# Fanning Wash Flood Prevention CENE 486C

Fanning Four Water Design (F4) : Maria Jauregui, Sneha Joshi, and Caleb Smith

Date: 4/25/2023

# Introduction

Client: City of Flagstaff, Sharon Lopez (Hydrologist)

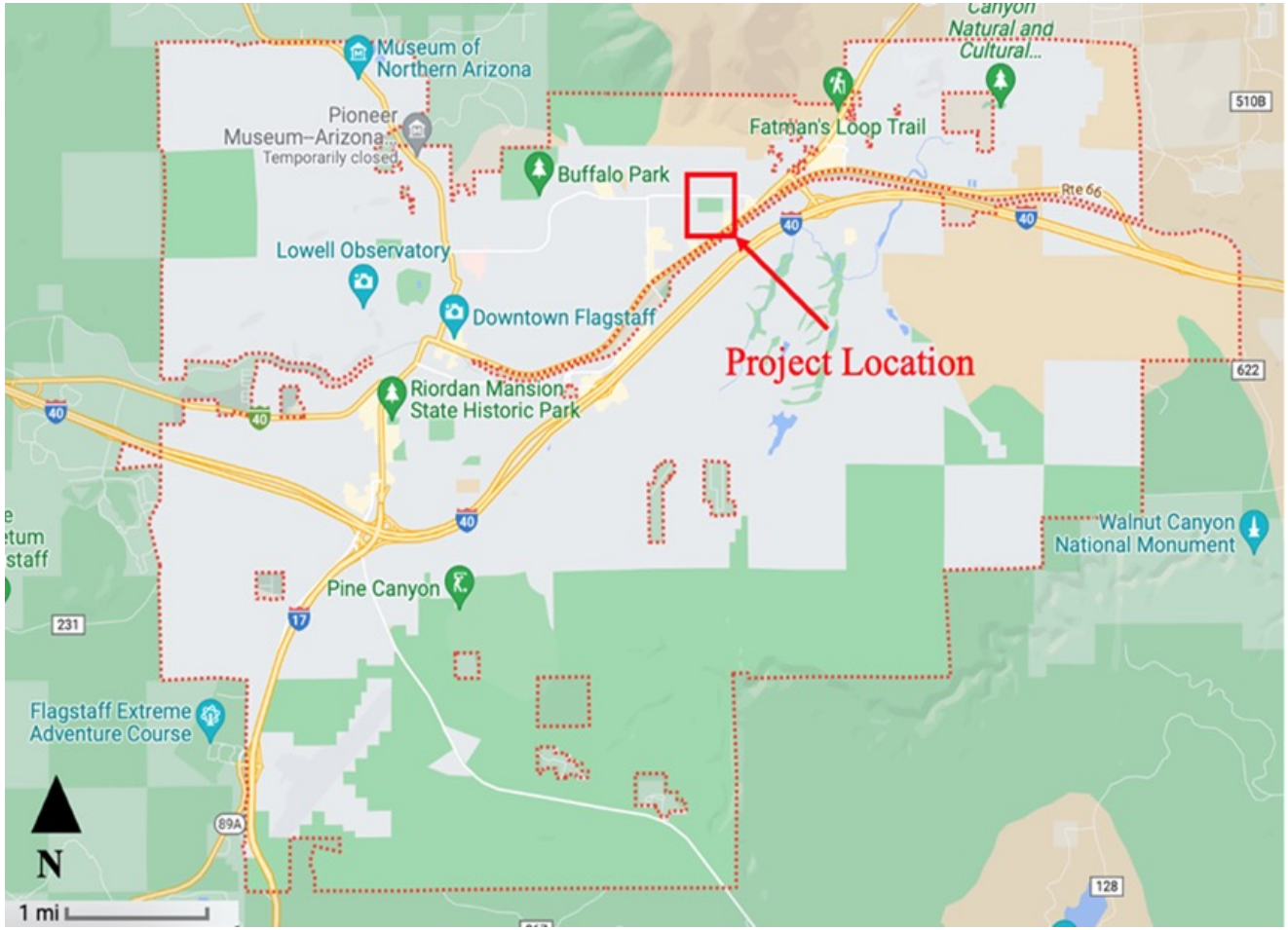



Fig 1: Project Location
Credit: Google Maps

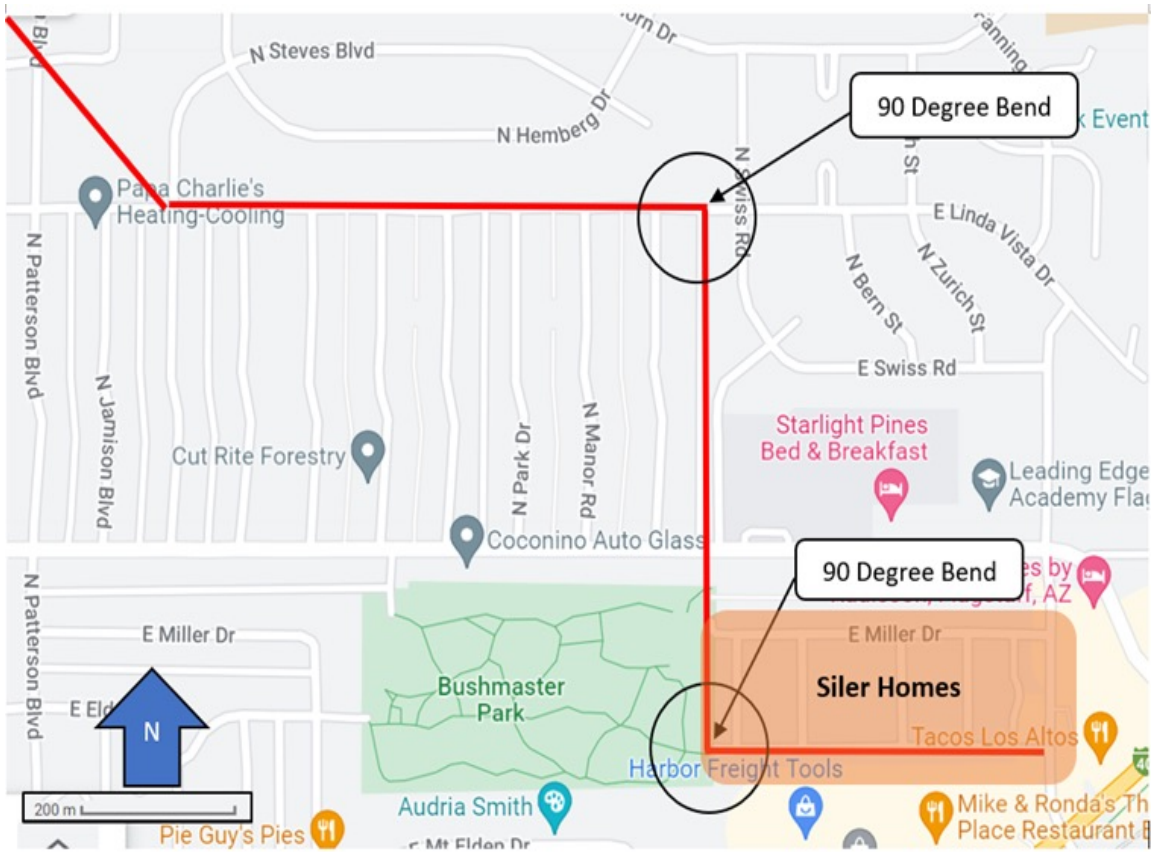



Fig 2: Fanning Wash Problem Points
Credit: Client, Sharon Lopez

# Research

## City of Flagstaff Stormwater Management Design Manual

For Hydrologic Analysis: Rational equation, Runoff coefficient, Time of concentration

For Open channel & Culvert

## Existing Topography

USGS maps and the ArcGIS program used to develop a 1-foot contour line map

## Existing Plans/Studies

## FEMA Floodplain Research

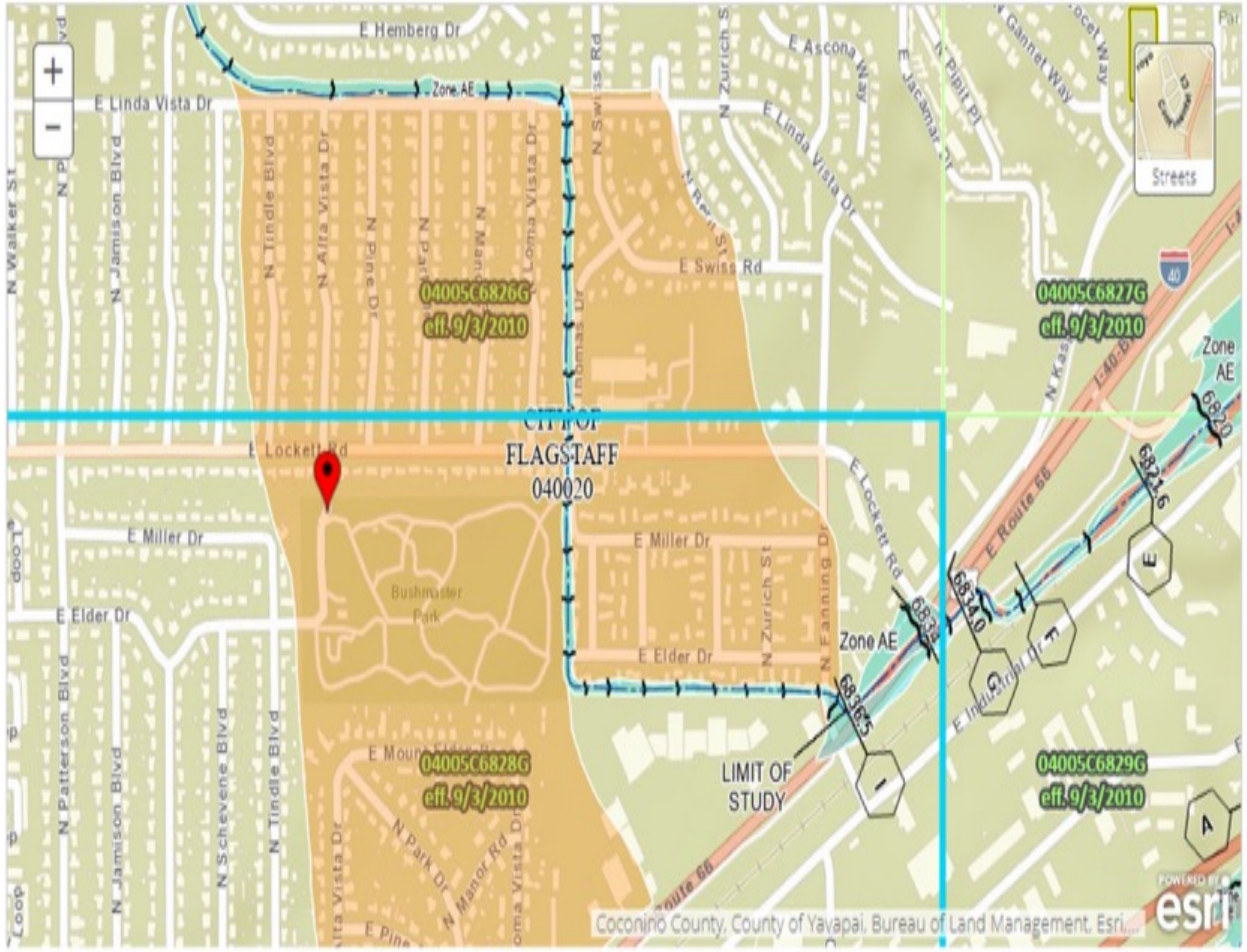



Fig 3: FEMA Floodplain, Credit: FEMA Website

# Site Investigation

- Area Surveyed was behind the Bushmaster Park

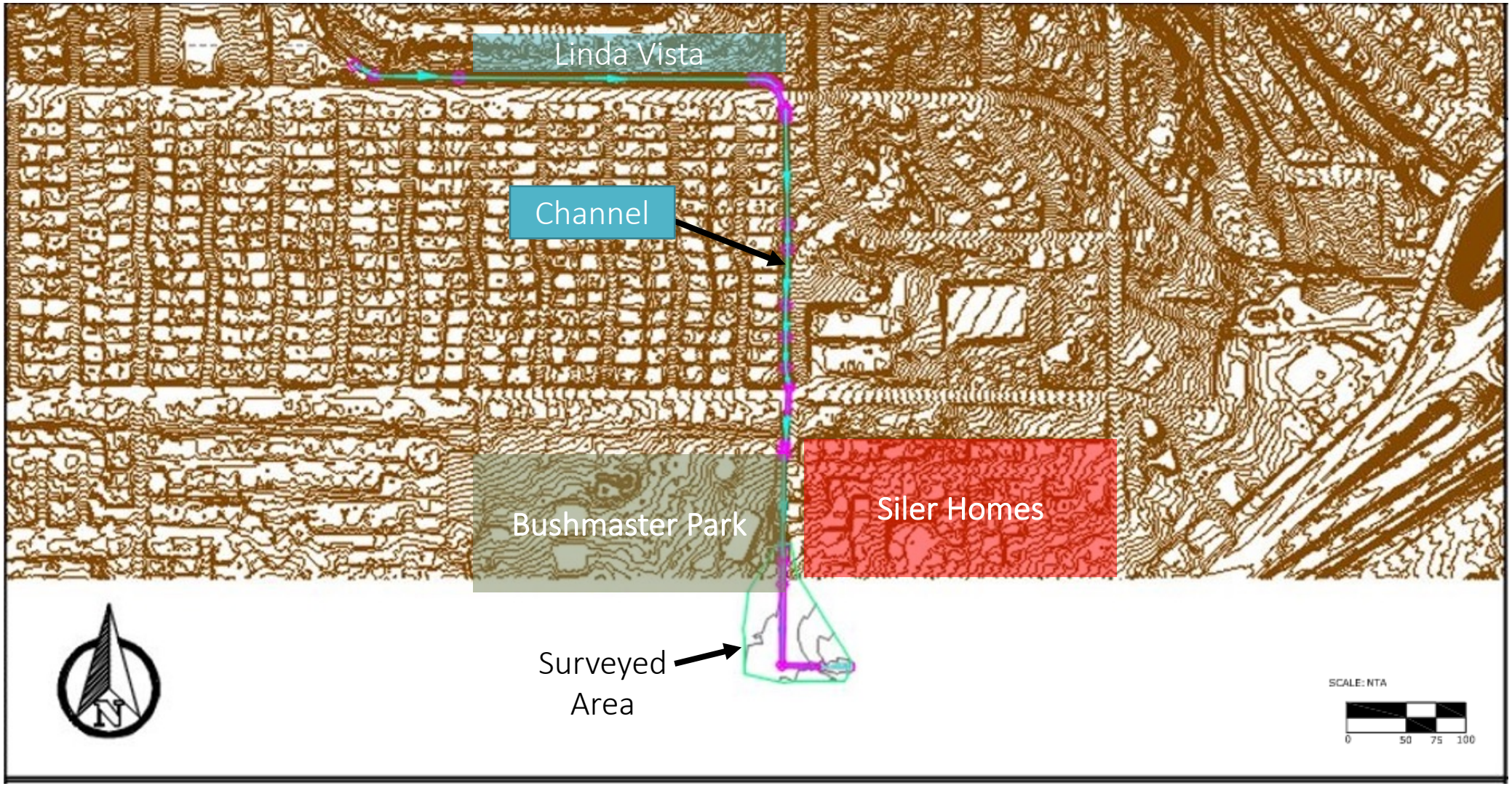



Fig 5: Topo Map of surveyed site, Credit: Caleb Smith

# Hydrologic Analysis

Table 1: Time of concentration for 25 year and 100 year

| | 25-Year Design Storm | | 100-Year Check Storm | |
|---|---|---|---|---|
| Flow Path | Time (min) | I (in/hr) | Time (min) | I (in/hr) |
| Line path 1 | 45 | 2.37 | 37 | 3.61 |
| | 44 | 2.41 | 36 | 3.66 |
| | 43 | 2.45 | 35 | 3.71 |
| | 42 | 2.48 | 34 | 3.76 |
| | 41 | 2.52 | 33 | 3.81 |
| | 40 | 2.56 | 32 | 3.86 |
| Line path 2 | 40 | 2.56 | 30 | 3.96 |
| | 39 | 2.59 | 29 | 4.09 |
| | 38 | 2.63 | 28 | 4.22 |
| | 37 | 2.67 | 27 | 4.34 |
| | | | 26 | 4.47 |
| Line path 3 | 25 | 4.54 | 25 | 4.6 |
| | 24 | 4.58 | 24 | 4.73 |
| | 23 | 4.62 | 23 | 4.86 |
| | 22 | 4.66 | 22 | 4.98 |
| | 21 | 4.69 | 21 | 5.11 |
| | 20 | 4.73 | 20 | 5.24 |

Equation 4-1: Time of Concentration Estimation Equation [1]

$$T_C = 11.4 \times L^{0.5} \times k_b^{0.52} \times S^{-0.31} \times i^{-0.38}$$

Where,
$T_c$ = time of concentration (hours)
L = length of the longest flow path (miles)
$K_b$ = watershed resistance coefficient
S = slope for the longest flow path (ft/mile)
i = average rainfall intensity for a duration of rainfall equal to $T_c$ (in/in)

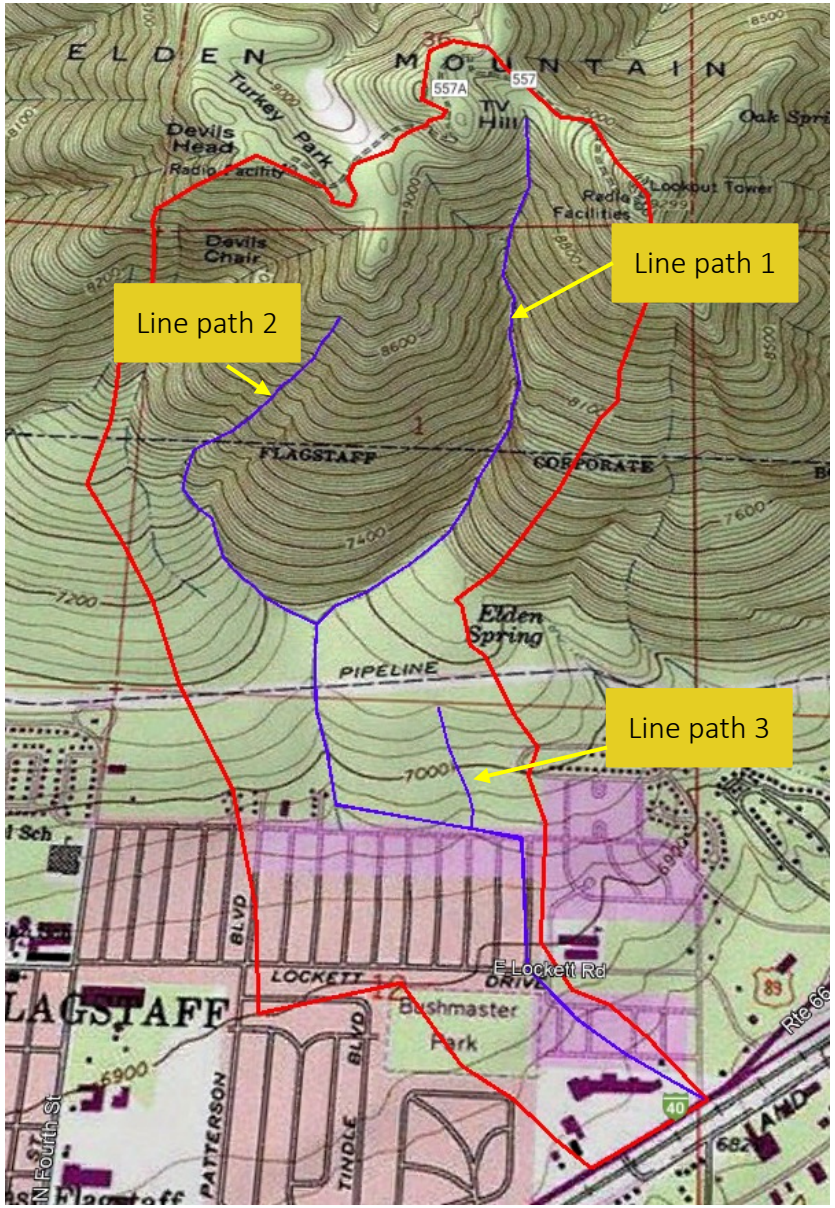



Figure 4: Flow paths of Watershed Credit: Google Earth

# Rainfall Intensity and Runoff

Table 3: Rainfall Intensity

| *Rainfall Intensity* | | | |
|---|---|---|---|
| | ***Flow Path*** | ***Resultant Tc (min)*** | ***Rainfall Intensity (in/hr)*** |
| ***25-Year Design Storm*** | ***Line path 1*** | 41 | 2.52 |
| | ***Line path 2*** | 40 | 2.56 |
| | ***Line path 3*** | 23 | 4.62 |
| ***100-Year Check Storm*** | ***Line path 1*** | 35 | 3.71 |
| | ***Line path 2*** | 30 | 3.96 |
| | ***Line path 3*** | 23 | 4.86 |

Table 4: Runoff

| *Runoff* | | |
|---|---|---|
| ***Parameter*** | ***25-Year*** | ***100-Year*** |
| ***Discharge Q (cfs)*** | 439.1 | 701.3 |
| ***Rational Coefficient-C*** | 0.2 | 0.22 |
| ***Computed Tc (min)*** | 40.3 | 35 |

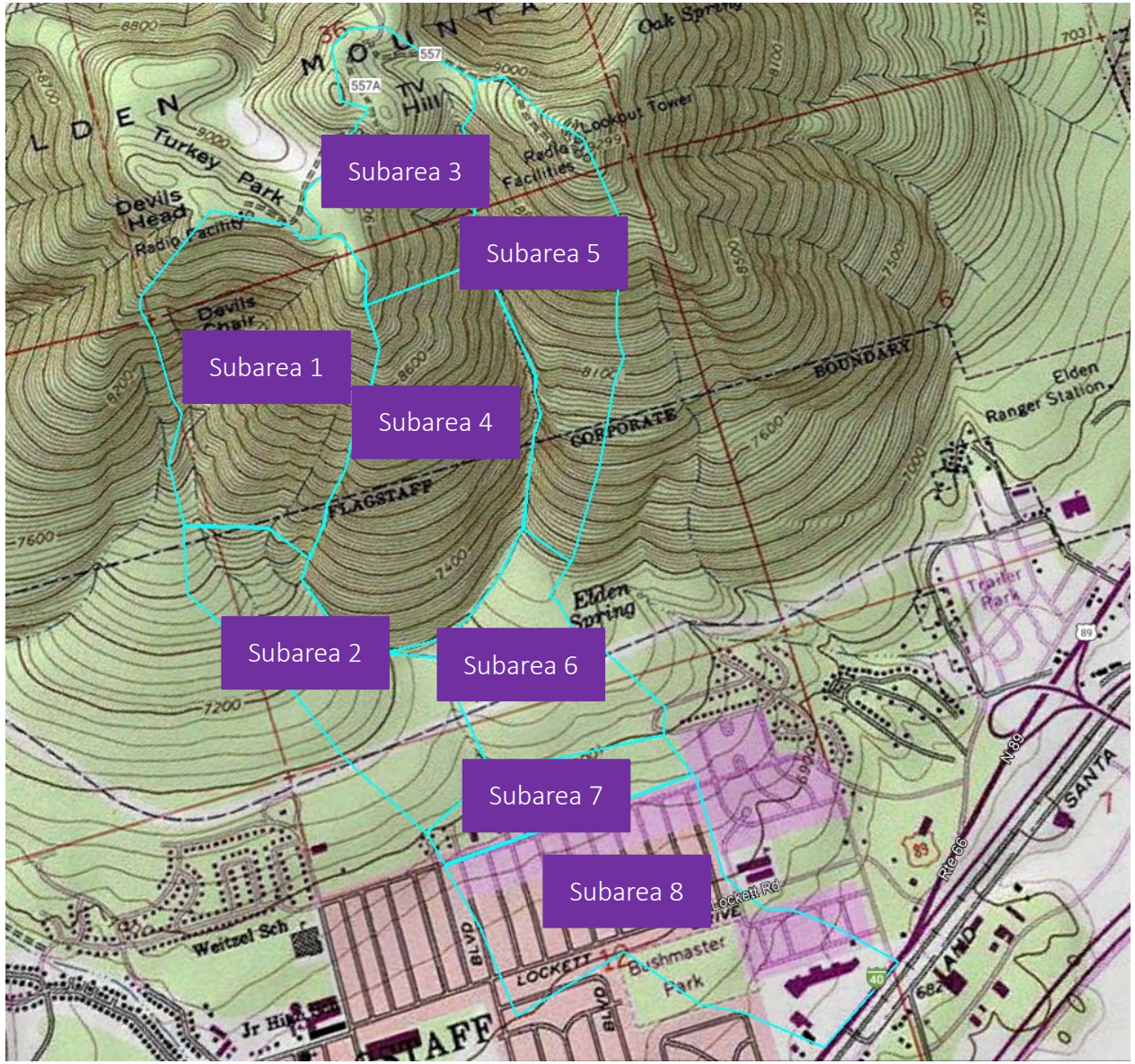



Figure 3: Subbasin and Subareas Credit: Google Earth

# Hydraulic Analysis of Existing Structures

## Open Channel Analysis

| | |
|---|---|
| LV | Linda Vista Culvert |
| BC | Box Culvert |
| SH | Siler Homes Culvert |

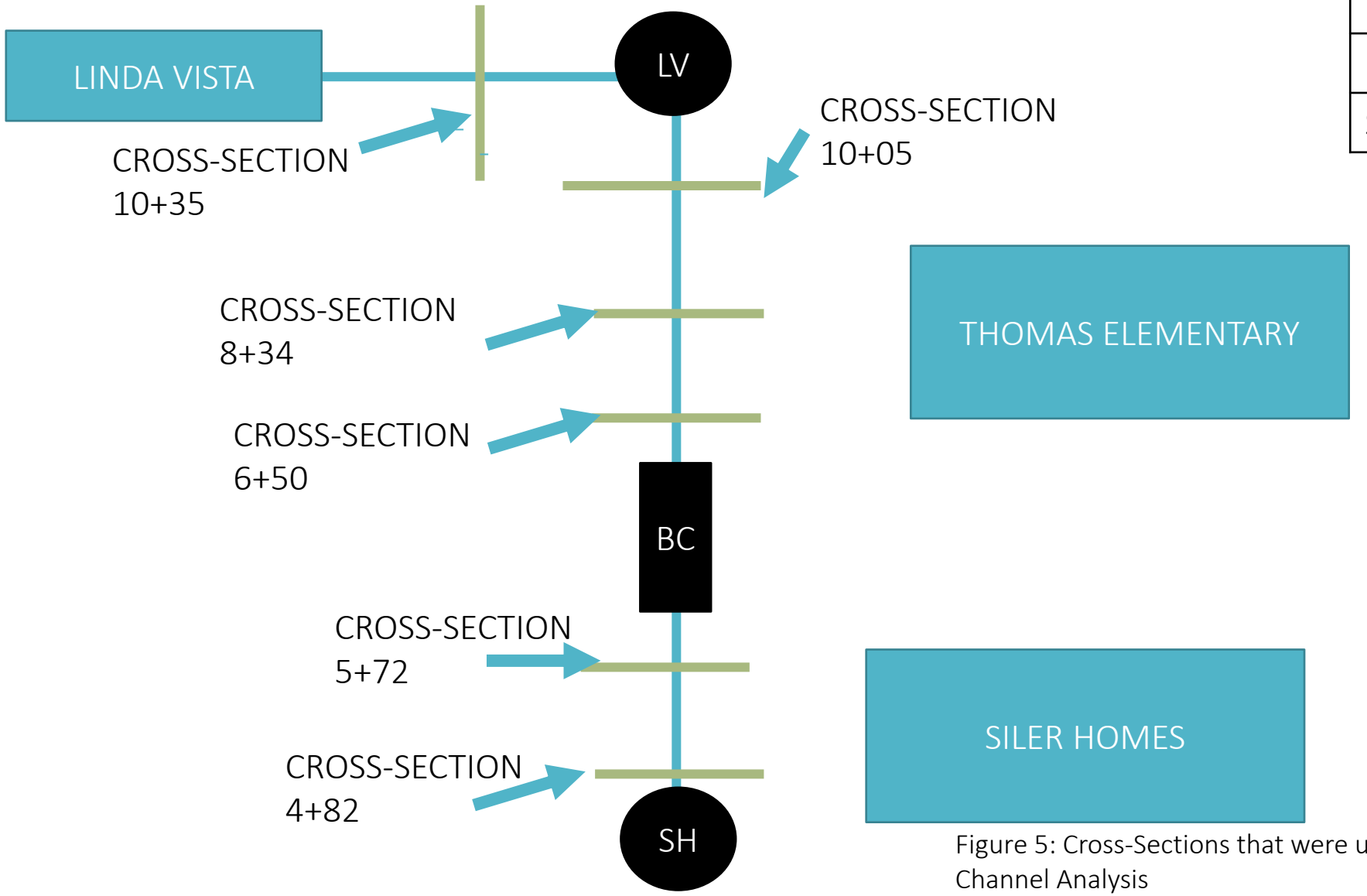



Figure 5: Cross-Sections that were used for the Open Channel Analysis

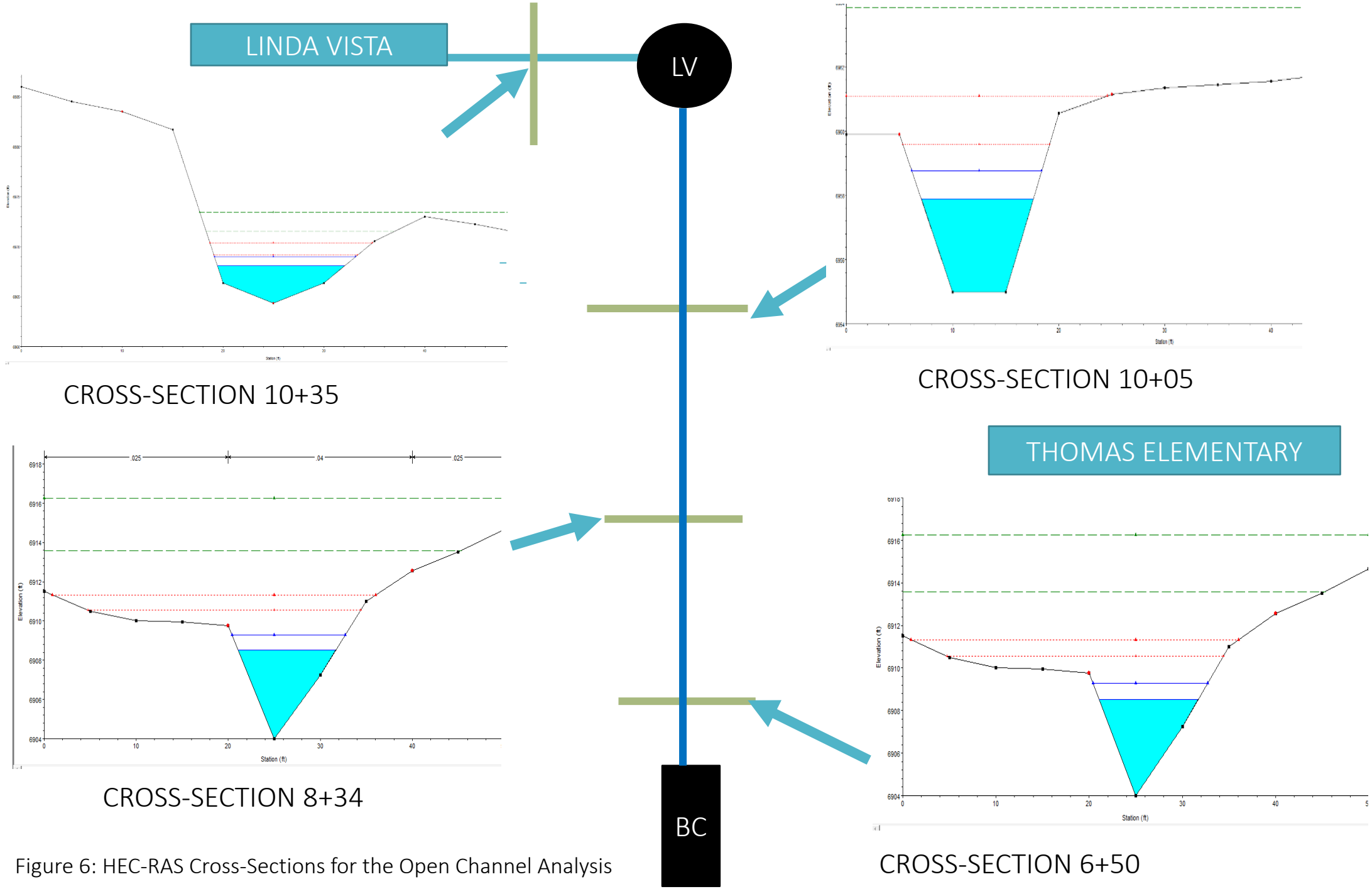
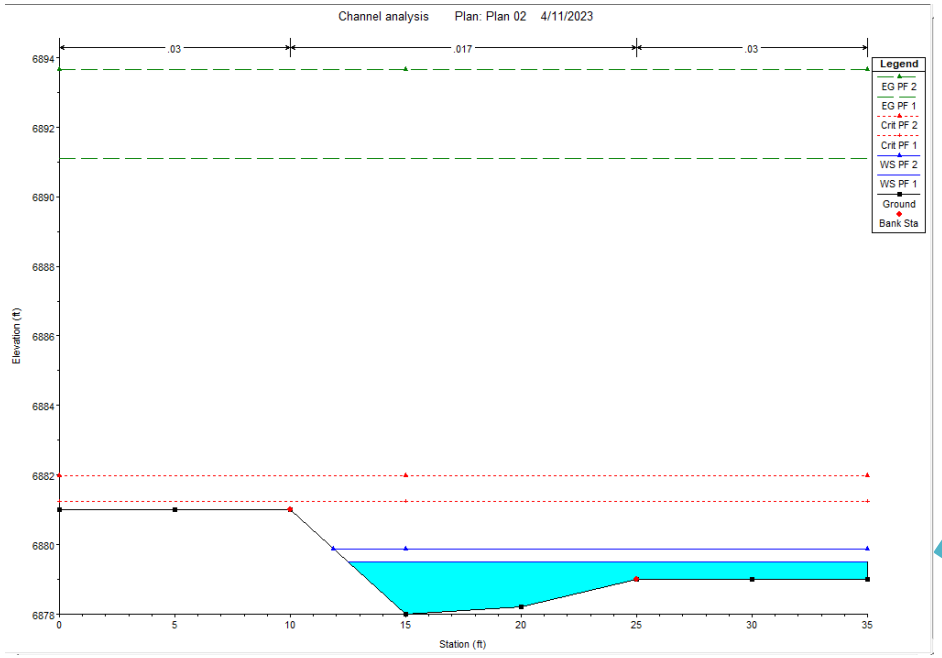
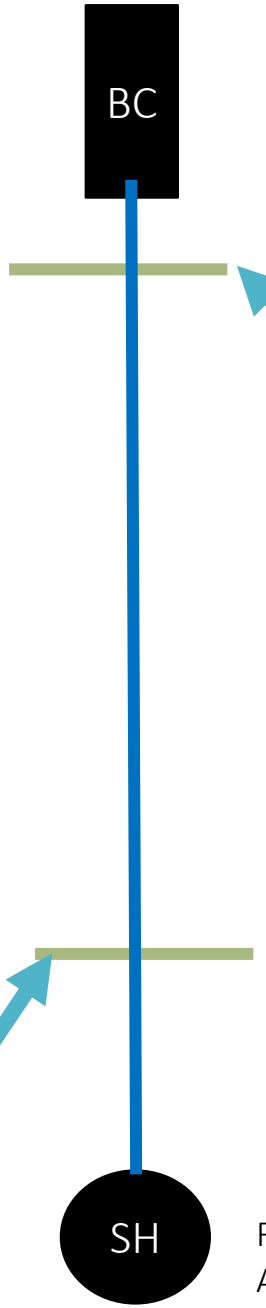
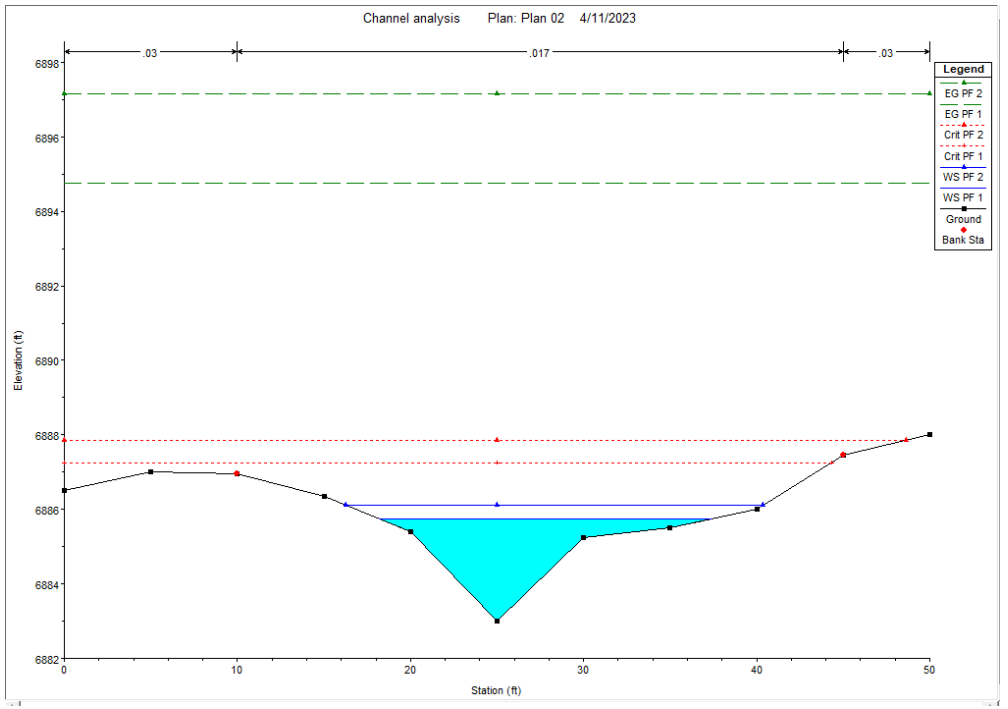



Figure 6: HEC-RAS Cross-Sections for the Open Channel Analysis




CROSS-SECTION 4+82




CROSS-SECTION 5+72

SILER HOMES

Figure 7: HEC-RAS Cross-Sections for the Open Channel Analysis

Table 5: Open Channel analysis

| River Station | | Flow Rate (cfs) | Velocity (ft/s) | Compliance | Freeboard | Compliance |
|---|---|---|---|---|---|---|
| 10+35 | 25 yrs | 439.1 | 14.99 | <18 ft/s | 1.8 | >1 ft |
| | 100 yrs | 701.3 | 16.97 | <18 ft/s | 2.3 | >1 ft |
| 10+05 | 25 yrs | 439.1 | 18.74 | <18 ft/s | 2.1 | >1 ft |
| | 100 yrs | 701.3 | 20.75 | <18 ft/s | 2.6 | >1 ft |
| 8+34 | 25 yrs | 439.1 | 21.9 | <18 ft/s | 2.5 | >1 ft |
| | 100 yrs | 701.3 | 24.8 | <18 ft/s | 3.1 | >1 ft |
| 6+50 | 25 yrs | 439.1 | 20.13 | <18 ft/s | 2.6 | >1 ft |
| | 100 yrs | 701.3 | 22.82 | <18 ft/s | 3.3 | >1 ft |
| 5+72 | 25 yrs | 439.1 | 24.08 | <18 ft/s | 2.9 | >1 ft |
| | 100 yrs | 701.3 | 26.65 | <18 ft/s | 3.5 | >1 ft |
| 4+82 | 25 yrs | 439.1 | 28.8 | <18 ft/s | 3.6 | >1 ft |
| | 100 yrs | 701.3 | 32.04 | <18 ft/s | 4.5 | >1 ft |

# Culvert Analysis

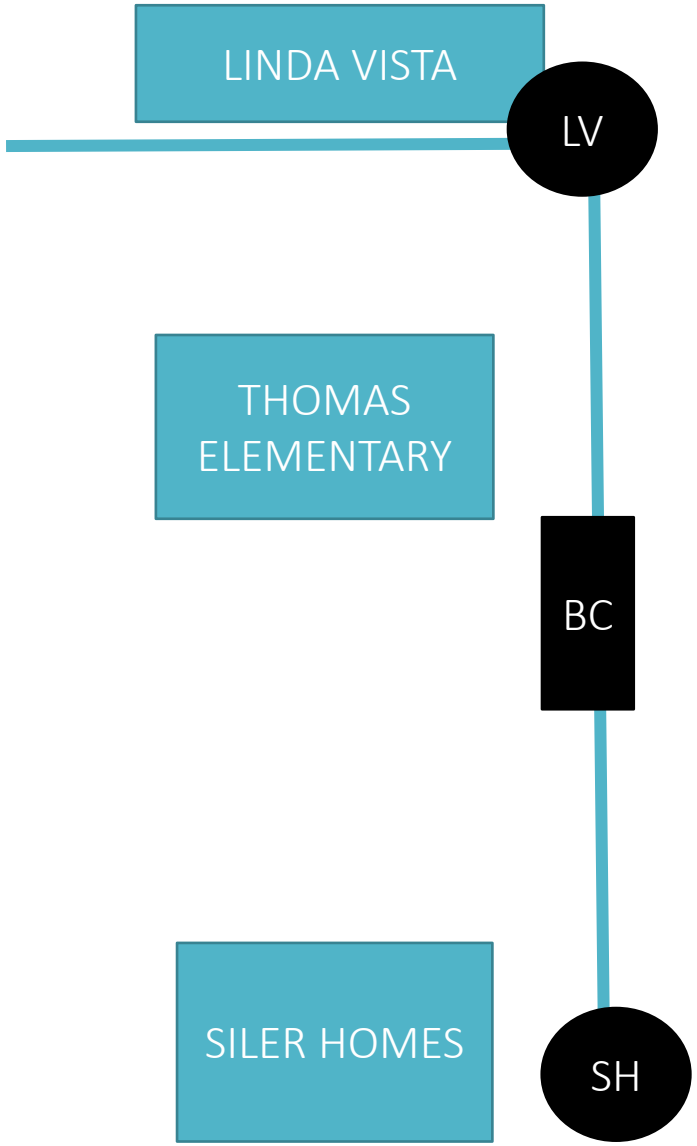



Table 6: Culvert Analysis

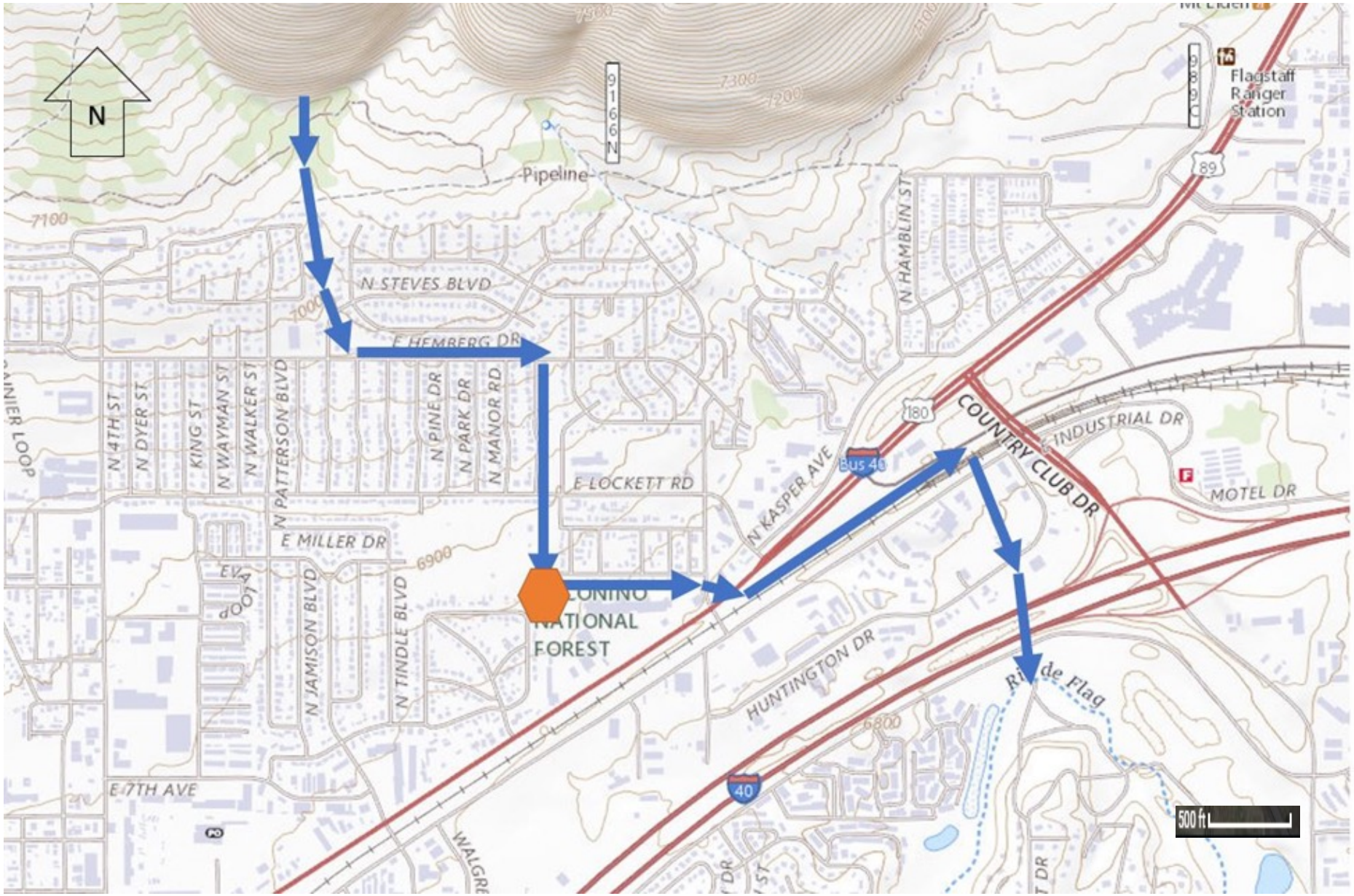
| | | *Flow Rate (cfs)* | *Velocity (ft/s)* | |
|---|---|---|---|---|
| ***Culvert*** | | ***Data*** | ***Data*** | ***Compliance*** |
| ***Linda Vista (LV)*** | 25 yrs | 439.1 | 21.27 | <20 ft/s |
| | 100 yrs | 701.3 | 23.49 | <20 ft/s |
| ***Box Culvert (BC)*** | 25 yrs | 439.1 | 7.65 | <20 ft/s |
| | 100 yrs | 701.3 | 8.35 | <20 ft/s |
| ***Siler Homes (SH)*** | 25 yrs | 439.1 | 48.2 | <20 ft/s |
| | 100 yrs | 701.3 | 53.85 | <20 ft/s |

# Develop Design Alternative

## Alternative 1: Drainage System from Linda Vista Drive to the existing Detention Basin on Route 66


Figure 8: Linda Vista Drainage system Credit: USGS & Caleb Smith

# Alternative 2: Detention Basin at Bushmaster Park

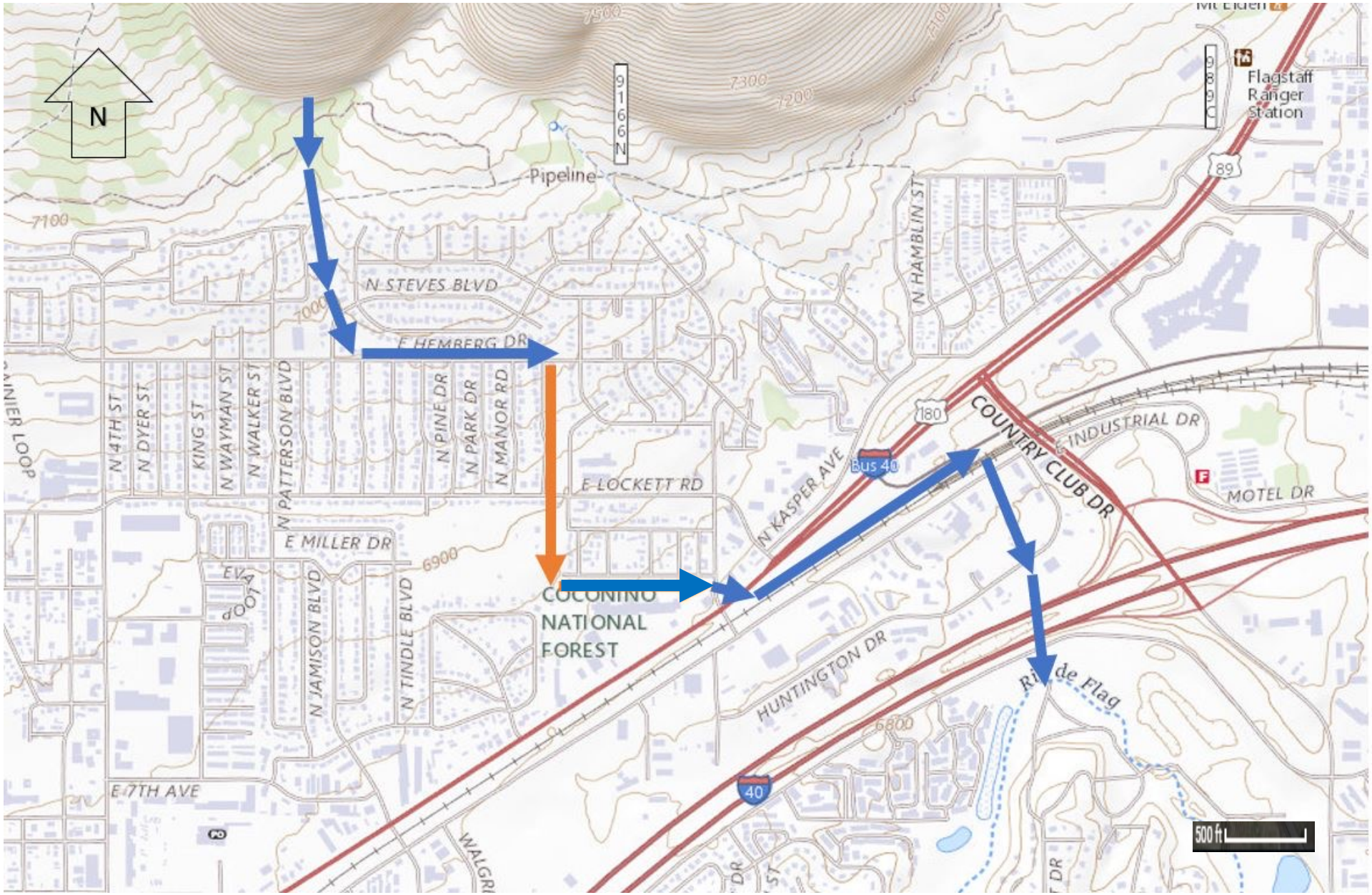



Existing

New

Figure 9: Detention Basin @ Bushmaster Park Credit: USGS & Caleb Smith

# Alternative 3: Channel Rehabilitation




| | |
|---|---|
| | Existing |
| | New |

Figure 10: Channel Rehabilitation Credit: USGS & Caleb Smith

# Alternative 4: Detention Basin and Channel Rehabilitation

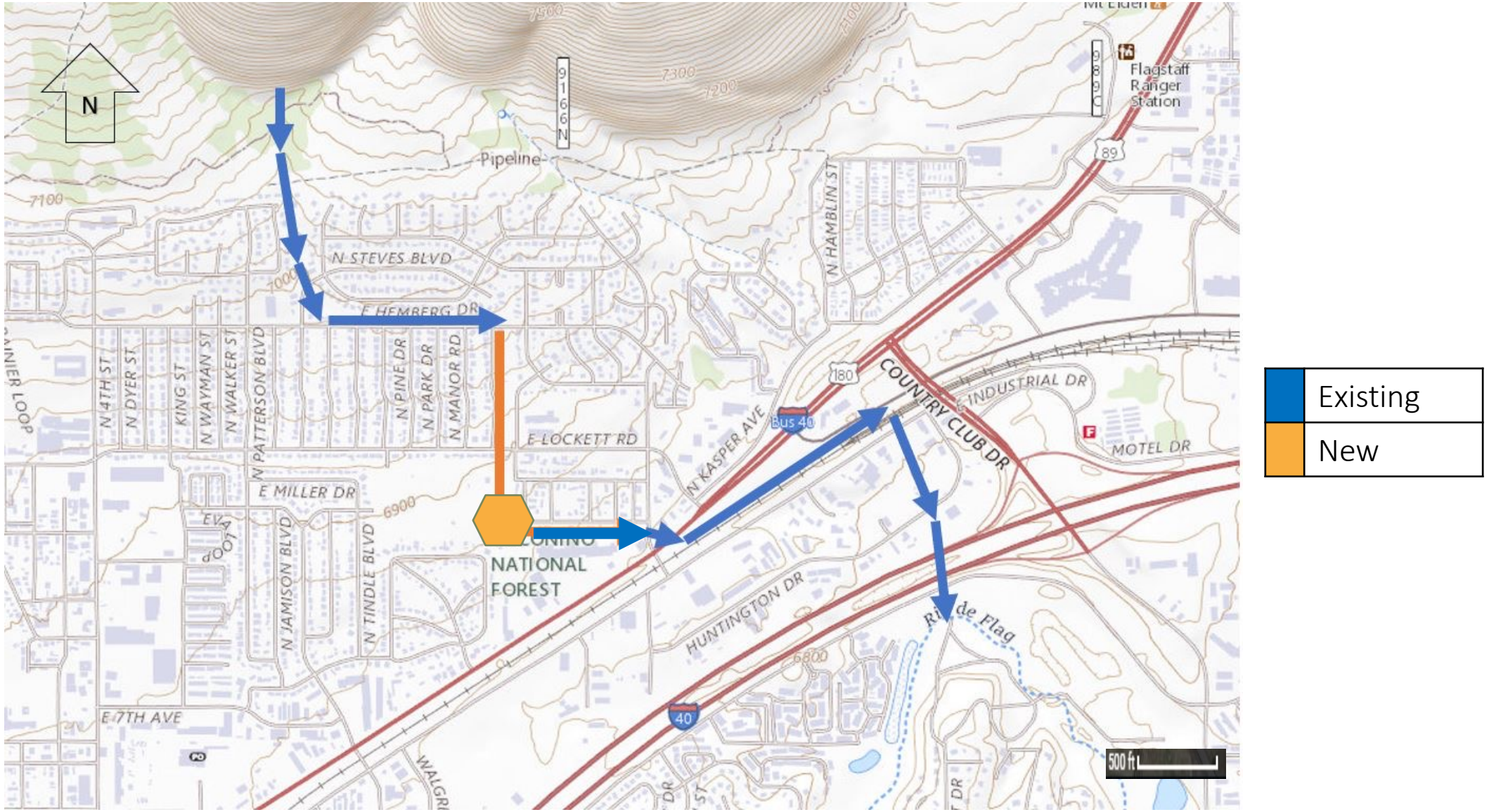



Figure 11: Channel Rehabilitation Credit: USGS & Caleb Smith

# Alternative 5: Drainage system and Channel Rehabilitation


Figure 12: Drainage System and Channel Rehabilitation Credit: USGS & Caleb Smith

# Identify Constraints and Criteria

Table 7: Decision Matrix Criteria

| | ***Flood Prevention*** | ***Societal Impact*** | ***Easements*** | ***Maintenance*** | ***Cost*** |
|---|---|---|---|---|---|
| 1 | Floods at 100-year storm | Impacts Negatively | >5 | Continuous maintenance needed | >10,000,000 |
| 2 | Minimal flooding | Minimal Impact | >1 | Does not change | >5,000,000 |
| 3 | Alleviates all flooding | Impacts Positively | 0 | Little to no maintenance | >1,000,000 |

# Select Best Alternative

Table 8: Decision Matrix

| | Weight (%) | Alternative 1: Drainage system through Linda Vista | Alternative 2: Detention Basin @ Bushmaster | Alternative 3: Channel Rehabilitation | Alternative 4: Detention Basin and Channel Rehabilitation | Alternative 5: Drainage system & Channel Rehabilitation |
|---|---|---|---|---|---|---|
| Flood Prevention | 40% | 2 | 1 | 1 | 2 | 3 |
| Societal Impact | 10% | 1 | 2 | 2 | 1 | 3 |
| Easements | 5% | 3 | 3 | 3 | 3 | 2 |
| Maintenance | 15% | 3 | 2 | 3 | 1 | 3 |
| Cost | 30% | 2 | 3 | 3 | 2 | 2 |
| Total | 100% | 2.1 | 2.0 | 2.1 | 1.8 | **2.7** |

# Final Design Decision - Drainage system & Channel Rehabilitation


Existing

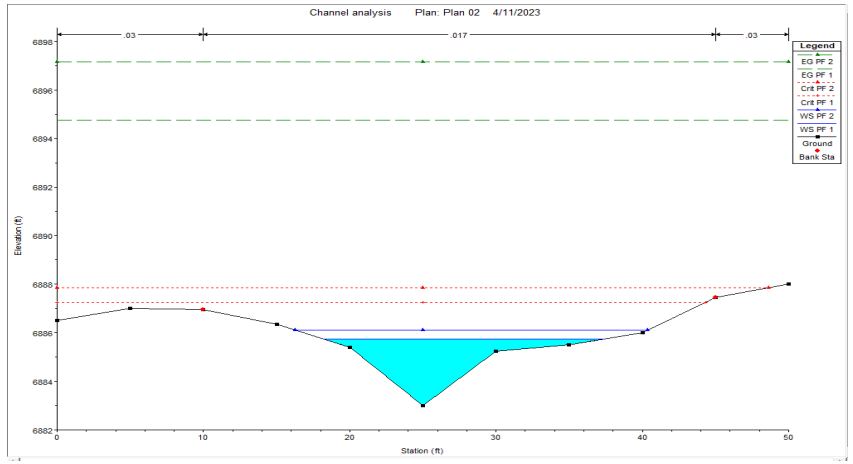
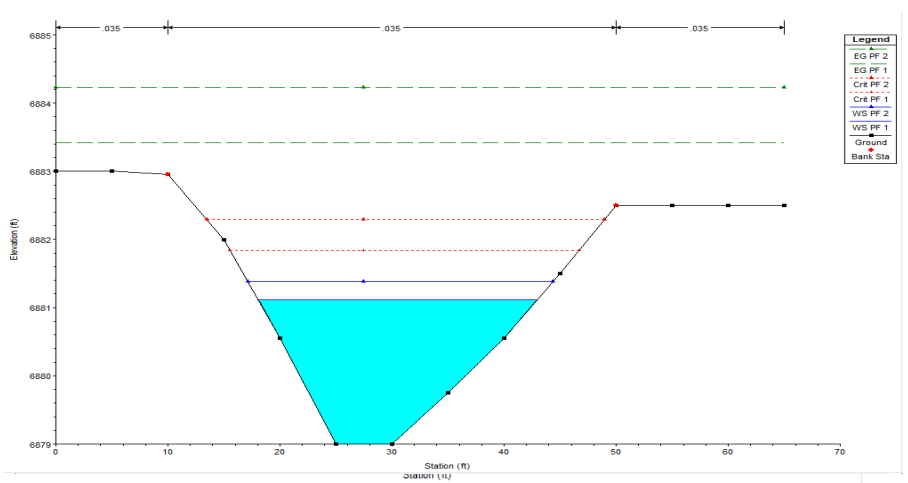
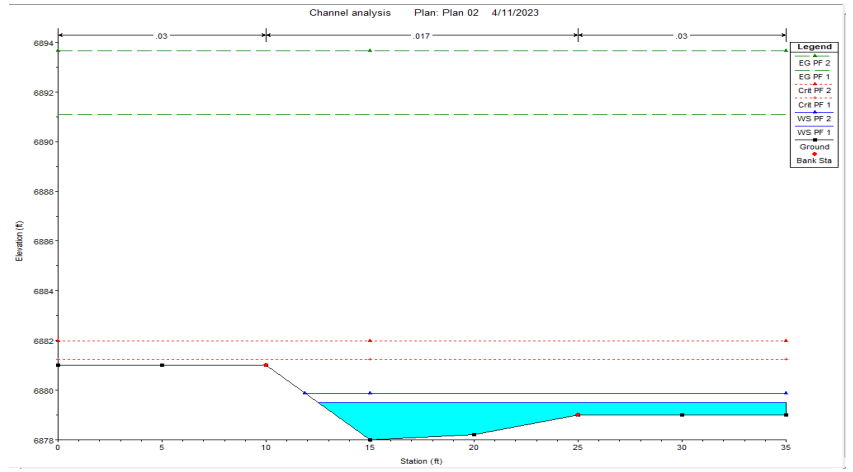
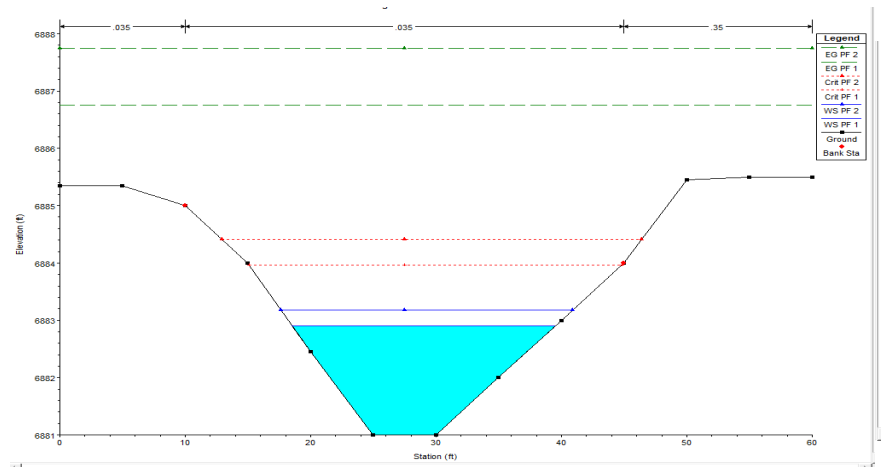
New

Figure 17: Drainage System & Channel Rehabilitation

# Final Design Plan

## Channel Rehabilitation

LINDA VISTA

| | Before | After |
|---|---|---|
| STA 5+72 |  |  |
| STA 4+82 |  |  |

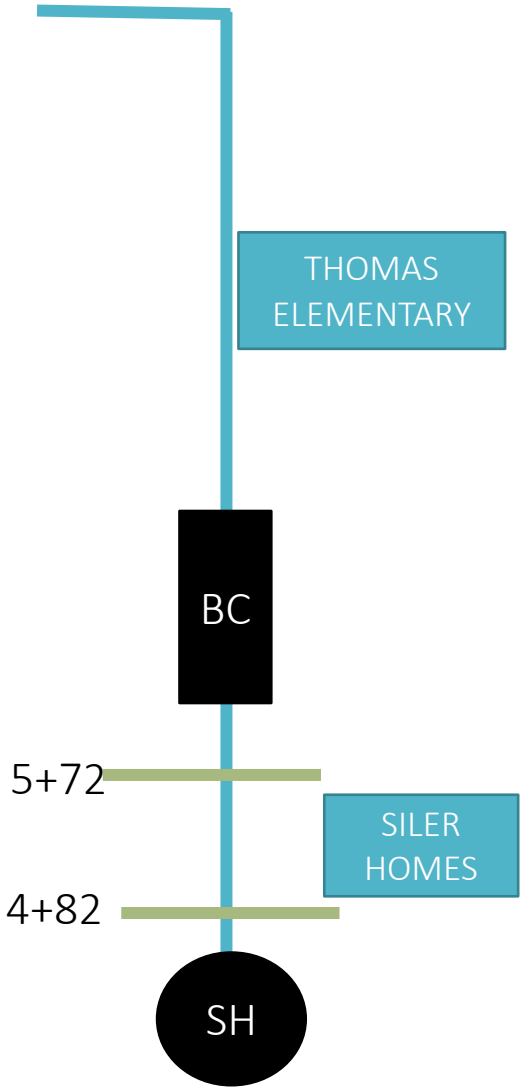



Figure 13: Comparison Cross-Sections for Open Channel Analysis

Table 9: HEC-RAS data compared with City Codes

| River Station | | Flow Rate (cfs) | Velocity (ft/s) | Compliance | Freeboard | Compliance |
|---|---|---|---|---|---|---|
| 10+35 | 25 yrs | 391.09 | 14.36 | <18 ft/s | 1.69 | >1 ft |
| | 100 yrs | 531.3 | 15.67 | <18 ft/s | 1.61 | >1 ft |
| 10+05 | 25 yrs | 391.09 | 17.23 | <18 ft/s | 1.63 | >1 ft |
| | 100 yrs | 531.3 | 18.56 | <18 ft/s | 1.72 | >1 ft |
| 8+34 | 25 yrs | 391.09 | 24.2 | <18 ft/s | 2.75 | >1 ft |
| | 100 yrs | 531.3 | 25.71 | <18 ft/s | 3.09 | >1 ft |
| 6+50 | 25 yrs | 391.09 | 20.69 | <18 ft/s | 2.04 | >1 ft |
| | 100 yrs | 531.3 | 23.11 | <18 ft/s | 2.52 | >1 ft |
| 5+72 | 25 yrs | 391.09 | 15.75 | <18 ft/s | 1.56 | >1 ft |
| | 100 yrs | 531.3 | 17.14 | <18 ft/s | 1.14 | >1 ft |
| 4+82 | 25 yrs | 391.09 | 12.18 | <18 ft/s | 1.10 | >1 ft |
| | 100 yrs | 531.3 | 13.52 | <18 ft/s | 1.31 | >1 ft |

# Channel Details

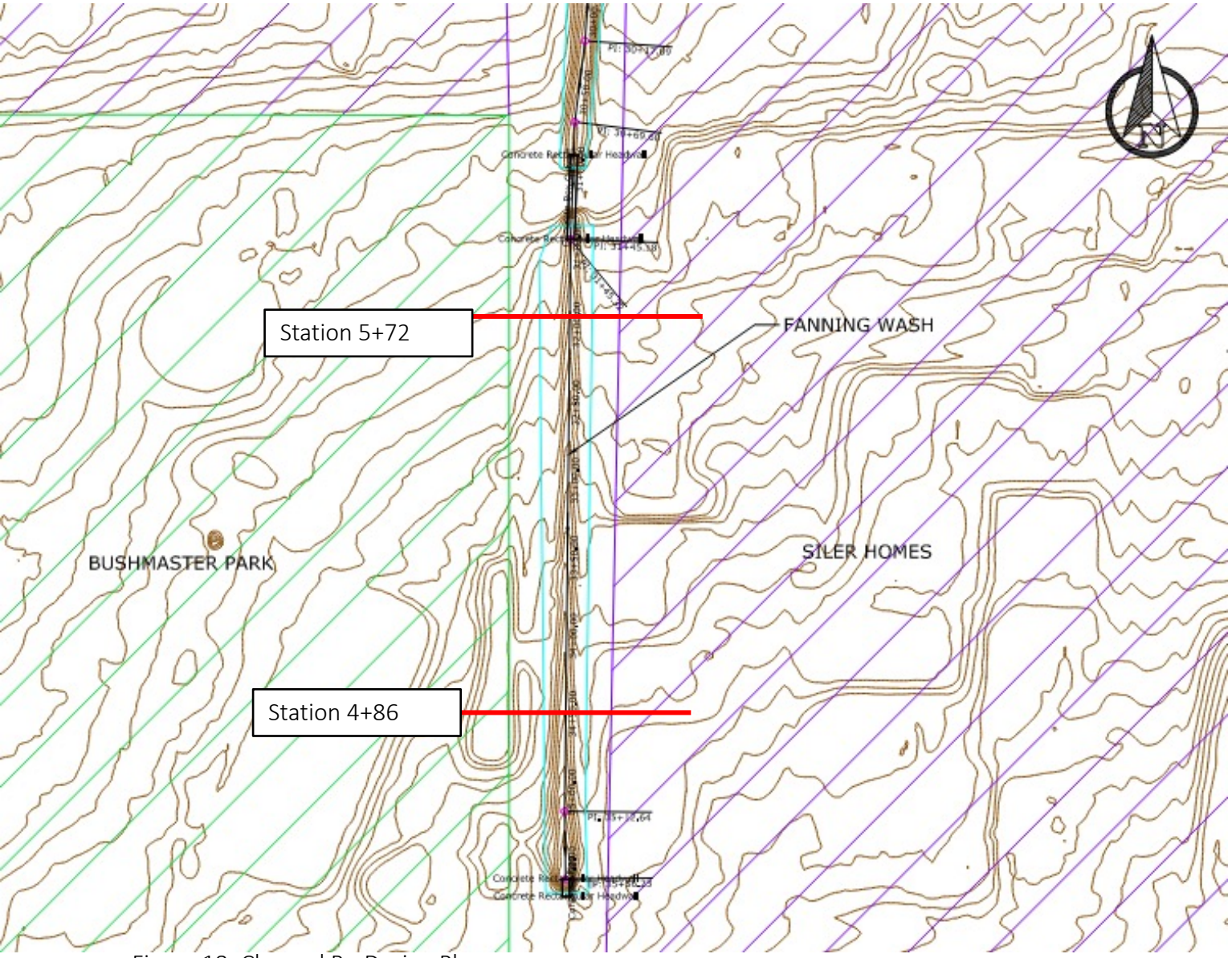



Figure 18: Channel Re-Design Plans

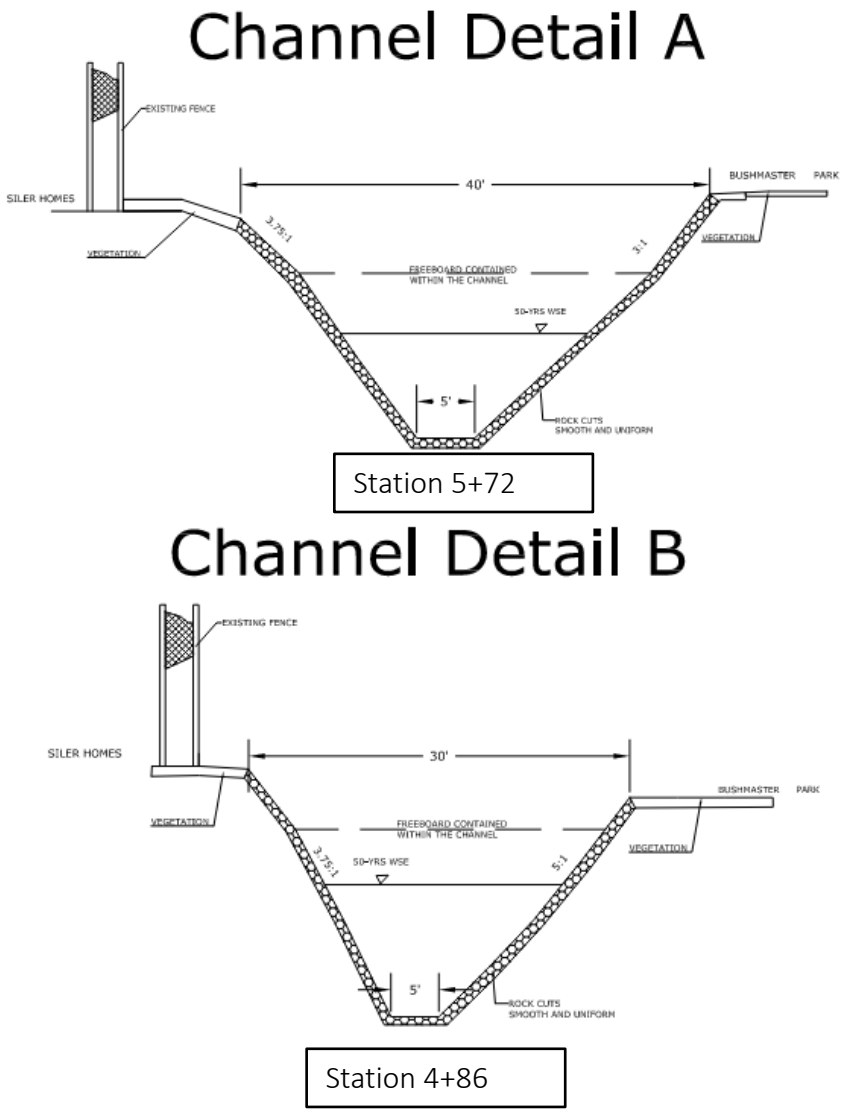



Figure 19: Channel Details

# Drainage System

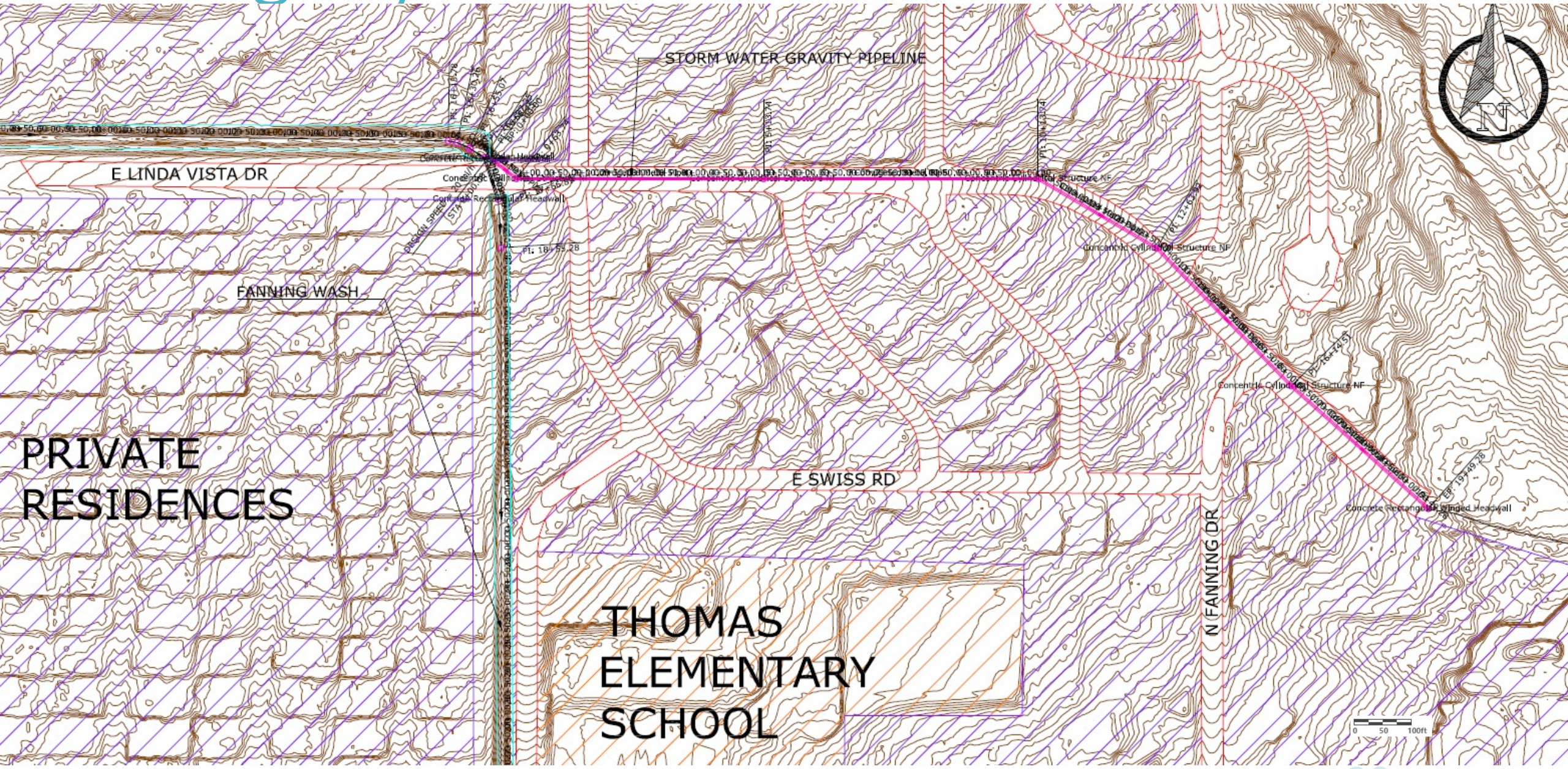
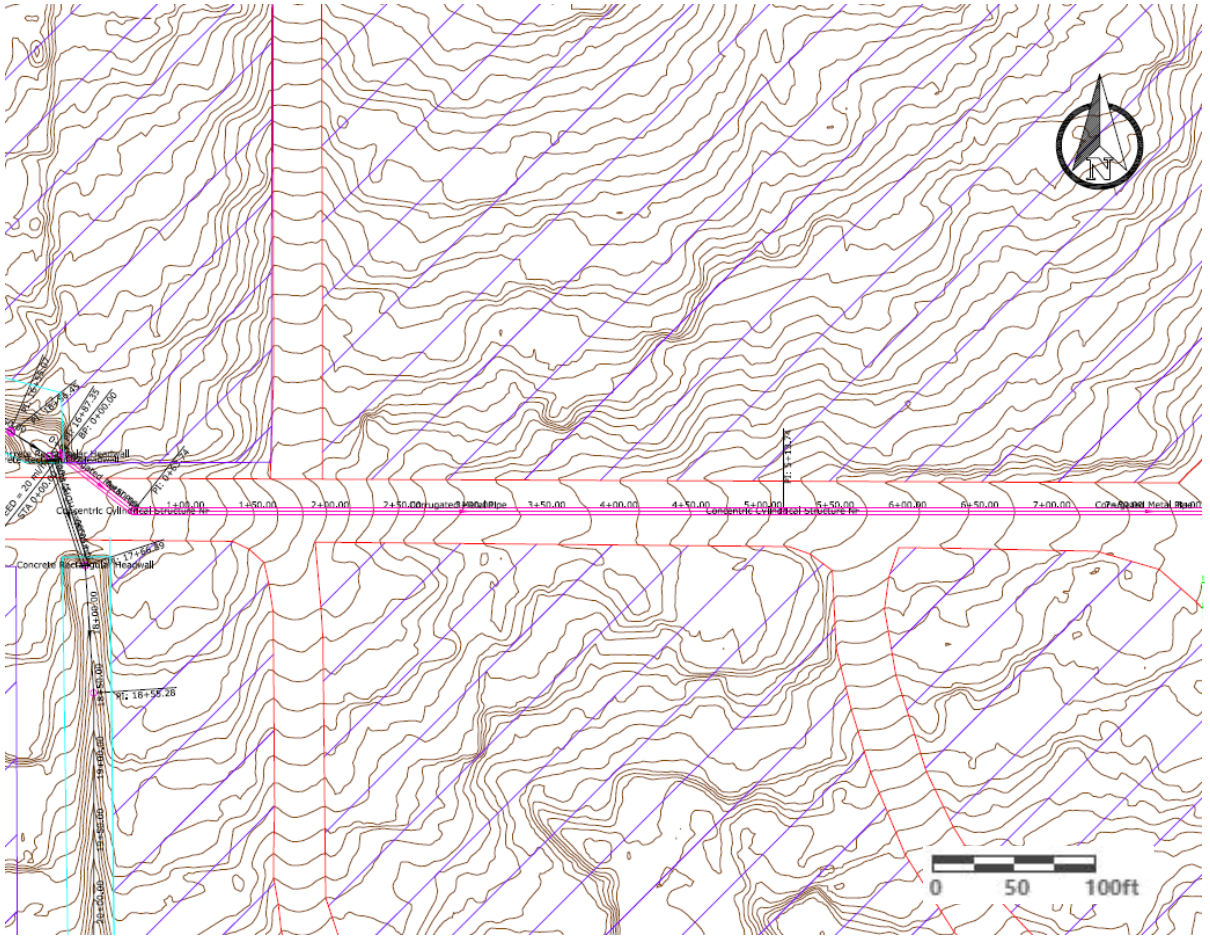
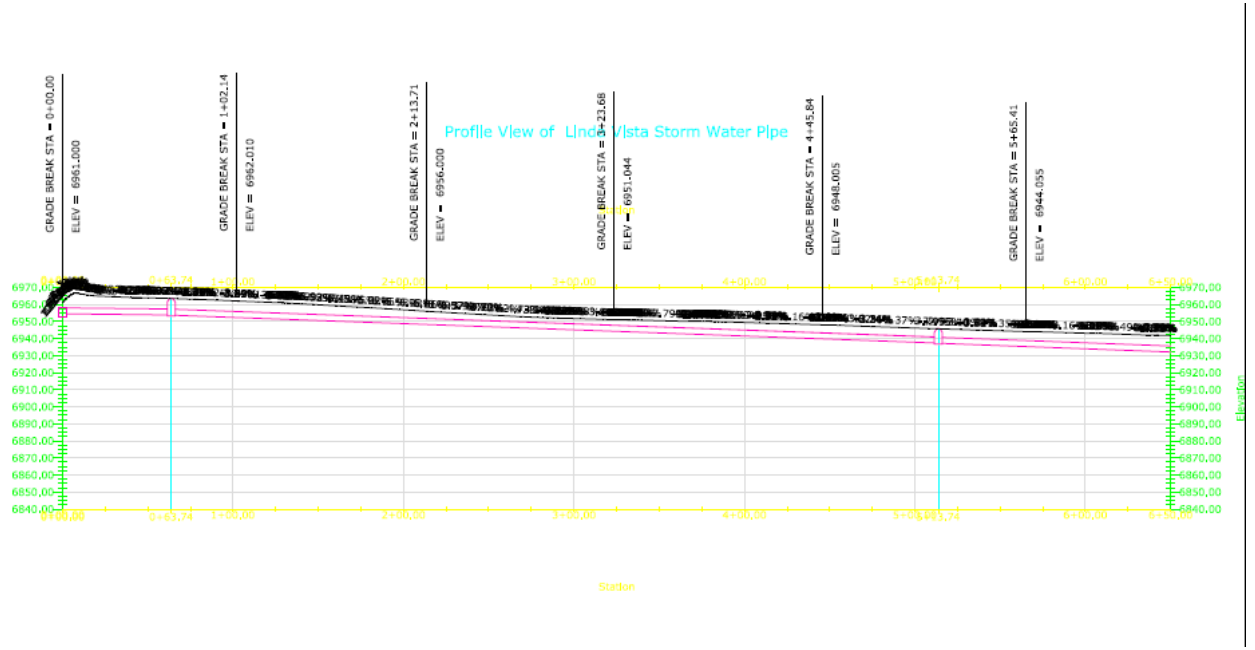



Figure 20: Storm Water Gravity Sewer Pipeline Plans

# Drainage System

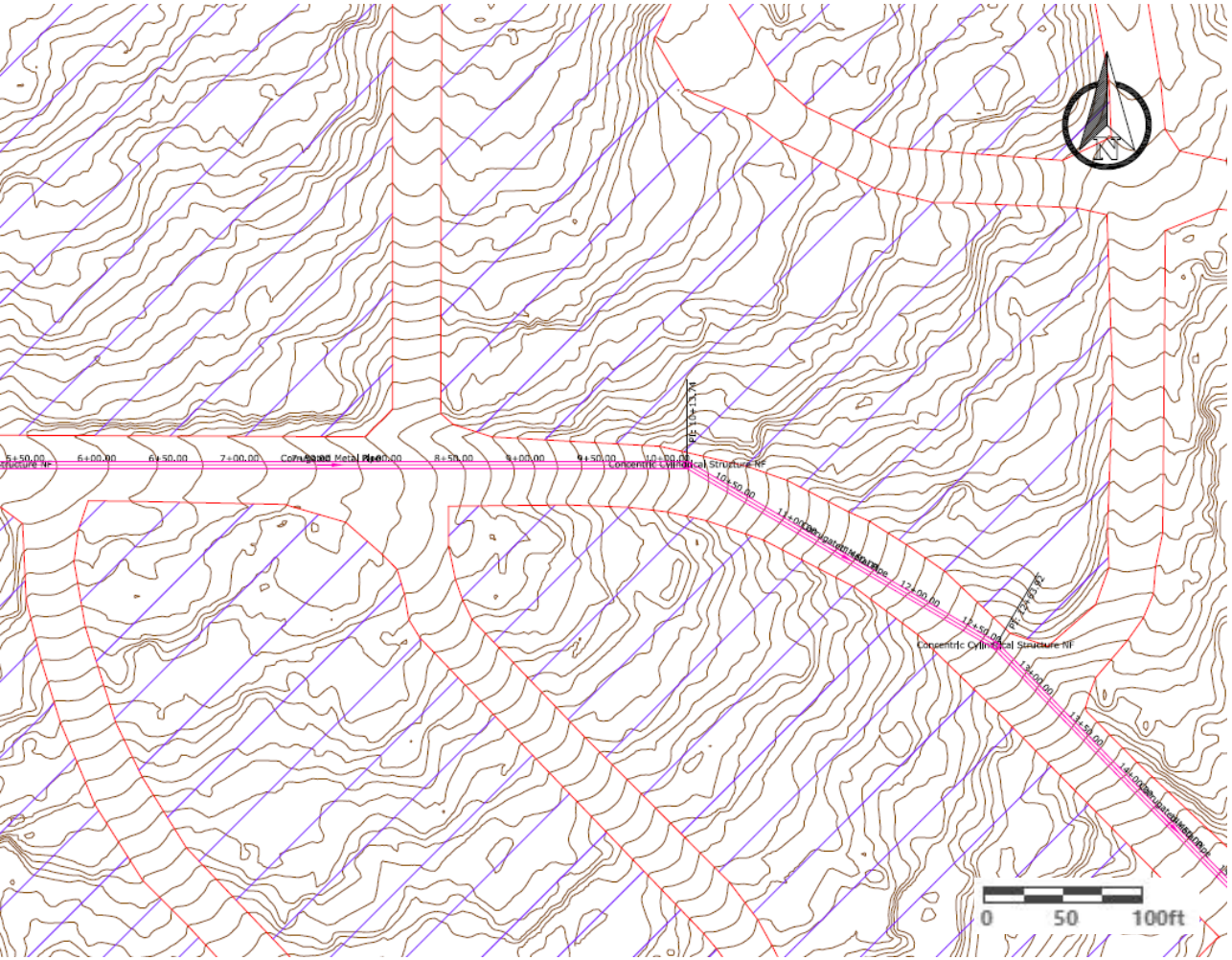



- 100-year flood carrys 701.3 cfs
- Stormwater Pipe will carry 30% of 100- year storm at 206 cfs
- 1,949 ft long

Figure 21: Plan and Profiles of the Pipeline 1

# Drainage System



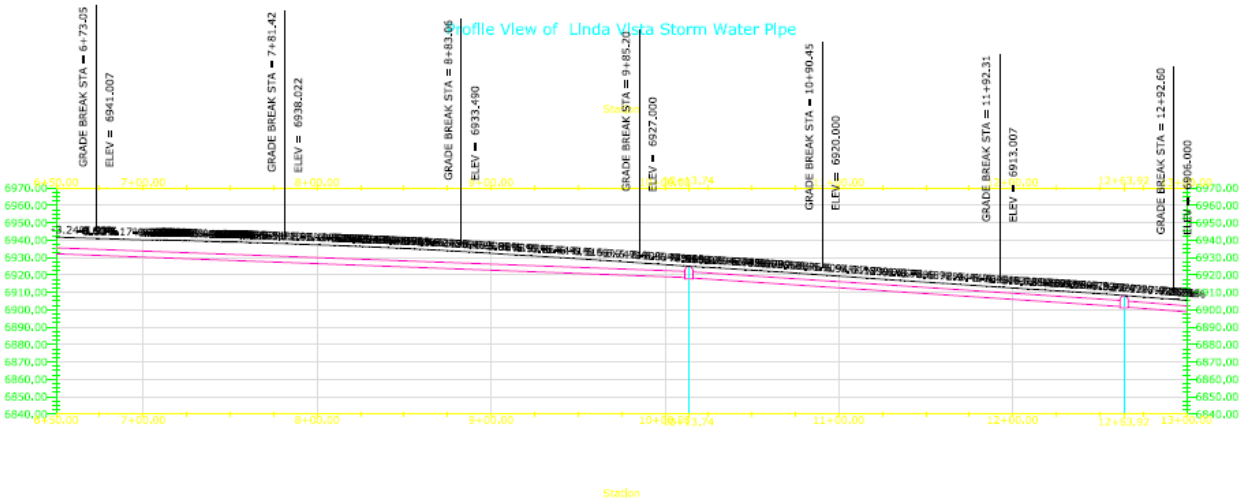
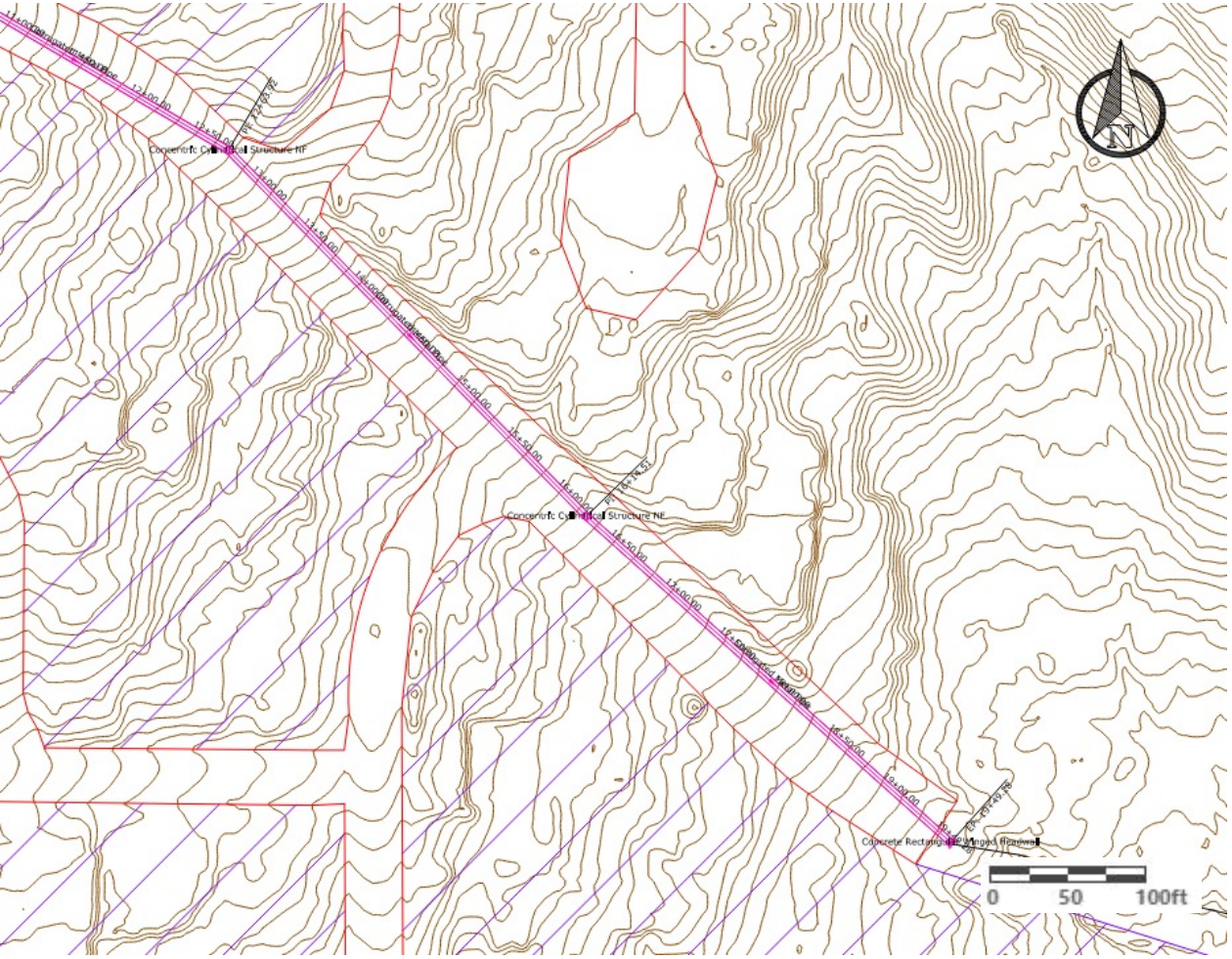




Figure 22: Plan and Profiles of the Pipeline 2

# Drainage System



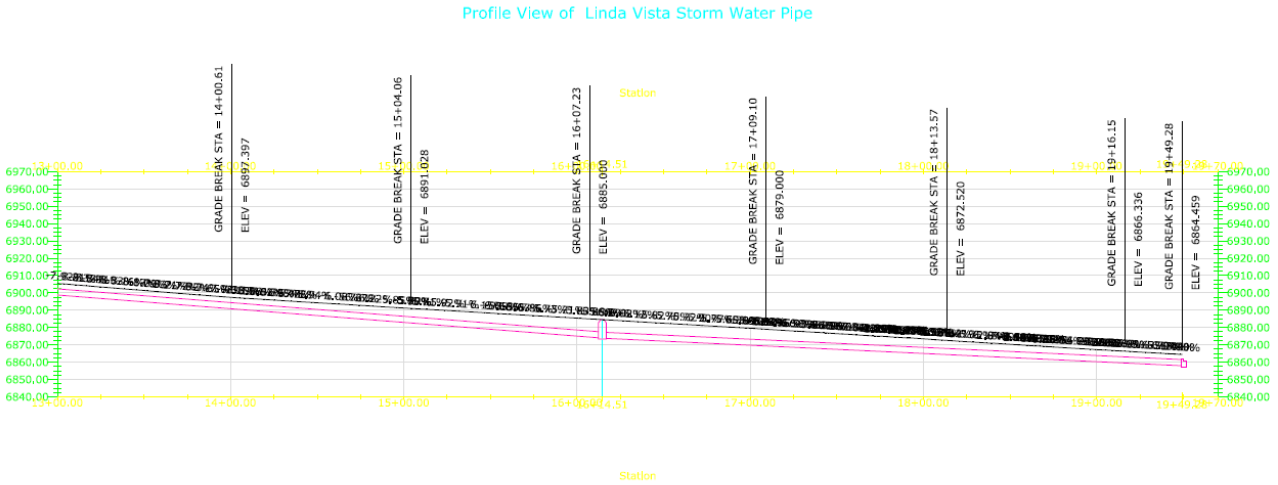




Figure 23: Plan and Profiles of the Pipeline 3

# Construction Plan

## Culvert Inlet Detail

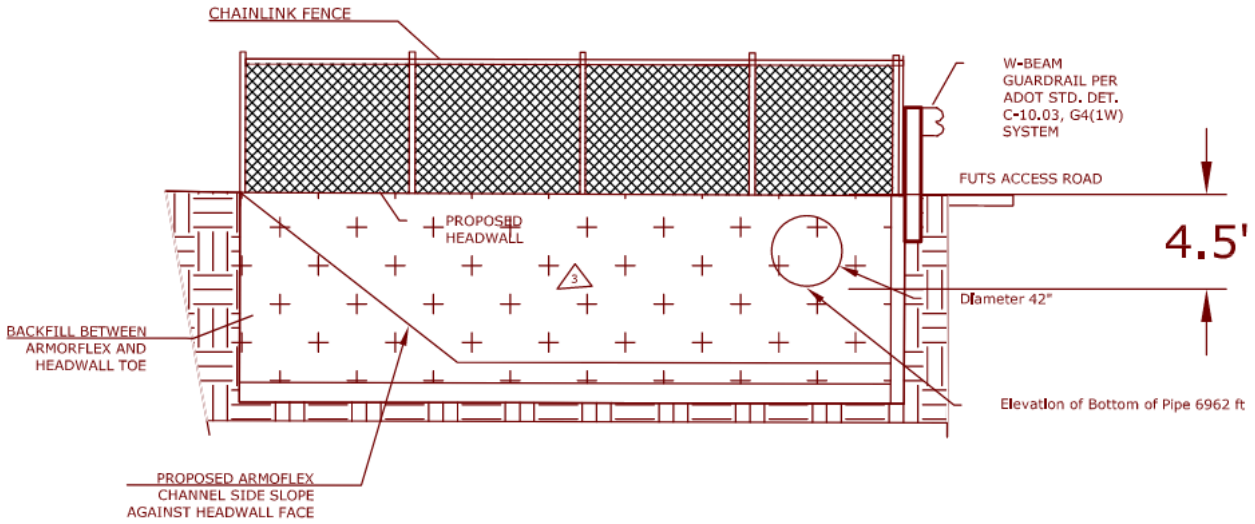
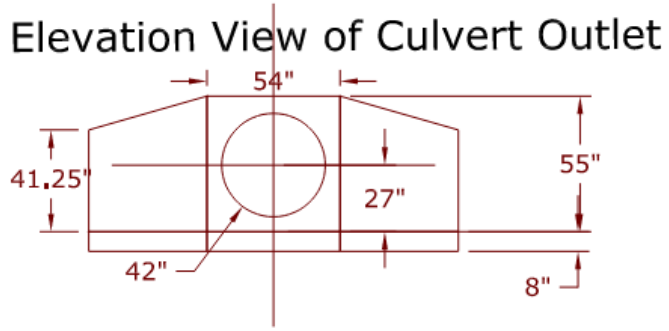



Figure 24: Culvert Inlet Detail



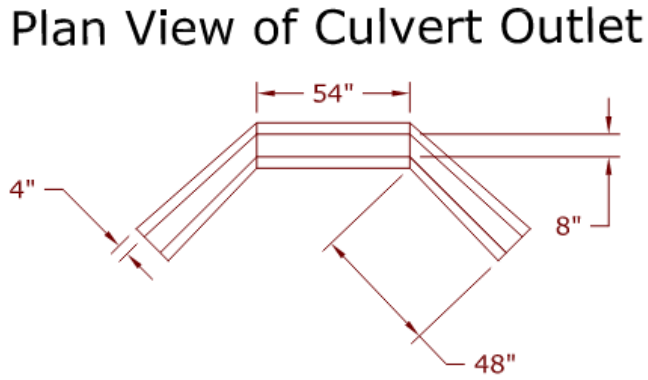




Figure 25: Culvert Outlet Detail

# Construction Cost

Table 10: Construction Cost Estimate

| | | | Materials | | Installation | | Total |
|---|---|---|---|---|---|---|---|
| Description | Qty | Units | $/Unit | Total | $/Unit | Total | |
| Pipe: | | | | | | | |
| Pipe Bedding | 2,000 | LF | 15.6 | 31,210 | 10.0 | 19,952 | $51,161 |
| Gravity Storm Drain Trench Backfill (Import) | 48,000 | CF | 28.4 | 1,361,880 | 11.3 | 544,752 | $1,906,632 |
| Pavement Removal & Disposal-8" | 8,000 | SF | 11.3 | 90,792 | | - | $90,792 |
| Pavement Replacement Over Trench - Asphalt - 8' Wide | 16,000 | SF | | - | 85.1 | 1,361,880 | $1,361,880 |
| Pipe (42" Diameter 5x1 and 3x1 Steel and Aluminum Corrugation) | 40 | SF | 166.3 | 6,651 | | - | $6,651 |
| Land Excavation Labor, Basic | 360 | /hr. | | - | 208 | 74,880 | $74,880 |
| Land Excavation Equipment Allowance | 1 | EA | 221 | 221 | | | $221 |
| Land Excavation Debris Disposal | 2700 | CY | 54 | 145,800 | | | $145,800 |
| Manhole: | | | | | | | |
| Inlet Manhole, 6' Diam. x 10' deep | 5 | EA | 7,150 | 35,750 | 3291.2 | 16,456 | $52,206 |
| Haul and Dispose Excess Excavated Material | 10 | CF | | - | 20.4 | 204 | $204 |
| Land Excavation Labor, Basic | 360 | /hr. | | - | 208 | 74,880 | $74,880 |
| Land Excavation Equipment Allowance | 1 | EA | 221 | 221 | | | $221 |
| Land Excavation Debris Disposal | 13 | CY | 54 | 702 | | | $702 |
| Channel: | | | | | | | |
| Channel Construction | 84,000 | CF | 11.3 | 953,316 | | - | $953,316 |
| Smooth Rocks (Bricks) | 5,328 | SF | 4.5 | 24,187 | | - | $24,187 |
| Land Excavation Labor, Basic | 360 | /hr. | | - | 208 | 74,880 | $74,880 |
| Land Excavation Equipment Allowance | 1 | EA | 221 | 221 | | | $221 |
| Land Excavation Debris Disposal | 3120 | CY | 54 | 168,480 | | | $168,480 |
| Total | | | | | | | $4,987,315 |

# Impact Analysis

| Economic Impact | Environmental Impact | Social Impact |
|---|---|---|
| • Eliminate home-owner flood repair<br>• Increase in property value<br>• Improve access to business<br>• Increase stormwater fee | • Emission during construction (Short term)<br>• Increase in sedimentation going into the detention basin from erosion at the end of the pipe<br>• Promote wildlife's access to water | • Improve quality of life with no flooding<br>• Noise pollution (Short term)<br>• Detours during construction (Short term)<br>• Improve access to business |

Figure 26: Fanning Wash Flooding

# References


[1] ADOT. *Arizona Department of Transportation Highway Drainage Design Manual.* 2nd Edition. Phoenix, AZ, US. ADOT, 2014

[2] City of Flagstaff. (2023, April). Flagstaff City Code. Flagstaff, Arizona: Code Publishing Company.

[3] Coconino County Public Works. *Coconino County Drainage Design Manual.* Flagstaff, AZ, US. 2020.

[4] Google Maps [online] Available: https://www.google.com/maps/@35.2002321,-111.602334 3,12.32z

[5] Google Maps [online] Available: https://www.google.com/maps/@35.2194301,-111.6029503,16z

[6] The City of Flagstaff Utilities Division. *CITY OF FLAGSTAFF STORMWATER MANAGEMENT DESIGN MANUAL.* Flagstaff, AZ, US. City of Flagstaff Engineering Division Stormwater Management Section. 2009.

[7] *Northeast Area Master Drainage Study,* 28-Jul-2010. [Online]. Available: https://www.flagstaff.az.gov/DocumentCenter/View/54860/Master_Plan_-Phase_-3_-Report?bidId=. [Accessed: 13-Feb-2023].

[8] *The Rio de Flag Drainage Through the City of Flagstaff*. [Online]. Available: https://friendsoftheriodeflag.org/wp-content/themes/FC12-child/pdf/subwatersheds_3Dview.pdf. [Accessed: 13-Feb-2023].

[9] "Steady vs. Unsteady Flow Modeling", HEC-RAS 2D User's Manual, available online: https://www.hec.usace.army.mil/confluence/rasdocs/r2dum/6.0/steady-vs-unsteady-flow-and-1d-vs-2d-modeling/steady-vs-unsteady-flow modeling#:~:text=So%2C%20the%20use%20of%20a,the%20system%20during%20the %20event.

[10] "Stormwater and Drainage Master Plan", Kennedy Jenks, Available[online]: https://www.ashland.or.us/SIB/files/City_of_Ashland_Final_Draft_Storm_Water_and_Drainage_Master_Plan.pdf [Published: 19-Nov-2020]

[11] CPI Inflation Calculator, U.S. Economy, Available [online]: https://www.in2013dollars.com/us/inflation/2020?amount=1&future_pct=0.02#:~:text=Chained%20inflation%20averaged%205.00%25%20per,of%20%240.17%20for%20All%20Items).)

[12] Homewyse "Cost to excavate land", Available [online]: https://www.homewyse.com/services/cost_to_excavate_land.html [Update: Feb-2023]

[13] "Manholes ASTM C-478 & Components", Northern Concrete Pipe, Inc. - Durable, Reliable, Infrastructure, Available [online]: https://www.ncp-inc.com/price3.html [Accessed: 2020]

# Questions?