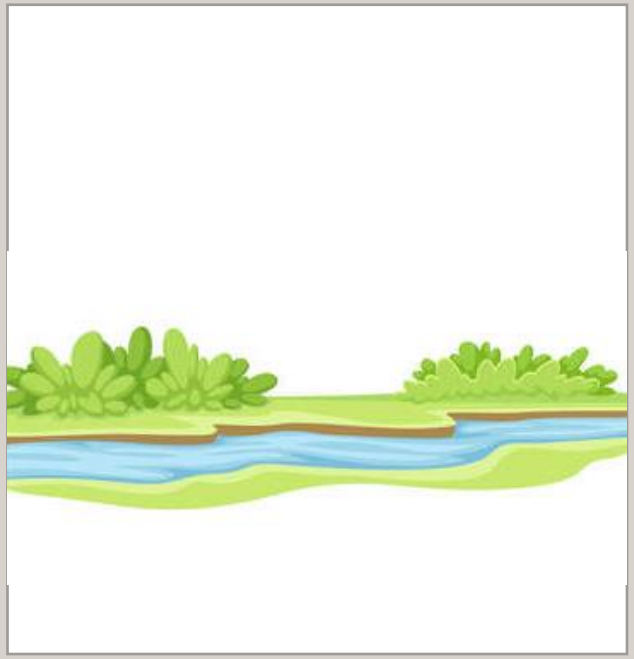


Figure 33 _ Channel

Natural Channel Usage

Questions

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