Rio de Flag Drainage Study

Artemis Designs

Team Members:

Emily Frazer | Destiny Gourley | Jenna McCaffrey | Daniel Segal

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List of Abbreviations

ADWR	Arizona Department of Water Resources
ATV	All-Terrain Vehicle
CFS	Cubic Feet Per Second
COE	Corps of Engineers
COF	City of Flagstaff
CWA	Clean Water Act
EIT	Engineer In Training
FAST	Flagstaff Area Stream Team
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
FPS	Feet Per Second
FUTS	Flagstaff Urban Trail System
LID	Low Impact Development
MSL	Mean Sea Level
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
PM	Project Manager
SMDM	Stormwater Management Design Manual
USFS	United States Forest Service
USGS	United States Geological Survey
WSE	Water Surface Elevation
WSS	Web Soil Survey

Acknowledgements

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1.0 Project Introduction

This project is focused on analyzing the channel conditions for the section of Rio de Flag flowing from Herold Ranch Road to Foxglenn Park. This includes identifying the major points of concern within the channel and where the points of concern occur. Currently, the area suffers from poor stream conveyance, creating standing water pools in areas of heavy public use (this increases insect load, a potential health hazard) causing excessive erosion in these areas and reduces the flow available to downstream portions of the reach.

1.1 Project Location

The reach is located in the City of Flagstaff in Coconino County, Arizona between the upstream culvert at Herold Ranch Road, due East of the junction with S. River Valley Road, and the downstream culvert at Foxglenn park crossing under East Butler Ave. The area can be seen highlighted in yellow in Figure 1, below, while Figure 2 provides a closer image of the reach.

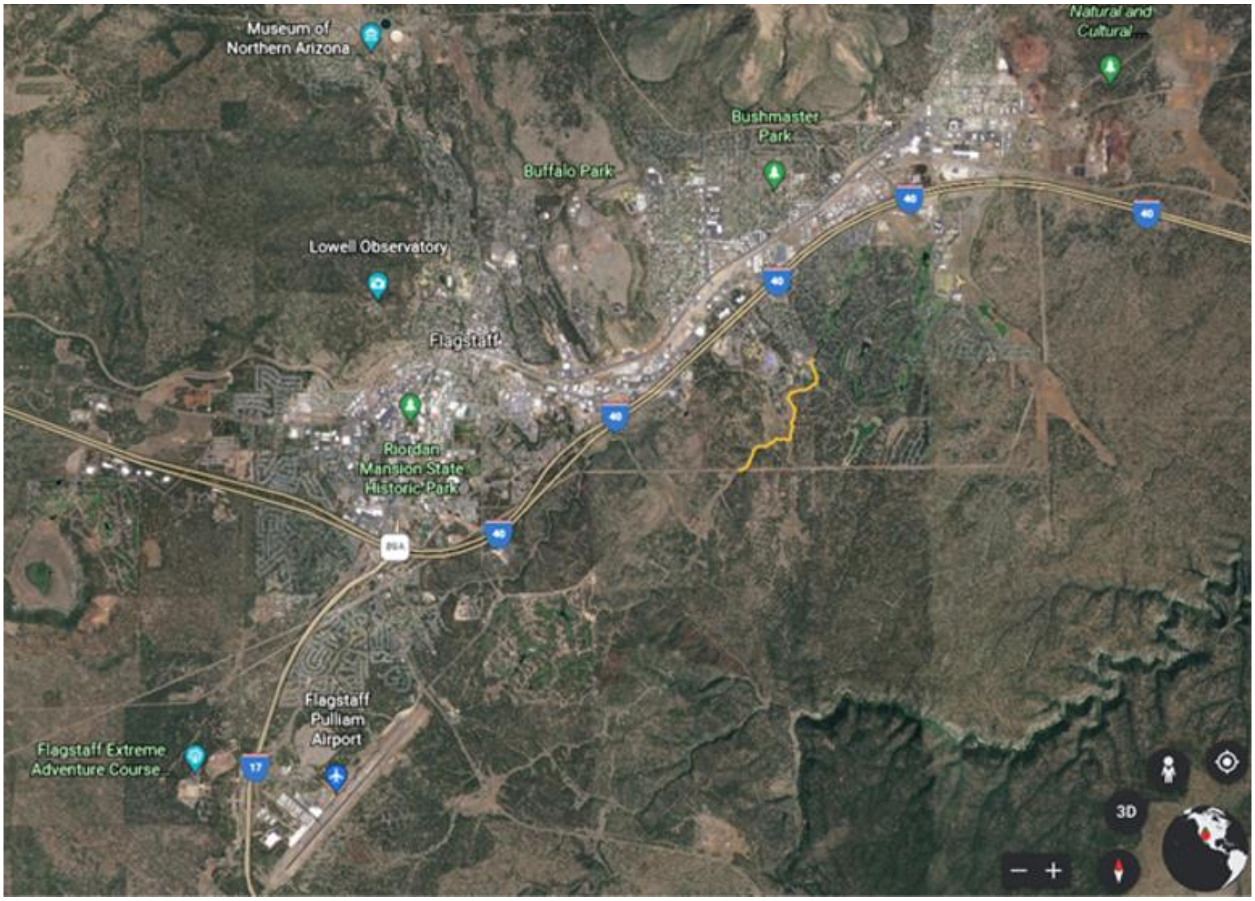


Figure 1: Vicinity Map, Studied Reach Highlighted in Yellow [1]

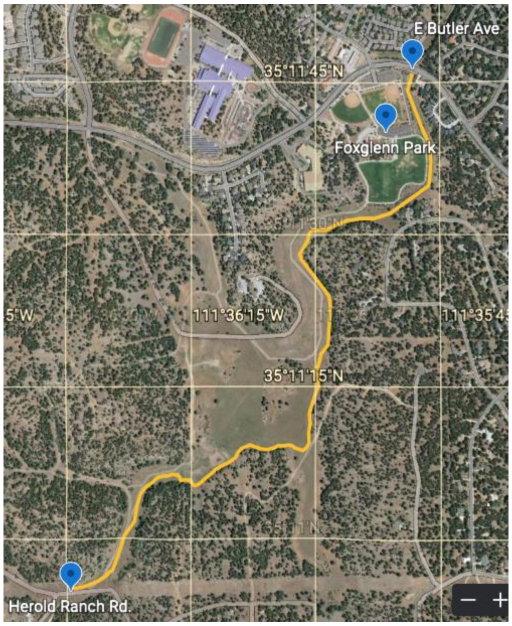


Figure 2: Overview of Reach [1]

Much of the reach runs along a portion of the FUTS, an organization of mixed-use, recreational trails that weave through and around the City of Flagstaff, which are owned and maintained by the City of Flagstaff. Figure 3-3 below is a satellite image of the channel (right), the FUTS trail (center), and a rogue ATV trail (left), highlighting the issues related to the mixed-use nature of this section.

Figure 3: Example of Multi-use Section of Reach [1]

1.2 Current Conditions

This section of Rio de Flag currently acts as a part of the city stormwater management system, as such, the City of Flagstaff Stormwater Manager supplied the solicitation for this project and has described the current conditions of the reach as "a real mess." Aspects that need to be addressed include the proliferation of invasive plants, the buildup of public refuse from recreational and homeless use, and soil degradation caused by unrestricted off-roading and ATV usage, erosion, detention, stream bifurcation, and retention.

1.3 Project Constraints

One of the major constraints for this project is the lack of information that is available for this area of Flagstaff. This section of Rio de Flag is almost 1.5 miles long and has extreme shifts in channel design needs that would require a lot of time, planning, and money. A shift in land ownership could prolong or even alter the design process.

1.4 Objectives

The major objectives for this project consist of identifying the prominent issues within the reach and creating a suite of potential solutions for these points of concern. The first objective will be completed by conducting a thorough investigation of the site, gathering all available information for this area, and collating all relevant data. The second objective will be completed by assembling all potential solutions to these issues and paring down the suite to the most applicable and feasible alternatives given the set of project constraints.

2.0 Site Investigation

An initial site investigation was conducted. Photographs taken by the team are found below Figure 4 to Figure 8. Prior to the site investigation, all members of the group created and signed a safety plan document, which can be found in Appendix A. Based on the results found during the site investigation, the existing channel conditions have many geomorphic instabilities. The areas of concern throughout the reach have been grouped into five different categories. The five different categories are detention, retention, erosion, silting, and garbage pollution.

2.1 Field Visits

Field notes were taken during the site investigation events, these detail the current conditions of the channel. The hand-written field notes can be found in Appendix B.

The images below denote specific areas of concern within the reach that were used to create the five different categories of focus for the drainage study. A photo log, which contains more images of the current conditions of the site, can be found in Appendix C.

The image below provide examples of detention within the reach of the Rio de Flag.

Figure 4: Detention Representation Within the Reach, photo by Jenna McCaffrey

The image below provides an example of retention within the reach of the Rio de Flag.

Figure 5: Retention Representation Within the Reach, photo by Destiny Gourley

The image below provides an example of silting within the reach of the Rio de Flag.

Figure 6: Silting Representation Within the Reach, photo by Jenna McCaffrey

The image below provides an example of erosion within the reach of the Rio de Flag.

Figure 7: Erosion Representation Within the Reach, photo by Emily Frazer

The image below provides an example of garbage pollution within the reach of the Rio de Flag.

Figure 8: Garbage Pollution Within the Reach, photo by Daniel Segal

2.2 FAST Form

In the FAST (Flagstaff Area Stream Team) form, found in Appendix D, one will find the stream reach inventory form. This form provides a general idea of the current conditions of the area being surveyed. The first part of this form discusses what the average channel reach conditions are like. It gives a general indication of what condition the site is in, denoting if it is in dire need of immediate restoration. The rest of the form outlines other specific types of data like soil material, vegetation, and other special observations. This form also outlines immediate recommendations for the area including inferences for possible solutions to the issues at hand.

2.3 Identification of Improvement Areas

During the initial site visits, team members walked along the reach and identified different areas that needed improvement. This was determined if the team members found that the area was failing due to signs of erosion, detention, garbage pollution, silting, retention, etc... 13 areas in need of improvement were identified during this process, and an image showing the locations can be found in Appendix C.

After analyzing the 13 improvement areas, the team narrowed the original improvement area sites into 9 sites that were spread out evenly throughout the reach and conveyed all major concerns. An image showcasing the 9 selected sites is shown below.

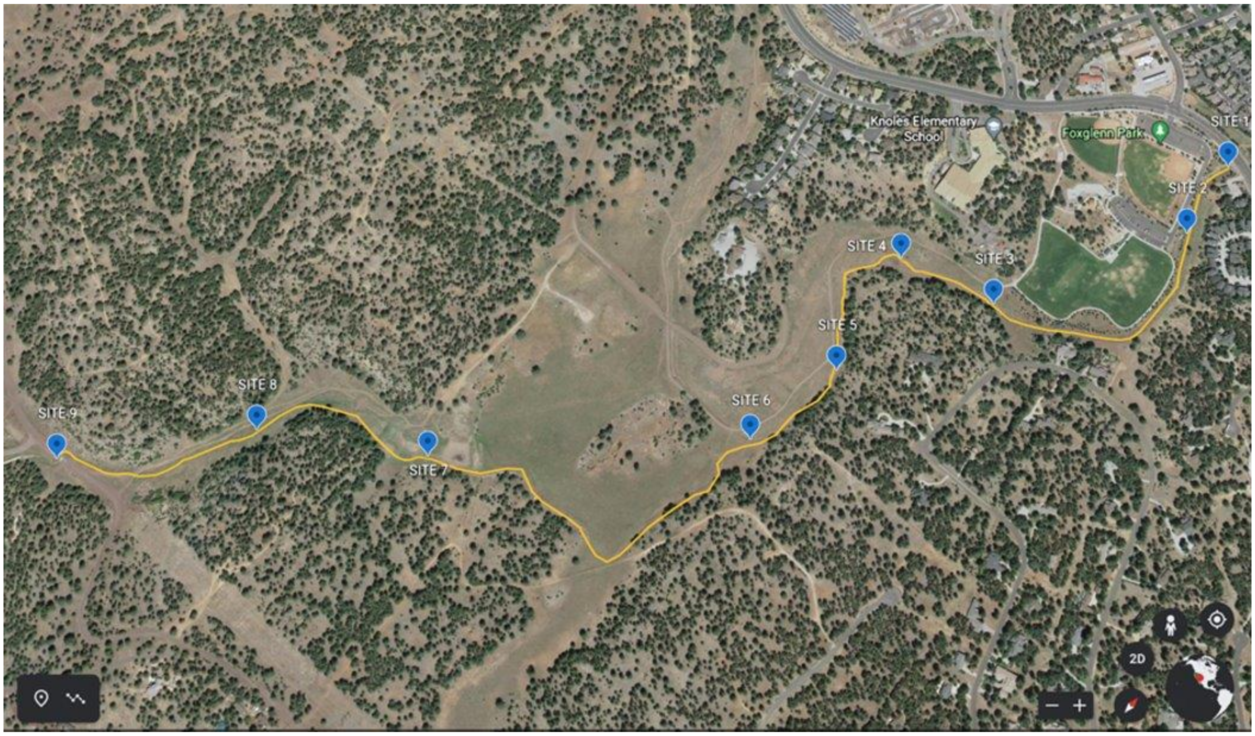


Figure 9: Site Overview Map [1]

2.3.1 Site 1

Site 1 was determined to have signs of erosion as seen circled in red in figure 10.

Figure 10: Image of Site 1, photo by Destiny Gourley

The cross-section analysis for Site 1 can be found in Appendix I, showing the cutting of the thalweg (circled in red to the right) and incision of the bank (circled red, left) due to excessive erosion.

2.3.2 Site 2

Figure 11 shows Site 2 which contained pooling water, a sign of detention (as seen circled in red) followed by signs of siltation. Detention and silting are concerning for they inhibit water conveyance.

Figure 11: Image of Site 2, photo by Daniel Segal

Appendix I contains the cross-section analysis conveying these concerns.

2.3.3 Site 3

Site 3 shows signs of erosion. The velocity in this area is higher than it should be, which can lead to erosion occurring. Figure 12 shows site 3, and the red circle shows where there are signs of erosion.

Figure 12: Image of Site 3, photo by Emily Frazer

The cross section of site 3 can be found in Appendix I.

2.3.4 Site 4

Site 4 shows signs of detention and silting. The red circle in Figure 13 shows where there were signs of detention in this section of the channel. The slope in this area is extremely small, which could easily lead to detention within the channel.

Figure 13: Image of Site 4, photo by Destiny Gourley

The NRCS analysis of this cross-section can be found in Appendix I.

2.3.5 Site 5

Figure 14 shows Site 5 with evidence of erosion circled in red.

Figure 14: Image of Site 5, photo by Jenna McCaffrey

Site 5 showed evidence of high velocity discharge with a lack of vegetation in and around the channel, large boulders deposited, and no evidence of standing water. The results of the hydraulic analysis of this site can be found in Appendix I.

2.3.6 Site 6

Figure 15 shows Site 6, including the outlet of one of the two culverts connecting the Rio de Flag to Spruce Wash.

Figure 15: Image of Site 6, photo by Emily Frazer

Site 6 is the confluence with Spruce Wash, there are two culverts that convey the discharge. This site is subject to excessive sedimentation due to the museum fire scar that is part of the spruce wash watershed. The geometry of the site is constantly in flux due to this silting and the very shallow slope at this section of the channel. The image shows one culvert (circled red, above) and a newly formed sandbar due to silting (circled red, lower left).

2.3.7 Site 7

Site 7 showed obvious signs of retention within the channel. In the photograph below, the retention is highlighted in the red circle.

Figure 16: Image of Site 7, photo by Destiny Gourley

The cross section of this site can be found in Appendix I. The overall bankfull width of this section of the channel is nearly 50 feet while the slope is only around 0.05% which is very small. Due to the large bankfull width and the small slope, this was assumed to be the reason for retention within this site.

2.3.8 Site 8

Site 8 was classified as a major area of concern because the channel at this site has separated into two different channels. This was assumed to have occurred from ATV riders creating their own trail without thinking of the negative impacts that may occur from creating this new channel. Figure 17 shows both channels circled in red.

Figure 17: Image of Site 8, Photo by Jenna McCaffrey

The cross section of this site can be found in Appendix I. The cross section shows how there are two defined channels in this area, each including their own banks and thalwegs. It was important to improve this area so that there can be more control over the stormflow when conditions exist. This could be accomplished by combining the two channels into one for better stream conveyance.

2.3.9 Site 9

The following figure shows Site 9 where detention and silting were prevalent. It can be seen there are high water levels which often lead to overflow onto Herold Ranch Rd.

Figure 18: Image of Site 9, Photo by Emily Frazer

See Appendix I for the NRCS cross-section analysis of this site.

3.0 Hydrologic Data

Hydrological studies performed in the past by City of Flagstaff and FEMA are used to determine mean and typical to extreme flow conditions of the Rio de Flag. Data provided by USGS is used to develop a broader understanding of the current conditions upstream of the reach.

3.1 Previous Site-Specific Study Assessment

Artemis Designs analyzed results from the Flood Insurance Study (FIS) to obtain the peak discharge values within the watershed and nearby streams [2]. The flooding sources used were found under the Rio de Flag category noted as: “At confluence of Switzer Canyon Wash” and under Switzer Canyon Wash as, “At confluence with Rio de Flag.” The 10-year discharge for the reach at the confluence with Switzer Canyon was found to be 1050 cfs, while the discharge in Switzer Canyon wash is 280 cfs. Therefore, the discharge upstream of this confluence was determined to be 770 cfs, this value will be the threshold flow rate for the channel length as it fulfils the NRCS (see section 4.0 for details) and FIS results. The discharge values for these and other locations determined from the FIS are shown in Appendix E, while Appendix F contains the discharge rating table for only the studied reach [13].

3.2 Subbasin Delineation

To determine the area contributing to the flow within the reach, the team delineated the subbasin via a service offered by the USGS called Stream Stats. The entire drainage basin encompasses 100.04 square miles, with a perimeter of 72.68 square miles, seated at an average elevation of 7619 feet (MSL) with the outlet at 6777.59 ft (MSL). The Southern face of the San Francisco Peaks provides the initial flow capture at 12337.87 feet (MSL), conveyed through the City of Flagstaff via the natural Rio de Flag channel as well as the public storm drainage system maintained by COF.

3.3 Subbasin Properties

The team used USGS application WSS to determine the various properties of the subbasin as stated in the previous section [3]. It was determined that the subbasin has an annual average of 24.1 inches of precipitation, with August and March being the months of greatest precipitation at 2.8 inches while June has the lowest average monthly precipitation of 0.5 inches. 74% of the land within the subbasin is considered having high permeability, which provides avenues for much of the precipitation to be absorbed into the soil and aquifer below before entering the reach depending on the intensity of rainfall. The soil base is predominantly alluvial Lynx Loam with 0% to 2% slopes, the full WSS Report can be found in Appendix G.

4.0 Hydraulic Data

The hydraulic properties of the reach were determined through surveys of each of the improvement areas. This data was entered into NRCS X-Sec Analyzer and HEC-RAS hydraulic modeling software to determine the flow characteristics of the reach at each cross section using the hydrologic information determined earlier.

4.1 Input Data Development

The team conducted in person surveys of each improvement area to determine the geometric layout as well as other physical properties of each respective cross section. Appendix H contains some field notes taken from the surveys including some sketches of the improvement area, topological survey data taken with an auto level, and general notes.

4.2 Hydraulic Modeling

The data collected from the surveys were entered into NRCS X-Section Analyzer, a software developed by USGS to determine flow properties using various forms of Manning's Hydraulic Equations. Each cross section was modeled to determine bankfull flow rates and associated WSEs (see Appendix I). These values were used to create a full channel analysis using HEC-RAS. The HEC-RAS models utilize the standard step method to determine flow regime, WSE, velocity, and critical values for the entire channel at each cross section. The results from the HEC-RAS models can be found in Appendix J and were used to determine the conditions within each area of interest. Where velocities were greater than those enumerated in the SWMDM, it was determined that erosion was of great concern. In areas where water flow velocities were found to be too low, these were determined to be areas of water detention and excessive silting. This data was used to compile the list of improvement area categories as shown in the following section.

The prevailing flow regime for the reach as studied was sub critical, which is readily demonstrated by the excessive silting and water detention. Appendix K shows an example of the reach orthogonal view for flows under bankfull conditions at site 1 (extreme downstream). Appendix L contains allowable velocity values from the COF SWMDM to determine the standard values for erodible channels. Where velocities exceed 3.5 fps, these are areas of erosive concern.

The NRCS X-Section Analyzer was used for each of the nine different sites, this created unique cross sections for each site, the site-specific cross sections can be found in the appendices below in Appendix I.

5.0 Categorical Analysis of Improvement Areas

Appendix C below includes a photo log from the site investigation where major sections of the reach were determined and deemed critical for the feasibility analysis. The photo log provides examples of different types of areas where at least one of the five categories of improvement areas were present.

5.1 Detention

Detention is defined as an impoundment which temporarily detains runoff and releases that runoff at a controlled rate over a specified period of time. Currently, the detention basin is not functioning in the way it was designed, and thus a major area of concern for the drainage study.

There are currently many different sections of the channel within the reach that create, or have, detention. This is when the slope from the thalweg to the right/left of bank is too large to generate a high enough flow for the fluid within the channel to continue to properly flow. As seen in the photo log, it is apparent that when there is detention, the change in slope from the thalweg to the banks is far too steep for the water to continue to flow throughout the channel.

5.2 Retention

Retention basins are used to manage stormwater runoff and prevent downstream erosion while improving the quality of the water within the stream. The retention pond should allow particles to settle and various types of vegetation to take up nutrients if created correctly. Currently, the retention basin is failing to function in the way it was designed, and thus a major area of concern for the drainage study.

At the time of site investigation, there was only one retention basin that was found. In the appendices below, one can find photographs taken at the site that detail the retention basin. The retention basin found within the reach was the largest area of concern in terms of surface area. This retention basin was found to be in an area with very little change in elevation from the banks, thalweg, and top of banks. Although little change in elevation is in the design of retention basins, it should include areas for discharge flow along with inflow. In the retention basin within the channel, there is no location for discharge, so the pond was not designed for discharge flow.

5.3 Erosion

Erosion is caused by the detachment and transport of soil by rainfall, runoff, melting snow or ice, and irrigation. Excessive erosion can threaten the production of agricultural and forest products. From the current conditions of the channel, erosion is one of the known causes of silting, detention, and retention within the channel.

Erosion causes the greatest amount of damage within the selected areas of concern within this reach. Erosion is present in nearly every section studied. Prior to the site investigation, there was a large flooding event caused by the Museum Fire Burn scar. This generated 100+ storm year flow events which the channel was not originally designed for. This could have been a key reason for the excessive amounts of erosion within the channel at the time of the site investigation.

In the reach, most of the erosion was found on the sides of the banks. This showed that the design of the channel was not designed to withstand the harsh stormwater flows that came in the months prior. The banks were failing to withstand structure when the flows were higher.

The following table shows the determined velocities in the channel at each cross section under 10-year flood conditions.

Table 1: Channel Velocity (10-year flood)

Site	Flowrate (cfs)	Velocity (fps)
1	770	5.54
2	770	6.18
3	770	7.98
4	770	3.73
6	770	9.59
8	770	6.86
9	770	4.60

Table 1 shows the modeled flow velocity for the channel cross sections that exceed the standard value of 3.5 fps for alluvial soils in COF stormwater channels- sites 1, 2, 3, 4, 6, 8 and 9. These sites are marked as areas of erosion concern.

Table two demonstrates the velocities in the channel at each cross section that exceeds 3.5 fps under bankfull conditions at site 1.

Table 2: Channel Velocity (bankfull Site 1)

Site	Flowrate (cfs)	Velocity (fps)
3	34.50	4.84
6	34.50	4.26
8	34.50	4.27

Table 2 shows the modeled flow velocity for the channel cross sections that exceed the standard value of 3.5 fps for alluvial soils in COF stormwater channels- sites 3, 6, and 8. These sites are marked as areas of erosion concern, under yearly conditions.

5.4 Silting

Siltation, or the deposit of particulate matter within waterways, is caused by upstream soil erosion from fast moving water and/or effluent from earthworks. The current siltation issues in this reach are attributed to the recent release of soil upstream from the Spruce Wash watershed, associated with the burn scar from the Museum Fire of 2019.

Silting, along with erosion, was also one of the largest areas of concern within the reach. Silting and erosion go hand-and-hand. Erosion from the banks of the channel creates excess particulate matter within the channel surface. The material of the silting within the channel can be many different sizes and shapes all relying on the material that was holding the bank walls up prior to eroding. Other sources of silting were found in the bed of the channel where silting from the banks of the stream has been transferred through flooding events.

Sites where the flow slows to speeds below the water's capability to transport the silts further will accumulate an increasing amount of material as the issue is compounded by each deposition. Sites that do not reach the minimum self-cleaning velocity of 2 fps [3] are areas of silting concern. Table 3 lists the sites and the flow rates modelled that match this concern.

Table 3: Modeled Flow Velocities for Silting Sites

Site	Flowrate (cfs)	Velocity (fps)
1	34.50	1.76
2	34.50	1.16
4	34.50	1.81
5	34.50	0.30
7	34.50	0.62
9	34.50	1.40

Though no site exhibits sub-2 fps velocities at the typical 10-year flood flow rate, the table shows all the sites where these velocities do occur under bankfull conditions at Site 1. These values are low enough to position these sites as areas of silting concern, especially during low-water events.

5.5 Garbage Pollution

Garbage pollution is caused by community members not disposing of their trash correctly, winds collecting trash from nearby garbage collection facilities, and from upstream precipitation bringing unwanted pollution into the storm channel.

Although garbage pollution is not super apparent in the photo log, it is an especially important aspect to the feasibility analysis. Garbage pollution can change on a day-to-day basis. It can depend on the number of community members visiting the nearby park, Fox Glenn, and the number of community members using the FUTS that a section of this reach parallels. Garbage Pollution can depend on the weather, as windy days can cause garbage to blow into the channel, rainy weather can also have a significant impact on the pollution within the channel. As this channel typically only flows during large stormwater events, garbage from other upstream connecting channels can be swept down into this section.

6.0 Suite of Potential Solutions

Below, several potential solutions are discussed for each of the areas of concern. One solution or a combination of multiple solutions were chosen for each of the five areas of concern. However, the solutions did sometimes vary from site to site. The variations between sites will be discussed below.

6.1 Detention

6.1.1 Potential Solutions

6.1.1.a Excavation

Since the current slope of the channel in some areas is causing unwanted detention within the reach, the slope of the channel will need to be adjusted to fix this issue. This can be done by excavating these improvement areas of the channel. Sediments and debris in these improvement areas can be removed to reshape the channel and increase its slope, allowing the water to flow properly and without unwanted detention. The slope will be increased where needed and this will allow the water to flow properly.

The areas where detention is an issue are those areas where the hydraulic models showed very low velocity values. These models will help to identify the major points within improvement areas that are causing unwanted detention due to concerning slope values. Since these specific areas are now identifiable, plans can be made to decide exactly how to reshape these channel areas that are impeding flow. The proper amount of sediment and debris can be removed to fix the slope, and this sediment can be used for other aspects of the channel restoration.

6.1.1.b Extended Detention Basin

Constructed through filling and/or excavating which provides temporary storage of stormwater runoff. An outlet structure details and attenuates the runoff inflows while promoting settlement of pollutants. Extended detention basins are designed typically with multiple stages to provide runoff storage and attenuation for both stormwater quality and quantity management. It increases the time which the basin releases the stormwater runoff volume. A typical extended detention basin ranges from 3-12 feet in depth [4]

6.1.1.c Subsurface Extended Detention Basin

Like what was discussed in alternative solution 6.1.1.b above, but a subsurface extended detention basin is located completely below the ground surface. The runoff is stored in either a vault, pipe, or stone bed. The water is then released from storage when the channel can withstand the added flow [4].

6.1.1.d Emergency Spillway

Used for conveying stormwater runoff from 25-year, 25-hour storms while maintaining at least one foot of freeboard between the peak storage elevation. It should safely convey estimated 100-year storms without overtopping the embankment. Overflow must discharge to the stable channel/ stable area. An emergency spillway should be located on undisturbed non-fill soil to prevent excess erosion within the channel [5].

6.1.2 Assemble Most Probable Solutions

For the detention concern that is seen throughout the reach, the most probable solution is to excavate the area affected by detention to help fix the channel shape which will aid in properly conveying the flow.

6.2 Retention

6.2.1 Potential Solutions

6.2.1.a Fill

There is currently a retention pond within the channel reach. This retention pond should be a detention pond, but when it was constructed, it was dug too deep. So, the flow is not being released like it should be. Instead, it is creating an unhealthy standing pond. One possible solution to this concern is to use excavated soil (mentioned above in 6.1.1) to fill in this retention pond. This way it will not be as deep, and it will behave as a detention pond, which is how it should be functioning.

Use the excavated soil from 6.1.1 to act as fill.

6.2.1.b Flow Alteration

Reroute flows around the low points. Runoff that exceeds the capacity of the storm channel must be rerouted via the lower points of the section of the reach. This will decrease the amount of water that gets captured in the higher areas of the reach which cause unwanted retention. This can be done by creating several alternative routes along the lowest points of the channel [6].

6.2.1.c Aquatic Bench

Reduces pollutants and stabilizes soil. Comprised of a shallow area inside the perimeter of the normal retention pond that helps promote growth of aquatic and wetland plants. In return, it also helps to reduce shoreline erosion and captures floatable trash. It also acts as a barrier to re-suspension of sediments and other pollution deposited during storms [6].

6.2.2 Assemble Most Probable Solutions

For the retention issue that was seen in reach, the most probable solution is to fill in the areas that are suffering from this issue. Filling in these areas, so that there is less volume available, will help prevent standing water within the channel for extended periods of time.

6.3 Erosion

6.3.1 Potential Solutions

6.3.1.a *Terrace*

Develop terraces to reduce water velocity. Terraces reduce the amount of flow and the velocity of the water moving across the soil surface. Terraces are often viewed as “steps” and the “steps” help reduce the amount of soil washed away when a storm event occurs within the reach. They break up the rate of water decent into the middle section of the channel. It allows heavy rains to soak into the different steps rather than run off, taking soil with it, and creating silting within the channel too.

6.3.1.b Alternative Materials

Install alternative materials to channel bottom to increase friction thereby slowing flow velocity such as grasses, erosion control blankets, and fiber rolls. Erosion control blankets are meant to slow down speed which water moves across the surface [7]. The material is usually something with ridges and divots to slow down the flow. Fiber rolls are rolled into large diameter “logs”. They are placed on the banks of the channel and help pool up and slow down the water long enough for any sediment in water to settle out.

6.3.1.c Bioengineering

In cases that show light erosion within the channel, well-established vegetation can stabilize the soil. It is important to choose plants that are adapted to the condition of the site, in terms of both moisture and sun exposure. It is also important to use native species that will thrive in the environment so that they can perform at the fullest potential. Pole plantings, or live stakes, help provide an inexpensive approach to bank stabilization, this is due to native species growing up the pole plantings helping reduce erosion and silting within the channel [8].

6.3.1.d Retaining Wall (Rip Rap)

Install a range of rocky material places along the banks of the reach. The size of the rock needed depends on the steepness of the slope and how fast the water typically moves through the reach. It allows water to drain easily from the banks without carrying soil particles, causing more silting throughout the reach. It should be used on slopes steeper than 1V:1.5H [8].

6.3.1.e Coir Logs

Install coir logs in areas where the stream has a low-velocity flow. Coir logs are made from coconut fibers and biodegradable twine and rolled up into “logs”. A trench $^{2}/_{3}$ the diameter of the coir log is dug at the edge of the riverbed and the bank. Logs are secured using wooden stakes and provide a growing medium for new vegetation. Seeds/cuttings are installed in the log. So, as the coir log biodegrades, plants establish a root system into the bank, continuing to function as a "coir log" [7]. This both stabilizes the banks of the channel and protects excess silting from occurring within the channel.

6.3.2 Assemble Most Probable Solutions

For the erosion areas of concern seen throughout the channel, it was determined that the most probable solution is to install alternative materials at the bottom or sides of the channel to help prevent erosion from occurring in the future.

6.4 Silting

6.4.1 Potential Solutions

6.4.1.a Weirs

Build a series of weirs to reduce the transport of silt and contain it at an easily accessible location for future excavating. Weirs allow water to pool behind them, allowing water to flow steadily over the stop while pushing the sediment out of the surface of the flow [9]. Reducing the sedimentation within the flow downstream.

6.4.1.b Check Dams

A semi-permanent solution where a small dam is constructed across the channel to lower the velocity of flow. A check dam can be constructed out of stone, sandbags, or logs. Found in channels with little vegetation. It reduces flow in small channels by the material within the check dam halts the water from carrying sedimentation further downstream [10].

6.4.1.c Sediment Traps

Deep holes dug into the bottom of the channel, they catch excess sand and siltation within the flow as it moves downstream. It allows sediments within the water to settle out during infiltration before the runoff is discharged [11].

6.4.1.d Alternative Materials

See section 6.3.1.b above for details.

6.4.1.e Bioengineering

See section 6.3.1.c above for details

6.4.1.f Coir Logs

See section 6.3.1.e above for details.

6.4.2 Assemble Most Probable Solutions

The most probable solution for the silting issue seen within the channel is to install alternative materials within the channel to help prevent the channel materials from silting.

6.5 Garbage Pollution

6.5.1 Potential Solutions

6.5.1.a Grates

Apply culvert grates to inhibit garbage pollution from traveling into the channel from the tributary channels and park outlets.

6.5.1.b Garbage Cans

Supply more garbage bins along the FUTS parallel to Rio de Flag. This will create a convenience factor for the community members while near the channel.

6.5.1.c Increased Signage

Install more signs throughout the channel upper banks indicating where close garbage cans are to dispose of personal trash.

6.5.1.d Netting System

End of culvert netting is installed at the downstream section of the culvert. It wraps around the outside diameter of the culvert and catches garbage along with excess debris in the channel while water flows through [12].

6.5.1.e Trash Trap

Prevents any trash and debris from passing through the grates forming the trap above ground where the flow will reach at maximum capacity. The trash trap is placed over a section of the channel so that when the flow is high enough the trap will get trapped on top of the grates instead of flowing down the channel [12].

6.5.2 Assemble Most Probable Solutions

For the garbage pollution that was seen throughout the entire channel, the most probable solution is to install culvert grates to help prevent garbage from entering the channel.

6.6 Final Design Recommendations

Based on the information provided in sections 5 and 6, and the final design recommendations as highlighted and explained above, the following are determined to be the most probable solutions to each given conveyance concern.

Erosion affects sites 1, 3, 5, and 8. For sites 1, 3, and 5, it is recommended that alternative materials be used to armor the banks with riprap. This will help to slow the water velocity and therefore prevent erosion from continuing to occur in the future. Site 8 is different than the other three sites that suffer from erosion issues. Site 8 currently has two different channels that have formed. This leads to standing water in the area in addition to the other issues. So, it is recommended that for site 8 the second channel be filled, the main channel be excavated to help with flow, and the banks be armored with riprap after this is completed.

Detention and silting affect sites 2, 4, 6, and 9; however, due to the differing root causes, two different plans have been selected to rectify these issues. Site 2 is inundated with silts transported by the soccer field at Foxglenn park; as such, armoring the basin in the park with riprap or other alternatives would reduce the silts transported into the Rio. Currently, the Parks department simply pulls these silts a few feet away from the outlet of the culvert, which creates small ponds. Site 4 has a very shallow slope and is inundated with grasses that slow the water creating small detention ponds and allows particulates to settle. These sediments would be reduced when upstream conditions are improved, and the water would flow better after excavation to remove the grasses and improve the geometry of this channel section to more ideal dimensions. Sites 6 and 9 suffer from similar conveyance issues, namely large volumes of water confined to relatively flat, wide basins causing ponding that allows particles to settle. Both sites are ideal locations to restore the shape of channel to ideal geometry through excavation and installation of riprap. The installation of a weir, from which the natural silts could easily be collected, is ideal for these sites as they are adjacent to roads and have too shallow of a slope to facilitate cost-effective dredging.

The retention area of concern is only seen at site 7. This area was classified to be beyond the scope of this project. It is recommended that further engineering study be completed. This area is large in bankfull width (nearly 50 feet), which makes the area far too large for a simple drainage study recommendation. But it is assumed that excavating the area to remove the earth material, fill the area to make the section level, and then reroute the channel to avoid potential future retention could be a potential solution to this problem.

For the garbage pollution areas of concern, the design recommendation is to install culvert grates. Garbage pollution was seen in all nine sites. This option seems to be the most functional of all the options, as well as one of the most affordable solutions. The group would also like to install signage throughout the reach. This will help to show people using the FUTS trail or the footpaths at Fox Glenn park where the nearest garbage cans are so that they will not litter into the reach. Hedges and trees are also recommended to be planted on the banks of the reach to catch the garbage that floats down the stream, this will help to contain the garbage all in one place if it passes through the culvert grates. There are a total of 5 culverts that need grates throughout this reach. Three of the five culverts will need 2 grates each: one at the inflow and one at the outflow section of the culvert. This will ensure safety and maximum potential garbage collection.

These solutions are assembled in a tentative plan set (Appendix N) that shows the existing layout with the suggested improvements overlayed in the appropriate areas. These plans are simply made to illustrate how and where the recommended solutions can be implemented, these are not to be considered exact diagrams of the sites, nor as a legal document for construction. An example of the ideal channel cross section can be found in Appendix N, following the plan set. This exemplifies the ideal conditions for every cross section, though the exact dimensions will vary based on existing channel widths, depths, and floodplains.

7.0 Summary of Engineering Work

Appendix M contains the summary table of the total staffing hours completed for the project. The project schedule demonstrates when these hours were completed in the context of the complete project timescale. The project schedule enumerates each task, the starting date, and the date of completion, which is compiled into a GANTT chart in Appendix P. Appendix P also shows the proposed schedule for the project. When the group was initially creating the proposal GAANT chart and scope, the plan for the overall project was to perform a restoration study on the 1.5-mile section of the reach. After reevaluating the goals and time limit of this project, the overall goal of the project was shifted to creating a drainage study of the reach instead of a restoration study. Therefore, the scope from the proposal shows different categories of analysis than what is performed in this report. Upon comparing the proposed GANTT chart to the final, one can note the 'site investigation' was intended to be finished at the end of August but rather was finished at the beginning of October. Likewise, the entirety of the project was intended to be finished by late November but instead was completed at the beginning of December.

8.0 Summary of Engineering Costs

The total materials and labor costs (Appendix R) are used to calculate the estimated sitework bid for this project, these are then combined with the cost of the engineering design to determine the complete project cost.

8.1 Cost of Engineering Work

The cost of engineering work is divided into personnel work and software fees as seen in the following table for the final estimate. Table 8 contains the estimated cost of engineering services divided into personnel hours.

Table 4: Proposed Engineering Cost

Category	Classification	Hours	Rate, $/hr	Cost
	PM	94.5	200	$18,900
	ENG	196	140	$27,440
	EIT	376	90	$33,840
Personnel	TECH	67	60	$4,020
Software Fees		Yearly	1300	$1,300
TOTAL		766		$84,200

The following table shows the actual costs of engineering work completed. Comparing the projected cost to the final proposed cost one can see the initial cost estimate was less than the final cost estimate, though only by a margin of 4.6%, an acceptable range for most engineering.

Table 5: Actual Cost of Engineering Services

Category	Classification	Hours	Rate, $/hr	Cost
	PM	93.5	200	$18,700
	ENG	195.5	140	$27,370
	EIT	408	90	$36,720
Personnel	TECH	69	60	$4,140
Software Fees		Yearly	1300	$1,300
TOTAL		766		$88,230

8.2 Cost of Implementing Design Recommendations

Each site was noted with the appropriate category of concerns. For each area the decision matrix identified the most ideal solution to rectify the conveyance issue(s). At each site, each of the conditions were identified and a solution unique to each area of concern was used to calculate the total cost for the given site. For example, in Site 1 two conveyance issues were determined to be silting and erosion, the solution found using the decision matrix for erosion was excavating and the solution found for silting was utilizing alternative materials. In the table for Site 1, the costs for both excavating and implementing alternative materials are combined for the ultimate cost of Site 1 remediation. All sites are described in Appendix R.

The total cost for the siteworks at the project throughout all 9 sites (excluding site 7) and the garbage pollution areas of concern were found to be $25,704. An additional $2,000 was added to this price for soil transport. So, the final cost estimate came to $27,704. The table showing the breakdown for each site's cost and total cost can be found in Appendix Q. In this table, one can see the total predicted costs of the project, which includes the total excavation for the entire reach. This value is around 40 cubic yards. This value was derived from the cross sections collected during the initial site visits, and adding up the total volume of each cross section that required excavation.

9.0 Impacts

Economic, societal, and environmental impacts were analyzed as part of the triple bottom line analysis. These are used to inform stakeholders of the possible impacts the project can have within the community, as well as the potential benefits once completed.

9.1 Economic

Restoration of this section of the Rio de Flag is not likely to produce revenue for the city or future landowners; however, by allowing greater access to recreational activities due to less flooding events, more visitors are likely to avail themselves to the area and surrounding businesses. Additionally, reduction in flooding events will reduce the costs of cleanup and repairs within the channel and surrounding areas. These reductions in costs for the city with maintenance and repairs will be an economic stimulant for the city and the local community.

9.2 Societal

Restoration of this section of Rio de Flag will have an impact on the local community by creating a space for more recreational activities. This increase in personal recreation may inconvenience ATV users, who typically use the channel, FUTS trail, and other social trails at their leisure. This project will help beautify the area by reducing garbage and detritus pollution within the channel, it will also reduce the likelihood of flooding the FUTS trails that many community members use daily. Improving the water quality throughout the stream could help to create a positive correlation in the health of people living near the reach, including the proposed residential communities. The results of this project could be used to educate the community on the issues with, and methods to rectify these within a stream. Signage could be installed to inform the public of the restoration methods used and how they could possibly be more involved in future stream restoration projects.

9.3 Environmental

Restoration of this section of Rio De Flag will promote proper function of the channel, floodplain health, plant diversity, and wildlife habitat. Likewise, ATV impacts on the channel and surrounding environment will be reduced. Long-term goals for the project include positively impacting the environment with improved water quality due to better water conveyance and reduced urban runoff, as well as preserving the natural biota within the channel. These advancements can provide surrounding areas of the stream with more vital riparian habitats and enhanced biodiversity. Successful implementation of this project is likely to encourage other stream restoration projects in Flagstaff and the whole of Arizona.

10.0 Conclusion

Artemis Designs collected pertinent data for analyzing the current conveyance conditions within the selected reach of Rio de Flag. Using software to quantify these issues, the team was able to convey the primary concerns along with creating a suite of potential solutions. Necessary background information was provided for future analysis and design of the reach along with considerations of impacts the projects may have socially, economically, and environmentally. Suggested solutions for the areas of concern were showcased with tangible support for future design implementation. The team utilized surveying equipment, NRCS, HEC-RAS, and AutoCAD software, previous studies, and engineering judgement to complete the drainage study of this reach of Rio de Flag. The team assembled a cache of potential solutions for each respective area of concern with sufficient evidence to support these decisions for future engineering analysis.

11.0 References

[1] "Google Earth," [Online]. Available: https://earth.google.com/web/@35.18457654,-111.60653655,2077.3789976a,9446.49157517d,30y,0h,0t,0r/data=MicKJQojCiExWktGdEFQUk1QV1ctb1RJaUktaktpRTlWSldWcjNmOXQ. [Accessed 06 02 2021].

[2] "Flood Insurance Study (FIS)," City of Flagstaff, 03 09 2010. [Online]. Available: https://www.flagstaff.az.gov/3722/Flood-Insurance-Study-FIS. [Accessed 23 11 2021].

[3] "Web Soil Survey," [Online]. Available: https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx. [Accessed 01 11 2021].

[4] City of Flagstaff Stormwater Management Design Manual, Flagstaff: City of Flagstaff, 2009.

[5] "Extended Detention Basin," NJ Stormwater Technical Manual , 01 2011. [Online]. Available: https://www.njstormwater.org/pdf/tech_manl_6_4_extended_detention_basins.pdf. [Accessed 23 11 2021].

[6] "Chapter 3 - Detention Basins for Flooding Control," [Online]. Available: Chapter 3 - Detention Basins for Flooding Control . [Accessed 23 11 2021].

[7] "Draft District of Columbia Stormwater Management Guidebook," District of Columbia Stormwater Management, 08 2012. [Online]. Available: https://oaa.dc.gov/sites/default/files/dc/sites/ddoe/publication/attachments/Ch3.9StormwaterPonds_0.pdf. [Accessed 14 11 2021].

[8] K. W. R. Sutton, "Erosion Control," [Online]. Available: https://depts.washington.edu/propplnt/Chapters/erosioncontrolchapter%5B1%5D.pdf. [Accessed 14 11 2021].

[9] A. S. J. Garanaik, "River Bank Protection," 11 04 2013. [Online]. Available: https://www.engr.colostate.edu/~pierre/ce_old/classes/ce717/PPT%202013/River%20Bank%20Protection.pdf. [Accessed 14 11 2021].

[10] J. Hanania, K. Stenhouse, L. V. Suarez and J. Donev, "Weir," Energy Education, 28 04 2020. [Online]. Available: https://energyeducation.ca/encyclopedia/Weir. [Accessed 14 11 2021].

[11] E. Roy, "Check Dams," in *Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas*, Northampton, US EPA, 2003, pp. 64-67.

[12] "Sediment Trap," 01 10 2008. [Online]. Available: https://www.springfieldmo.gov/DocumentCenter/View/3447/Sediment-Trap-PDF. [Accessed 14 11 2021].

[13] "Trash Capture Technologies," EPA, 14 09 2020. [Online]. Available: https://www.epa.gov/trash-free-waters/trash-capture-technologies. [Accessed 14 11 2021].

[14] E. Schenk, "Flagstaff Area Stage-Discharge Rating Tables: Appendix D," 20 04 2021. [Online]. Available: https://www.hydroshare.org/resource/ca957576f7e947f298f076c21a817385/. [Accessed 23 11 2021].

[15] "Coir Mat - Biodegradable Erosion Control Matting," SandBaggy, 23 11 2021. [Online]. Available: https://sandbaggy.com/products/coir-mat?variant=31855835676777&currency=USD&utm_source=google&utm_medium=cpc&utm_campaign=google+shopping&gclid=Cj0KCQiAys2MBhDOARIsAFf1D1d_3e349jNTlti-b_wUY0aZpTYetGKH116gVqg2q2cenhSbWSHx3tUaAieMEALw_wcB. [Accessed 23 11 2021].

[16] "How Much Does Dredging Cost?," 09 08 2018. [Online]. Available: https://www.howmuchisit.org/how-much-does-dredging-cost/. [Accessed 23 11 2021].

12.0 Appendix

Appendix A: Field Safety Form

NAU NORTHERN ARIZONA UNIVERSITY

Environmental Health and Safety

Field Safety Checklist

This form is designed to assist the Principal Investigator (PI), or Supervisor with assessing potential hazards of fieldwork. **The completed checklist must be shared with all the members of the field team and a copy must be kept on file on campus.** Multiple trips to the same location can be covered by a single checklist, as long as any changes in hazards and/or participants are documented. NAU's Regulatory Compliance groups are available to review these plans, and will conduct periodic reviews of departmental checklists.

Before you go:

- This checklist must be completed, with a copy maintained on campus, prior to departure for any fieldwork.
- Prepare first aid kit and any documentation needed (SOPs, Chemical Safety Data Sheets, etc)
- Assemble and check safety provisions
- Check to assure all required immunizations are current for all team members
- Check to assure all emergency health care and insurance requirements have been met.

Principal Investigator/Supervisor: Ed Schenk, City of Flagstaff Stormwater Manager

Type of Field Work: ☐ Academic Field Trip ☐ Field Research ☒ Observation ☐ Other

Dates of Travel: *(List multiple dates if more than one trip is planned)*
09/08/2021 & 09/15/2021 & other potential dates between 09/2021 - 12/2021

Mode of Transportation:
Car

Location of Field Work:

Country: USA Geographical Site: 4200 E Butler Ave, Flagstaff AZ 86001

Nearest City: Flagstaff Distance from Site: Ø

Nearest Hospital/Distance (Attach map when applicable): Northern Arizona Healthcare, 2 miles

Field Work: (Please include a brief description of the field work)
Survey and analyze channel reach for feasibility analysis

No-Go Criteria: *(Any circumstance that would require cancellation of field work such as lightning, or otherwise)* Monsoon, Snow, or wildfire in area.

Emergency Procedures: *(Please include detailed plans for field location including evacuation and emergency communication; Include a separate sheet if necessary)*
Contact Emergency contact, bring first aid kit, & have team members seek help/transportation

University Contact (Name/ Phone): Mark Lamer / 928 699 3860

Local Field Contact (Name/ Phone): Ed Schenk / 928 666 0458

Special Medical Requirements: *(bee sting kits, insulin, etc.)*
First Aid kit to be carried at all times.

First Aid Training: *(Please list any team members who are first aid trained and the type of training they have)* Jenna, Daniel, Destiny, & Emily

Physical Demands: *(Please list any physical demands required for this field work, e.g., Diving, Climbing, Temperature Extremes, High Altitude)*
Walking on uneven surfaces & wear proper clothing/footware

Risk Assessment: Please list identified risks associated with the activity or the physical environment and the appropriate safety measures to be taken to reduce the risks (personal protective equipment, training, SOPs, etc); Include a separate sheet if necessary. Attach Safety Data Sheets (SDSs) and training documentation for any chemicals that will be used.

Identified Risk	**Safety Measures**
☒ Temperature Extremes	water, sun protective gear, and a first aid kit
☒ Work in Remote Locations	First Aid kit & protective gear/materials
☒ Limited Communication	walkie-talkies & buddy system
☐ Working at Heights (Ladders/Climbing/Rappelling)	
☐ Chemical Hazards (Cleaners, Sample Preservatives, etc)	
☐ Biological Hazards	
☐ Radiation Hazards	
☒ Wild Animals	Stay away from wildlife if they get close
☐ Venomous Reptiles/Insects	
☐ Endemic Diseases	
☐ Zoonotic Diseases	
☐ Firearms/Explosives	
☒ Regional Hazards (Hunting season, civil unrest, crime)	wear bright colors
☐ Heavy Machinery/Tools (Saws, Excavators, etc.)	
☒ Open Water/River Crossings	Ensure water stability, know how to swim
☐ Other	

Animal Studies: A field study is defined as any study conducted on free-living wild animals that doesnot involve an invasive procedure or materially alter the behavior of the animal under study. In order to help you determine if your study fits this criteria, please answer the following questions.

1. **Does your study greatly disturb the animals under study?** ☐ Yes ☒ No
   (ex. testing predator vocalization, supplemental feeding, nest manipulation)

2. **Does your study involve an invasive procedure?** ☐ Yes ☒ No
   (ex. blood sampling, tagging)

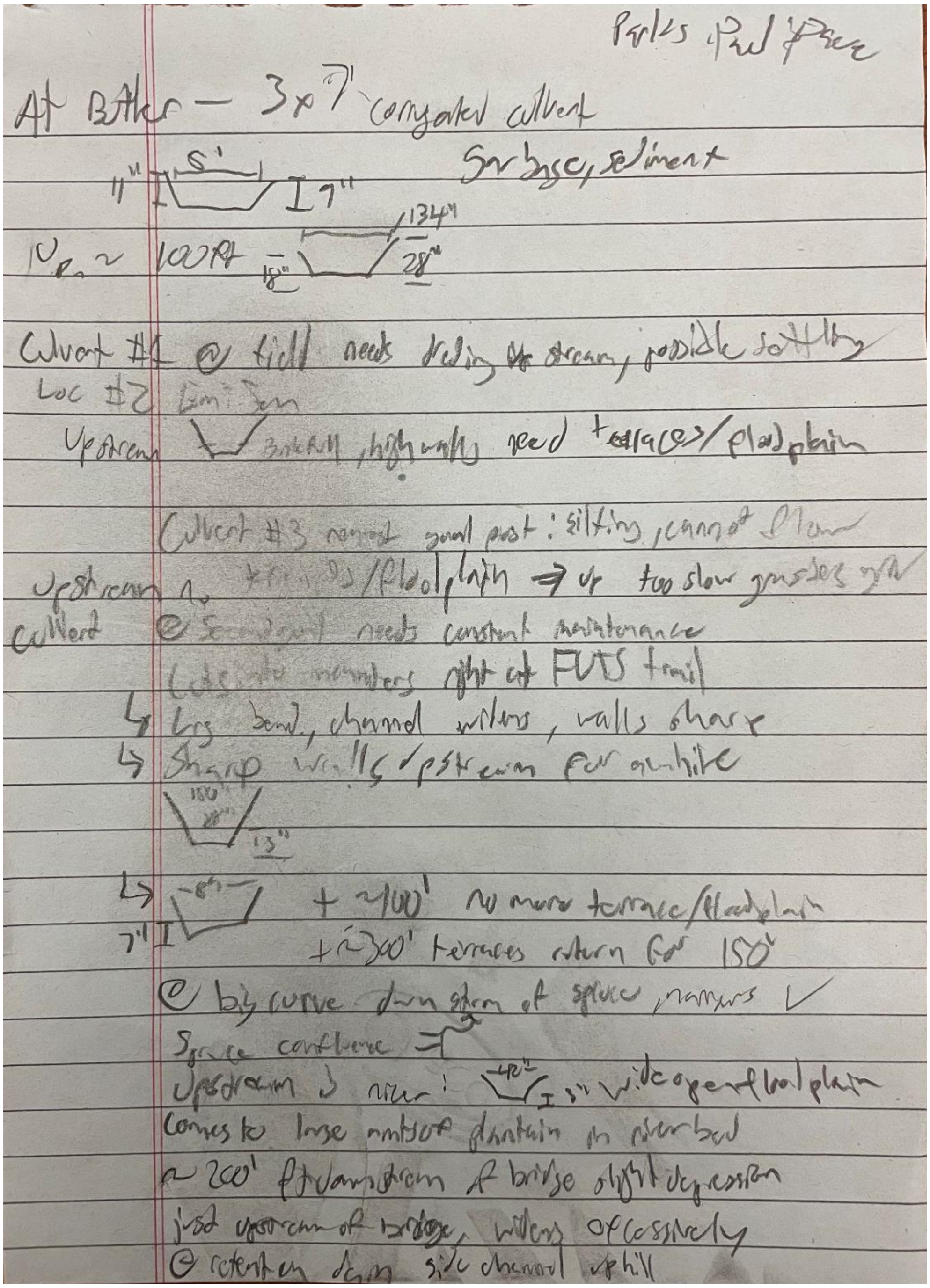
3. **Does your study cause potential harm/injury to the animal?** ☐ Yes ☒ No
   (ex. net and trap capture, bagging)

If you answered **YES to any** of these questions, your study involves invasive procedures or materially alters the behavior of the animal under study. Please fill out the full IACUC protocol application form. https://nau.edu/nau-research/research-safety-and-compliance/animal-care/animal-use-forms/

If you answered **NO to all three** of these questions and your study will only involve observation of free ranging animals, then an IACUC protocol is not required.

Field Team Membership (Please list the names of all members of the field team, and the Field Team Leader.) *Include a separate sheet if necessary.*
Name/Cell Phone Number (if applicable on site)
1 Daniel Segal / 928 380 2396
2 Destiny Gourley / 928 890 4328
3 Emily Frazer / 602 980 4773
4 Jenna McCaffrey / 303 731 7992
5

Appendix B: Field Notes



At Bethr — 3x7' corrugated culvert
Sur base, sediment
11" 5' 17"
134"
~100ft 18" 28"

Culvert #1 @ field needs [illegible] the stream, possible settling
Loc #2 [illegible]
Upstream [illegible], high walls need terraces/floodplain

Culvert #3 [illegible] good post: silting, cannot [illegible]
Upstream [illegible] /floodplain → [illegible] too slow [illegible]
culvert @ [illegible] needs constant maintenance
[illegible] meanders right of FUTS trail
↳ large bend, channel widens, walls sharp
↳ Sharp walls upstream for awhile
180" 13"
↳ + ~100' no more terrace/floodplain
7" + ~300' terraces return for 150'
@ big curve down stream of spruce, narrows ✓
Spruce confluence
Upstream [illegible] 42" 3" wide open floodplain
Comes to large amount of plantain in riverbed
~200' ft downstream of bridge slight depression
just upstream of bridge, widens occasionally
@ retention dam side channel uphill

Appendix B: Sample Field Notes

Appendix C: Photo Log

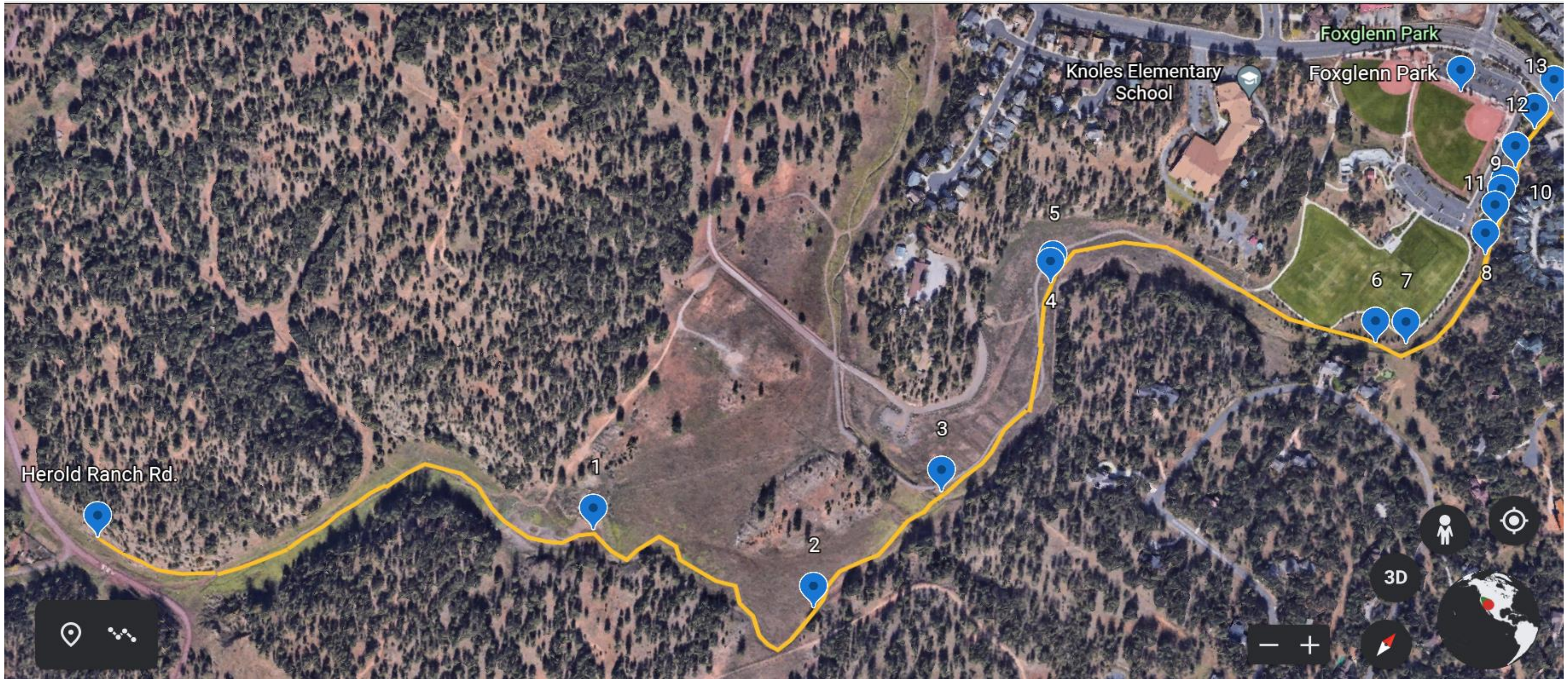


Photo Log: Rio de Flag Channel Improvement Areas

Photo Log 1: Rio de Flag channel station 23+42, looking downstream (north). This section shows retention and erosion.

Photo Log 2: Rio de Flag channel station 37+10, looking upstream (south). This shows silting and erosion

Photo Log 3: Rio de Flag channel station 44+06, looking downstream (north). This section of the channel shows silting and erosion.

Photo Log 4: Rio de Flag channel station 54+77, looking upstream (south). This section of the channel shows silting, erosion, and signs of detention.

Photo Log 5: Rio de Flag channel station 55+14, looking upstream (south). This section shows silting and erosion.

Photo Log 6: Rio de Flag channel station 70+09, looking downstream (north). This section of the channel shows silting, it is apparent that detention or retention would occur in this area had a flow been present.

Photo Log 7: Rio de Flag channel station 71+84, looking downstream (north). Silting and erosion are present.

Photo Log 8: Rio de Flag channel station 76+97, looking downstream (north). This image shows silting and erosion.

Photo Log 9: Rio de Flag channel station 78+15, looking upstream (south). This image shows silting and erosion.

Photo Log 10: Rio de Flag channel station 78+87, looking upstream (south). Detention, erosion, and silting is shown.

Photo Log 11: Rio de Flag channel station 79+35, looking downstream (north). This section is showing erosion, silting, and can be assumed detention would occur in the area if a flow was present.

Photo Log 12: Rio de Flag channel station 80+78, looking upstream (south), this section of the channel is showing erosion, silting, and detention.

Photo Log 13: Rio de Flag channel station 82+60, looking upstream (south). This section shows silting and erosion.

Appendix D: FAST Form

Flagstaff Area Stream Team - *F.A.S.T.*

Stormwater Management Section – Utilities Division

Stream Reach Field Inventory Form

Stream Name: _______Rio de Flag____________ Reach No.: _N/A_________

Optional Location Description: __From Herold Ranch Road to Fox Glenn Park_________________

Inspector(s): D. Segal, E. Frazer, J. McCaffrey, D. Gourley

Date of Inspection: 09-15-2021 Time: 12:30-2:30pm

Reach Photo #s: __5____

Average Channel Reach Conditions: **(Check below as applicable and describe below)**

1. **___ No signs of disturbance, good stable natural condition.**
2. **___ Disturbed, but mostly good stable condition/some localized unstable areas.**
3. **___ Fair to poor condition, unstable with indicators of active erosion and/or deposition.**
4. **_X__ Disturbed, very poor unstable conditions, active erosion and/or deposition.**
5. **___ No unique or unusual characteristics or resource values.**
6. **___ Has unique, or high resource values, or unusual characteristics.**
7. **___ Historically disturbed reach, no longer natural, but in good stable condition.**

Describe: The channel observed showed to be very unstable with indicators of active erosion and/or deposition. On the day of the site inspection, there was no water flow, but signs of recent flow due to the flooding that occurred in the months prior to the inspection from the Museum Fire Flooding events. Upon general research of the channel, there is very little regular flow within the channel, as it acts more of an aid for stormflow conditions. There was vegetation growth within the channels in between the rocks, trees, and bushes. There were sections of the channel where entire trees had fallen and were blocking direct flow pathways when the stream was flowing. There were multiple sections within the stream that showed significant signs of erosion from excess flow conditions. At sections, silting was present. Mostly in areas near high eroded banks, or when the slope within the channel bed was very flat and had little downslope where flow would be directed downstream. There were sections where there were boulders and irregular rocks within the channel that could potentially have an effect on how the stream flows when full. There were significant signs of ponding in floodplain areas from the recent flooding events. There was garbage buildup in front of culverts which could potentially lessen the control of flow within the channel. The slope from the banks to the center of the channel was very irregular throughout the entirety of the channel. This could be a factor to the erosion within sections of the channel. See photos in the report for supporting evidence of the condition of the channel at time of investigation.

Recommendations: **___ No Action Needed. __ X _ Additional detailed examination needed,**
Circle specialty areas: Erosion/Channel Morphology; Riparian/Wetland Vegetation; Archaeology; Recreation/Trails; Wildlife; Other: ____________________________

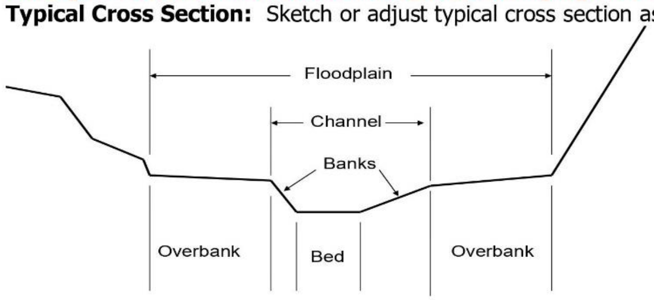
Action Needed For: _ X __ Cleanup; _ X __ Maintenance; _ X __ Restoration; _ X __ Preservation;___ Stabilization/Erosion Control;__ X _ **Priority:** ___ High; ___ Low; ___ Moderate; _ X __ Don't Know.

Comments:

Focus on areas concerning erosion, detention, retention, silting, and garbage pollution within the channel. Find the peak flow within the channel during 50+/year storm events in order to prepare for smaller flooding episodes. Focus on the slope of the channel being between 3:1 and 5:1 in order to prepare the channel for flooding events.

FAST Stream Field Inv Form V6

Average Reach Descriptive Data (Use: B=Bed; BK=Bank; OB=Overbank or A=Same all Areas)
____ Dry; __X_ Wet, Type:___ Flowing Stream:___ Spring; ___ Seep; __X__ Pond; Other: ______________
Describe: Pooling of water, extreme change in bank dimensions.
Soil Material: _X__Soil; __X_ Sand; ___ Gravel; ___ Boulders; ___ Bedrock; Other: ___________________
Describe: Occurrence of silting and desiccation.
Vegetation: Type: __ X _ Grass; _ X __ Pond. Pine; ___ Cottonwood; __ X _Cattails/Water Lilies; ___Sedges; ___Willows; ___ Wild Rose; ___ NM Locust; Other: ___________
Describe: Grassy in beds sporadically and in overbanks often, surrounded by ponderosa pines.
Noxious (Invasive) Species Observations (Use: P=Present; A=Absent; C=Common; D=Dominant)
___ Dalmatian Toadflax; __ P _ Yellow Starthistle; _ P__ Scotch/Bull Thistle; _ P __ Diffuse Knapweed; ___ Cheatgrass/Brome; __ P _ Russian Olive; ___ Siberian Elm; Other: ________________________
Describe: Abundance of scotch thistle.
Disturbed Channel Condition Indicators: ___ Unnatural Activity within the Bed, Banks or Floodplain; ___ Bare Ground; _X__ Erosion; _X__ Deposition; ___ Vertical Banks; _X__ Head Cutting; ___ Excav;___ Fill; ___ Gullies; ___ Grading; ___ Discharge: ____________; Adjacent land use:__Recreational, residential
Describe: Evidence of non-motorized/motorized vehicles through the channel bed are present.
Possible Causes:
Natural: _X__ Flood Event; __ Debris Dam; _X__ Wildfire; ___ Unknown; ___ Other: ________________
Describe: Recent flooding events caused by the Museum Fire Flooding that occurred months before channel investigation. A wildfire was the cause for the flooding on the mountainside.
Unnatural: _X__ Road; _X__ Trail; ___ Railroad; ___ Sewerline, ___ Waterline; ___ Gas Line;___ Dumping; ___ Channelization; ___ Runoff from Adjacent Development; ___ Excavation; ___ Fill; ___ Outlet Pipe; ___ Devegetation in Watershed; _X__ Residential; ___ Commercial; ___ Other: X_Four-wheelers/Dirt Bikers
Describe: Evidence of motorized and non-motorized vehicles through channel bed.
Possible Solution(s): _X__ Erosion Stabilization; _X__ Restoration: _X__ Cleanup; _X__ Maint.; ___ Other;
Describe: Field study investigation on specific locations of where erosion occurs. Restoration of detention and retention ponds. Change the slope of the channel and banks in order to have more control during high flow conditions. Create stable channels in order to decrease silting within channel bed. Regularly scheduled garbage cleanup within channel.
Recommended Follow-up: _X__ Detailed Field Inspection; ___ Enforcement Action _X_ Cleanup; _X__ Historical Analysis; ___ Other; Describe: Historical Analysis would help to see what the pak from is in order to desgin a new channel to withstand the needs during high flow conditions.
Typical Cross Section: Sketch or adjust typical cross section as applicable (looking downstream):



See photos of cross sections, the cross sections throughout the channel vary.
Wildlife Observations (list species or describe)
Animals: Nothing detected at time of visit.
Birds: Nothing detected at time of visit.
Insects: _N__ Y/N; _N__ Terrestrial; _N__ Aquatic; ____
Amphibians/Reptiles:____
Describe: Although no wildlife was seen in person, animal tracks belonging to elk and deer were observed.
Recreation and Trails Observations
Describe Types of Recreation Activity: _X__ Hiking; _X__ Biking; ___ Birding; Other: Motorized Sports
Type of Trail: ___ None; _X__ FUTS; __X_ AZ TRL; __X_ Social; ___ USFS; ___ Other: ___________________
Condition of Trail: _X__ Good; ___ Poor; ___ Needs Maint/Repair: __________________________________
Describe: ____

Appendix E: Discharge Data from FIS [2]

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
PEAK VIEW WASH					
At confluence with Rio de Flag (after diversion at Cooper Drive)	0.94	*	*	20	*
Just upstream of the intersection of Cooper Drive and Peak View Tributary Wash	0.94	*	*	105	*
PENSTOCK AVENUE WASH					
At confluence with Rio de Flag	2.3	30	90	140	310
RIO DE FLAG					
Approximately 3.0 miles upstream of confluence with San Francisco Wash (at downstream limit of study)	198.38	1,401	3,239	4,484	8,300
Flow upstream of Townsend Bridge	121.61	1,086	2,487	3,376	6,100
Flow upstream of final Tributary	129.55	1,123	2,573	3,502	6,500
Upstream of U.S. Highway 66	110.6	1,050	2,400	3,250	5,800
At confluence of Switzer Canyon Wash	98.9	1,050	2,400	3,250	5,800

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
SPRUCE AVENUE WASH					
At Santa Fe Avenue	7.3	240	460	580	930
Above East Linda Vista Drive	5.7	60	180	260	520
Near upstream limit of detailed study	5.3	50	160	230	480
SWITZER CANYON WASH					
At confluence with Rio de Flag	11.0	280	600	800	1,400

Appendix F: Discharge Rating Table for Rio de Flag at Foxglenn Park [13]

WSE (ft)	Surface Water Depth (ft)	Flow (cfs)
6772.1	0	0
6774.71	2.61	100
6775.19	3.09	200
6775.74	3.64	300
6776.28	4.18	400
6776.81	4.71	500
6777.3	5.2	600
6778.15	6.05	1050
6780.95	8.85	2400
6781.85	9.75	3250
6784.3	12.2	5800

Appendix G: WSS Full Report for Lynx Loam [3]

Map Unit Description

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions in this report, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named, soils that are similar to the named components, and some minor components that differ in use and management from the major soils.

Most of the soils like the major components have properties akin to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called non-contrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Some minor components, however, have properties and behavior characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. All the soils of a series have major horizons that are similar in composition, thickness, and arrangement. Soils of a given series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. Based on such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Additional information about the map units described in this report is available in other soil reports, which give properties of the soils and the limitations, capabilities, and potentials for many uses. Also, the narratives that accompany the soil reports define some of the properties included in the map unit descriptions.

Oak Creek-San Francisco Peaks Area, Arizona, Part of Coconino County

13—Lynx loam, 0 to 2 percent slopes

Map Unit Setting

National map unit symbol: 1vhk6
Elevation: 6,560 to 7,030 feet
Mean annual precipitation: 18 to 24 inches
Mean annual air temperature: 43 to 49 degrees F
Frost-free period: 90 to 115 days
Farmland classification: Not prime farmland

Map Unit Composition

Lynx and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the map unit.

Description of Lynx

Setting

Landform: Flood plains, alluvial fans
Landform position (two-dimensional): Summit

Landform position (three-dimensional): Dip
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Mixed alluvium

Typical profile

H1 - 0 to 60 inches: loam

Properties and qualities

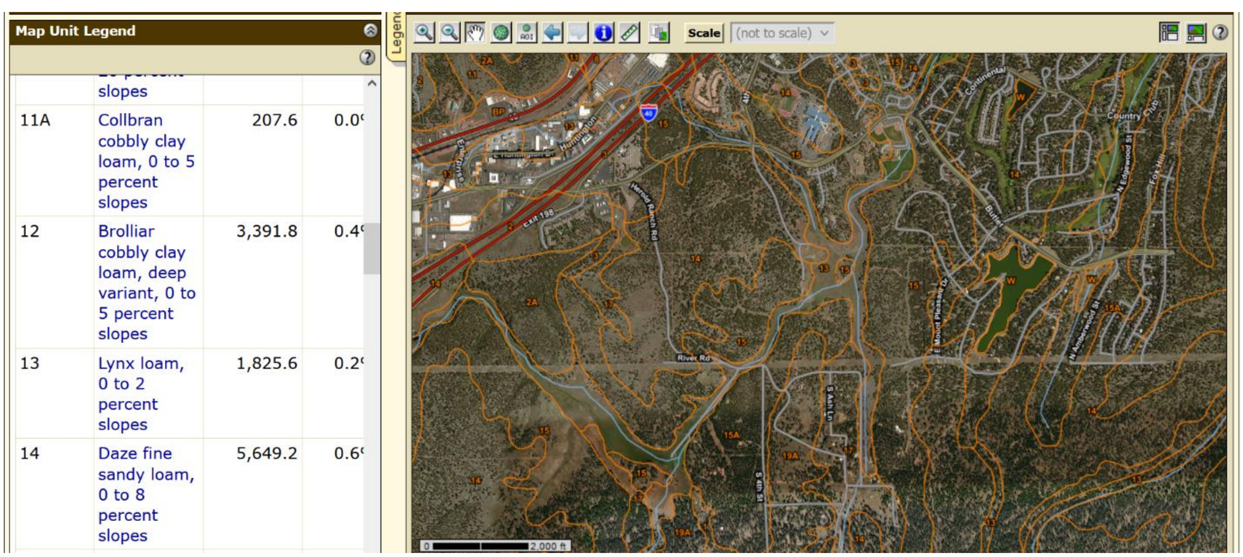
Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: FrequentNone
Frequency of ponding: None
Available water supply, 0 to 60 inches: Moderate (about 9.0 inches)

Interpretive groups

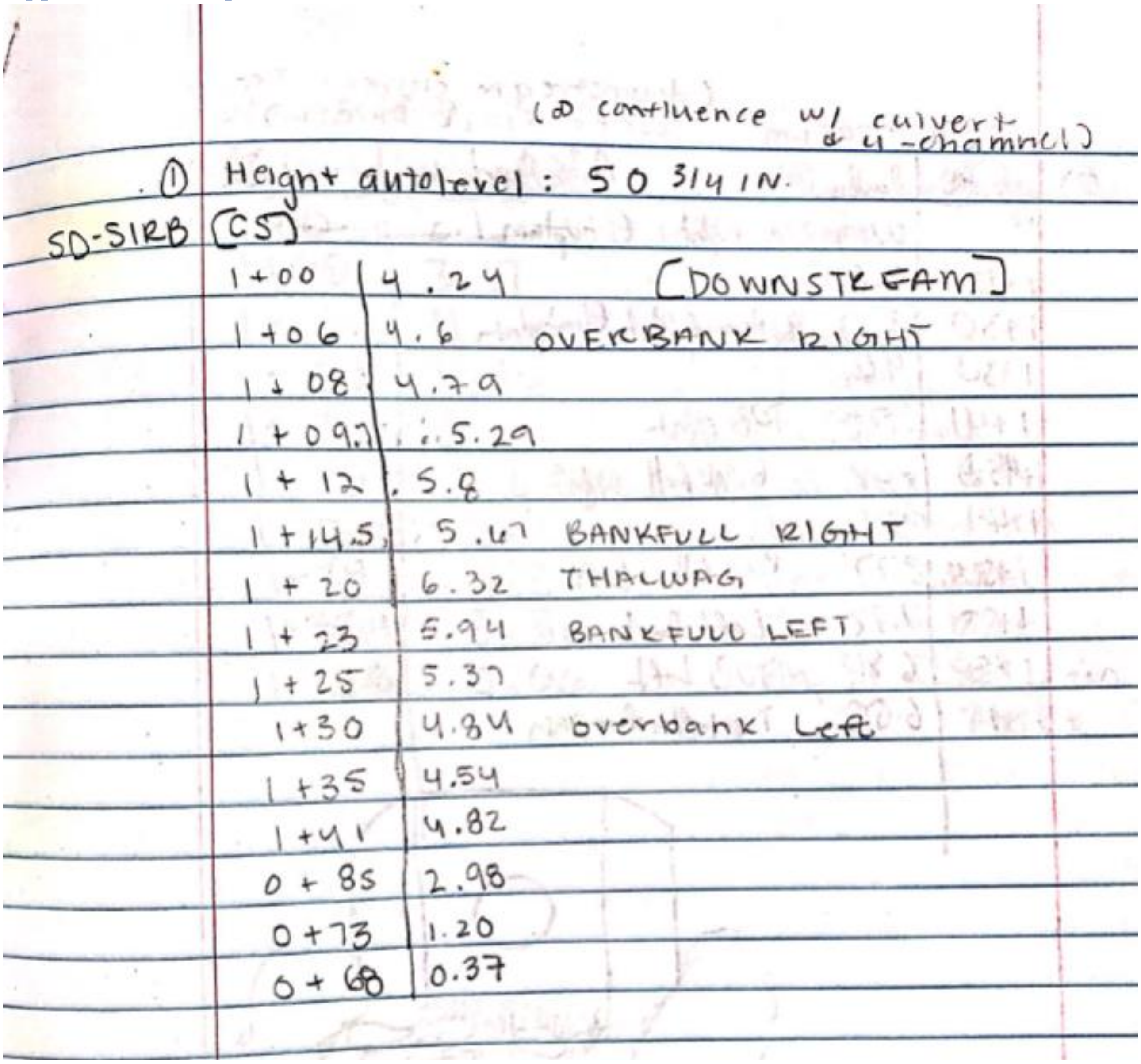
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: B
Ecological site: R039XA130AZ - Loamy Bottom 17-22" p.z. *Hydric soil rating:* No

Data Source Information

Soil Survey Area: Oak Creek-San Francisco Peaks Area, Arizona, Part of Coconino County
Survey Area Data: Version 11, Sep 16, 2021



Appendix H: Sample of Field Notes for Cross Sections



(@ confluence w/ culvert & 4-channel)

① Height autolevel: 5 0 3/4 IN.

SD-SIRB [CS]

1+00	4.24	[DOWNSTREAM]
1+06	4.6	OVERBANK RIGHT
1+08	4.79	
1+09.7	5.29	
1+12	5.8	
1+14.5	5.47	BANKFULL RIGHT
1+20	6.32	THALWAG
1+23	5.94	BANKFULL LEFT
1+25	5.37	
1+30	4.84	overbank Left
1+35	4.54	
1+41	4.82	
0+85	2.98	
0+73	1.20	
0+68	0.37	

Appendix H.1: Survey Notes from Site 1

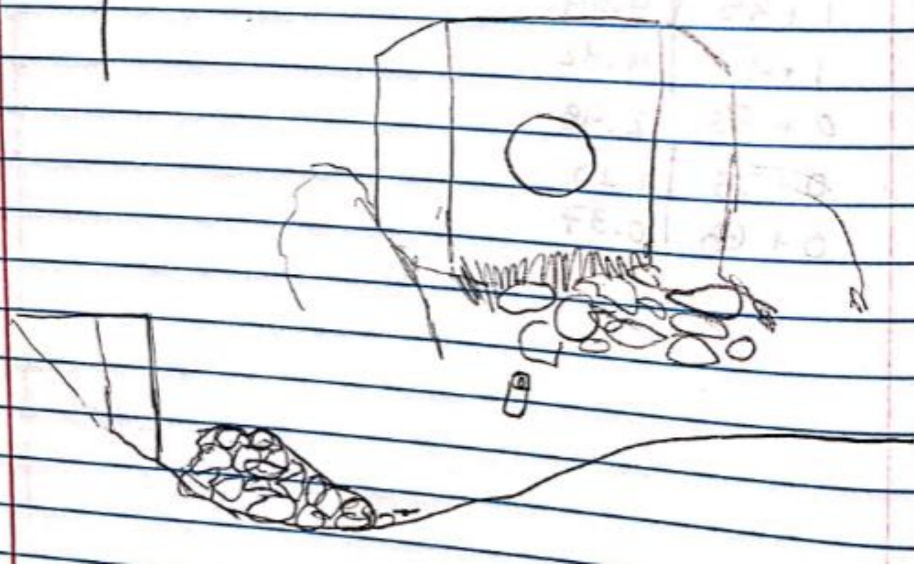
(downstream culvert for soccer FIELD DRAIN)

DOWNSTREAM

Auto level height : [illegible]

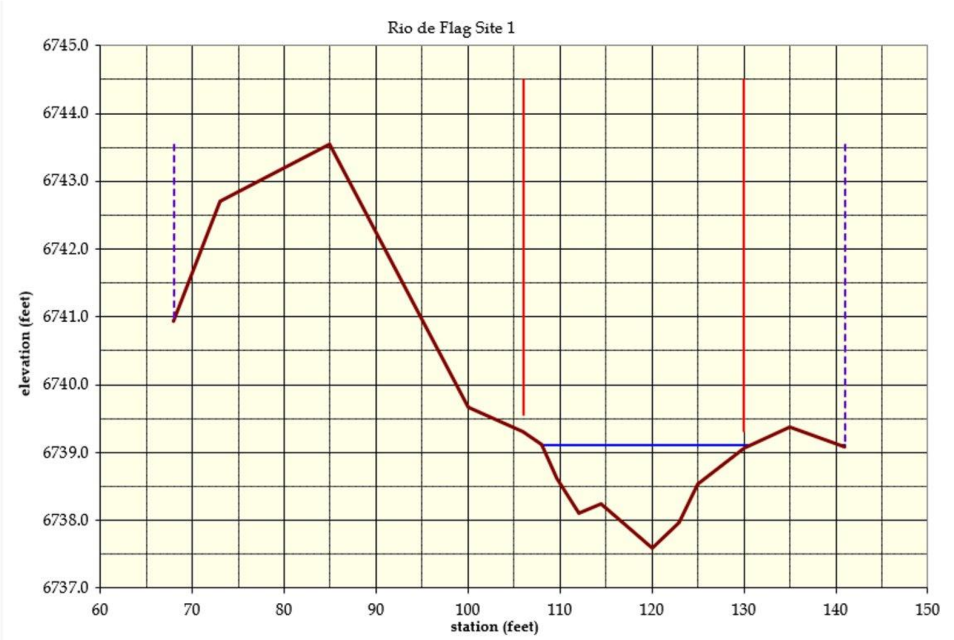
②

Sta (ft)	Reading (ft)	
1+00	0.49	Top right floodplain
1+12	2.61	
1+30	3.83	Bottom Right floodplain
1+34	4.64	
1+41	6.78	TOB right
1+45.5	8.48	Bankfull Right
1+49	9.21	
1+52.4	8.77	Bankfull Left
1+55	7.72	Left Bank
1+58	6.84	TOB Left
1+60.5	6.05	Top left floodplain

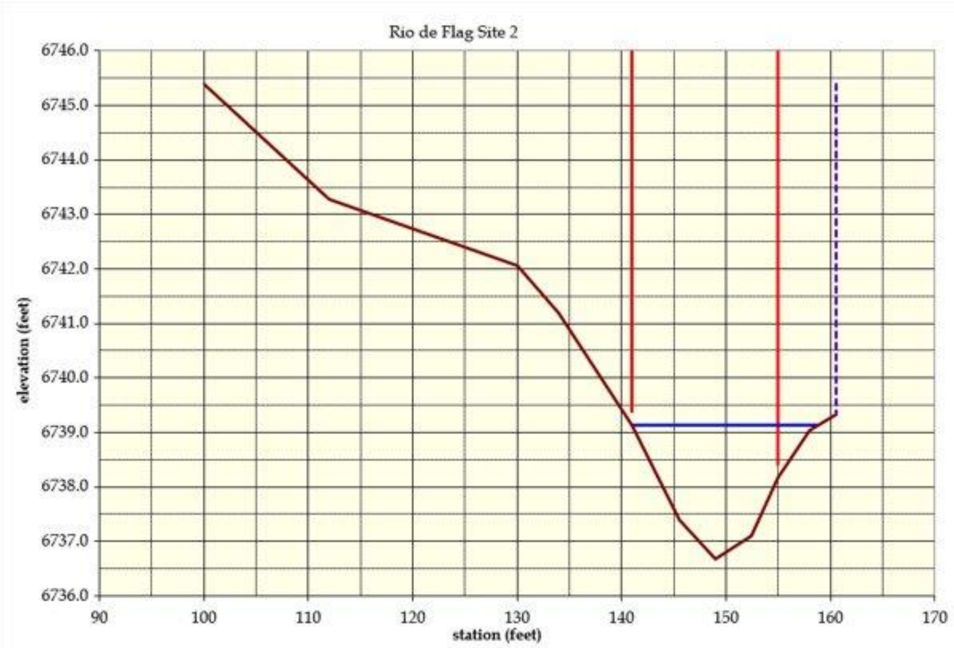


Appendix H.2: Survey Notes from Site 2

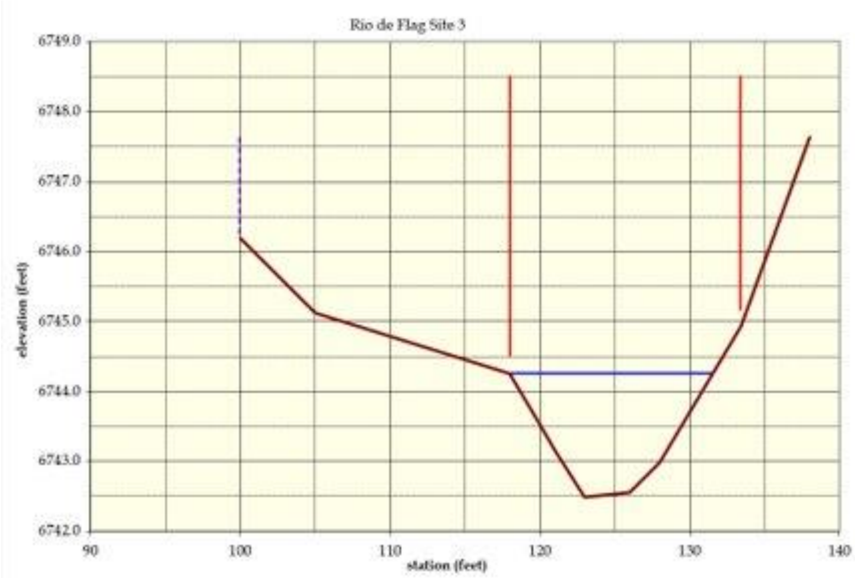
Appendix I: NRCS Graphical Results



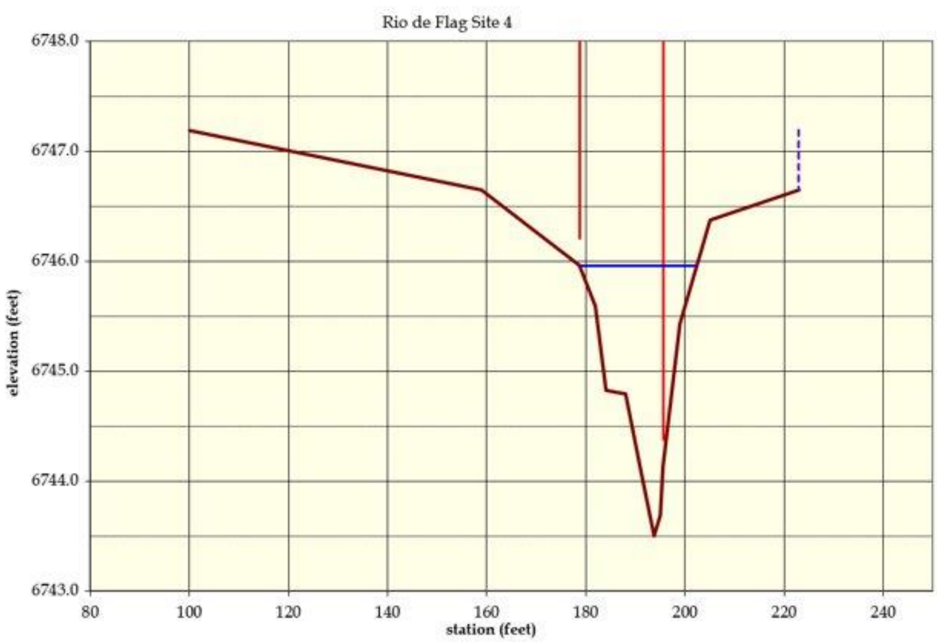
Appendix I.1: NRCS Results for Site 1



Appendix I.2: NRCS Results for Site 2



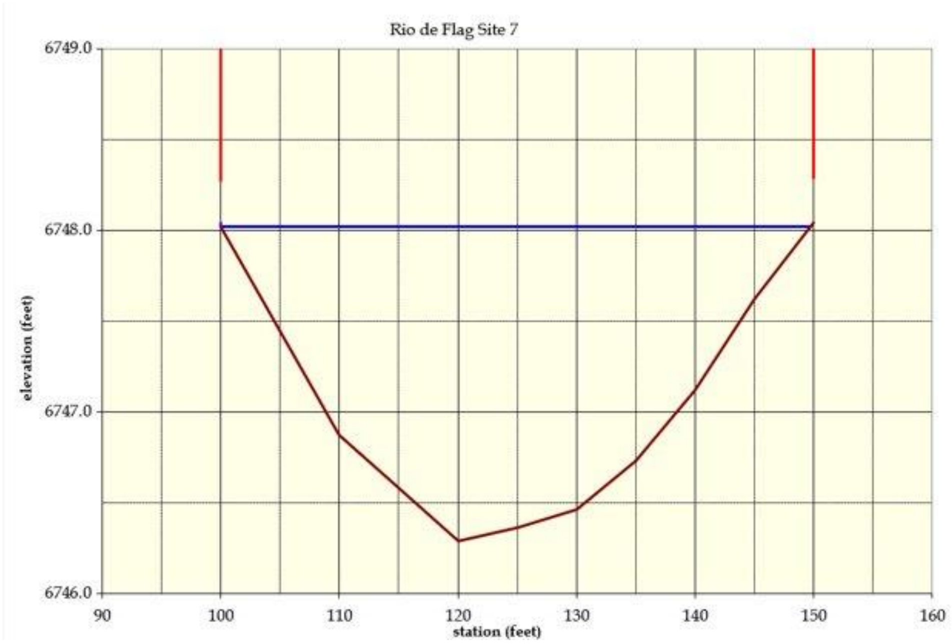
Appendix I.3: NRCS Results for Site 3



Appendix I.4: NRCS Results for Site 4

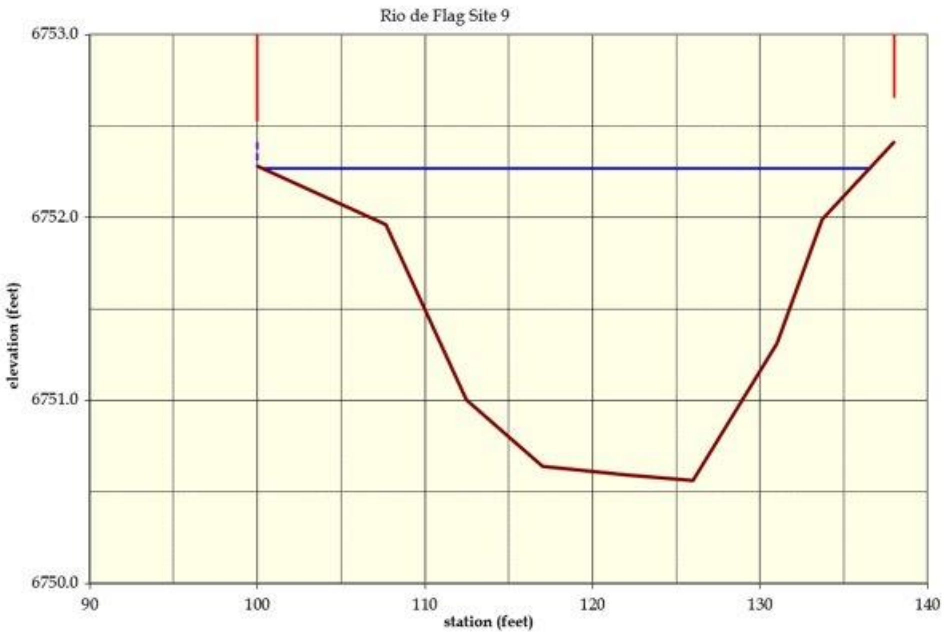
Appendix I.5: NRCS Results for Site 5

Appendix I.6: NRCS Results for Site 6



Appendix I.7: NRCS Results for Site 7

Appendix I.8: NRCS Results for Site 8



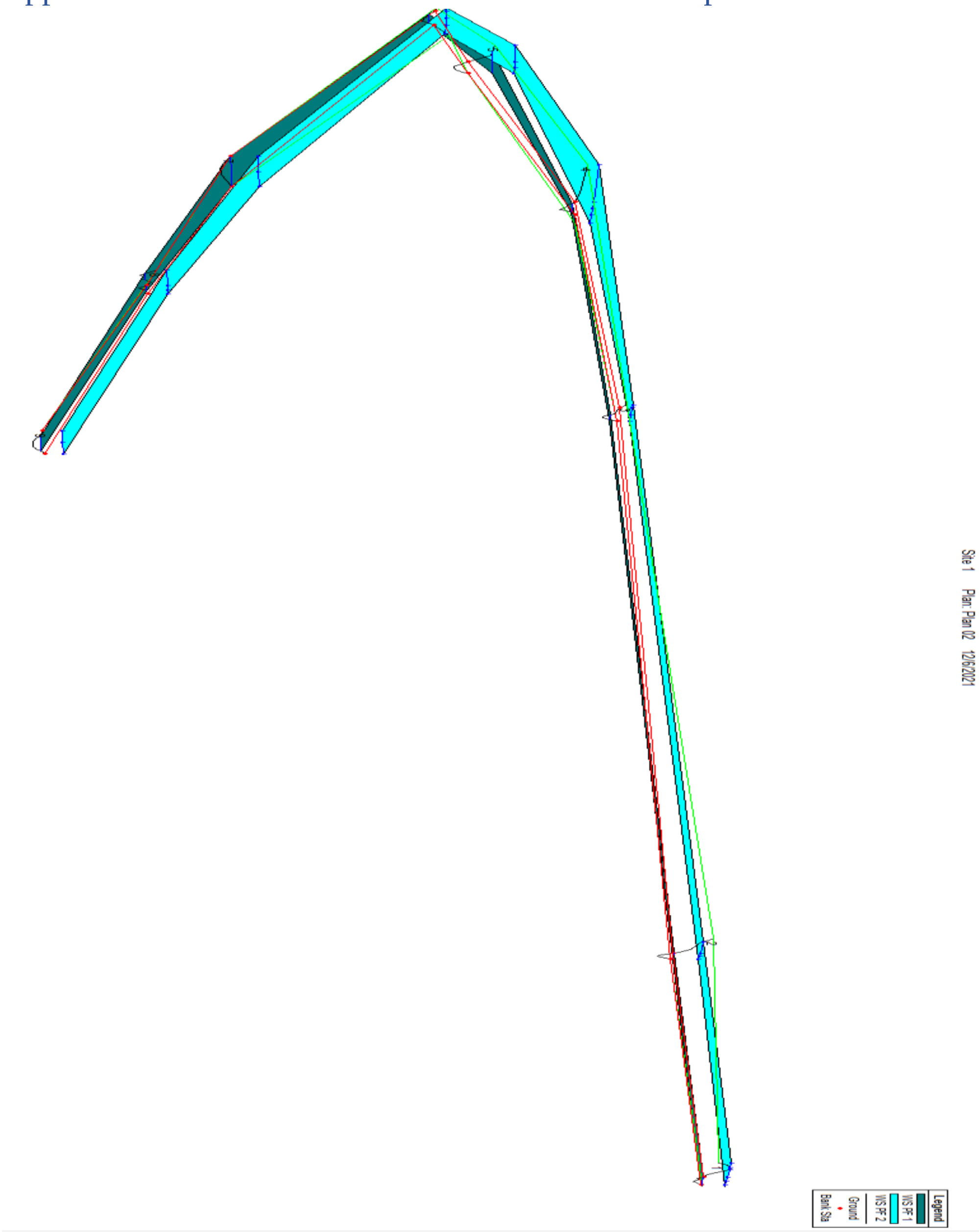
Appendix I.: NRCS Results for Site 9

Appendix J: Tabulated HEC-RAS Results for Bankfull Flow Site 1 and 10-Year Flood

HEC-RAS Plan: Plan 01 River: Rio de Flag Reach: Capstone

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Capstone	9	PF 1	34.50	6750.56	6751.92	6751.22	6751.95	0.000846	1.40	24.66	25.53	0.25
Capstone	9	PF 2	770.00	6750.56	6755.75	6753.67	6756.08	0.001501	4.60	167.37	38.00	0.39
Capstone	8	PF 1	34.50	6748.13	6749.46	6749.46	6749.66	0.016762	4.27	10.57	19.85	1.00
Capstone	8	PF 2	770.00	6748.13	6753.20		6753.71	0.004136	6.86	148.27	40.00	0.60
Capstone	7	PF 1	34.50	6746.29	6748.07	6746.89	6748.08	0.000134	0.62	55.99	50.00	0.10
Capstone	7	PF 2	770.00	6746.29	6752.85		6752.96	0.000330	2.61	295.15	50.00	0.19
Capstone	6	PF 1	34.50	6745.96	6747.00	6747.00	6747.28	0.016699	4.26	8.09	14.64	1.01
Capstone	6	PF 2	770.00	6745.96	6749.97	6749.97	6751.29	0.008265	9.59	96.54	41.90	0.95
Capstone	5	PF 1	34.50	6739.12	6745.68	6740.10	6745.69	0.000005	0.30	130.75	35.82	0.02
Capstone	5	PF 2	770.00	6739.12	6749.53	6743.73	6749.66	0.000363	3.28	304.90	45.90	0.19
Capstone	4	PF 1	34.50	6743.50	6745.62	6744.91	6745.67	0.001351	1.81	19.02	18.43	0.31
Capstone	4	PF 2	770.00	6743.50	6749.14		6749.28	0.000879	3.73	344.02	123.00	0.32
Capstone	3	PF 1	34.50	6742.49	6743.59	6743.59	6743.96	0.015348	4.84	7.13	9.83	1.00
Capstone	3	PF 2	770.00	6742.49	6747.25		6748.22	0.006056	7.98	101.70	33.40	0.77
Capstone	2	PF 1	34.50	6736.67	6739.45	6737.86	6739.47	0.000285	1.16	29.87	18.08	0.15
Capstone	2	PF 2	770.00	6736.67	6743.92		6744.43	0.001994	6.18	165.17	49.68	0.44
Capstone	1	PF 1	34.50	6737.59	6739.17	6738.58	6739.22	0.001500	1.76	19.69	24.22	0.33
Capstone	1	PF 2	770.00	6737.59	6743.25	6741.35	6743.64	0.001502	5.54	194.12	61.66	0.44

Appendix K: HEC-RAS Water Surface Profile Sample for Bankfull at Site 1



Appendix L: Allowable velocity table from COF SWMDM [3]

TABLE 4-1: ALLOWABLE VELOCITIES FOR ERODIBLE CHANNELS

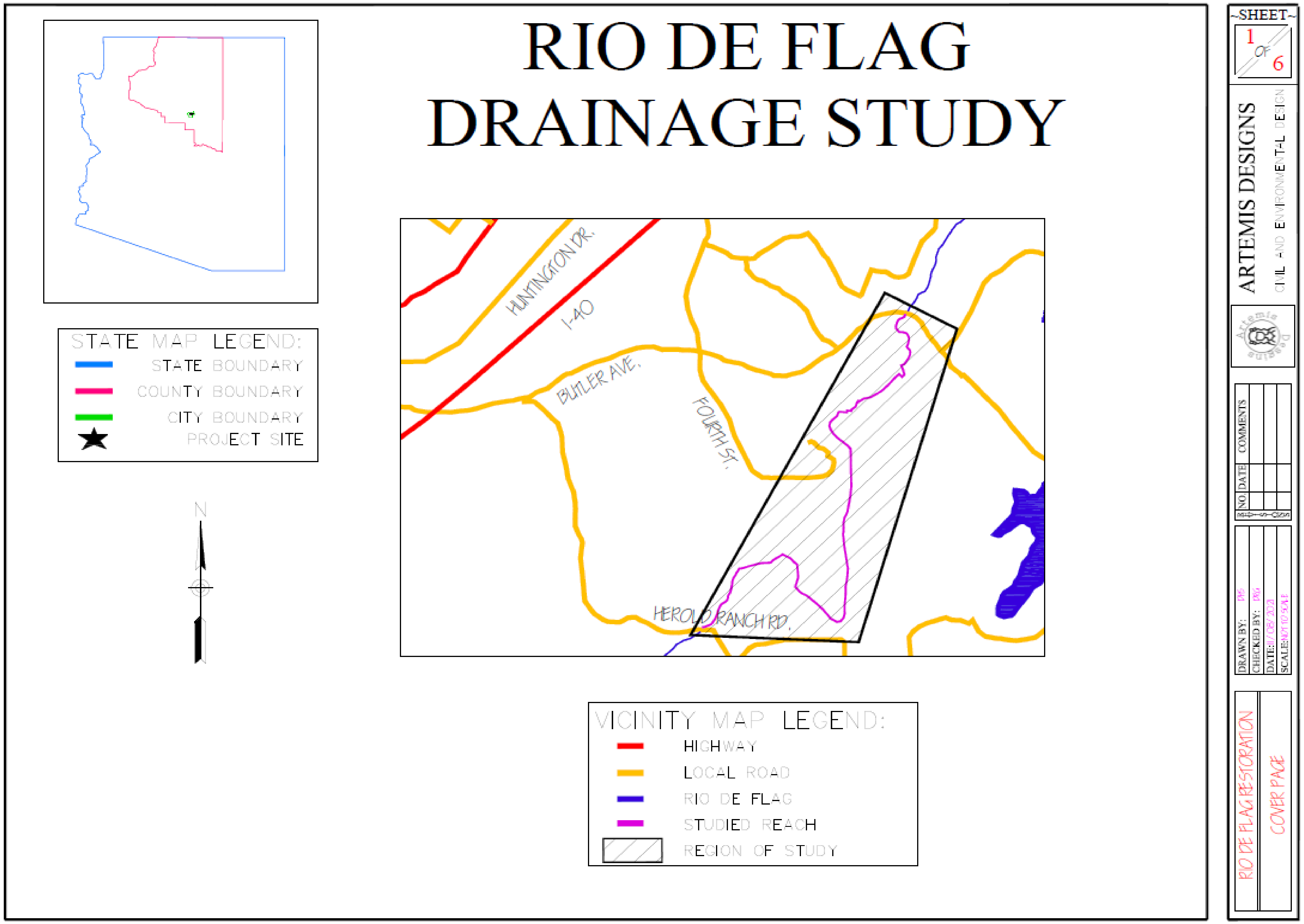
MATERIAL	VELOCITY (ft/sec)
Fine Sand (noncolloidal)	2.5
Sandy Loam (noncolloidal)	2.5
Silt Loam (noncolloidal)	3.0
Alluvial Silts (noncolloidal)	3.5
Alluvial Silts (colloidal)	5.0
Ordinary Firm Loam	3.5
Volcanic Ash	2.5
Fine Gravel	5.0
Stiff Clay (very colloidal)	5.0
Graded, Loam to Cobbles (noncolloidal)	5.0
Graded, Silts to Cobbles (colloidal)	5.0
Coarse gravel (noncolloidal)	6.0
Cobbles and Shingles	5.5
Shales and Hard Pans	6.0

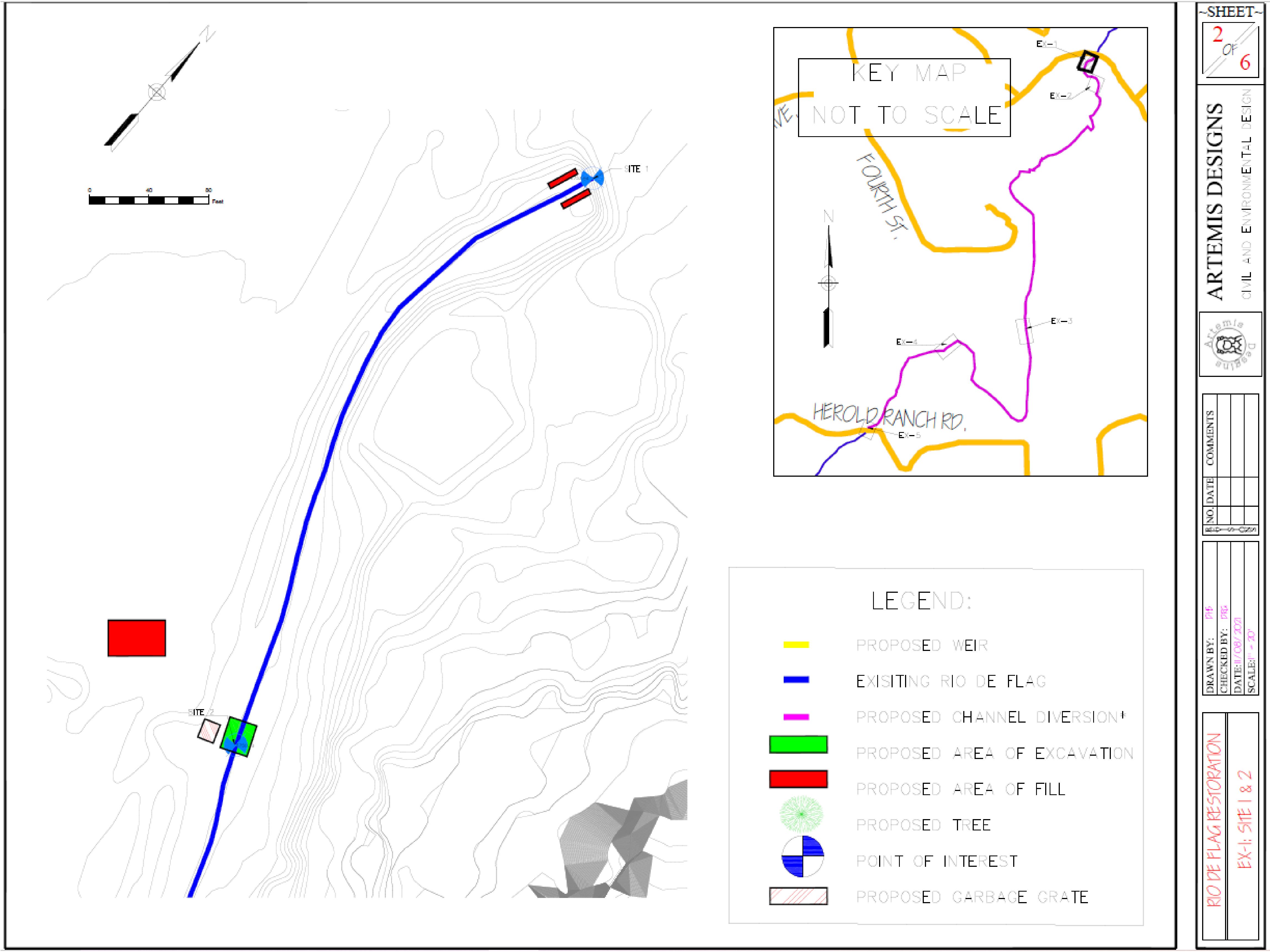
Appendix M: Summary of Engineering Work

	Hours				
Task Name	**(PM)**	**(ENG)**	**(EIT)**	**(TECH)**	
1.0 Project Due Diligence	6	29	100	0	**135**
1.1 Surveying Data	1	24	84	0	
1.1.2 FAST Form	0.0	0	2	0	
1.1.3 Topographic Survey	0.5	24	72	0	
1.1.4 Photo Log	0	0	10	0	
1.2 Previous Studies	1	1	12	0	
1.2.1 FEMA Floodway and FIS	0.5	0.5	6	2	
1.2.2 City of Flagstaff SMDM	0.5	0.5	6	2	
1.3 Representative Site Determination	4	4	4	0	
2.0 Hydrologic Data	**3**	**6**	**12**	**4**	**25**
2.1 Sub-Basin Delineation	0.5	1	4	0	
2.2 Sub-Basin Properties	0.5	0.5	4	4	
2.3 FEMA/City of Flagstaff	2	4	4	0	
3.0 Hydraulic Data	**2**	**4**	**34**	**0**	**40**
3.1 Input Data Development	1	2	14	0	
3.2 NRCS Analyzer	1	2	20	0	
3.3 HEC-RAS Analysis	0.5	0.5	30	0	
4.0 Design	**8**	**60**	**120**	**4**	**192**
4.1 CAD Drafting	4	30	60	0	
4.2 Hydraulic Software	4	30	60	4	
5.0 Deliverables	**23**	**51**	**101**	**29**	**204**
5.1 30% Submittal	2	10	16	4	
5.2 60% Submittal	4	10	8	4	
5.3 90% Submittal	4	10	16	4	

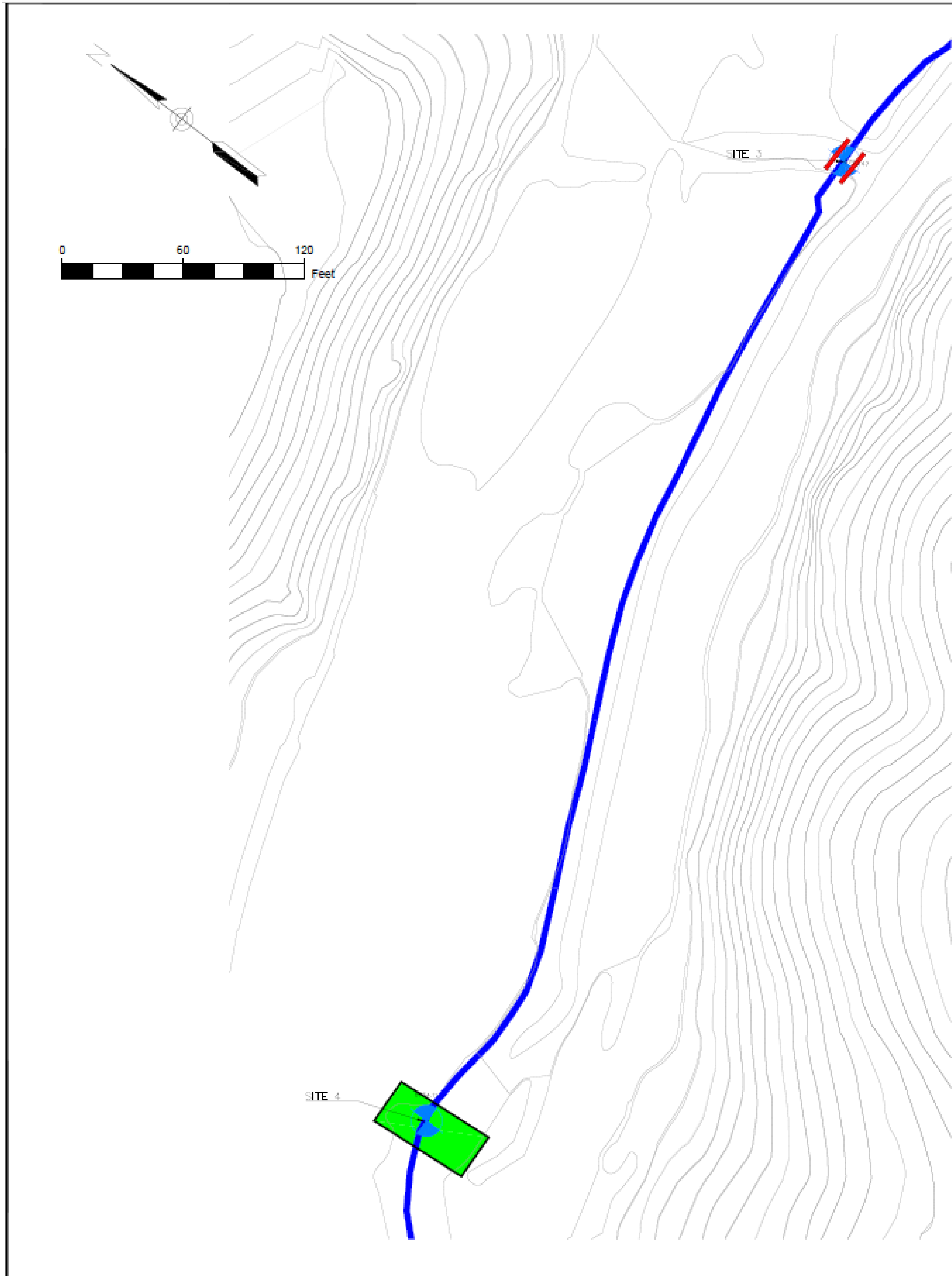
5.4 Final Report	4	8	10	2	
5.5 Final Presentation	6	8	8	4	
5.6 Meeting Memo Binder	1	1	3	1	
5.7 Website	2	4	40	10	
6.0 Project Management	**52**	**46**	**41**	**32**	**171**
6.1 Team Meetings	16	20	20	20	
6.2 Tech Advisor Meetings	8	8	8	8	
6.3 Client Meetings	16	2	0	0	
6.4 Schedule Management	2	6	0	0	
6.5 Resource Management	8	4	1	0	
6.6 Impacts	4	6	12	4	
Total Hours:	**94**	**196**	**408**	**69**	**766**

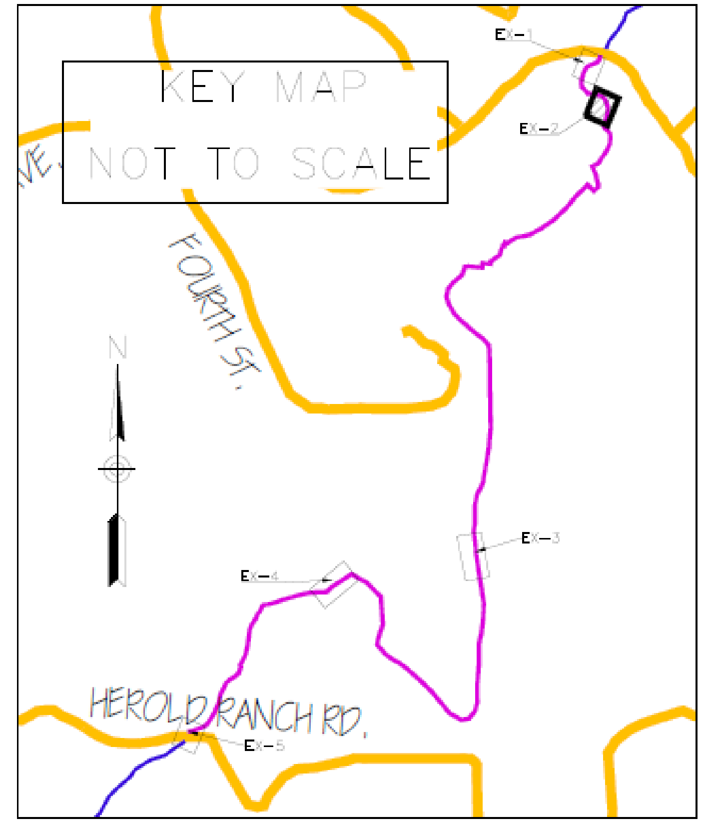
Appendix N: Final Design Plan Set





SITE 1
SITE 2
KEY MAP
NOT TO SCALE
FOURTH ST.
HEROLD RANCH RD.
N
LEGEND:
PROPOSED WEIR
EXISITING RIO DE FLAG
PROPOSED CHANNEL DIVERSION
PROPOSED AREA OF EXCAVATION
PROPOSED AREA OF FILL
PROPOSED TREE
POINT OF INTEREST
PROPOSED GARBAGE GRATE
~SHEET~
2 OF 6
ARTEMIS DESIGNS
CIVIL AND ENVIRONMENTAL DESIGN
NO.
DATE
COMMENTS
DRAWN BY:
CHECKED BY:
DATE:
SCALE:
RIO DE FLAG RESTORATION
EX-1: SITE 1 & 2





LEGEND:

- PROPOSED WEIR
- EXISITING RIO DE FLAG
- PROPOSED CHANNEL DIVERSION*
- PROPOSED AREA OF EXCAVATION
- PROPOSED AREA OF FILL
- PROPOSED TREE
- POINT OF INTEREST
- PROPOSED GARBAGE GRATE

~SHEET~ 3 OF 6

ARTEMIS DESIGNS

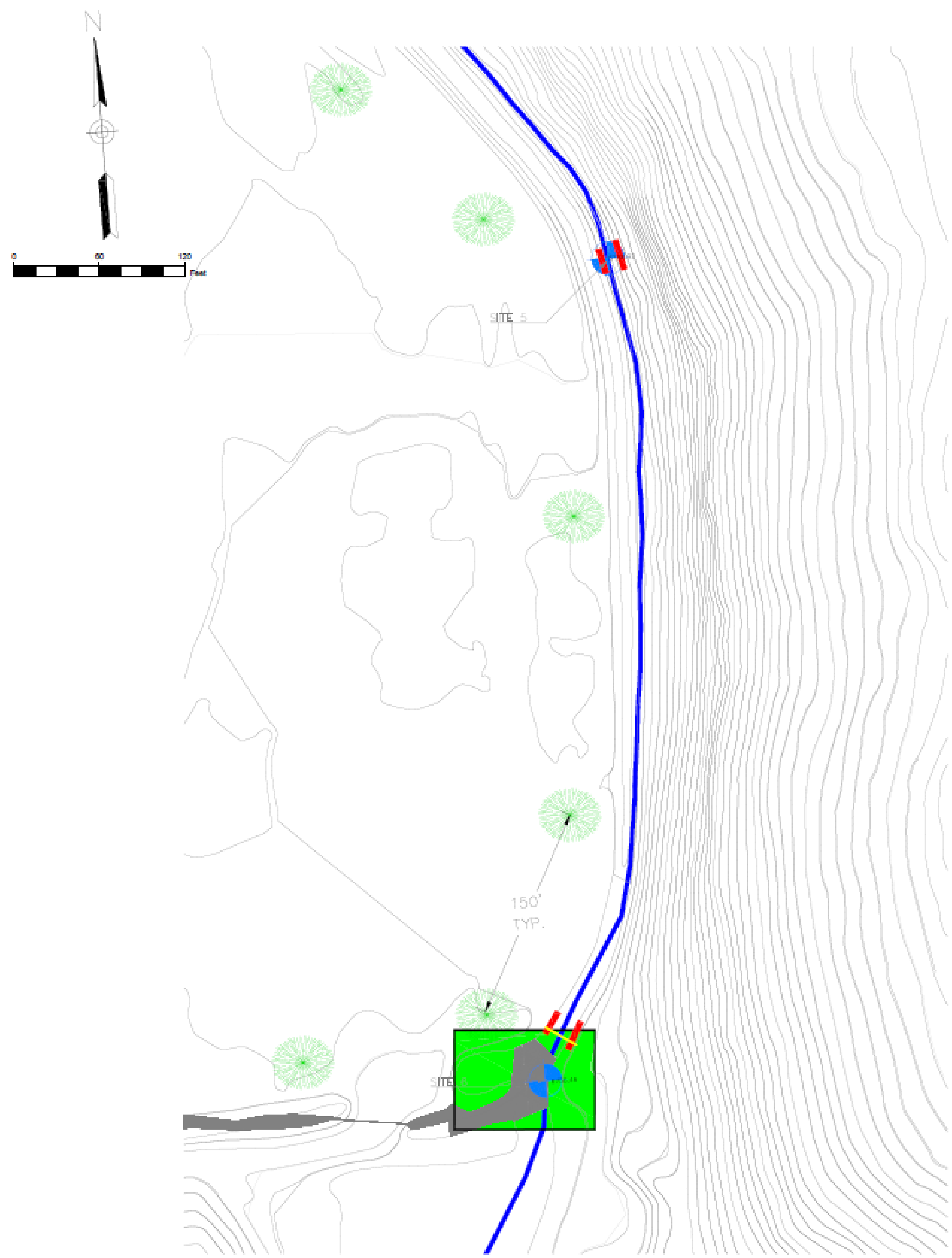
CIVIL AND ENVIRONMENTAL DESIGN

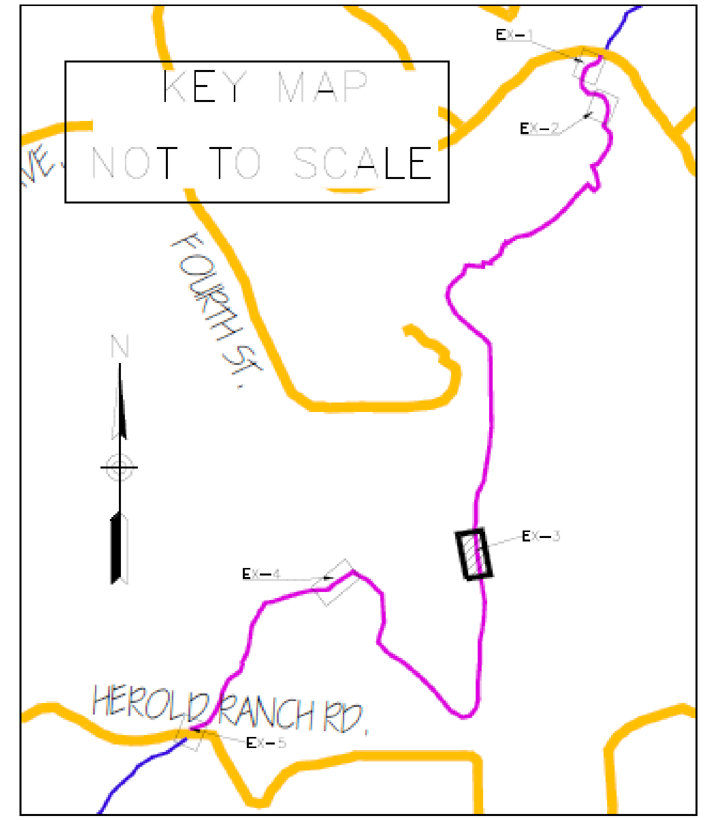
NO.	DATE	COMMENTS

DRAWN BY: PHS
CHECKED BY: PHG
DATE: 11/08/2021
SCALE: 1" = 20'

RIO DE FLAG RESTORATION

EX-2: SITE 3 & 4





LEGEND:

- PROPOSED WEIR
- EXISITING RIO DE FLAG
- PROPOSED CHANNEL DIVERSION*
- PROPOSED AREA OF EXCAVATION
- PROPOSED AREA OF FILL
- PROPOSED TREE
- POINT OF INTEREST
- PROPOSED GARBAGE GRATE

~SHEET~ 4 OF 6

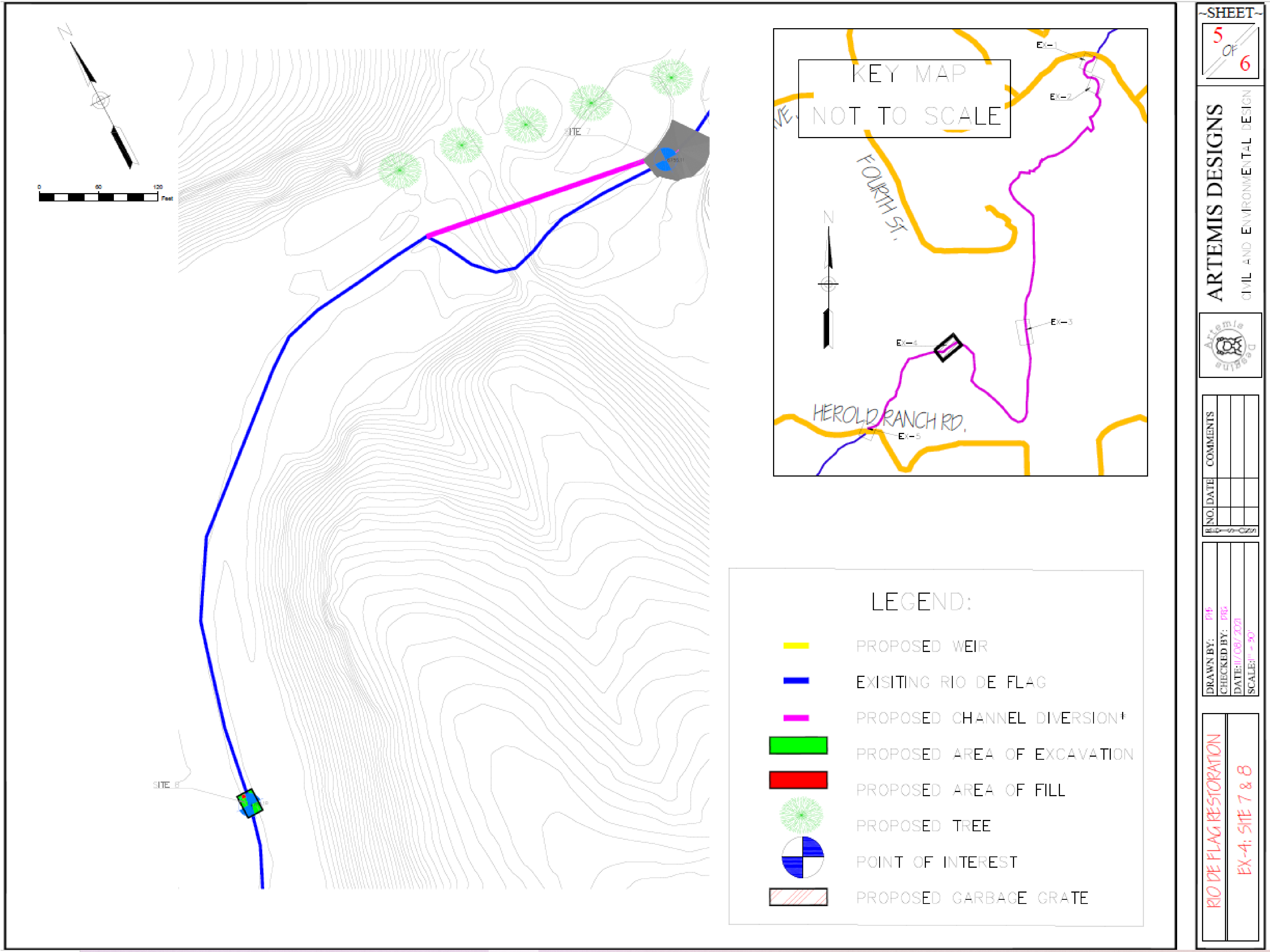
ARTEMIS DESIGNS
CIVIL AND ENVIRONMENTAL DESIGN

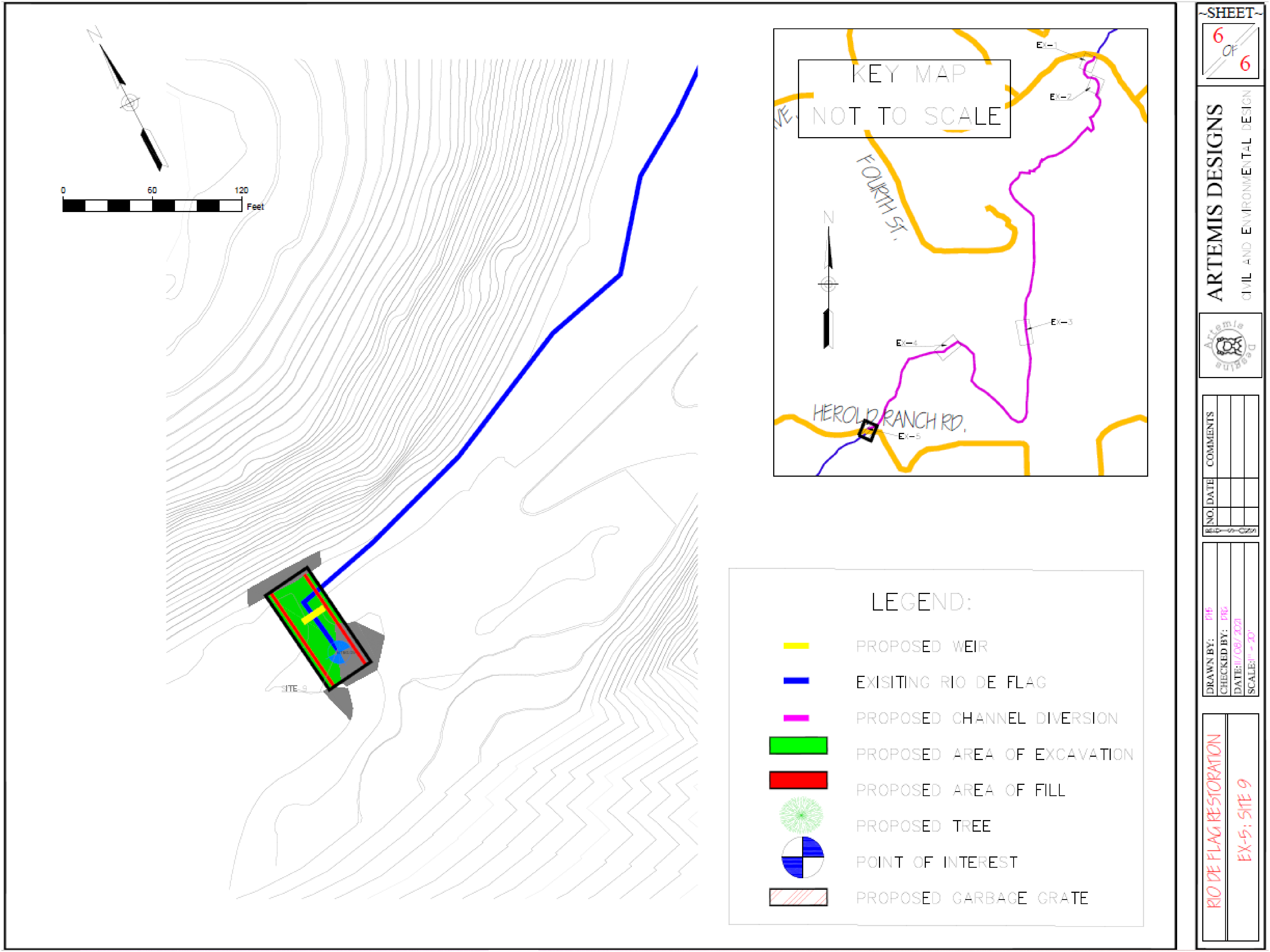
NO.	DATE	COMMENTS

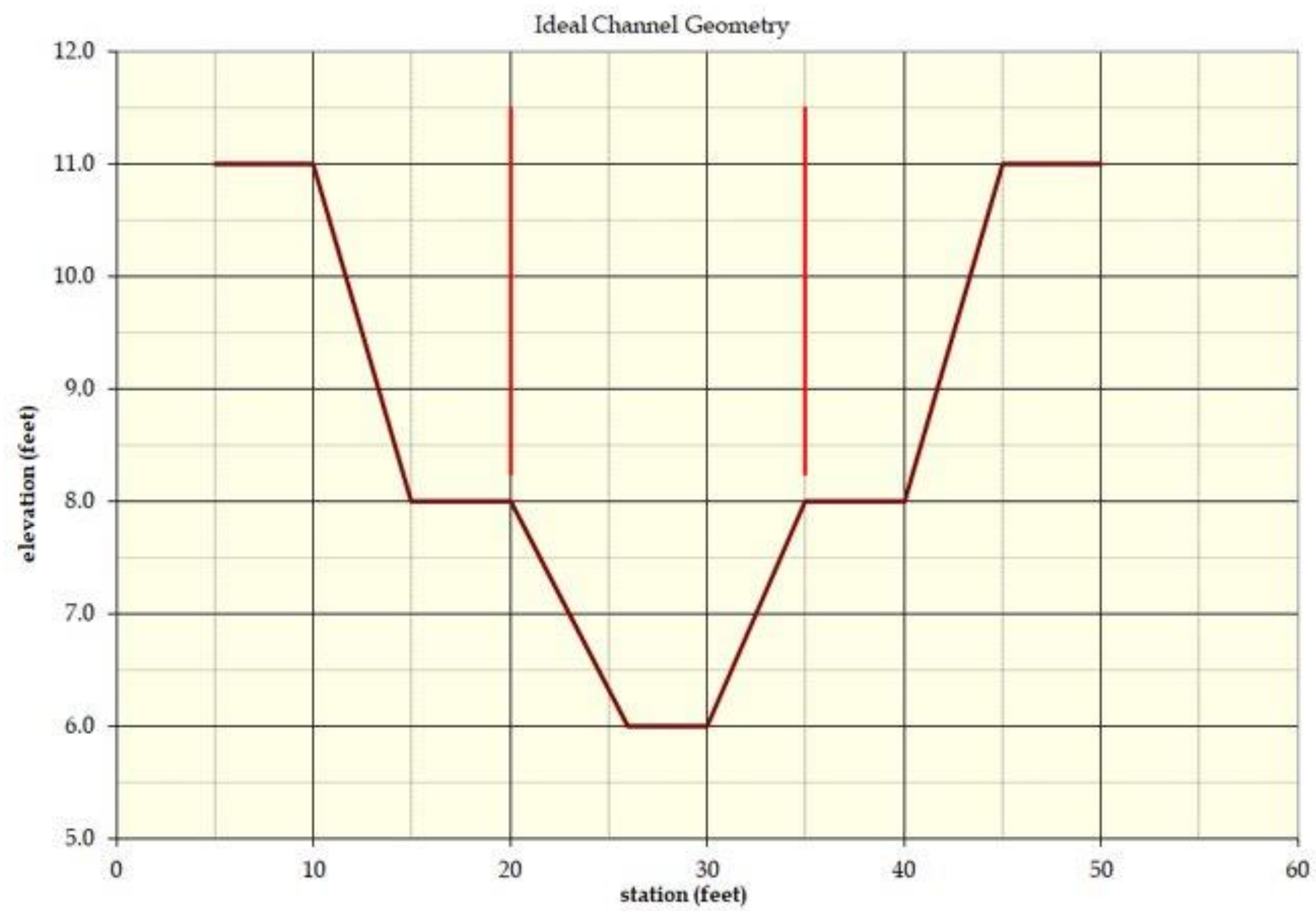
REVISIONS

DRAWN BY:
CHECKED BY:
DATE: 11/08/2021
SCALE: 1" = 30'

RIO DE FLAG RESTORATION
EX-3: SITE 5 & 6

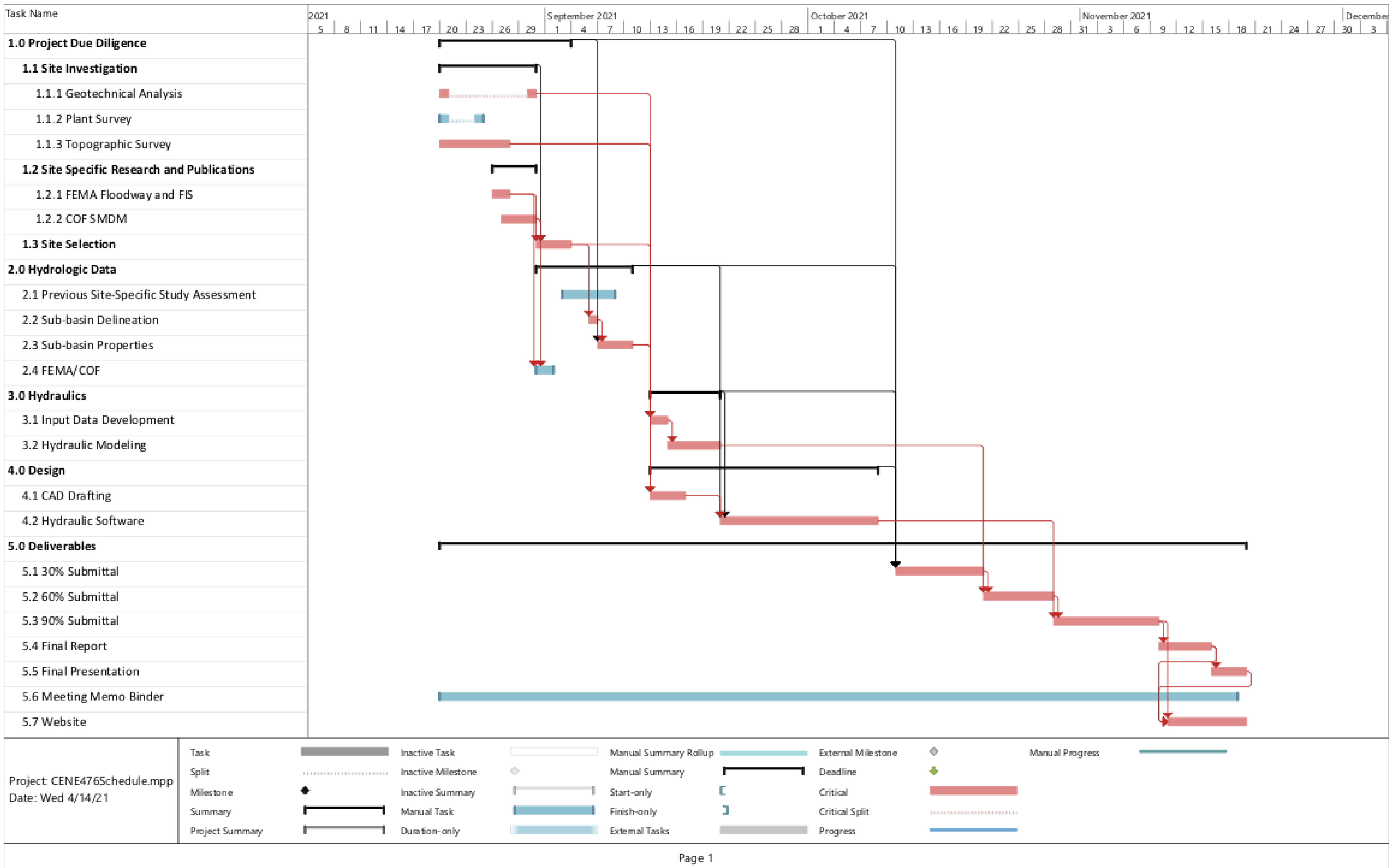

N
SITE 7
SITE 8
KEY MAP
NOT TO SCALE
FOURTH ST.
N
EX-1
EX-2
EX-3
EX-4
EX-5
HEROLD RANCH RD.
LEGEND:
PROPOSED WEIR
EXISITING RIO DE FLAG
PROPOSED CHANNEL DIVERSION
PROPOSED AREA OF EXCAVATION
PROPOSED AREA OF FILL
PROPOSED TREE
POINT OF INTEREST
PROPOSED GARBAGE GRATE
~SHEET~
5 OF 6
ARTEMIS DESIGNS
CIVIL AND ENVIRONMENTAL DESIGN
NO.
DATE
COMMENTS
DRAWN BY:
CHECKED BY:
DATE: 11/08/2021
SCALE: 1" = 90'
RIO DE FLAG RESTORATION
EX-4: SITE 7 & 8


0
60
120
Feet
KEY MAP
NOT TO SCALE
FOURTH ST.
HEROLD RANCH RD.
EX-1
EX-2
EX-3
EX-4
EX-5
N
LEGEND:
PROPOSED WEIR
EXISITING RIO DE FLAG
PROPOSED CHANNEL DIVERSION
PROPOSED AREA OF EXCAVATION
PROPOSED AREA OF FILL
PROPOSED TREE
POINT OF INTEREST
PROPOSED GARBAGE GRATE
~SHEET~
6 OF 6
ARTEMIS DESIGNS
CIVIL AND ENVIRONMENTAL DESIGN
NO.
DATE
COMMENTS
DRAWN BY:
CHECKED BY:
DATE: 11/08/2021
SCALE:
RIO DE FLAG RESTORATION
EX-5: SITE 9

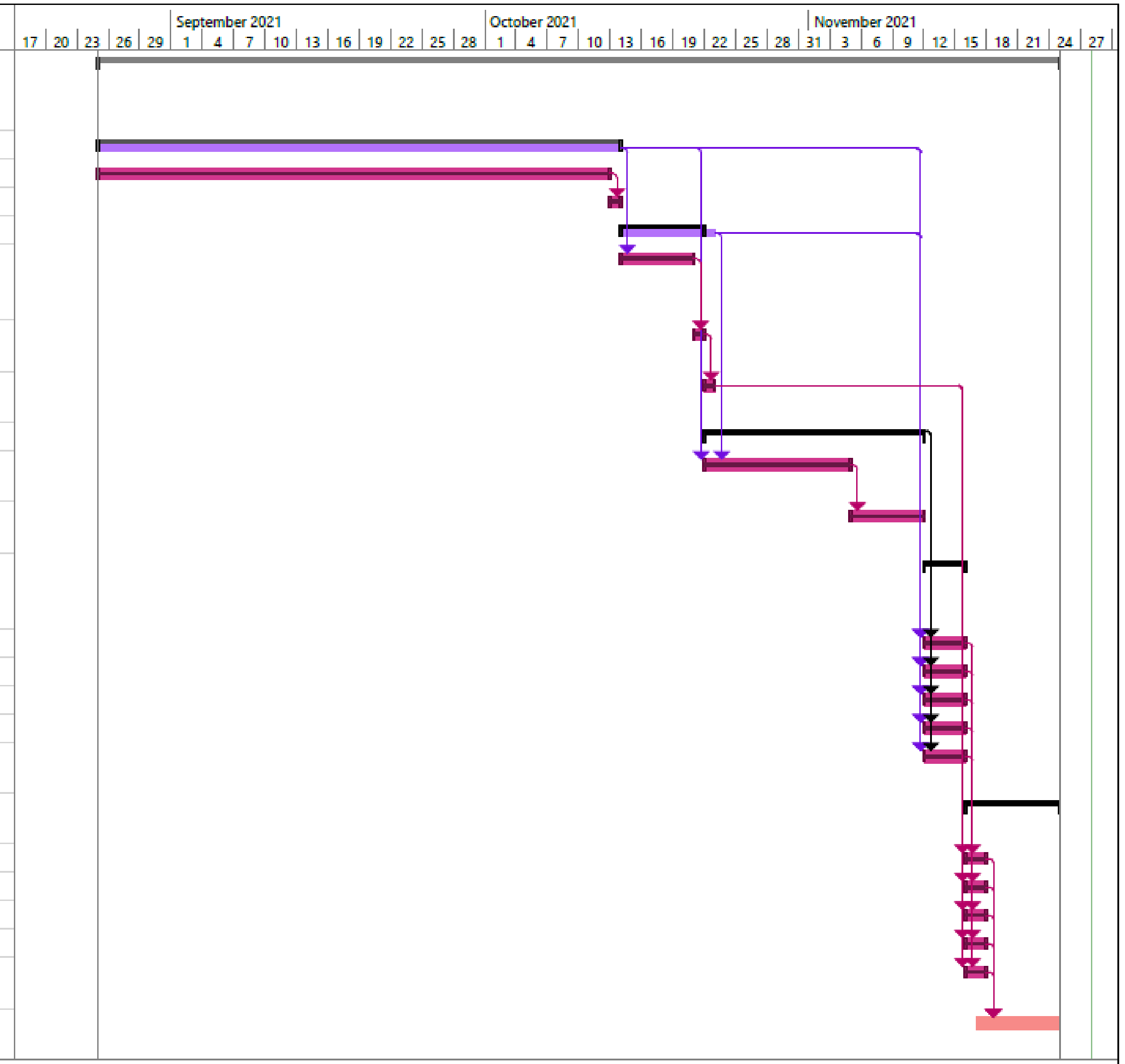


Appendix N 2 Ideal Channel Geometry

Appendix P: Team Schedule Gantt Chart



ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors	Resource Names
0			**Rio de Flag Restoration Feasibility Study**	**66 days?**	**Wed 8/25/21**	**Wed 11/24/21**		
1	✓		**1.0 Site Investigati**	**36 days**	**Wed 8/25/21**	**Wed 10/13/2**		
2	✓		1.1 Site Visit	35 days	Wed 8/25/21	Tue 10/12/21		
3	✓		1.2 FAST Form	1 day	Wed 10/13/2	Wed 10/13/2	2	
4	✓		**2.0 Hydrologic Dat**	**6 days?**	**Thu 10/14/2**	**Thu 10/21/2**		
5	✓		2.1 Previous Site-Specific Study	5 days	Thu 10/14/21	Wed 10/20/21	1	
6	✓		2.2 Subbasin Delineation	1 day	Thu 10/21/21	Thu 10/21/21	5	
7	✓		2.3 Subbasin Properties	1 day	Fri 10/22/21	Fri 10/22/21	6	
8	✓		**3.0 Hydraulic Data**	**15 days**	**Fri 10/22/21**	**Thu 11/11/2**		
9	✓		3.1 Input Data Development	10 days	Fri 10/22/21	Thu 11/4/21	1,4	
10	✓		3.2 Hydraulic Modeling	5 days	Fri 11/5/21	Thu 11/11/21	9	
11	✓		**4.0 Categorical Analysis of Improvement**	**2 days**	**Fri 11/12/21**	**Mon 11/15/21**		
12	✓		4.1 Detention	2 days	Fri 11/12/21	Mon 11/15/2	1,4,8	
13	✓		4.2 Retention	2 days	Fri 11/12/21	Mon 11/15/2	1,4,8	
14	✓		4.3 Erosion	2 days	Fri 11/12/21	Mon 11/15/2	1,4,8	
15	✓		4.4 Silting	2 days	Fri 11/12/21	Mon 11/15/2	1,4,8	
16	✓		4.5 Garbage Pollution	2 days	Fri 11/12/21	Mon 11/15/21	1,4,8	
17			**5.0 Suite of Potential**	**7 days**	**Tue 11/16/21**	**Wed 11/24/21**		
18	✓		5.1 Detention	2 days	Tue 11/16/21	Wed 11/17/2	7,12	
19	✓		5.2 Retention	2 days	Tue 11/16/21	Wed 11/17/2	7,13	
20	✓		5.3 Erosion	2 days	Tue 11/16/21	Wed 11/17/2	7,14	
21	✓		5.4 Silting	2 days	Tue 11/16/21	Wed 11/17/2	7,15	
22	✓		5.5 Garbage Pollution	2 days	Tue 11/16/21	Wed 11/17/21	7,16	
23			5.6 Final Design Recommendatio	6 days	Wed 11/17/21	Wed 11/24/21	18,19,20,21,22	



Project: Rio de Flag Restoration
Date: Sun 11/28/21

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

Appendix Q: Cost of Design Per Site

Cost of Design per Site	
Site 1	
Major Work Done at Site	Install alternative materials for erosion
Cost for Alt. Materials (Riprap) cu.yd [14]	$230
Cu.Yd Needed	18
Total Cost for Riprap	$4,140
Cost for Labor (4 hrs @$18/hr)	$72
Cost for Site 1	$4,460
Cost Overrun Protection (1.25% Total Cost)	$1,115
Total Cost for Site 1	**$5,575**
Site 2	
Major Work Done at Site	Excavate and remove the unnecessary material to improve slope and water conveyance; install alternative materials for erosion
Excavated Material Amount (cu.yd) [15]	5
Cost to Excavate per cu.yd	$25
Total Excavate Cost	$125
Cost for Alt. Materials (Riprap) cu.yd [14]	$230
Cu.Yd Needed	3
Total Cost for Riprap	$690
Cost for Labor (8 hrs @$18/hr) * 2 people	$288
Cost for Site 2	$1,361
Cost Overrun Protection (1.25% Total Cost)	$340
Total Cost for Site 2	**$1,701**
Site 3	
Major Work Done at Site	Install alternative materials for erosion
Cost for Alt. Materials (Riprap) cu.yd [14]	$230
Cu.Yd Needed	6
Total Cost for Riprap	$1,380
Cost for Labor (4 hrs @$18/hr)	$72
Cost for Site 3	$1,688

Cost Overrun Protection (1.25% Total Cost)	$422
Total Cost for Site 3	**$2,110**
Site 4	
Major Work Done at Site	Excavate and remove the unnecessary material to improve slope and water conveyance; install alternative materials for erosion
Excavated Material Amount (cu.yd) [15]	7
Cost to Excavate per cu.yd	$25
Total Excavate Cost	$125
Cost for Alt. Materials (Riprap) cu.yd [14]	$230
Cu.Yd Needed	3.00
Total Cost for Riprap	$690
Cost for Labor (8 hrs @$18/hr) * 2 people	$288
Cost for Site 4	$1,368
Cost Overrun Protection (1.25% Total Cost)	$342
Total Cost for Site 4	**$1,710**
Site 5	
Major Work Done at Site	Install alternative materials for erosion
Cost for Alt. Materials (Riprap) cu.yd [14]	$230
Cu.Yd Needed	2
Total Cost for Riprap	$460
Cost for Labor (4 hrs @$18/hr)	$72
Cost for Site 5	$532
Cost Overrun Protection (1.25% Total Cost)	$133
Total Cost for Site 5	**$665**
Site 6	
Major Work Done at Site	Excavate and remove the unnecessary material to improve slope and water conveyance; install alternative materials for erosion; install weir at this location
Excavated Material Amount (cu.yd)	17
Cost to Excavate per cu.yd [15]	$25
Total Excavate Cost	$415

Cost for Alt. Materials (Riprap) cu.yd [14]	$230
Cu.Yd Needed	4
Total Cost for Riprap	$920
Total Cost for Labor (excavate) (4 hours*2people) ($18/hr)	$144
Cost for Labor (riprap) (2 hrs @$18/hr)	$36
Total Cost of Concrete (per 2 cu.yd)	$600
Total Cost for Weir Install (8 hours @18/hr)*4 people	$576
Cost for Site 6	$2,691
Cost Overrun Protection (1.25% Total Cost)	$673
Total Cost for Site 6	**$3,364**
Site 7	
NA	
Site 8	
Major Work Done at Site	Excavate and remove the unnecessary material to improve slope and water conveyance; fill in secondary channel to prevent detention and push flow through one channel
Amount of Fill (cu.yd)	4
Excavated Material Amount (cu.yd) [15]	8
Cost to Excavate per cu.yd	$25
Total Excavate Cost	$200
Cost for Labor (4 hrs @$18/hr) * 2 people	$144
Cost for Site 8	$344
Cost Overrun Protection (1.25% Total Cost)	$86
Total Cost for Site 8	**$430**
Site 9	
Major Work Done at Site	Excavate and remove the unnecessary material to improve slope and water conveyance; install alternative materials for erosion; install weir at this location
Excavated Material Amount (cu.yd)	3
Cost to Excavate per cu.yd [15]	$25

Total Excavate Cost	$75
Cost for Alt. Materials (Riprap) cu.yd [14]	$230
Cu.Yd Needed	4
Total Cost for Riprap	$920
Total Cost for Labor (excavate) (4 hours*2people) ($18/hr)	$144
Cost for Labor (riprap) (2 hrs @$18/hr)	$36
Total Cost of Concrete (per 2 cu.yd)	$600
Total Cost for Weir Install (8 hours @18/hr)*4 people	$576
Cost for Site 9	$2,506
Cost Overrun Protection (1.25% Total Cost)	$627
Total Cost for Site 9	**$3,133**
Garbage Pollution Cost	
# of Culverts to Install Grates On	5
Cost per Grate [12]	$200
Cost for All Grates	$1600
Labor Cost (12hrs @18/hr)	$216
Total Grate Cost	**$2,016**
Total Cost for Transport of Equipment and Materials:	**$5,000**
Total Cost for Initial Siteworks:	**$25,704**

Construction Cost	
	Total Cost ($)
Site 1	$5,575
Site 2	$1,701
Site 3	$2,110
Site 4	$1,710
Site 5	$665
Site 6	$3,364
Site 7	NA
Site 8	$430
Site 9	$3,133
Garbage Pollution Cost	$2,016
Total Cost for Transport of Equipment and Materials	$5,000
Total Cost for Soil Transport	$2,000
Total Construction Cost	**$27,704**

Appendix Q 2: Construction Costs for Reach including costs for each site, garbage pollution, transport of equipment and materials, and soil transport.