PRELIMINARY ENGINEERING REPORT:

Mountain View Drive
Stream Restoration Project
City of Harrisonburg, Virginia

October 2017

Prepared for:

City of Harrisonburg
Public Works Department

Prepared by:

AMT CONSULTING ENGINEERS

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1.0 INTRODUCTION

The City of Harrisonburg Public Works Department seeks to implement a public works improvement project to stabilize or restore 1,730 feet of eroding stream channel adjacent to Mountain View Drive in the City of Harrisonburg, Rockingham County, Virginia. The stream reach has a 361-acre contributing drainage area of highly impervious commercial and transportation development which lacks adequate stormwater management controls. The unmanaged stormwater from this drainage area is contributing to the overall instability and accelerated erosion along the subject stream reach. This has resulted in the exposure of existing sewer lines and private utilities and the loss of land in the rear yards of several properties along Mountain View Drive. In support of this project, A. Morton Thomas and Associates (AMT) has been contracted by the City of Harrisonburg to assess current stream conditions and propose concepts to stabilize or restore the channel. The Mountain View Drive: Stream Restoration Project, will entail data collection and review; hydrologic/hydraulic analysis; stream assessment; water quality assessment; the development of conceptual plans; and a concept recommendations report.

1.1 PROJECT GOALS AND OBJECTIVES

The overall project goals are to analyze the existing stream condition and identify measures to stabilize or restore the stream channel. Specifically, the project goals focus on two options for implementing a public works improvement project in this area:

1. Utilize natural channel design techniques to stabilize, improve and beautify the stream corridor, which will provide water quality benefits towards the city's TMDL program; or
2. Provide minimal improvements as necessary to stabilize the channel bank behind residential properties along Mountain View Drive and protect at-risk infrastructure, including sanitary sewer and existing utility assets, without consideration for overall stream stability and restoration through the channel reach.

This report documents the Stream Assessment Study portion of the project. AMT has completed field and desktop evaluations to develop proposed stream restoration and/or stabilization concept designs.

2.0 WATERSHED CHARACTERIZATION

2.1 WATERSHED DESCRIPTION

The 361-acre watershed is located in the City of Harrisonburg, Rockingham County Virginia. The watershed lies in the Ridge and Valley physiographic province. The watershed drains to Blacks Run, which is a tributary of the Shenandoah River, and ultimately flows to the Chesapeake Bay. The predominant land use in the watershed is commercial at 64.1 % (230.7 acres) followed by roads which account for 19.3% (69.4 acres) of land use in the watershed. Table 2.1 lists the land use by category for the watershed.

Table 2-1 Watershed Land Use

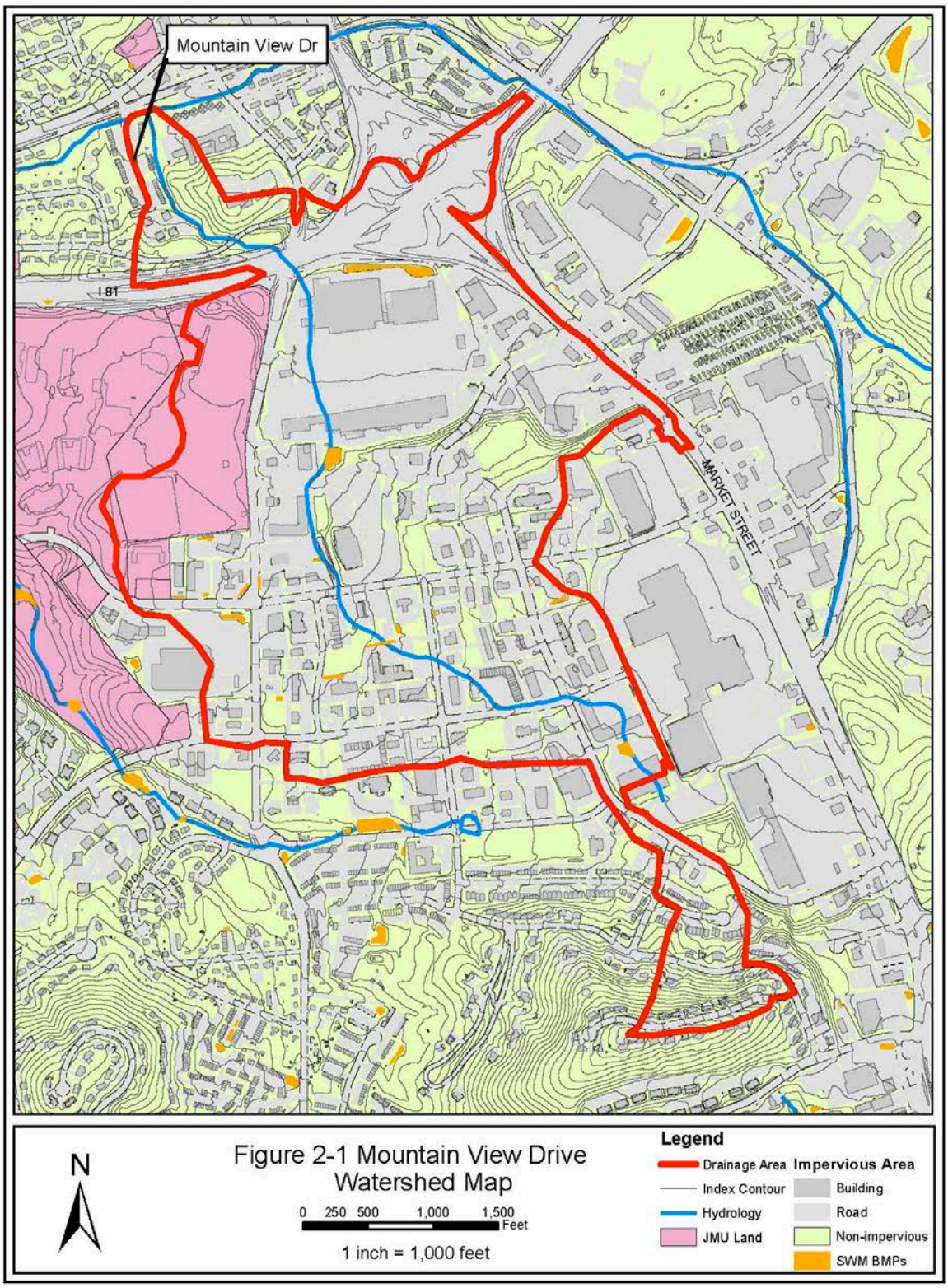
Land Use	Acreage		Percent
Commercial	230.7		64.1
Road	35.66		9.9
Road with Median	33.78		9.4
Open Space	30.51		8.4
Residential 1/8 Acre Labels	12.29		3.5
Residential ½ Acre Labels	6.97		1.9
Forest	10.22		2.8
Total	**360.13**		**100**

Figure 2.1 provides a watershed map.

2.2 UPPER WATERSHED BMP'S

There are multiple privately owned and maintained best management practices (BMP's) in the upper watershed which have not been included in the watershed model, since they handle small portions of the total contributing runoff, and since they are older BMP's with limited records in several cases.

Figure 2.1 depicts the BMP locations within the watershed.


Mountain View Dr
I 81
MARKET STREET
N
Figure 2-1 Mountain View Drive
Watershed Map
0 250 500 1,000 1,500
Feet
1 inch = 1,000 feet
Legend
Drainage Area
Index Contour
Hydrology
JMU Land
Impervious Area
Building
Road
Non-impervious
SWM BMPs

2.3 SOILS

A U.S. Department of Agriculture - Natural Resources Conservation Service (USDA - NRCS) Custom Soil Resource Report for the study area (USDA - NRCS, 2016) indicates that Frederick/Lodi silt loams (29C2 :7-15% slopes and 29D2: 15-25% slopes) is present along most of the stream located adjacent to Mountain View Drive. Frederick/Lodi silt loams consists of silt loam, clay, and silty clay and is not subject to flooding. It is well drained with a depth to water tables of more than 80 inches. Upstream of the subject reach, the soils are classified as Urban Land located South East of the Frederick/Lodi silt loams is the Urban Land (73). To the East of the stream is Carbo-Endcav-Rock outcrop complex, a well-drained material with a water to depth of more than 80 inches. Table 2-2 summarizes these soil characteristics.

All of these soils are categorized as Hydrologic Soil Group (HSG) B, with the exception of 12C, 28A, and 50C, which are categorized as HGS D when in an un-drained condition. The Fluvaquents (28A) soil is also considered a hydric soil. Figures 2-2 and 2-3 shows the soil types within the Study Area.

Table 2-2 Watershed Soil Characteristics

Soil Symbol	Soil Series	% Slope	Flood Frequency	Drainage Class	Hydrologic Soil Group*	Hydric Soil
12C	Carbo-Endcav-Rock outcrop complex	7-15	None	Well Drained	D	No
28A	Fluvaquents	NA	Frequent	Poorly Drained	B/D	Yes
29B2	Frederick/Lodi silt loams	2-7	None	Well Drained	B	No
29C2	Frederick/Lodi silt loams	7-15	None	Well Drained	B	No
29D2	Frederick/Lodi silt loams	15-25	None	Well Drained	B	No
31C2	Frederick and Lodi gravelly silt loans	7-15	None	Well Drained	B	No
31D2	Frederick and Lodi gravelly silt loans	15-25	None	Well Drained	B	No
31E2	Frederick and Lodi gravelly silt loans	25-45	None	Well Drained	B	No
32C	Frederick and Lodi very gravelly silt loams	7-15	None	Well Drained	B	No
50C	Nixa-Frederick-Lodi gravelly loams	7-15	None	Moderately Well Drained	D	No
68B	Timberville variant silt loam	0-7	Frequent	Well Drained	B	No
Urban	Urban Land	NA	NA	NA	NA	NA

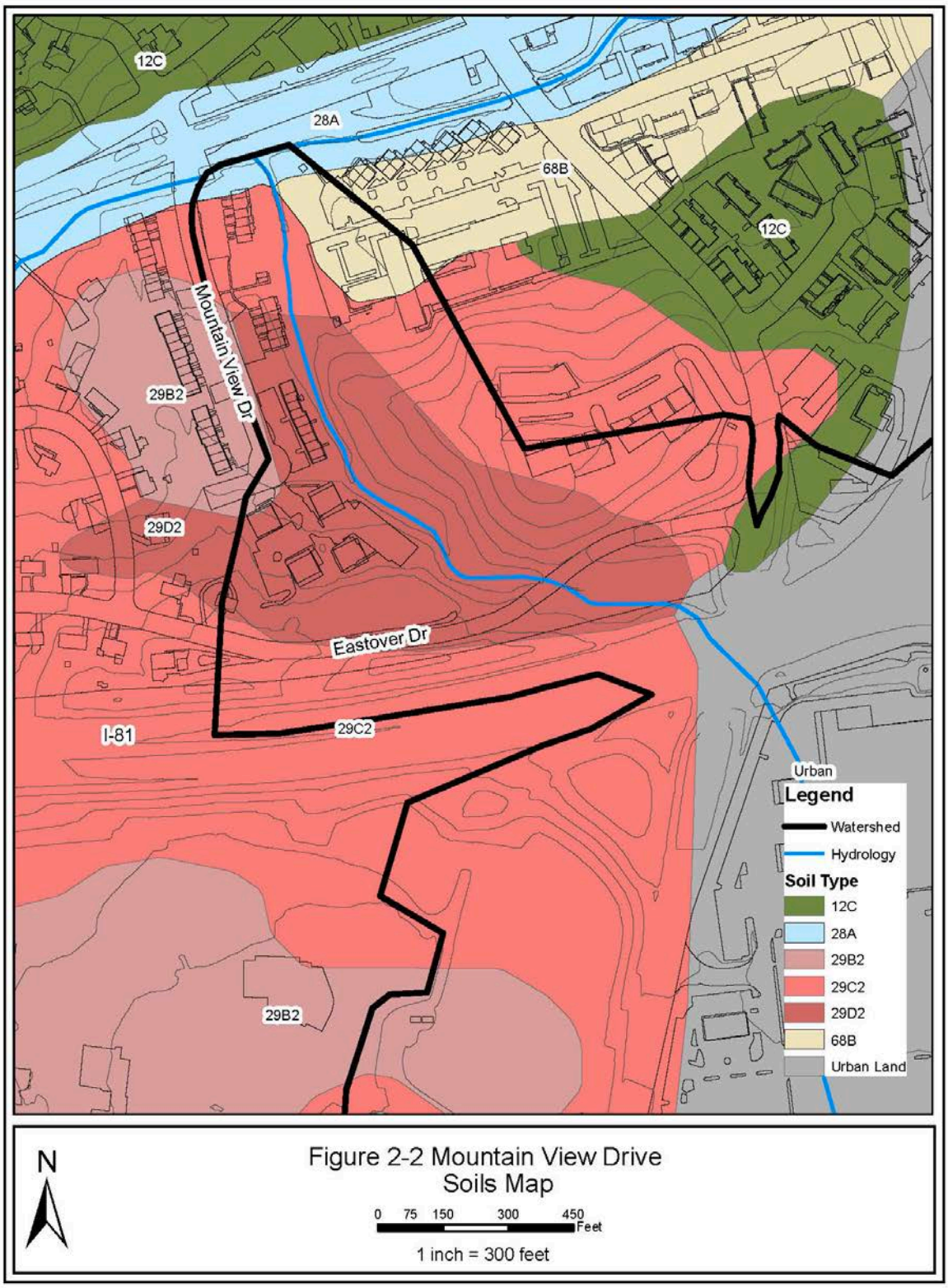


Figure 2-2 Mountain View Drive
Soils Map

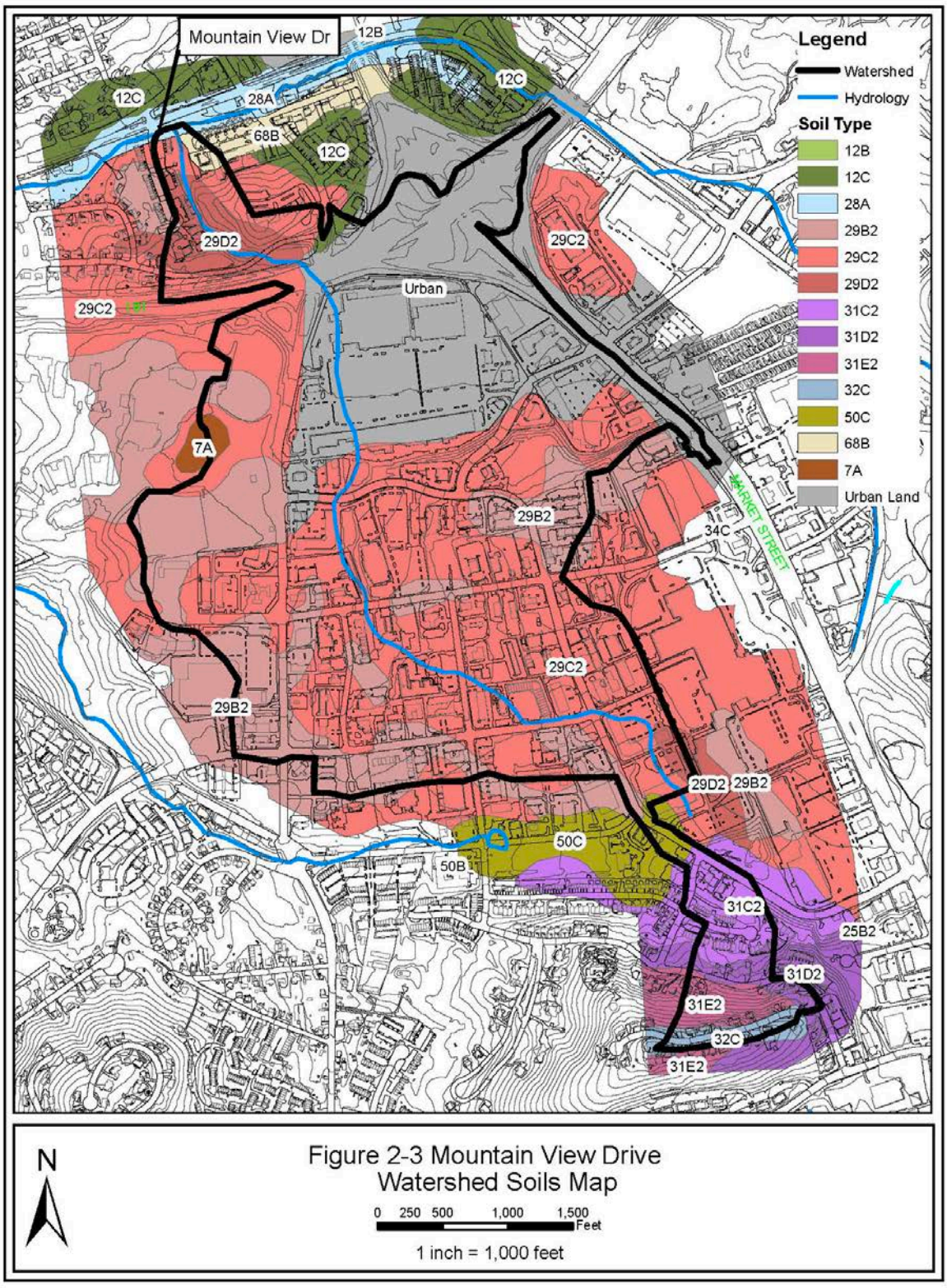


Figure 2-3 Mountain View Drive Watershed Soils Map

2.4 VEGETATIVE COMMUNITIES

Currently, forest occupies 2.8% of the drainage area and is predominately located just east of Mountain View Drive. Red maple (*Acer rubrum*), white oak (Quercus *Alba*), and honey locust (*Gleditsia triacanthos*) are the dominant vegetation along the stream for this 10.2 acre wooded area shown in green on Figure 2.4.

2.4 FEMA 100-YEAR FLOODPLAINS

The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (Figure 2-4) for the area indicates that a portion of the study area lies within a FEMA mapped floodplain. The mapped floodplain covers approximately 45% of Reach 2, which is between Martin Luther King, Jr. Way and Eastover Drive. If restoration activities occur within the mapped 100-year floodplain, FEMA coordination will be necessary for any map modifications.

2.5 PROPERTY OWNERSHIP

The study area includes multiple parcels of land. The City of Harrisonburg owns the parcels along right of way for Eastover Drive where Reach 1 is located. Along Mountain View Drive on the east side of Reach 2 are a multi-family residential property (apartments) and approximately 22 single family attached residences and associated common areas. To the east of Reach 2 are three medium density residential properties that front on Reservoir Street. Figure 2-5 depicts the properties adjacent to the stream.

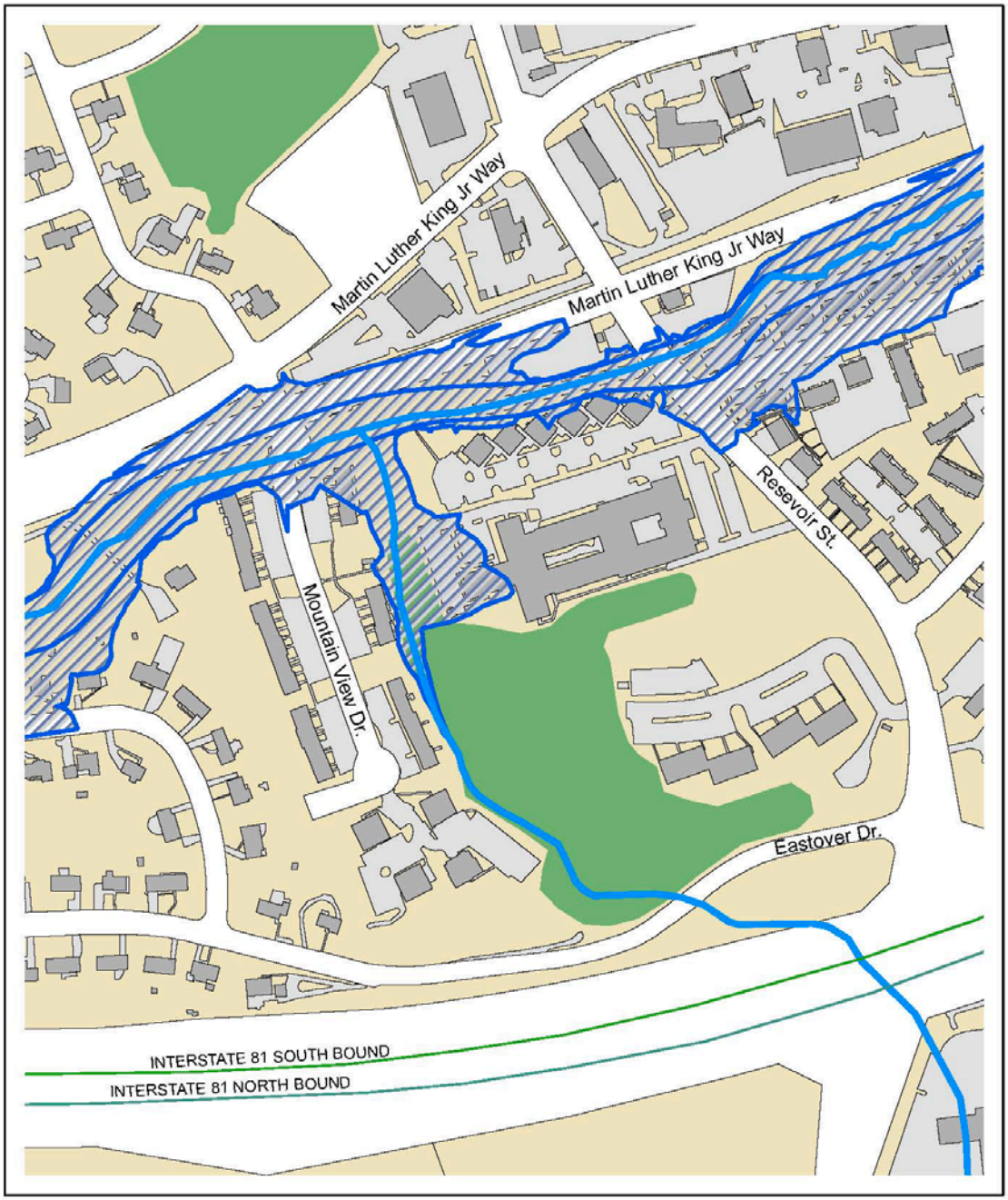


Figure 2-4 Mountain View Drive
FEMA 100-Year Floodplain Map

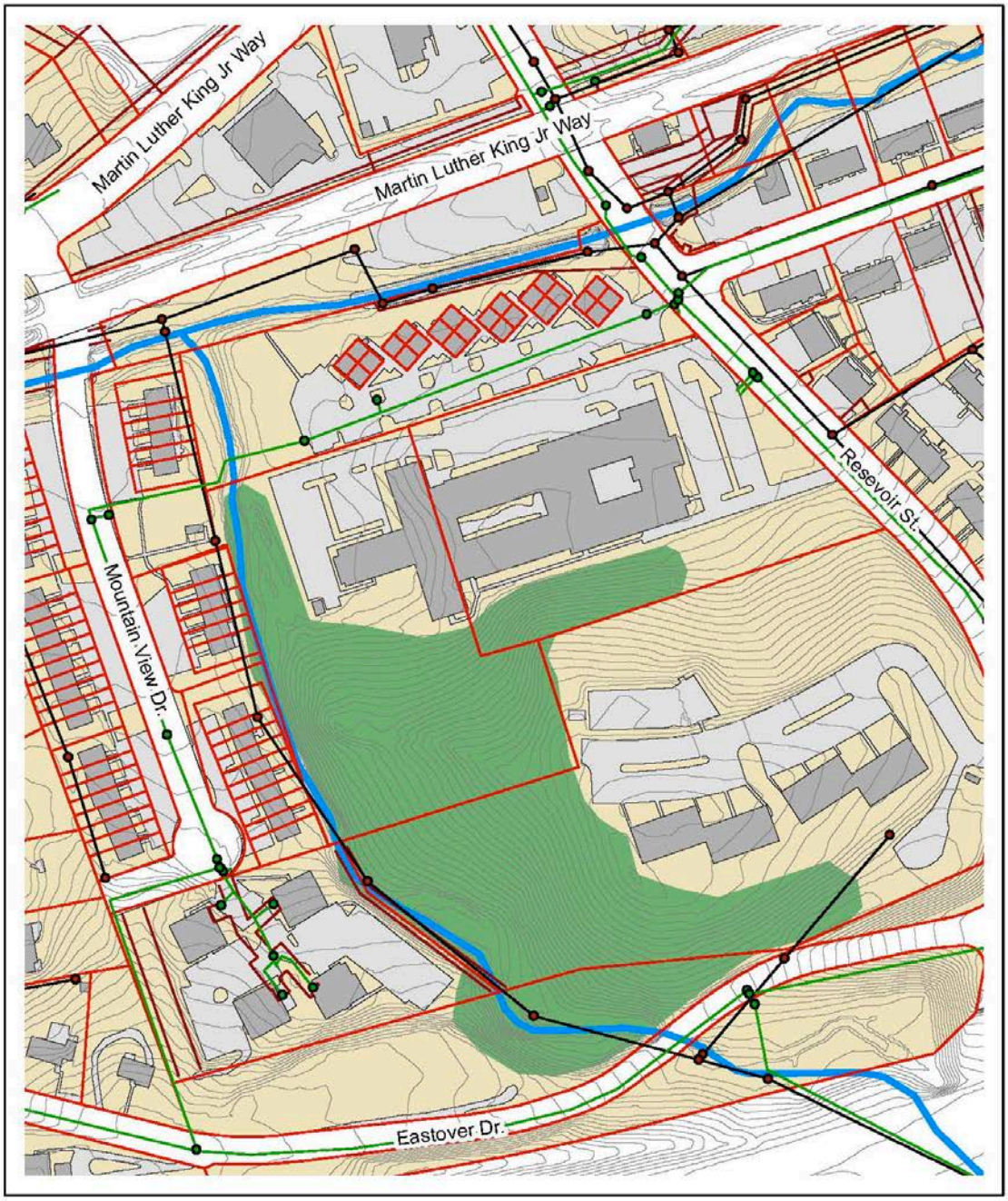


Figure 2-5 Mountain View Drive
Study Area Property Map

N

0 100 200 400 Feet

1 inch = 200 feet

Legend

- waterlines
- Sewer Lines
- Easements
- Property Lines
- Stream
- Contours
- Building
- Ground
- Impervious
- Forest

3.0 EXISTING STREAM CONDITIONS

The goal of the existing conditions assessment was to gain an understanding of the existing hydraulic and morphological characteristics of the project reaches to aid in the development of restoration concepts. Field mapping for the assessments was developed using GIS layers and aerial photography. Longitudinal profiles, cross sections, streambed materials, and bank stability indices were analyzed along the entire stream reach. The data collected yielded channel dimensions and parameters from which design concepts can be evaluated.

The stream channel within the study area has been significantly altered due to stormwater runoff from impervious surfaces. Based on the existing condition assessment, the stream was divided into two reaches. Reach 1was found to be predominantly unstable with short reaches of stable riffles that showed clear bankfull indicators and had well-vegetated streambanks. Reach 2 was found to be very unstable and actively degrading along its entire length with exposed sewer and utility lines both within and adjacent to the active channel.

3.1 STREAM REACH ASSESSMENTS

3.1.1 Mountain View Drive Stream - Reach 1

Reach 1 begins at the outfall of a double box culvert beneath Interstate 81 and ends at a culvert beneath Eastover Drive. This 403-linear foot, partially incised/eroded, intermittent stream channel is vertically stable as there are fixed upstream and downstream elevations provided by the two culverts. Consequently, the primary channel adjustment mechanism is accelerated lateral migration. Based on the hydrology and field assessments, it can be assumed the US Army Corp of Engineers (USACE) and the Department of Environmental Quality (DEQ) would regulate this reach as a jurisdictional stream. The channel has an average bankfull width of 14.43 feet, with an average slope of 1.5%. The channel has the attributes of a relatively unstable Rosgen type "C" channel (Rosgen, 1996). Figure 3-1 provides a key to the Rosgen stream types. Figures 3-2 through 3-5 depict typical conditions along Reach 1.

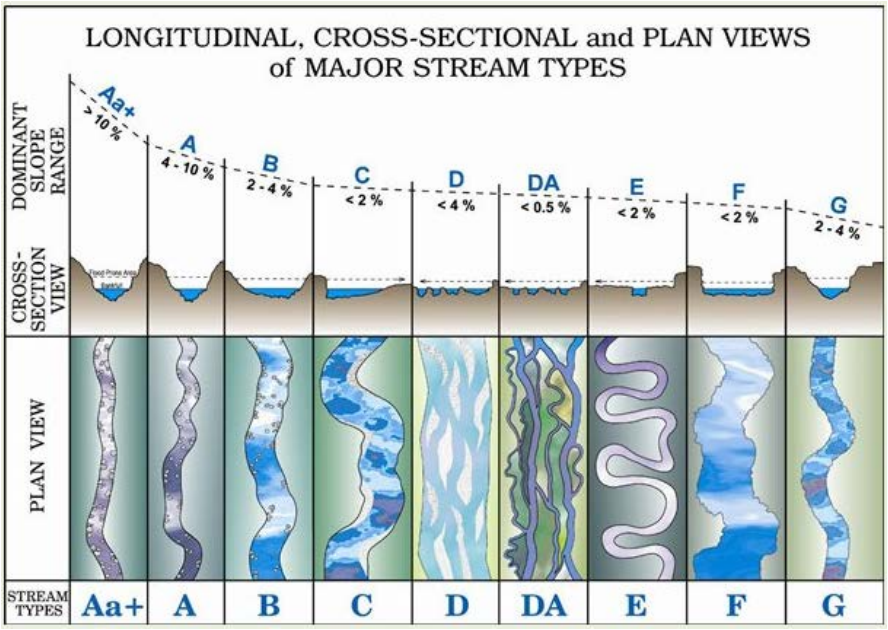


Figure 3-1 Rosgen Stream Classification System

Figure 3-2 Culvert Outfall and plunge pool at the Head of Reach 1

Figure 3-3 Looking Downstream Along Reach 1

(Large boulders, debris jam, cattle fence)

Figure 3-4 Eroded Streambank Meander Bend/exposed Pipe Along Reach 1

Figure 3-5 Looking downstream along a relatively stable section of Reach 1

3.1.2 Mountain View Drive Stream – Reach 2

Reach 2 begins at the outfall of the box culvert running beneath Eastover Drive and ends at the confluence with Siebert Creek downstream. This 899-linear foot reach differs from Reach 1 in that it is deeply incised and has predominately unstable streambanks. Approximately 400 linear feet of Reach 2 is characterized by eroding streambanks in the rear yards of the single family attached houses along Mountain View Drive. This streambank erosion has exposed various utility assets. Reach 2 has an average bankfull width of 21.3 feet and a total channel width of 31.6 feet with an average slope of 3.2 %. This reach displays the attributes of a highly unstable Rosgen type "F" channel. A cross section from Reach 2 is depicted in Figure 3-6. Figure 3-7 shows an aerial view of the reach. Figures 3-8 through 3-14 depict typical conditions along Reach 2.

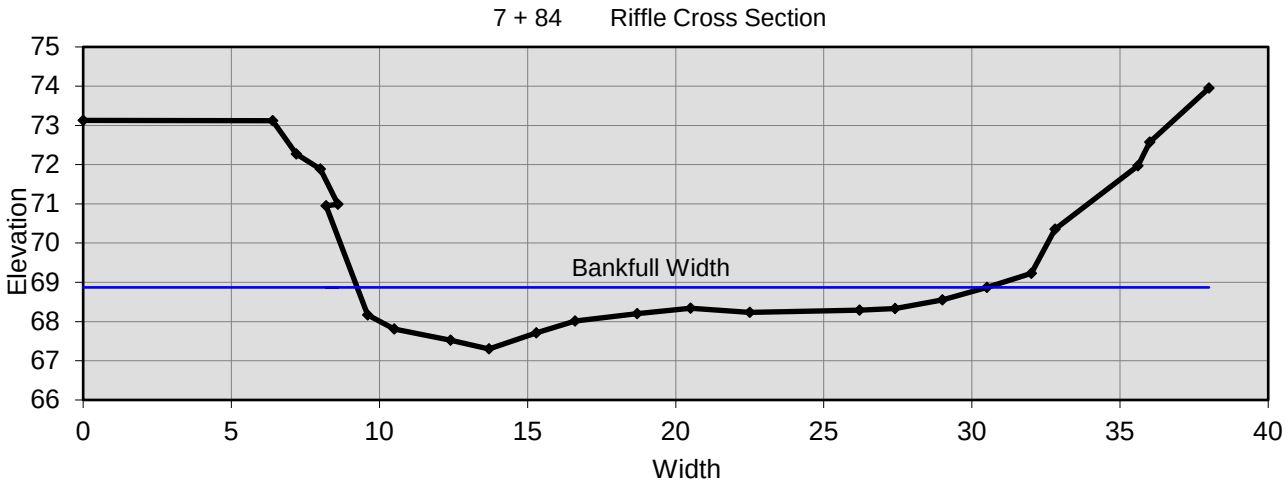


Figure 3-6 Reach 2 Riffle Cross Section

To assess the degree to which channel has incised and widened, its channel dimensions were compared to geomorphic regional equations developed by the U.S. Geological Survey (USGS) for the non-urban Ridge and Valley Physiographic Province (USGS, 2005). Table 3-1 presents the bankfull width, depth, cross sectional area, and discharge parameters derived from the field survey and the parameters for a stream with a similiar drainage area derived from the regional equations. The differences from the regional equations indicates significant alteration caused by the stormwater runoff from impervious surfaces in the watershed.

In addition, the bankfull channel is confined within a much larger channel. Storm flows in excess of bankfull cannot access the floodplain and are confined within the channel. Confined flows are highly erosive and can lead to continued accelerated channel erosion. Reach 2 also has significant areas of bedrock exposure along the reach invert. This bedrock is providing grade control in areas preventing channel incision and causing lateral (streambank) erosion or widening.

Table 3-1 Comparison of Field Derived and Regional Equation Channel Parameters for Reach 2

Parameter	Regional Equation	Field Assessment
Bankfull Width	9.69 ft.	21.3 ft.
Bankfull Depth	0.85 ft.	0.8 ft.
Bankfull Cross Sectional Area	8.3 sq. ft.	16.3 sq. ft.
Bankfull Discharge	27.4 cfs	79.3 cfs

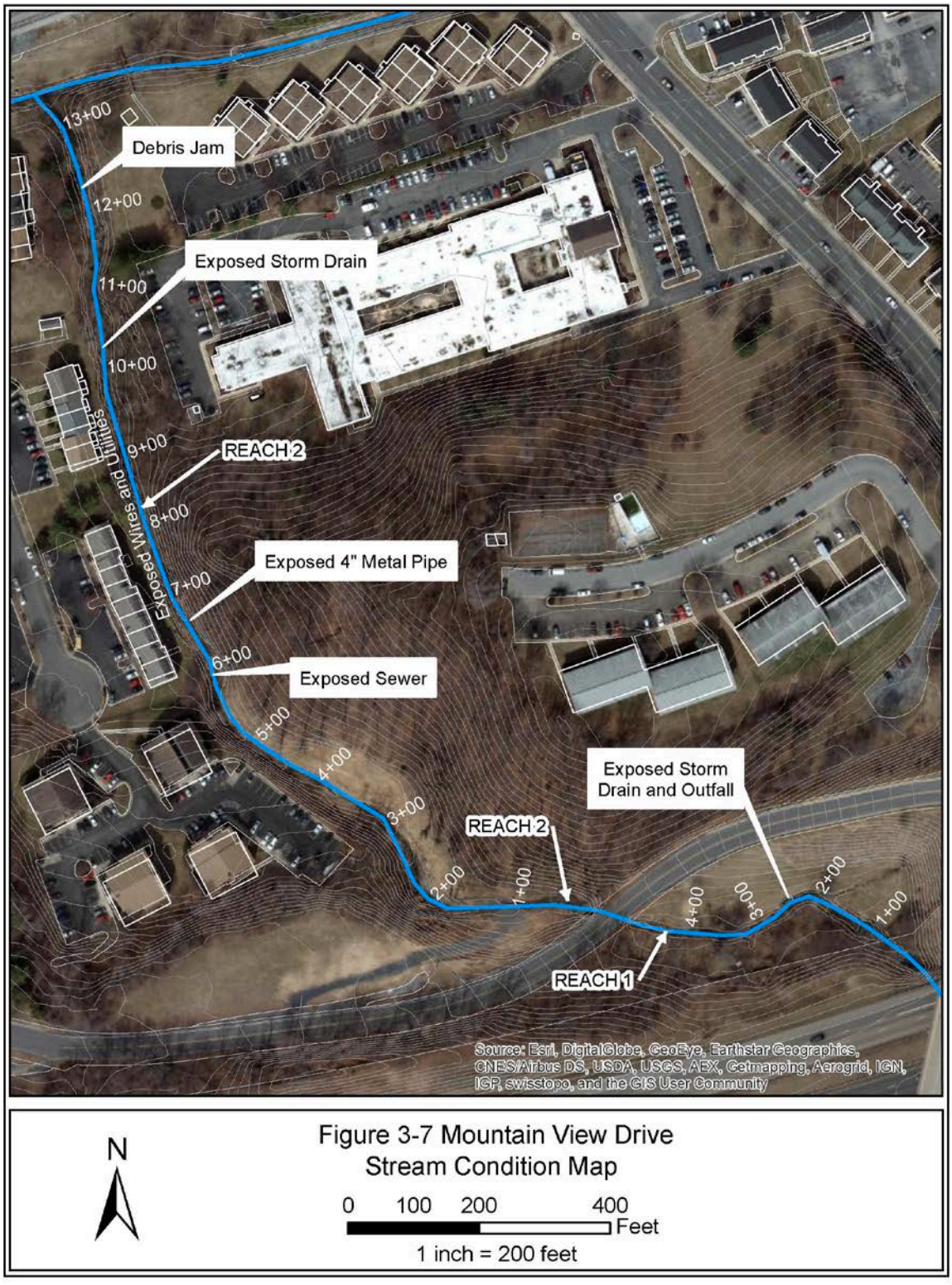

13+00
Debris Jam
12+00
Exposed Storm Drain
11+00
10+00
9+00
REACH 2
8+00
Exposed Wires and Utilities
Exposed 4" Metal Pipe
7+00
6+00
Exposed Sewer
5+00
4+00
3+00
2+00
1+00
Exposed Storm Drain and Outfall
REACH 2
4+00
3+00
2+00
1+00
REACH 1
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
N
Figure 3-7 Mountain View Drive
Stream Condition Map
0 100 200 400
Feet
1 inch = 200 feet

Figure 3-7 Exposed sewer line through stream section (6+00)

Figure 3-8 Exposed pipe in Reach 2 (6+75)

Figure 3-9 Looking up stream at eroding channel along Reach 2 (8+00)

Figure 3-10 Looking upstream at eroding banks and exposed utilities along Reach 2 (7+50)

Figure 3-11 Looking downstream to eroded bank and large rocks within channel (10+00)

Figure 3-12 Exposed utilities along eroding bank (8+00)

Figure 3-13 Exposed underdrain (9+50)

4.0 PRELIMINARY HYDROLOGIC ANALYSIS

Design storm event information pertinent to the project site was obtained from the NOAA Atlas 14 website (http://hdsc.nws.noaa.gov/hdsc/pfds/) and entered into TR-55. Design storm events analyzed include the 1-, 2-, 10-, 50-, and 100-yr return period, 24-hr duration events and the 1- and 2-yr return period, 6-hr duration events with standard NRCS Type II distribution and antecedent moisture condition 2. Table 4-1 summarizes the rainfall depth per design storm event used in the hydrologic analyses. Tables 4-2 and 4-3 summarize the TR-55 input and output for the events analyzed.

Table 4-1 Design Storm Event Summary

Return Period (yrs)	Duration (hrs)	Rainfall Depth (in)
1	6	1.53
1	24	2.17
2	6	1.53
2	24	2.62
10	24	3.87
50	24	5.40
100	24	6.15

Table 4-2 Mountain View Drive Basin Statistics

Study Point	Drainage Area (sq. mi.)	Runoff Curve Number (RCN)	Impervious Area (%)	Physiographic Region
Outfall@ Mt. View Stream	360.1	89	37.2	Valley and Ridge

Table 4-3 Mountain View Drive Peak Discharges

Return Period (yrs)	Duration (hrs)	Outfall @ Mt. View Stream Peak Discharge (cfs)
1	6	287.0
1	24	353.7
2	6	400.6
2	24	473.7
10	24	753.0
50	24	1241.5
100	24	1449.0

5.0 ALTERNATIVE ANALYSIS

The overall project goals are to analyze the existing stream conditions and identify measures to stabilize or restore the stream channel. Specifically, the project goals focus upon two options for implementing a public works improvement project in this area:

1. Utilize natural channel design techniques to stabilize, improve and beautify the stream corridor, which will provide water quality benefits towards the city's TMDL program; or

2. Provide minimal improvements as necessary to stabilize the channel bank behind the residential properties along Mountain View Drive and protect at-risk infrastructure, including sanitary sewer and existing utility assets, without consideration for overall stream stability and restoration through the channel reach.

The stream assessment report describes accelerated lateral channel erosion along Reach 1 and substantial channel erosion and instability along all of Reach 2. To address the project goals described above, two concepts were evaluated.

Concept 1 represents the minimal improvements necessary to stabilize the channel behind the multi-family and single family residential properties (Figure 5-1). It would involve armoring the left streambank (looking downstream) for approximately 600 feet behind these properties. The armoring would consist of large rock placed along the toe of the west streambank and stacked to a height sufficient to protect the streambank from further erosion. The rock would be placed channelward of the existing streambank a sufficient distance to allow exposed utilities to be reburied and protected. The average height of the stacked stone would be at least four feet above the current stream invert. At least one course of stone would need to be placed below the channel invert as a footer course, making the total stacked height of the rock approximately six feet. Construction costs for the activities described in Concept 1 range from $300 to $400 a linear foot. These construction costs do not include soft costs for design, permitting, and construction (inspection/management) services. An estimate of construction, design/permitting, and construction services costs are presented in Table 5-1. The total project cost estimate for Concept 1 ranges from $290,000 to $350,000.

As Concept 1 does not include measures to reduce the energy gradient of the current storm flows (i.e., step pools) or direct the flows away from the streambank (i.e., rock vanes), the design will need to be robust enough and the stone sized to withstand current and anticipated erosive forces. As Concept 1 is intended to protect property and infrastructure on the west streambank only, it would not be considered stream restoration and would not be eligible to receive TMDL nutrient and sediment pollution reduction credits. It could also result in negative effects on the east streambank.

Figure 5-1 Mountain View Drive
Concept 1 Restoration Map

Table 5-1 Mountain View Drive (Concept 1) Cost Estimate

Category	Linear feet	Construction Cost Range	
		Low	High
Total Construction Cost	600	$180,000	$240,000
Design/Permitting Cost	$90,000		
Construction Services	$20,000		
Cost Estimate Range		**$290,000**	**$350,000**

Concept 2 would involve a comprehensive stream restoration design approach utilizing natural channel design principals (Figure 5-2). Concept 2 would be considered a stream restoration project and would be eligible to receive TMDL nutrient and sediment reduction credits. Concept 2 includes two options. Option 1 would limit stream restoration work to approximately 1,300 linear feet of Reach 2. Option 2 would extend the comprehensive approach to include Reach 1 for a total project length of approximately 1,730 linear feet. Reach 1 is located on the City owned right-of-way for Eastover Drive, is more stable than Reach 2, and will require less intensive restoration efforts. Option 2 is recommended as it would be the more cost effective option and would reduce the overall "per foot" construction cost and "per pound" pollutant removal cost in comparison to Option 1 alone.

The Concept 2 restoration plan for Reach 1 proposes a natural channel design focusing on streambank grading and thalweg alignment, as lateral instability is the primary impairment. Grade control is provided for Reach 1 by the upstream and downstream culverts. However, additional secondary grade controls may be required to establish/maintain the new thalweg alignment.

The Concept 2 restoration plan for Reach 2 divides the reach into three sections. Restoration along the upper reach would entail relocating the thalweg away from the left streambank utilizing cross vanes and/or J-hooks as grade controls and to direct flow. Restoration along the central portion of the reach would entail a reinforced left streambank, likely utilizing a rock toe revetment, along with step pools to reduce stream energy. Along the lower portion of reach 2, where the channel is less constrained, restoration would entail a natural channel design approach that involves regrading streambanks to provide greater floodplain access for storm flows, as well as adding sinuosity. The specific restoration measures and their locations will require additional field and office assessment as part of the final design. Construction costs for comprehensive stream restoration as outlined for Concept 2 will vary based on the intensity of the restoration effort. In Reach 1 where streambank grading and thalweg alignment will be the primary activities construction costs typically range from $400 to $600 per linear foot. In upper and central portions of Reach 2, where restoration activities will be most intensive, construction costs typically range from $800 to $1,000 per linear foot. Construction costs for the lower portion of Reach 2, where the intensity of restoration efforts is moderate, construction costs typically range $400 to $500 per linear foot. These construction costs do not include soft costs for design, permitting, and construction (inspection/management) services. An estimate of construction, design/permitting, and construction services cost are presented in Table 5-2. The total project cost estimate for Concept 2 ranges from $1,402,000 to $1,778,000.

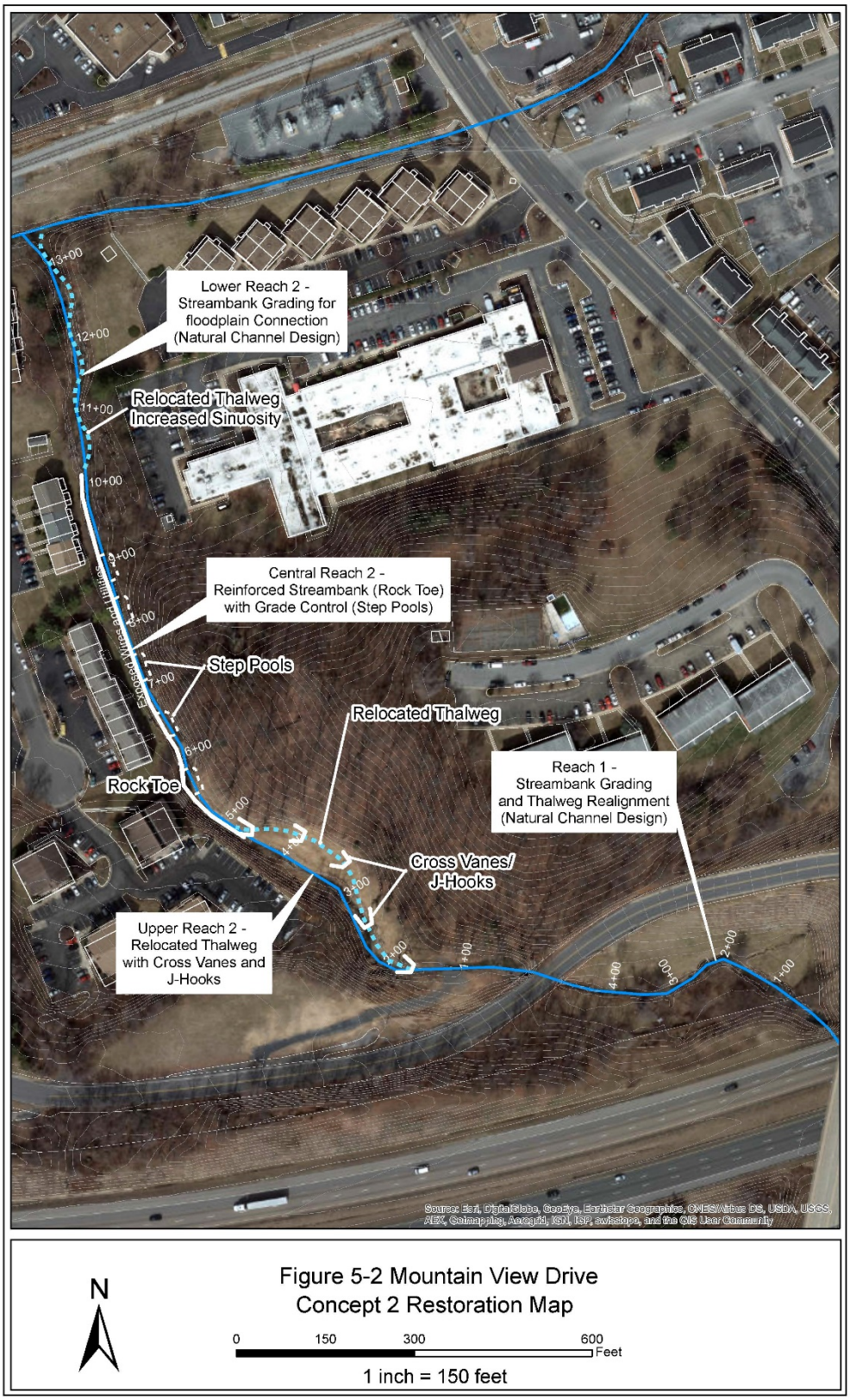

13+00
12+00
11+00
10+00
9+00
8+00
7+00
6+00
5+00
4+00
3+00
2+00
1+00
Lower Reach 2 - Streambank Grading for floodplain Connection (Natural Channel Design)
Relocated Thalweg Increased Sinuosity
Central Reach 2 - Reinforced Streambank (Rock Toe) with Grade Control (Step Pools)
Step Pools
Relocated Thalweg
Rock Toe
Reach 1 - Streambank Grading and Thalweg Realignment (Natural Channel Design)
Cross Vanes/ J-Hooks
Upper Reach 2 - Relocated Thalweg with Cross Vanes and J-Hooks
Existing Thalweg
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
N
Figure 5-2 Mountain View Drive
Concept 2 Restoration Map
0
150
300
600
Feet
1 inch = 150 feet

Table 5-2 Mountain View Drive (Concept 2) Cost Estimate

Reach	Linear feet	Construction Cost Range	
		Low	High
Reach 1	430	$172,000	$258,000
Reach 2 – Upper/Central	1000	$800,000	$1,000,000
Reach 2 – Lower	300	$120,000	$210,000
Total Construction Cost	**1,730**	**$1,092,000**	**$1,468,000**
Design/Permitting Cost	**$210,000**		
Construction Services	**$100,000**		
Cost Estimate Range		**$1,402,000**	**$1,778,000**

6.0 WATER QUALITY BENEFITS

The Virginia Department of Environmental Quality Chesapeake Bay TMDL Action Plan Guidance provides interim urban stream restoration removal rates for nutrients and sediments. Reduction credits are achieved on a per linear foot basis of 0.075 lbs/ft for total nitrogen, 0.068 lbs/ft for total phosphorus, and 444.88 lbs/ft for sediment. In terms of TMDL nutrient and sediment reduction credits, Concept 1 would not be eligible to receive credits. Concept 2 would be eligible to receive for credits. Table 6-1 presents the potential nutrient and sediment reduction credits for Concept 2.

Stream restoration is only one of several activities eligible to receive TMDL pollutant reduction credits. BMP installation, restoration, and retrofit, urban nutrient management, redevelopment, as well as other activities are also eligible. To evaluate the relative cost/benefit of achieving credits through stream restoration activities, Table 6-2 presents the cost per pound of nutrient and sediment reductions for the proposed concepts.

Table 6-1 Estimated Nutrient and Sediment Reduction Credits

Concept/Reach	Reach Length (LF)	Total Nitrogen (lbs)	Phosphorus (lbs)	Sediment (lbs)
Concept 1	600	0	0	0
Concept 2 - Reach 1	430	32.25	29.24	191,298.4
Concept 2 - Reach 2	1300	97.5	88.4	578,344.0
	Totals =	**129.75**	**117.64**	**769,642.4**

Table 6-2 Estimated Nutrient and Sediment Reduction Costs

Concept/Reach	Reach Length (LF)	Restoration Cost Range*		Total Nitrogen ($/lb)		Phosphorus ($/lb)		Sediment ($/lb)	
		Low	High	Low	High	Low	High	Low	High
Concept 2 - Reach 1	430	$249,500	$335,500	$7,736	$10,403	$8,533	$11,474	$1.30	$1.75
Concept 2 - Reach 2	1300	$1,152,500	$1,442,500	$11,820	$14,795	$13,037	$16,318	$1.99	$2.49
Concept 2 – Totals =	**1,730**	**$1,152,500**	**$1,442,500**	**$8,882**	**$11,118**	**$9,797**	**$12,262**	**$1.50**	**$1.87**

* 25% of the soft costs are attributed to Concept 1 with 75% to Concept 2

7.0 CONCLUSIONS

In comparing the two concepts presented above, Concept 1 represents the "minimal improvements" to stabilize the west streambank and protect infrastructure and private property behind multi-family and single family residential properties along Mountain View Drive. Concept 1 does not mitigate the erosive forces acting on the streambank, rather it attempts to armor the streambank to withstand those forces. The armoring will likely result in higher velocities, greater shear stresses, and scour along the opposite toe of the streambank and an increase in streambank erosion downstream of the armoring. The armoring will need to be more robust in design and materials than if it was combined with measures to reduce stream velocities and energy. Even a "robust" design may be subject to scour and failure in the long term.

A comprehensive channel design approach utilizing natural channel design principals along the entire Reach 2 is the recommended approach in Concept 2. Reach 1 is more stable than Reach 2 and would require less intensive stream restoration efforts, so combining it with efforts in Reach 2 would be the most cost effective option. In addition, the comprehensive channel design approach would be eligible to receive pollutant removal credits for TMDL nutrient and sediment reductions. At $1,442,500 cost and 117.64 pounds of TP removal, the unit cost is only $12,262 per pound. Restoration of the entire 1,730 linear feet is recommended.

Regardless of the concept selected, any work within the stream channel will require coordination and authorization from the Virginia Department of Environmental Quality and the U.S. Army Corps of Engineers. If the stream restoration alters the mapped 100-year floodplain, a FEMA map revision may also be required. These authorizations would be in addition to easement acquisitions and local permit approvals, as part of the final engineering design.

8.0 REFERENCES

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology Books, 1481 Stevens Lake Road, Pagosa Springs, Co. 81147, 385 pp

Rosgen, D. 1997. A Geomorphological Approach to Restoration of Incised Streams. Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision, 1997. ISBN 0-937099-05-8

Schueler, T. and B. Stack. 2014 Recommendation of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects, January 2014. Chesapeake Stormwater Network and The Center for watershed Protection. Ellicott City, MD

U.S. Department of Agriculture - Natural Resource Conservation Service (USDA - NRCS). 2017. Custom Soil Resource Report. United States Department of Agriculture - Natural Resource Conservation Service. Washington, DC.

U.S. Geological Survey. 2005. Development and Analysis of Regional Curves for Streams in the Non-Urban Valley and Ridge Physiographic Province, Maryland, Virginia, and West Virginia. Scientific Investigations Report 2006-5076. U.S. Department of Interior, Washington, DC.