34th Annual WERC Competition
Task 1: Stormwater Management for Community Resilience
CENE 486C
May 3rd, 2024

Aguatierra

ENGINEERING

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Project Introduction

Site

- Joseph City, Arizona
- Joseph City Wash

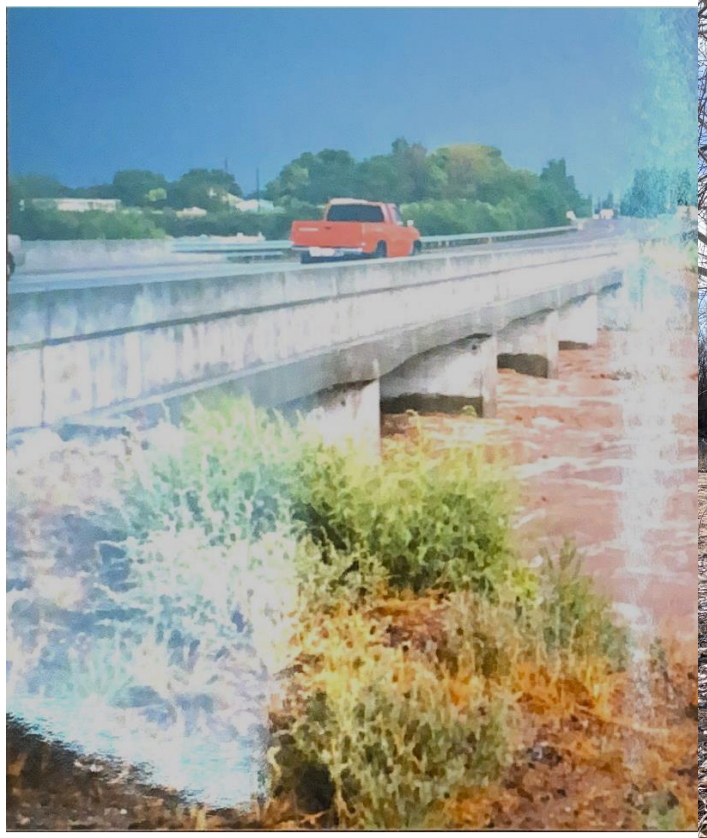
Figure 1: Project Location

Issues and Task

- Overbank flooding
- Low-cost & innovative solution

Figure 2: Flood Visual

Flooding Photos – Joseph City, AZ



Figures 3-5: Historic and Current Flooding Evidence

Site Visit

Figure 6: Site Visit – in wash

Figure 7: BNSF Underpass

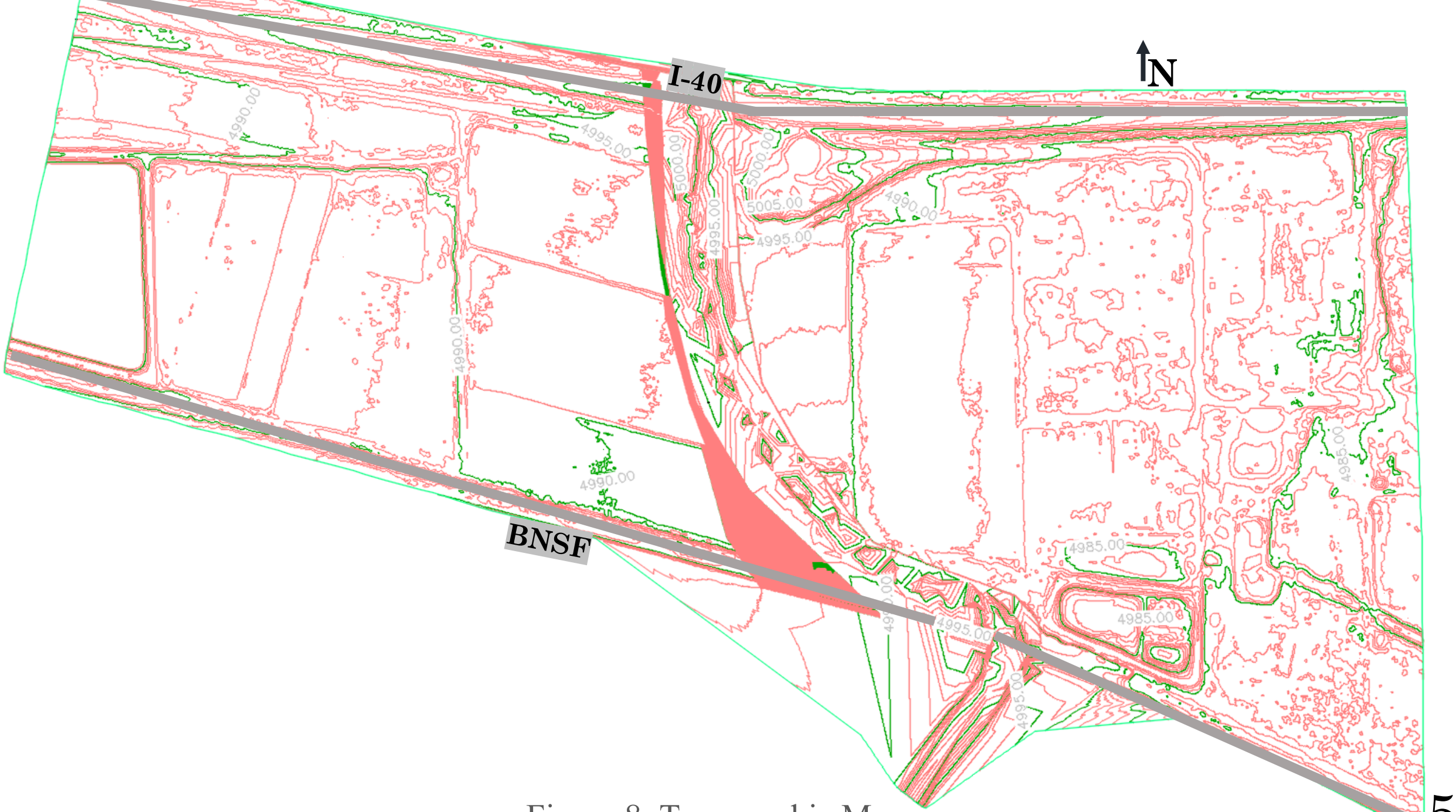


Figure 8: Topographic Map

Hydrologic Analysis

Table 1: Calculated Watershed Areas

Mesa Wash (mi^2)	Joseph City Wash (mi^2)	Confluence (mi^2)	Highway I-40 (mi^2)	Santa Fe Railroad (mi^2)
6.54	23.50	30.04	30.82	32.40

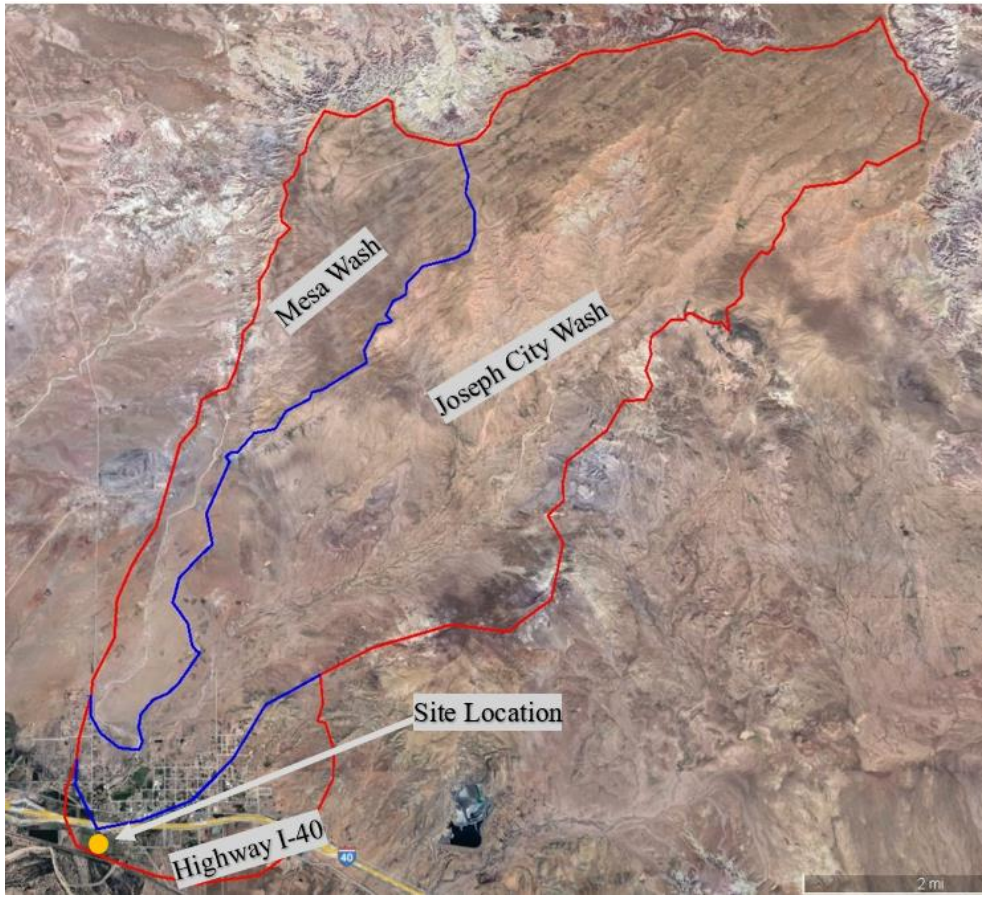


Figure 9: Watershed Delineation

Flooding Source and Location	Drainage Area (Square Miles)
MESA WASH	
At Confluence With Joseph City Wash	6.37
JOSEPH CITY WASH	
At Santa Fe Railroad	32.50
Just Downstream of Highway 40	
At Interstate Highway 40	30.64
Immediately Below Confluence With Mesa Wash	29.71
At Confluence With Mesa Wash	23.34

Figure 10: FEMA Firm Panel Watershed Areas
Figure Credit: FEMA

Hydrologic Analysis

Table 2: HMS Inputs

HEC-HMS Model Inputs	
Curve Number	66
Impervious Loss (% area)	2.083
Point Depth (in.)	2.83
Lag Time (min.)	313
Watershed Area (mi^2)	32.5

Table 3: HMS Assumptions

HEC-HMS Model Assumptions	
Depth Area Reduction	TP40 of whole watershed
Breakouts	Ignored due to lack of data
Hydrograph	Single basin approach
SCS Method	Type II 24-hour rainfall distribution using NOAA Atlas 14

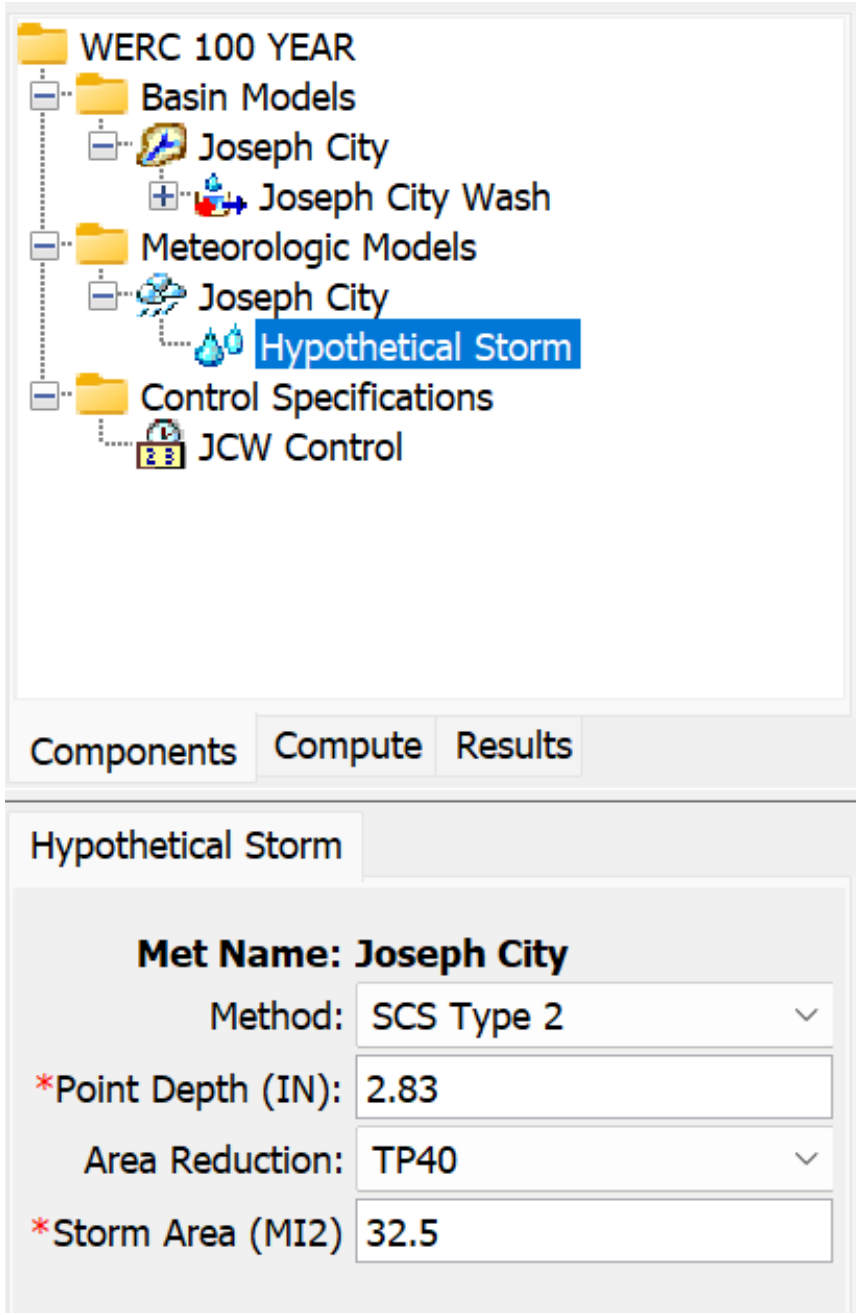


Figure 10: HEC-HMS Input

Hydrologic Analysis

Table 4: HMS Outputs

Outputs	
Peak Volume (in.)	0.68
Peak Discharge (cfs)	1,430

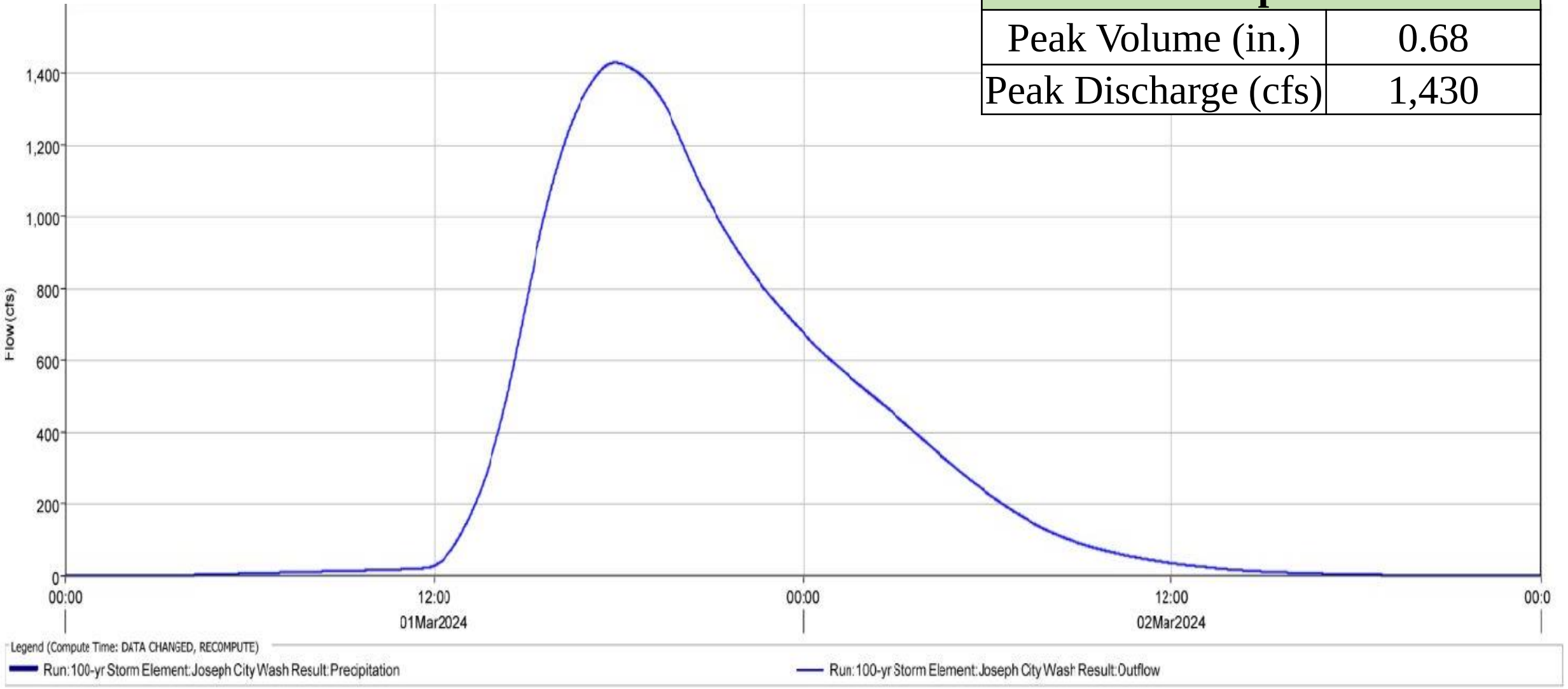


Figure 12: 100-yr Storm Hydrograph

Existing Hydraulic Analysis

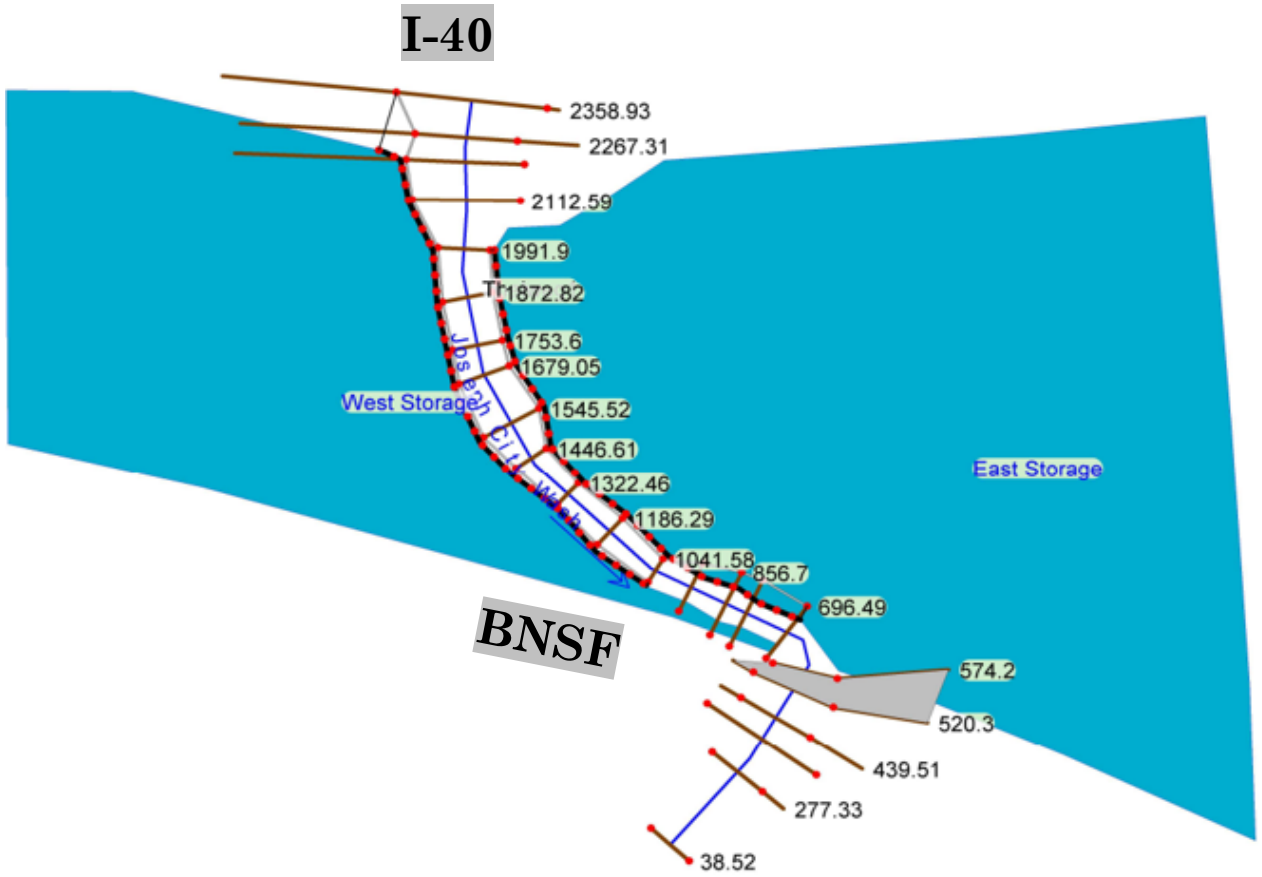


Figure 13: Joseph City River Reach

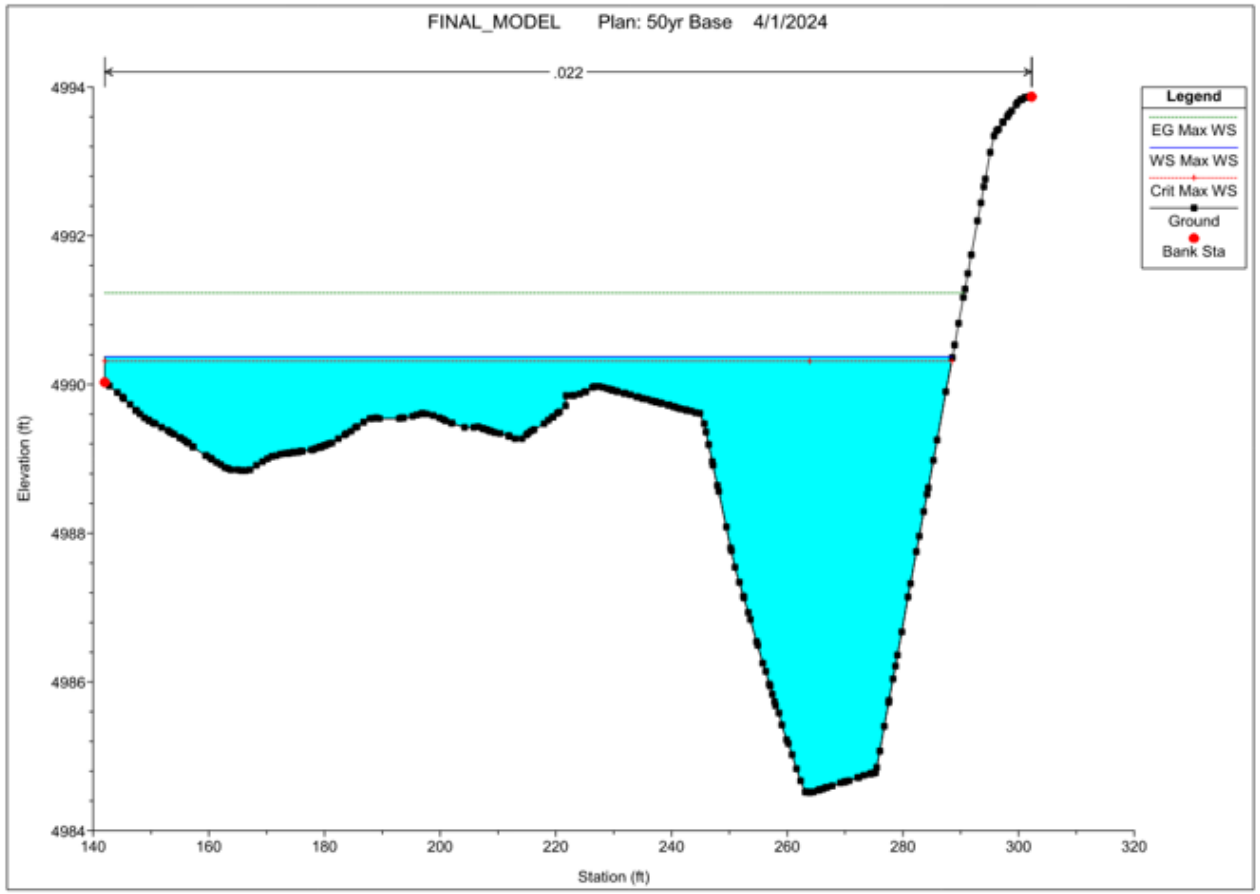


Figure 14: Average Cross-Section

Design Alternative Criteria

Stormwater Management Effectiveness

- How well an alternative manages storm flows

Cost

- Consideration of an alternatives cost effectiveness

Innovativeness

- Consideration of how new and different an alternative is

Operation and Maintenance

- Labor and cost needed to maintain and operate the alternative

Community Co-Benefit

- Evaluation of an alternative's impact on local community

Design Alternatives

Gabion Watershed Modifications

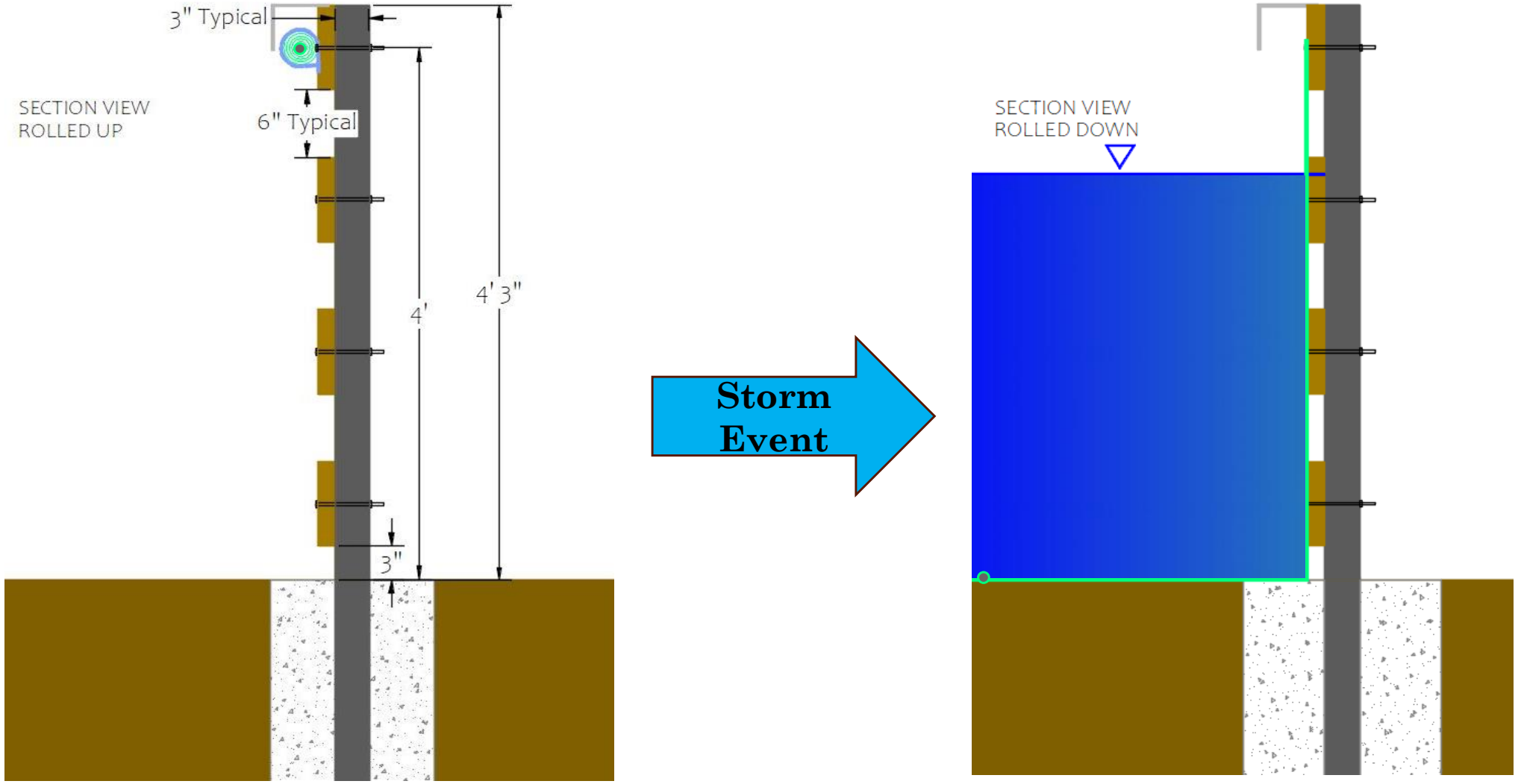
Cross-Vane Weir Channel Flow Control

Storm Barrier

Table 5: Design Alternative Decision Matrix

Alternative	Stormwater Management Effectiveness	Cost	Innovativeness	Operation and Maintenance	Community Co-Benefits	TOTAL
Watershed Modification	+	- -	+	+	0	**+1**
Storm barrier	+	+	+	-	+ +	**+4**
Cross Vane Weir	-	+	0	-	0	**-1**

LinerLogic Design



+ Cost effective
+ Highly innovative
+ Readily deployable
+ Considers climate scenarios
+ Efficiently manages large volume
+ Highly Applicable

LinerLogic Design

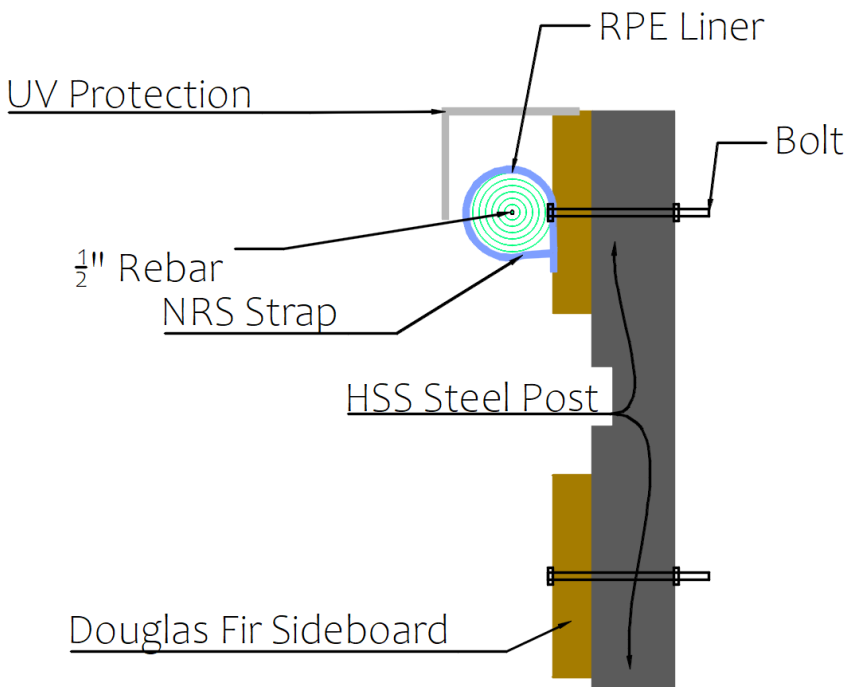


Figure 15: Liner Components

Table 6: LinerLogic Materials

Material	Function
40 mil Reinforced Polyethylene (RPE) Liner	Watertight barrier
NRS Ratchet Straps	Fasten stored liner
Roof Flashing	Liner UV protection
HSS Steel Posts	Fence support
Douglas Fir Side Boards	Liner support
1/2” Rebar	Weighting liner to ground
Steel Stakes	Liner anchor to ground
Concrete	Fence post anchor

LinerLogic Design

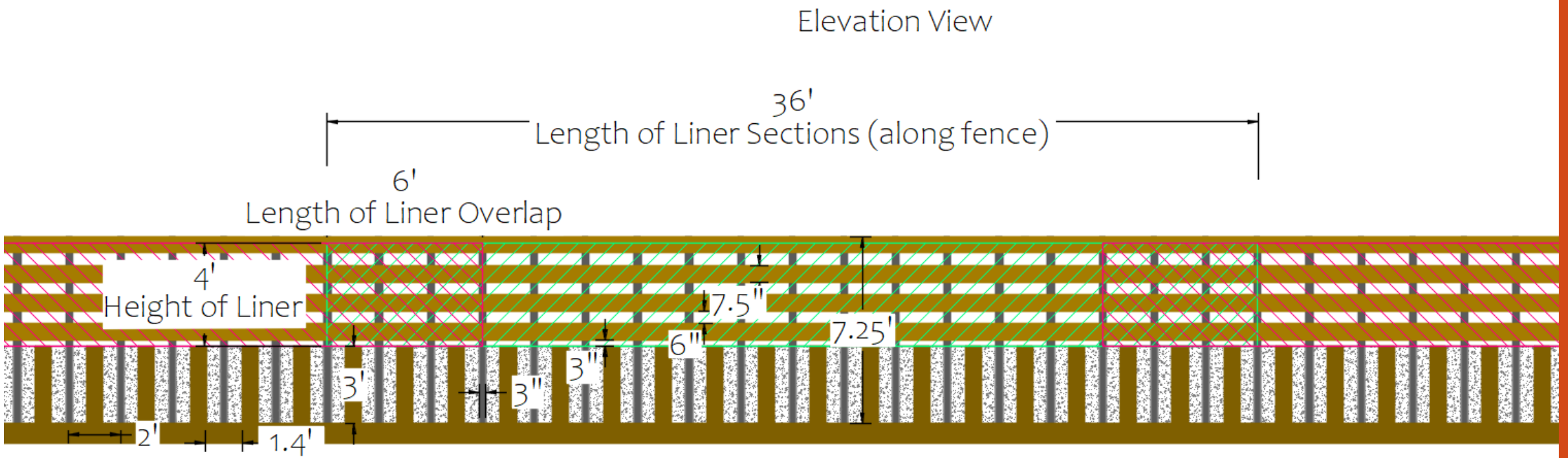
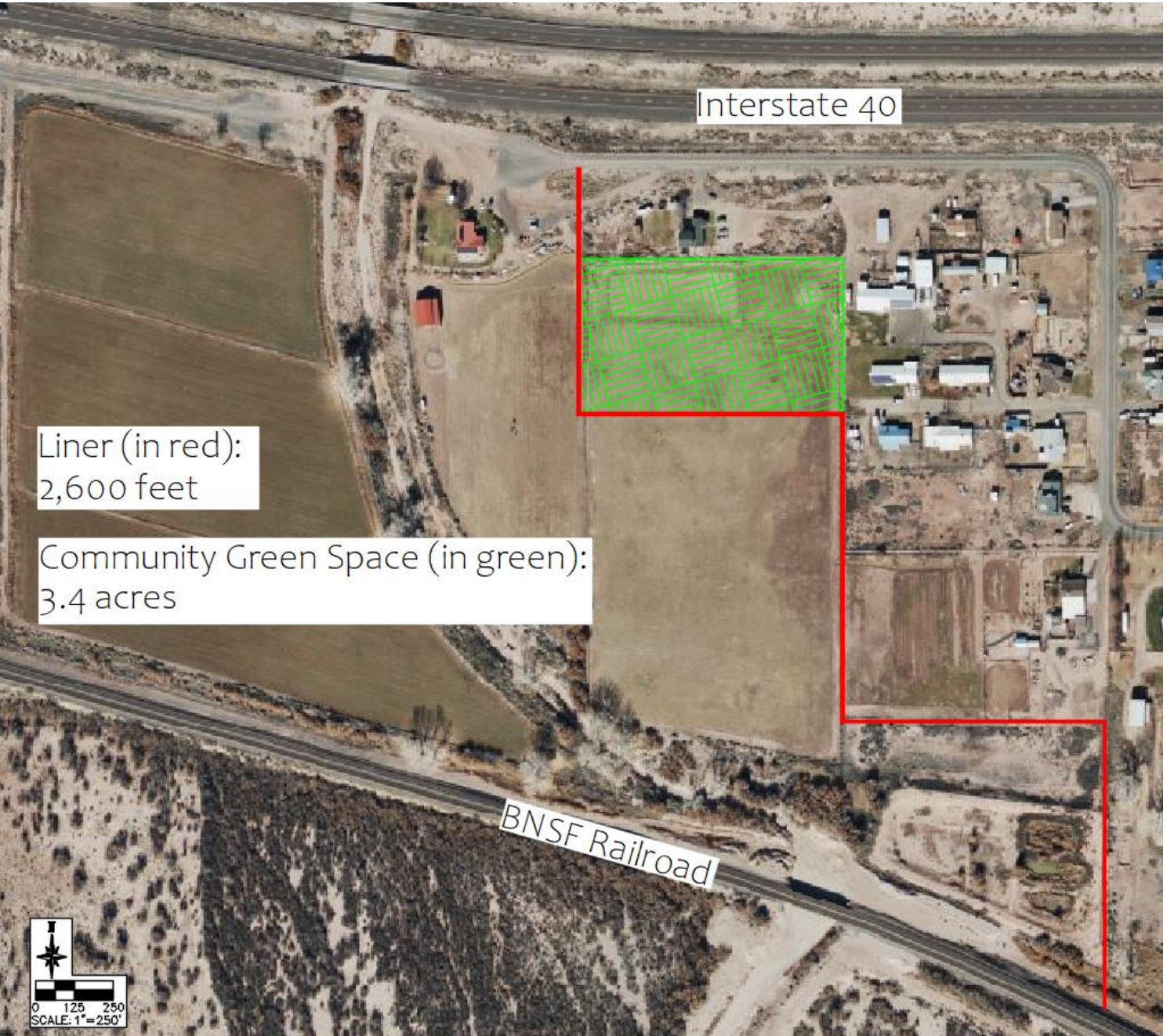


Figure 16: Elevation View

Table 7: Liner Demonstrations

Deployment Facts	
RPE Liner Section Length	36 Feet Per Section
RPE Liner Overlap	6 Feet Per Section
RPE Liner Rebar Weight	Along Entire Section
RPE Ground Anchoring	6 Foot Increments
Sectional Deployment Time	3 min (2-3 people)

Joseph City Site Plan



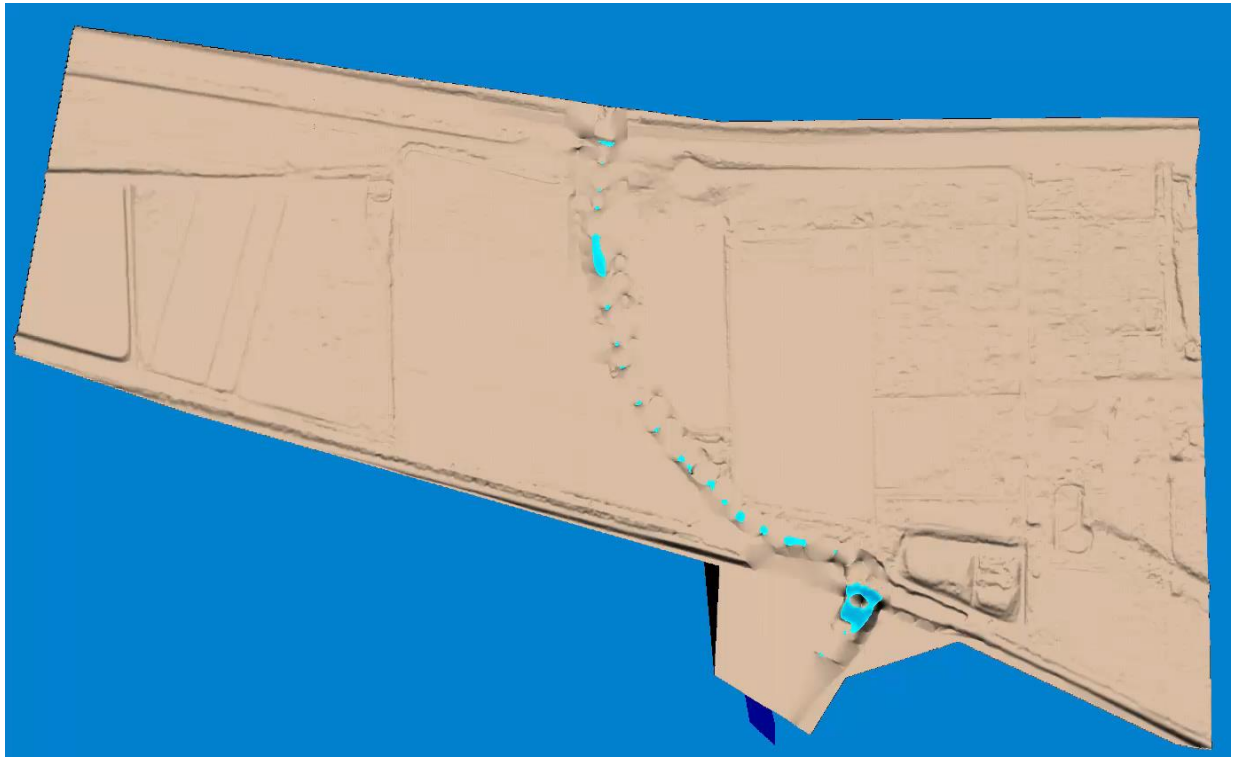
Community Garden :

- Increased community connection
- Outdoor engagement
- Educational opportunities
- Community food
- Joseph City residents decide

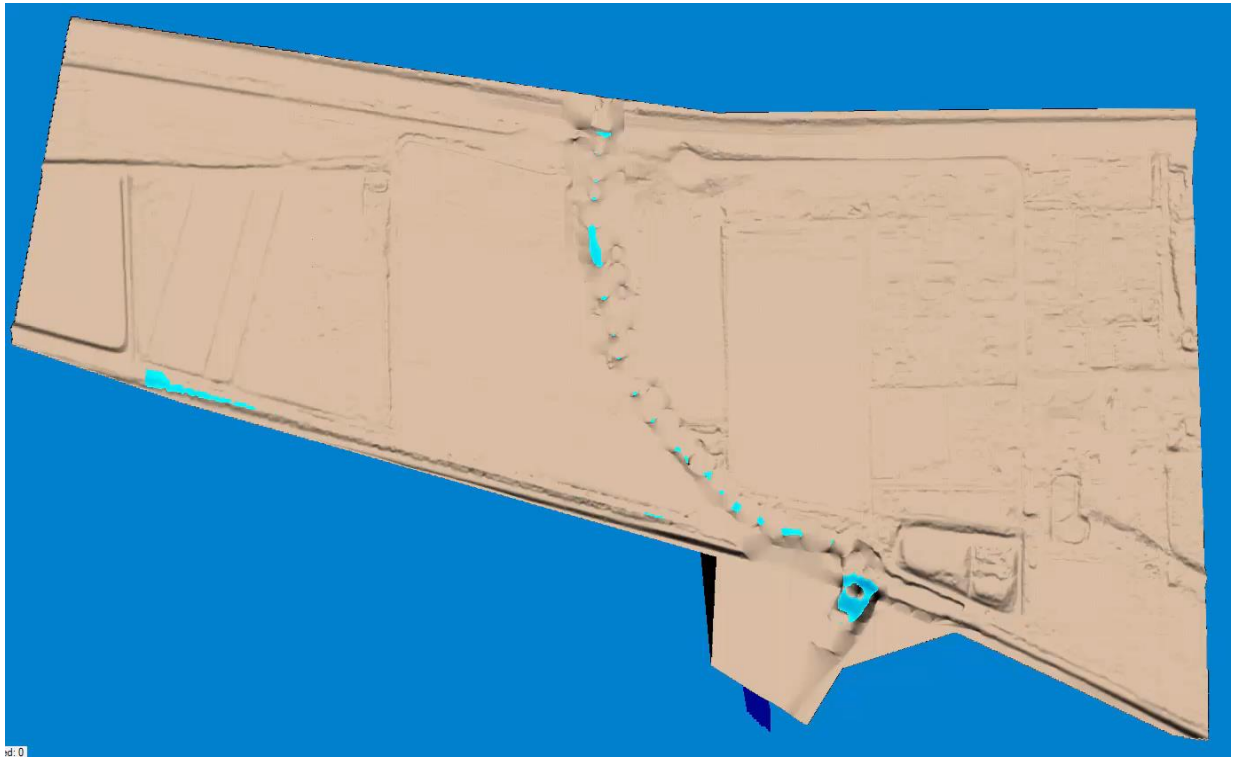
LinerLogic:

- Deployment time 4.5 hours
- Flood warning system
- Prevents sediment spread

Digital Modeling – HEC-RAS

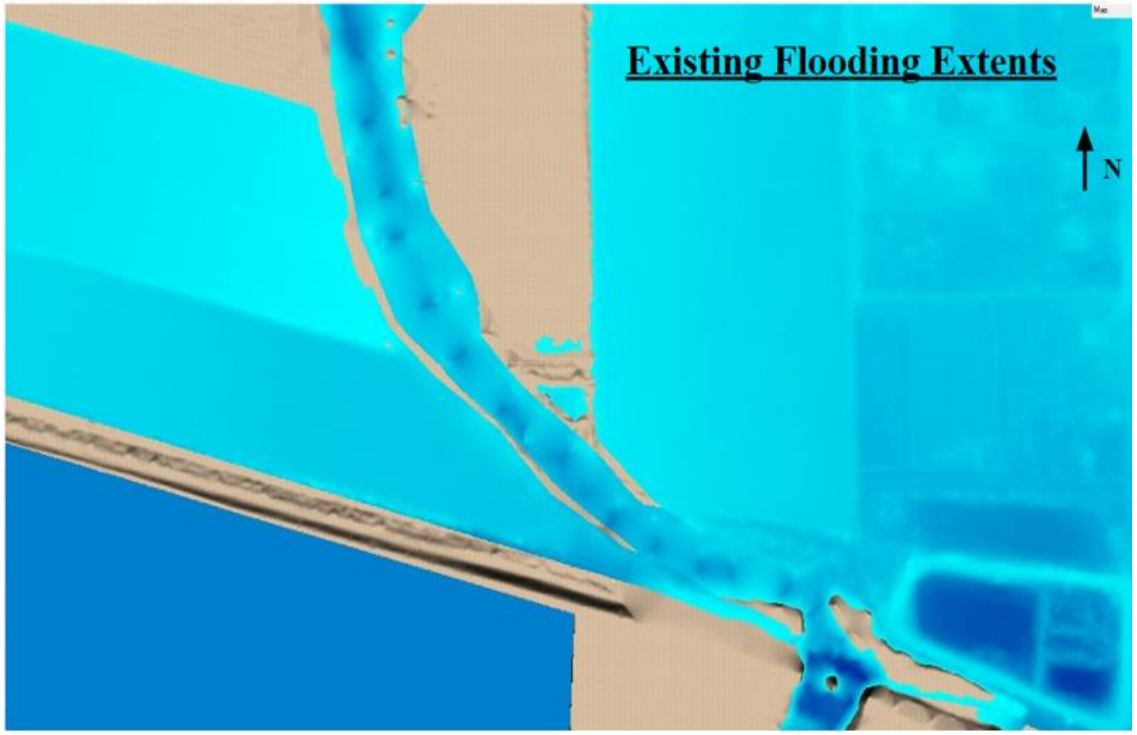


Flooding Video Without Design



Flooding Video With Design

Digital Modeling – HEC-RAS



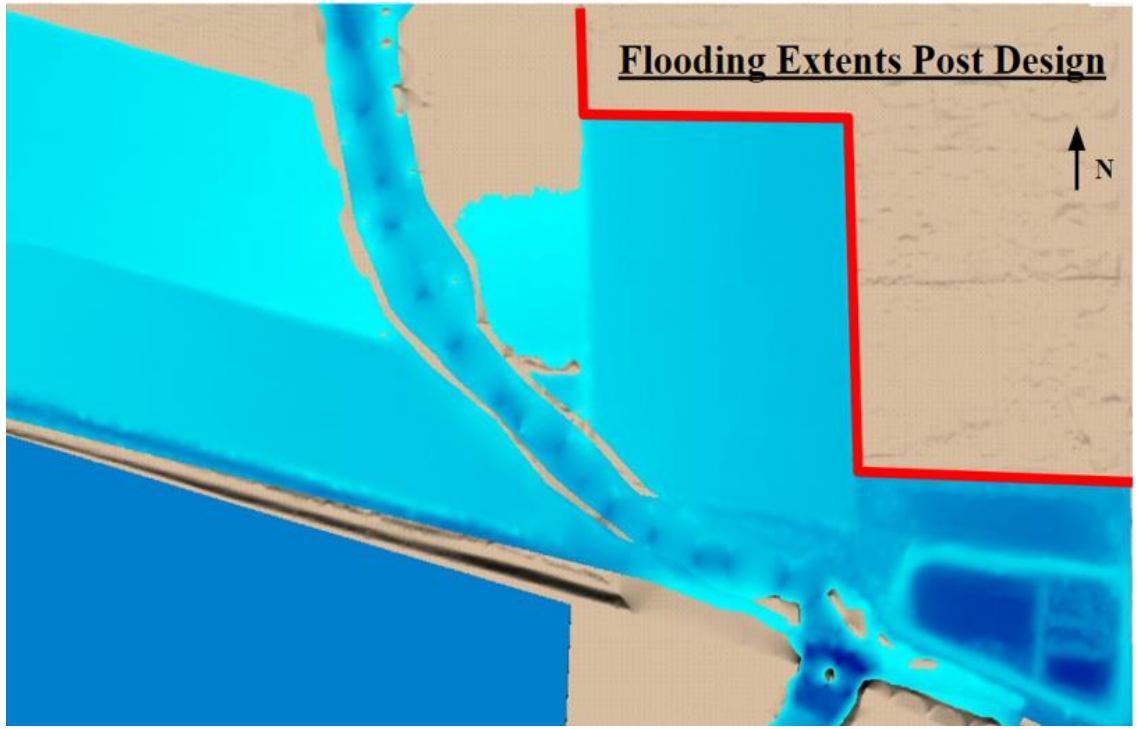
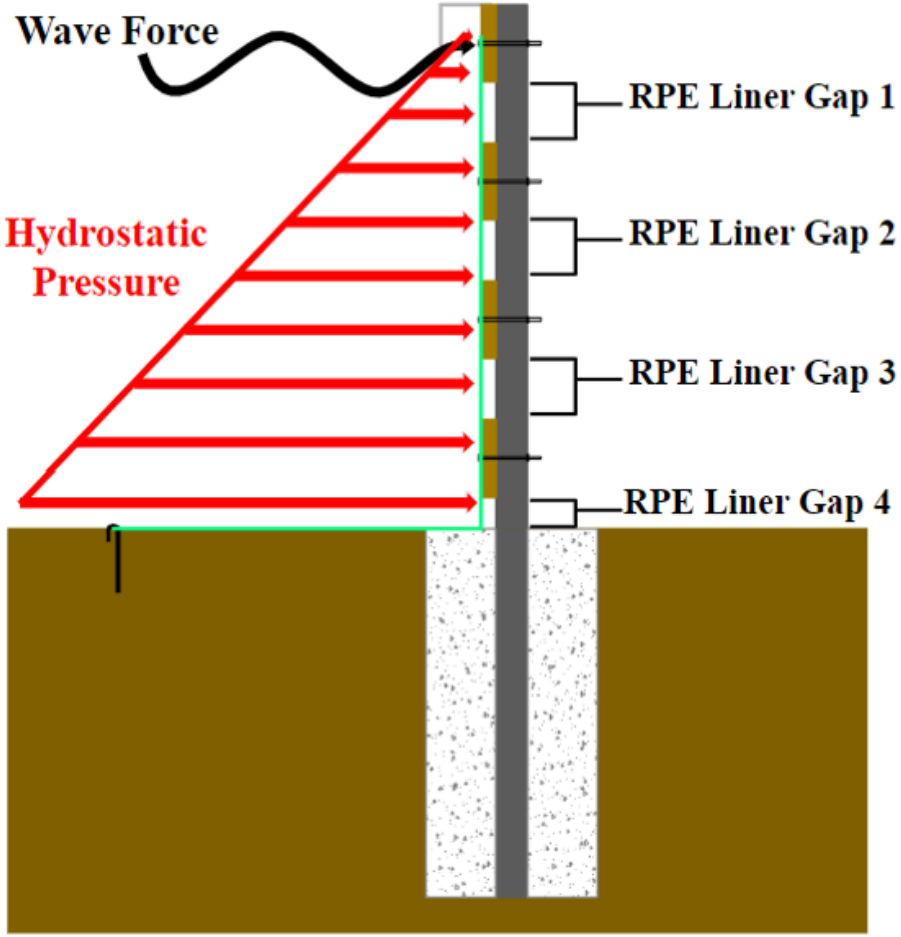


Figure 17: HEC-RAS Flooding Extents Before (Left) & After (Right)

Storm Event	Existing Flood Depth (ft)	Implemented Final design Flood Depth (ft)
10-year	No Flooding	No Flooding
25-year	No Flooding	2.36
50-year	2.42	3.61
100-year	4.26	6.03

Table 8: HEC-RAS Outputs

Structural Analysis



Hydrostatic Pressure

$$P = \rho g h$$

Where:

P is pressure, lbs/ft^2

ρ is density of water, 1.940 slugs/ft^3

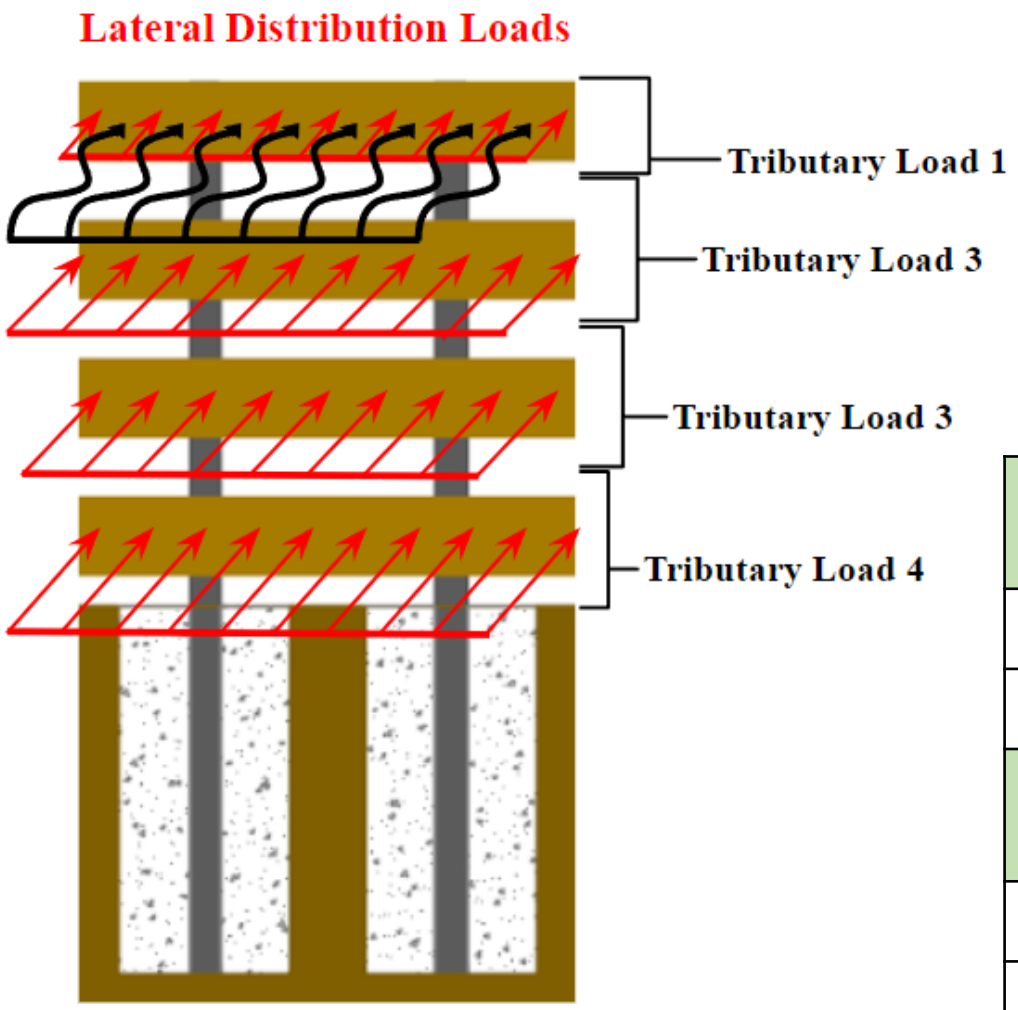
g is gravity, 32.174 lbs/ft^2

h is depth, ft

Table 9: Structural Analysis

Section	Liner Stress Pressure (psi)	Liner Bursting Capacity (psi)
Gap 1 (Top)	0.3	685
Gap 4 (Bottom)	1.7	

Structural Analysis



Equation 6 Bending Stress Load (on a board)

$$\sigma_b = \frac{M_{max}}{\frac{bd^2}{6}}$$

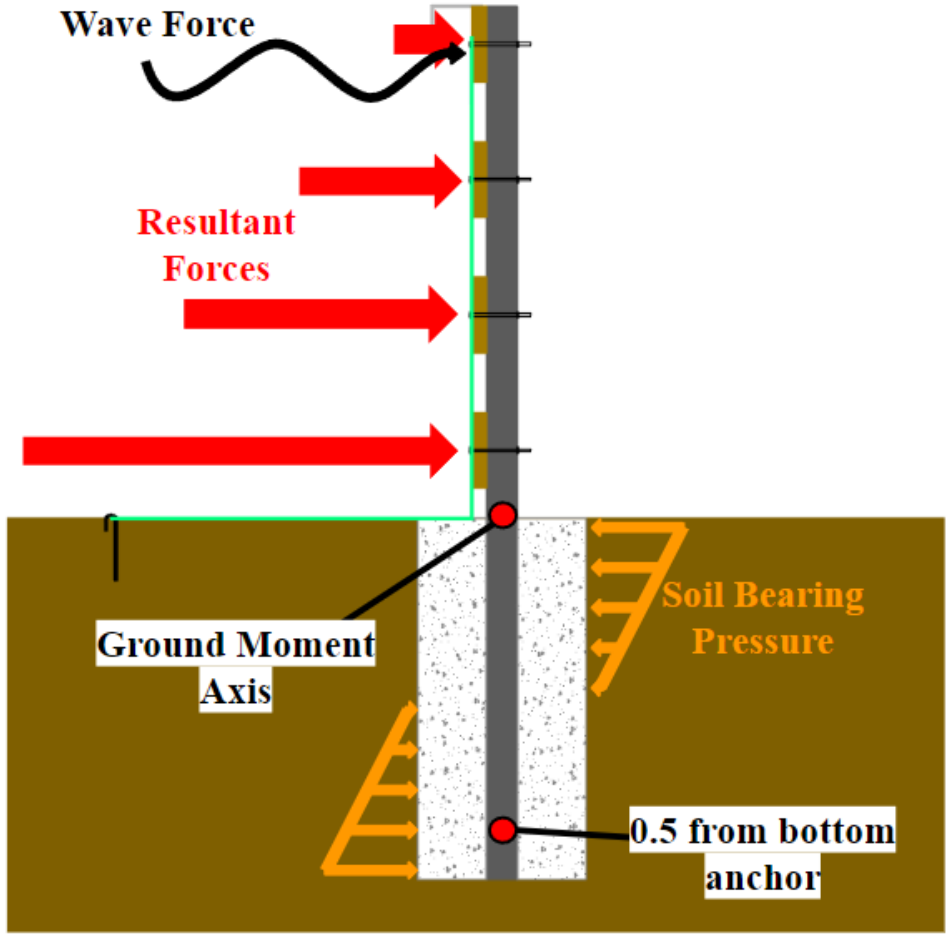
Where:

σ_b is bending stress load, psi
M_{max} is max moment distributed load, lbs*ft
b is nominal breadth of board, 7.5 in
d is nominal depth of board. 1.5 in

Table 10: Structural Analysis

Section	Bending Stress Load (psi)	Douglas Fir Bending Capacity (psi)
Tributary 1 (Top)	316	900
Tributary 4 (Bottom)	241	
Section	Shear Stress (psi)	Douglas Fir Shear Capacity (psi)
Tributary 1 (Top)	19.7	170
Tributary 4 (Bottom)	32.2	

Structural Analysis



Equation 8 Bending Stress Load (on steel beam)

$$\sigma_b = \frac{M_{max} * C}{I}$$

Where:

σ_b is bending stress load, ksi
M_{max} is max moment distributed load, lbs*in
c is distance to extreme fiber, in
I is moment of inertia, in

Table 11: Structural Analysis

Section	Bending Stress (ksi)	HSS Steel Bending Capacity (ksi)
Ground Connection	24.9	50
Section	Soil Bearing Stress (psf)	Soil Bearing Capacity (psf)
0.5 ft Bottom Anchor	1492	1500

Capital Costs

Table 12: Capital Expenses Economic Analysis

Item	Quantity	Units	Cost	Total Cost
40mil RPE Liner (7' x 36')	87	S.F.	$ 197	$ 17,139
87" Long Steel Posts (3 x 3 x 1/8 in.)	1300	EA	$ 92	$ 119,464
Douglas Fir Boards (2" x 8" x 8')	5200	EA	$ 10	$ 52,416
Concrete (0.12 cy/ fence post)	156	C.Y.	$ 160	$ 24,960
NRS (1" x 1' - 2 pack)	217	EA	$ 12	$ 2,604
Roof Flashing (4" x 5" x 10')	260	EA	$ 22	$ 5,590
1/2" x 20' #4 Rebar	157	EA	$ 12	$ 1,834
Carriage Bolt and Nut (1/4" x 7" - 100 count)	13	EA	$ 60	$ 778
Grommets (5/8" - 50 pack)	87	EA	$ 10	$ 870
Steel Rebar Stakes (8 pack)	55	EA	$ 22	$ 1,210
Rainfall Gauge	1	EA	$ 947	$ 947
Rainfall Transmitter	1	EA	$ 1,027	$ 1,027
Land Grading	9,100	S.F.	$ 1.4	$ 12,740
			MATERIALS SUBTOTAL	**$ 241,578**
Construction Services	1	L.S.	10% of Material Cost	$ 24,158
Engineering Design	1	L.S.	15% of Material Cost	$ 36,237
			PERSONNEL SUBTOTAL	**$ 60,395**
			PROJECT TOTAL	**$ 301,973**

Business Plan

Table 13: Summarized Costs

CAPEX	
Project Total	$ 301,000
OPEX	
Annual Total	$ 6,500

Flood Damages		
Water Depth (in.)	Damage Cost ($/2,500 ft^2 homes)	Total Cost (24 homes)
1	$ 26,807	$ 620,000
6	$ 52,037	$ 1,200,000
9	$ 62,100	$ 1,500,000
24	$ 87,326	$ 2,100,000
36	$ 94,538	$ 2,300,000
48 (Design Capacity)	$ 103,355	$ 2,500,000

Joseph City Implementation

Task Name	Responsible Party	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Community Outreach	Engineers													
Pre-Construction														
Permit & Licensure	Navajo County													
Secure Financing	Bank of Choice													
Contractor Bidding/Approval	Navajo County & Contractors													
Obtain Insurance	Insurance Company													
Construction														
Staking	Contractor													
Fencing	Contractor													
Re-Deployable Liner	Contractor													
Community Garden	Contractor													
Post-Construction														
Quality Check	Engineers and Contractors													
Open to Public	Local Public													

Figure 18: Implementation Schedule

Project Impacts

Environmental:

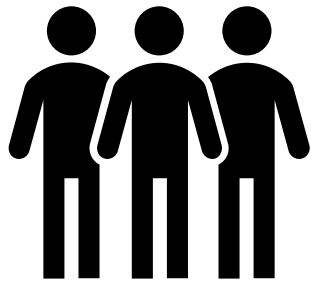
+ Reduced flood damage
+ Community green space

- Possible downstream effects
- Construction

Social:

+ Community engagement
+ Environmental education

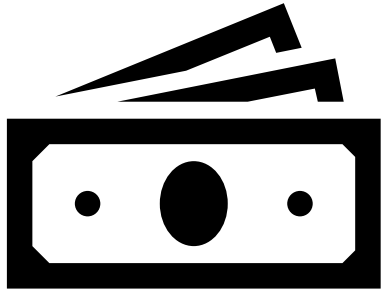
- Land acquisition
- Deployment



Economic:

+ Flood mitigation investment
+ Reduced flood damages expenses

- Construction



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Thank You!