TECHNICAL MEMORANDUM

DRAFT Stream Degradation Analysis and Setback Policy Recommendations

To: Papillion Creek Watershed Partnership

From: Aaron Hirsh, PE, CFM and Dave Lampe, PE

Date: March 31, 2021

RE: Stream Degradation Analysis
Papillion Creek Watershed Partnership (PCWP)
Papio-Missouri River Natural Resources District (P-MRNRD)
FHU Reference No. 120078-01

1.0 INTRODUCTION

1.1 Background

The Papillion Creek Watershed Partnership (PCWP) has experienced ongoing issues with the current stream setback policy resulting in inadequate stream setbacks thereby creating potential threats to properties, structures, and infrastructure. Due to this the PCWP is interested in analyzing the stream setbacks for both the existing stream bed slopes and assumed future stream bed slopes in select, undeveloped areas within the Papillion Creek watershed. The Papio-Missouri River Natural Resources District (P-MRNRD) serves as the Partnership's Administrative Agent.

On April 13, 2020 Felsburg Holt & Ullevig (FHU) was contracted by the Papio-Missouri River Natural Resources District to conduct a stream degradation analysis on three representative sub-watersheds located within the Papillion Creek Watershed. The analysis focused on the United States Geological Survey – National Hydrography Dataset (USGS NHD) mapped streams and tributaries within the sub-watersheds. The USGS NHD data includes each stream's Strahler stream order which denotes the branching order (first order streams have no tributaries, second order streams are formed when two first order streams join, third order streams are formed when two second order streams join, etc). The focus areas are depicted in Figure 1 on the following page and include:

1. South Papillion Creek and tributaries upstream of 168th and Briar Street (27 miles of stream)
2. Wehrspann Creek and tributaries upstream of Highway 370 (18 miles of stream)
3. North Branch West Papillion Creek and tributaries upstream of Flanagan Lake (13 miles of stream)

This study entailed (a) mapping the approximate areas of stream setbacks using existing stream slopes and current setback policy upon all USGS NHD mapped streams and tributaries within the sub-watersheds, (b) analysis of the assumed stable channel slopes under full buildout conditions, (c) mapping approximate areas of stream setbacks based on future stream slopes on select reaches, and (d) developing recommendations for improvements to the current setback policy.

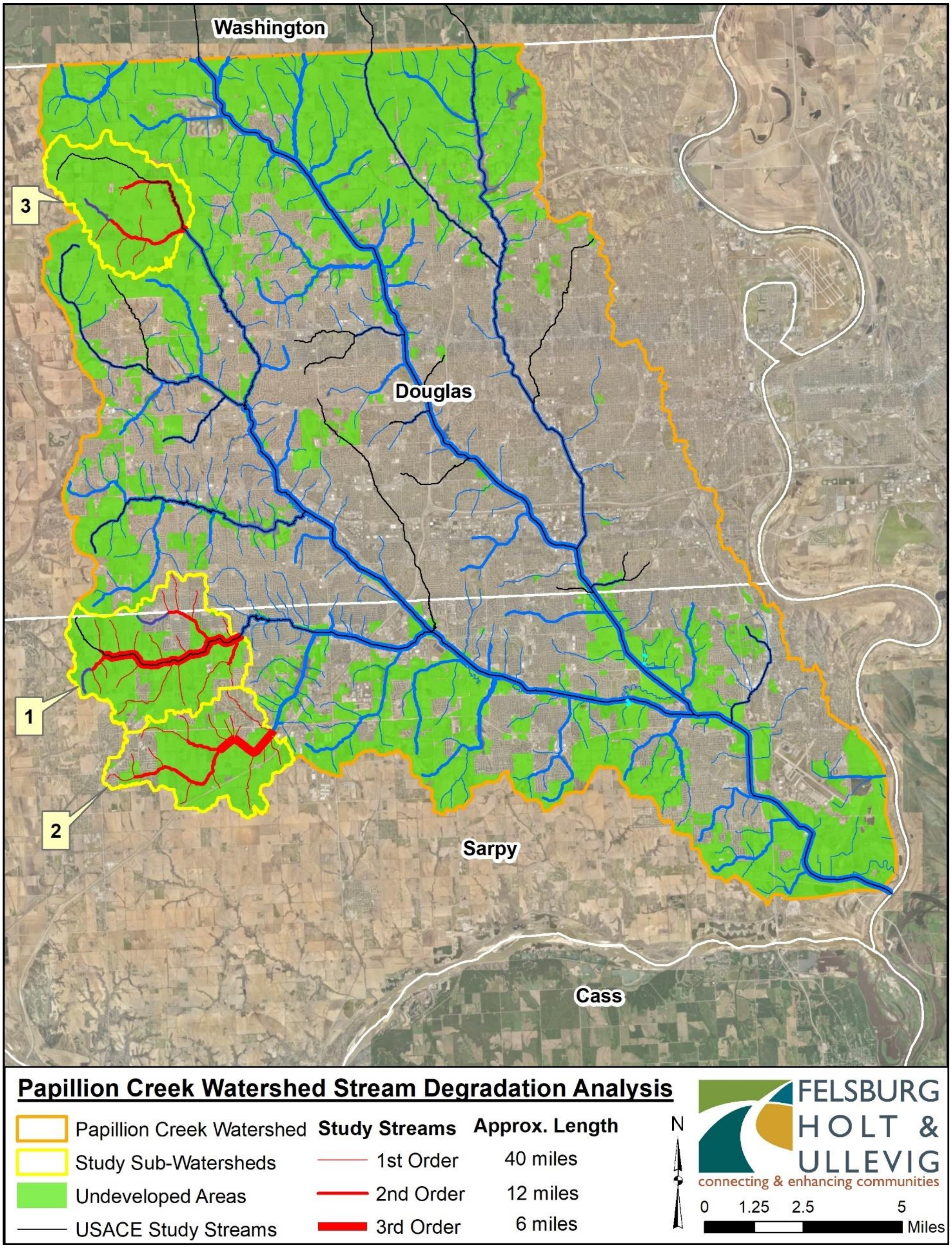


Figure 1. Proposed Study Area

1.2 Issues

During several meetings with the PCWP and P-MRNRD, issues that have begun to arise over time with the existing stream setback policy were discussed. Core issues that were identified are summated as follows:

- Subjectivity of terms including channel bottom, normal low flow, and watercourse
- Designers using old survey data that does not reflect current stream profile
- The existing setback policy does not adequately address future degradation
- SIDs get incorporated before streams have degraded, delayed problems turn up after that
- Once stream degrades it threatens existing infrastructure and structures
- Repairs and mitigation are then the responsibility of the local governments
- Would prefer a policy that provides for either grade control or wider setbacks

One main goal of this project is to develop a new stream setback policy which addresses these issues.

1.3 Presentations

FHU's approach to the project was centered around recurrent communication with the P-MRNRD and PCWP to make sure we were aligned with the Partnership's vision and goals. Throughout the course of the project several meetings and presentations were conducted, with several more planned within the near future. The completed and planned presentations for the project are listed below. For several of the PCWP Meeting presentations ArcGIS Story Maps were created to help disseminate the information and present during virtual teleconferencing. The respective links to the ArcGIS story maps are found below.

- Papillion Creek Watershed Partnership Meetings
  - September 24, 2020 – presented Existing Setback Analysis (https://arcg.is/1fnKq1)
  - October 22, 2020 – presented Future Setback Analysis (https://arcg.is/Wibn)
  - December 3, 2020 – presented Setback Policy Recommendations
  - January 7, 2021 - presented refined Setback Policy Recommendations (https://arcg.is/1vjKPi0)
  - January 28, 2021

- South Sarpy Watershed Partnership Meetings
  - January 21, 2021

- Omaha Sediment & Erosion Control Seminar
  - February 4, 2021

- Stakeholder Meetings with Developers
  - March/April 2021

2.0 EXISTING SETBACK ANALYSIS

2.1 Proposed Methodology

The geospatial analysis methodology that was proposed for this project is laid out in Figure 2 below. FHU often uses Arc Toolboxes and Model Builder to help automate the processing and did so on this project. The Arc Toolboxes utilized on this project are publicly available, and therefore the geospatial processing could be replicated by other GIS analysts on other stream systems.

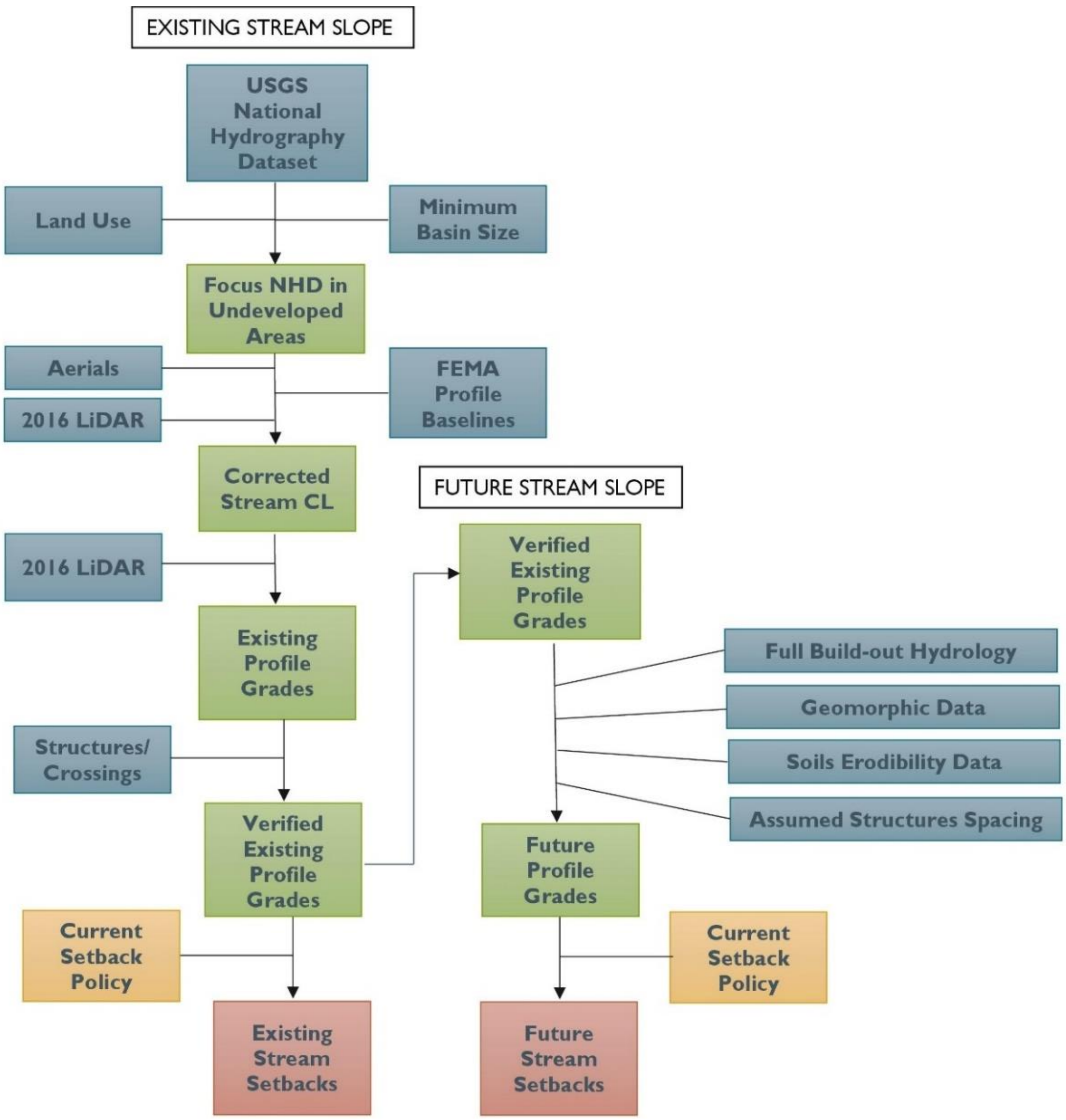


Figure 2. Preliminary Proposed Methodology

2.2 Existing Stream Analysis Process

The existing stream analysis was conducted using geospatial information systems (GIS) processing in an ArcGIS Version 10.5.1 environment using Arc HYDRO Toolbox Version 10.2.0.75 and the United States Geological Survey (USGS) DEM Geomorphology Toolbox Version 1.0. The USGS NHD and 2016 LiDAR information was obtained from the USGS National Map (https://viewer.nationalmap.gov/advanced-viewer/). The GIS modeling process for the existing stream analysis can is shown in Appendix A of this document.

2.3 Existing Stream Analysis Results

Results from the existing stream analysis were presented at the PCWP Meeting on September 24, 2020. The ArcGIS Story Map presentation can be viewed using the following link (https://arcg.is/1fnKq1). The results of the existing stream analysis are also located in Appendix B of this document.

The existing stream setback policy is a 3:1 slope projection from the channel bottom at edge, which is considered to be the waters edge at normal low flow, plus 50-feet at streams identified in the Papillion Creek Watershed Management Plan or 20-feet on all other watercourses. The 3:1 slope location was determined using the process detailed in Section 2.2, which was then offset at 20-foot and 50-foot for comparison.

Through the analysis of the existing streams and the existing setback policy it was found that the existing stream slopes are variable and increase as you move further upstream. Due to this, upstream tributaries have the highest vulnerability to head cutting and to negative impacts from stream setbacks that are too narrow.

When examining a portion of North Wehrspann Creek from approximately 168th Street to Highway 370 it was found a future degradation slope of 0.20% could easily result in 25-feet of head cutting occurring at the downstream ends of existing structures. If grade control were installed at a maximum 1/4-mile spacing significant improvements were seen on the downstream end, yet the steeper upstream ends could still display about 10-feet of head cutting. The stream profile is shown in Figure 3 on the following page.

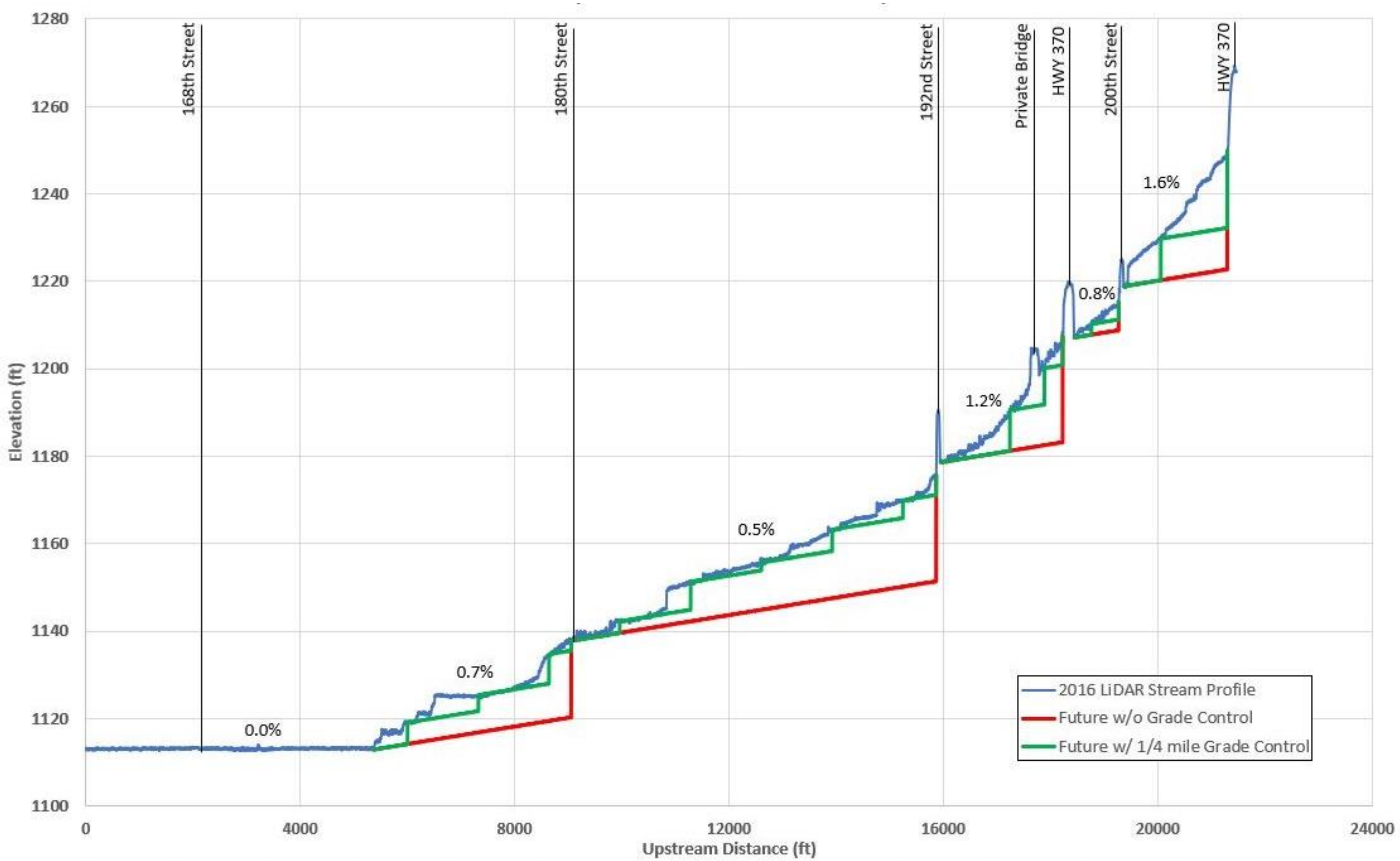


Figure 3. North Wehrspann Creek Stream Profile Comparison

3.0 FUTURE DEGRADATION ANALYSIS

3.1 Future Stream Slope Determination

To complete the future degradation analysis the determination of a future stream slope was required. This future stream slope is considered the representative stable bed slope for streams, otherwise known as the threshold channel, wherein aggradation and degradation are equalized. Although the stable bed slope can vary across topography and soil conditions, it was desired to establish a single value for the entire watershed.

The United States Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS) Part 654 Stream Restoration Design National Engineering Handbook was used to determine the allowable velocities for threshold channel design based upon silty clay bed material, which is the predominant soil type across the project area. Referencing Table 8-4 of the USDA-NRCS Part 654 Handbook, the allowable mean channel velocity for silty clay is 3.5-ft/s. Using Bentley FlowMaster Version 8i software and an assumed trapezoidal channel with a Manning's roughness of 0.035, 5-foot bottom width, 3:1 side slopes, and normal depth of 5.68-feet – the 0.15% channel slope results in just under the 3.5-ft/s threshold velocity. The originally assumed 0.20% stable bed slope results in a velocity around 4.0-ft/s which reflects a slightly more cohesive clay type soil. This 0.15% - 0.20% estimated stable bed slope range coincides well with conditions observed on Thomas Creek and Blood Creek within the Papillion Creek Watershed, as well as with other past stabilization work and studies completed in the area.

Throughout the future degradation analysis an assumed stable bed slope of 0.20% was used to compute the future degradation depths. However, during coordination with the South Sarpy Watershed Partnership (SSWP) group conducting a similar setback policy study it was decided that a future stable bed slope of 0.15% shall be used for the computation of the future degradation depth. This was to ensure similar policies would be implemented across both watershed partnerships.

3.2 Future Stream Analysis Process

The future stream analysis was conducted using GIS processing in an ArcGIS Version 10.5.1 environment using Arc HYDRO Toolbox Version 10.2.0.75 and the USGS DEM Geomorphology Toolbox Version 1.0. The future stream degradation analysis was conducted using an estimated stable bed slope of 0.20%, The GIS modeling process for the future stream analysis can is shown in Appendix A of this document.

3.3 Results

The results from the existing stream analysis were presented at the PCWP Meeting on October 22, 2020. The ArcGIS Story Map presentation can be viewed using the following link (https://arcg.is/Wibn). The results of the future stream analysis are also located in Appendix B of this document.

The future stream degradation analysis examined an unnamed tributary to Beadle Creek within the South Papillion Creek subwatershed. The unnamed tributary is located at approximately 189th and Harrison Streets heading northward upstream to South 190th Terrace. The future stream degradation analysis was conducted using an estimated stable bed slope of 0.20%. Using the assumed future degradation slope of 0.20% the estimated degradation within this stretch of stream could easily result in 20-feet of head cutting at Y Street. The stream profile is shown in Figure 4 on the following page.

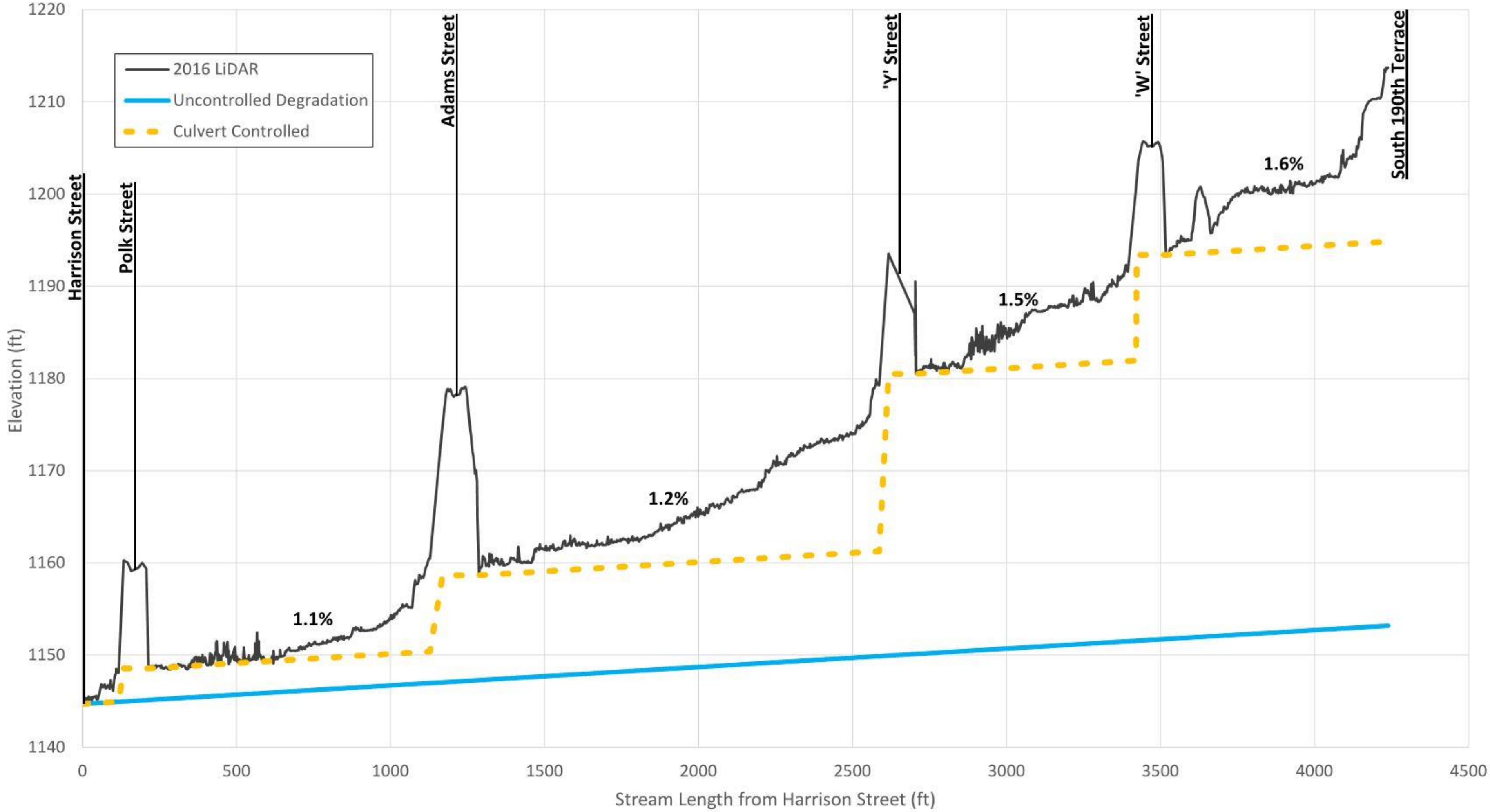


Figure 4. Stream Profile Comparison for Unnamed Tributary to Beadle Creek

From the future stream degradation analysis, it was determined that the future 3:1 slope projection based upon an assumed future degradation slope of 0.20% exceeds the existing setback plus 50-feet boundary at the Y Street crossing. The mapping of the future stream degradation analysis is shown in Appendix B-4. This result indicates that a 3:1 plus 50-foot stream setback policy is not adequate to address future degradation if the running stream length (distance between grade control) is greater than 1200-feet. It also indicates that mandating grade control at a 1/4-mile spacing may be effective in lower reaches with flatter slopes, but quickly becomes ineffective with steeper upstream reaches.

To work towards a new setback policy, the table displayed below (Table 1) was developed to demonstrate the running stream length (grade control spacing) at which variable existing and future stream slopes would exceed the existing stream setback buffers of 20 and 50-feet.

Table 1. Stream Slope Comparison for Grade Control Spacing Determination

20-ft Buffer	Existing Stream Slope (%)									
Future Stream Slope (%)	0.25	0.5	0.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5
0.05	3333	1481	952	702	556	460	392	342	303	272
0.1	4444	1667	1026	741	580	476	404	351	310	278
0.15	6667	1905	1111	784	606	494	417	360	317	284
0.2	13333	2222	1212	833	635	513	430	370	325	290
0.25		2667	1333	889	667	533	444	381	333	296
0.3		3333	1481	952	702	556	460	392	342	303
0.35		4444	1667	1026	741	580	476	404	351	310
0.4		6667	1905	1111	784	606	494	417	360	317
0.45		13333	2222	1212	833	635	513	430	370	325
0.5			2667	1333	889	667	533	444	381	333

50-ft Buffer	Existing Stream Slope (%)									
Future Stream Slope (%)	0.25	0.5	0.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5
0.05	8333	3704	2381	1754	1389	1149	980	855	758	680
0.1	11111	4167	2564	1852	1449	1190	1010	877	775	694
0.15	16667	4762	2778	1961	1515	1235	1042	901	794	709
0.2	33333	5556	3030	2083	1587	1282	1075	926	813	725
0.25		6667	3333	2222	1667	1333	1111	952	833	741
0.3		8333	3704	2381	1754	1389	1149	980	855	758
0.35		11111	4167	2564	1852	1449	1190	1010	877	775
0.4		16667	4762	2778	1961	1515	1235	1042	901	794
0.45		33333	5556	3030	2083	1587	1282	1075	926	813
0.5			6667	3333	2222	1667	1333	1111	952	833

LEGEND
- 1/8-mile spacing - Buffer will be exceeded
- 1/4-mile spacing - Buffer will be exceeded
- 1/2-mile spacing - Buffer will be exceeded
- 1-mile spacing - Buffer will be exceeded

The process of determining the grade control spacing is displayed in Figure 5, where given an existing stream slope of 1.5% and a future stream slope of 0.2% it would only take 513-feet of running stream length for the future 3:1 slope projection to exceed the existing 3:1 plus 20-feet setback boundary. Therefore, as shown in Table 1 above, a 20-foot buffer is inadequate for most cases even with grade control at 1/8-mile (660-ft) spacing, while a 50-foot buffer is inadequate for most cases even with grade control at 1/4-mile (1,320-ft).

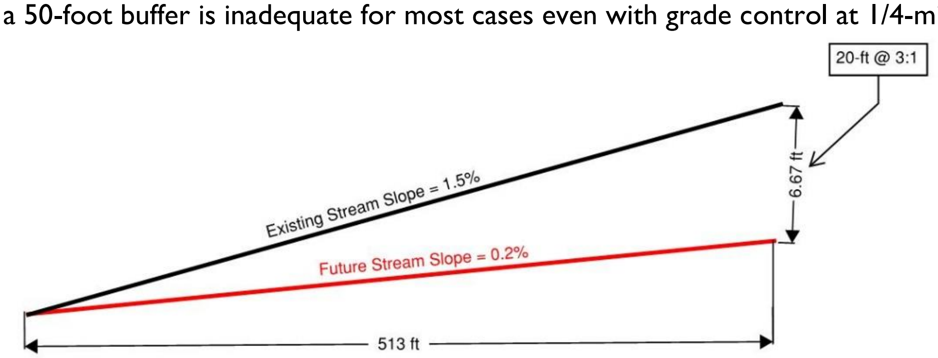


Figure 5. Grade Control Spacing Determination Example

4.0 SETBACK POLICY RECOMMENDATIONS

4.1 Setback Policy Comparison

Throughout the project, several potential modifications to the PCWP setback policy were discussed and options were weighed. These options included minor modifications to the existing policy language as well as different setback policy approaches altogether. One such policy considered is similar to the policy currently being proposed by the City of Lincoln. Further information on City of Lincoln stream corridor revisions can be found at the following web addresses:

https://app.lincoln.ne.gov/city/ltu/watershed/dcm/revisions/pdf/draft-minimum-stream-corridor-revisions.pdf
https://app.lincoln.ne.gov/city/ltu/watershed/dcm/revisions/pdf/minimum-stream-corridor-handout.pdf

Ultimately, the goal of the project was to assess the existing and future stream degradation and develop a new stream setback policy. The core issues with the existing stream setback policy and the ways that they were address with the new setback policy recommendations are listed below.

- Subjectivity of terms including channel bottom, normal low flow, and watercourse was addressed by using Ordinary High Water Mark for stream geometries and defining that watercourses are all drainageways with 40 or more acres of contributing drainage area
- Designers using old survey data that does not reflect current stream profile was addressed by defining that the survey must be current within two years of submittal
- The existing setback policy does not adequately address future degradation was addressed by the incorporation of future degradation depth in setback calculation and incorporation of grade control at arterials and public infrastructure crossings
- SIDs get incorporated before streams have degraded, delayed problems turn up after that was similarly addressed by the incorporation of future degradation depth in setback calculation
- Once stream degrades it threatens existing infrastructure and structures was similarly addressed by the incorporation of grade control at arterials and public infrastructure crossings
- Repairs and mitigation are then the responsibility of the local governments was similarly addressed through the incorporation of grade control at arterials and public infrastructure crossings, which may be potential cost sharing opportunities
- Would prefer a policy that provides for either grade control or wider setbacks was addressed through the future degradation point computation which is based on running stream length, resulting in either wider setbacks or more frequent grade control to limit the setback widths

The comparison matrix shown in Table 2 on the following page lists the different setback policy options considered and their ability to address the concerns listed above. Found in Figure 6 on the following pages is a graphical representation of each policy and their respective setback boundary for comparison, and within Table 3 is a comparison of the areal impact of each policy.

The recommended setback policy is found as an Attachment to this report. The proposed setback policy is considered "Policy E" in the comparison matrix and comparison documents, with an exemption, which is considered to be "Policy F."

Table 2. Setback Policy Comparison Matrix

	Setback Policy Option	Pros	Cons
	Existing stream setback policy	• No change to setback policy • No increase in setback	• Does not address survey timing (old data used) • Subjectivity of water surface and watercourse definitions • Does not account for grade control • Does not adequately address future degradation
A	Existing policy with minor modifications (survey timing, water surface, watercourse definition)	• Easiest to implement	• Does not account for grade control • Does not adequately address future degradation
B	Policy A with modifications to buffer width (50-ft buffer all streams)	• Better fit to address future degradation • Easier to implement	• Does not account for grade control • Does not adequately address future degradation • Increased setback compared to existing policy
C	Contributing drainage area defines setback width (i.e. DA<100-ac = 90-ft, 100-ac<DA<200-ac = 100-ft, DA>200ac = equation based setback)	• Simplfied process to determine setback widths • Allows for variable setback widths (based on drainage area) • Similar to proposed City of Lincoln setback policy	• Does not account for grade control • Does not adequately address future degradation • Increased setback compared to existing policy
D	Grade control at variable intervals with <u>constant</u> setback width computed at upstream end	• Promotes grade control • Adequately addresses future degradation (accounts for varying stream slopes)	• Increased setback compared to existing policy • Constant buffer width may be overly conservative
E	Grade control at variable intervals with <u>variable</u> setback width computed at maximum 200-ft intervals	• Promotes grade control • Adequately addresses future degradation (accounts for varying stream slopes) • Variable buffer width increases developable land	• Increased setback compared to existing policy
F	Stream stabilization with geomorphic stream assessment and natural channel design considerations (similar to current exemption)	• Promotes grade control • Variable buffer width increases developable land	• Requires additional engineering/regulatory review • Additional costs associated with assessment and design/construction

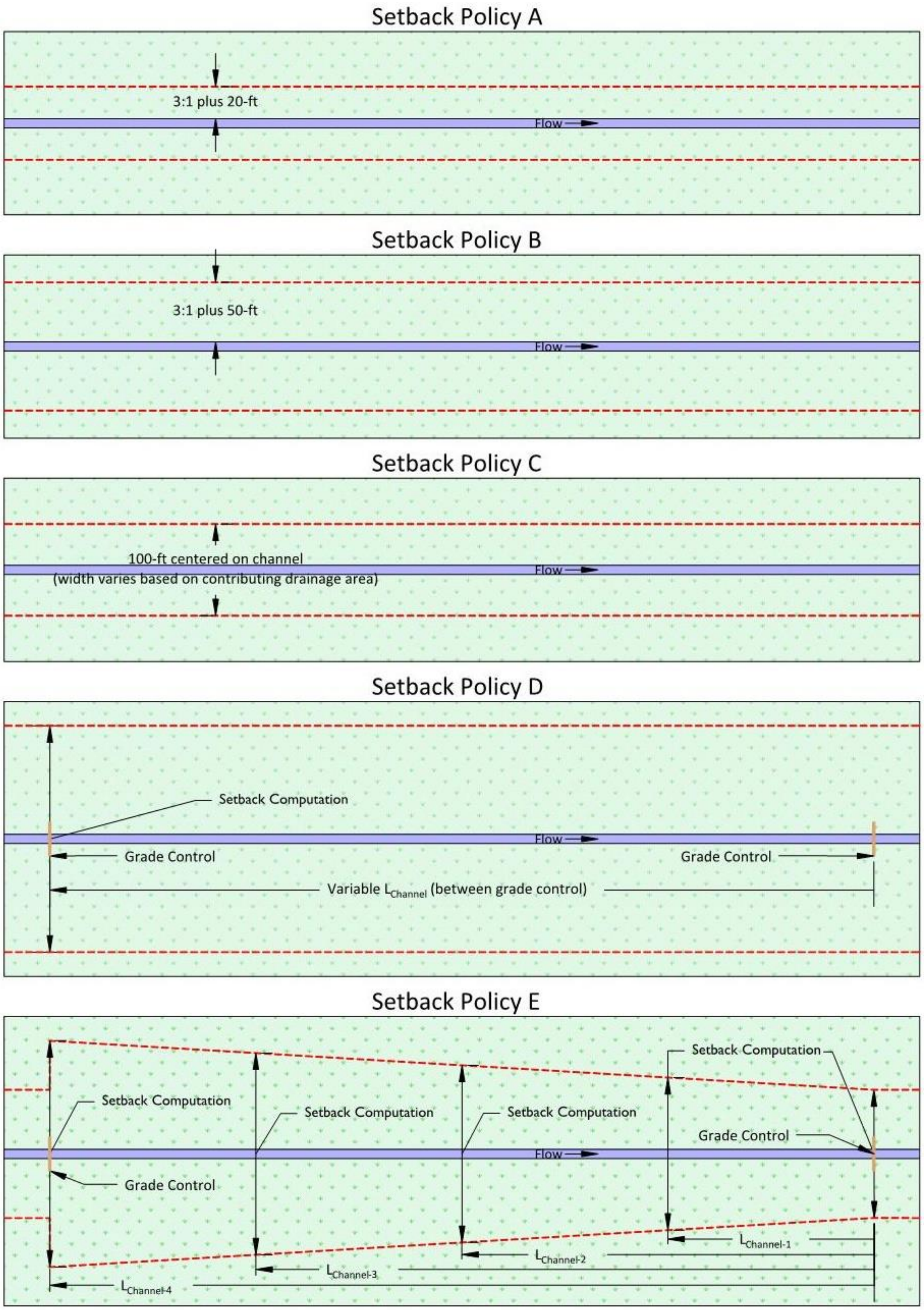


Figure 6. Setback Policy Comparison

Note: This graphic representation assumes the channel length is 1/4-mile (1,320-ft), channel width is 10-ft, channel depth is 5-ft, existing slope is 1.5%, future slope is 0.15%, and stream buffer is 50-ft.

Table 3. Setback Policy Areal Impact Comparison

Setback Policy Option		Setback Width (ft)	Setback Area Increase per 1/4-mile Stream Length (acre)
A	Existing policy with minor modifications (survey timing, water surface, watercourse definition)	80	0.0
B	Policy A with modifications to buffer width (50-ft buffer all streams)	140	1.8
C	Contributing drainage area defines setback width (i.e. DA<100-ac = 90-ft, 100-ac<DA<200-ac = 100-ft, DA>200ac = equation based setback)	100	0.6
D	Grade control at variable intervals with constant setback width computed at upstream end	247	5.1
E	Grade control at variable intervals with variable setback width computed at maximum 200-ft intervals	140 to 247	3.4

4.2 Proposed Setback Policy Example

The proposed setback policy example was conducted using GIS processing in an ArcGIS Version 10.5.1 environment using Arc HYDRO Toolbox Version 10.2.0.75 and the USGS DEM Geomorphology Toolbox Version 1.0. The proposed setback policy analysis was conducted using an estimated stable bed slope of 0.15%. This example uses 2016 LiDAR and a simplified GIS process for quickly mapping the proposed setback boundary for analysis purposes. The GIS modeling process for the proposed setback policy analysis can is shown in Appendix A of this document.

4.3 Results

The results from the setback policy recommendation and setback policy example were presented at the PCWP Meeting on January 7, 2021. The ArcGIS Story Map presentation can be viewed using the following link (https://arcg.is/1vjKPi0).

The proposed setback policy example looked at a portion of South Papillion Creek located between 204th and 216th Street. The proposed setback policy example was conducted using an estimated stable bed slope of 0.15% for determination of the future degradation point and proposed setback. The results of the proposed setback policy analysis are also located in Appendix B of this document.

5.0 NEXT STEPS

Moving forward there are several recommendations that can aid in the implementation of the setback policy as well as the design and permitting of grade control structures. These recommendations are listed below:

- **Design/Review Checklist** – To ease implementation of the setback policy across the numerous communities within the PCWP, it would be beneficial to establish a common design/review checklist. The checklist would help developers, consultants, and reviewers during the platting and design of properties with stream setbacks. The first step of the checklist could be a pre-application meeting wherein the developer, consultant, and reviewer meet to discuss the setback policy implementation, existing stream condition, and any concerns.

- **Grade Control Standards** - To aid in the design and permitting of grade control structures it is recommended that grade control standards be developed and incorporated into the Omaha Regional Stormwater Design Manual (ORSDM). Some potential types of grade control standards that could be developed include bridge floors and sheet pile or other grade control structures for culverts and sanitary sewer crossings. By establishing these standards, it would help to ensure adequate protection against degradation as well as help reduce future repair and maintenance issues.

- **US Army Corps of Engineers Coordination** - Installing grade control can have significant implications on the stream and Waters of the United States. In conjunction with the development of grade control standards it is recommended that coordination with the US Army Corps of Engineers (USACE) Regulatory Office be conducted to ensure that the proposed grade control standards would be acceptable and adhere to USACE criteria.

6.0 REFERENCES

Bernard, J.M., Fripp, J., and Robinson, K. (Eds.), 2007, Stream Restoration Design Handbook (National Engineering Handbook, 210–VI–NEH, Part 654): US Department of Agriculture, Natural Resources Conservation Service,

Cartwright, J.M., and Diehl, T.H., 2016, The DEM geomorphology toolbox: tools for geomorphic and hydrologic analysis of digital elevation models, version 1.0: U.S. Geological Survey data release, http://dx.doi.org/10.5066/F78C9TBQ

ATTACHMENT – PCWP Stream Setback Policy Recommendations

Papillion Creek Watershed Partnership Stream Setback Policy Recommendations
DRAFT – March 31, 2021

SUB-POLICIES

1) For new development or significant redevelopment, provide a stream setback on all watercourses the greater of (a) 3:1 plus 50 feet from the future degradation point or (b) top of high bank plus 50 feet as displayed in Figure 1 below. The future degradation depth shall be calculated at 200-ft intervals maximum along the stream with channel length being cumulative from the downstream grade control. Cross sections shall be provided at 200-ft intervals maximum showing existing grades, ordinary high water mark (OHWM), future degradation depth, 3:1 slope projections, and 50-ft setbacks. All measurements of the existing stream shall be determined by current topographic survey.

   Future Degradation Depth = $L_{Channel} \times S_{Channel} - L_{Channel} * 0.0015$

   Where: $L_{Channel}$ = Channel length – feet (along stream centerline, measured from downstream grade control)
   $S_{Channel}$ = Channel slope – foot/foot (average slope of the channel along the channel length as determined by ordinary high water marks)

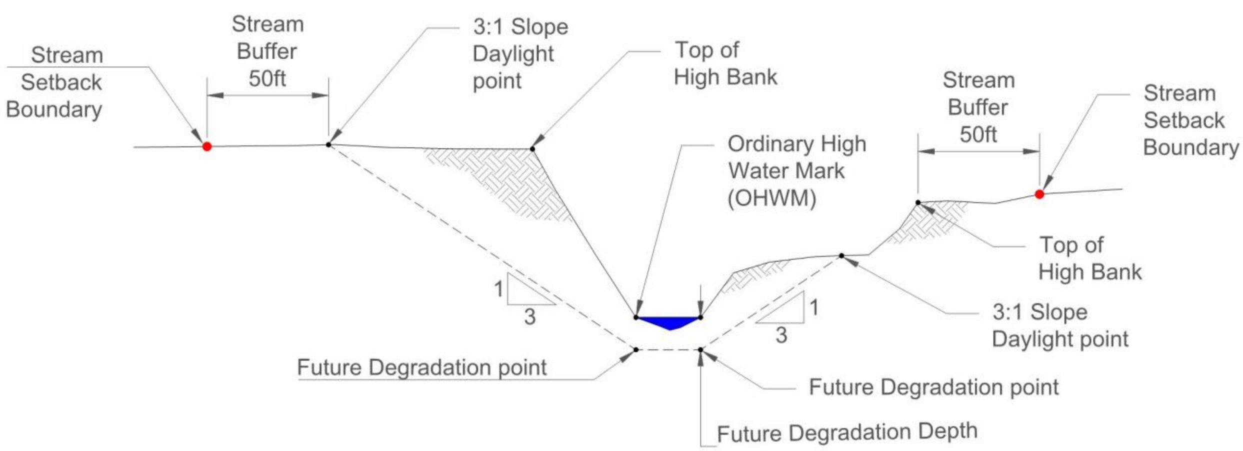


Figure 1 – Creek Setback Schematic

2) For streams with a geomorphic stream assessment and stream stabilization design completed by a licensed professional engineer or other natural sciences professional with training and experience in stream stabilization/restoration; or along streams already stabilized or improved by a licensed professional engineer or natural sciences professional with training and experience in stream stabilization/restoration, the stream setback shall be 50-feet from top of high bank.

   The stream stabilization design must demonstrate that future degradation along the entire project stream reach will be addressed and that "natural channel design" and "bioengineering techniques" have been considered as part of that design. In all cases the stream stabilization design must adhere to all local, state, and federal regulations which may be more stringent.

3) Grade control shall be installed at a minimum at the following locations:
   a. Arterial roadway crossings
   b. Sanitary sewer crossings and other public utilities less than 10-ft below stream bed (measured from top of pipe to stream bed)

DEFINITIONS

1) Stream setback. A stream setback as calculated using the equation(s) above shall be required for any above or below ground structure exclusive of stream/bank stabilization structures, poles, or sign structures adjacent to any watercourse. Grading, stockpiling, sewer/utility lines (except for crossings), and other construction activities are not allowed within the setback area and the setback area must be protected with adequate erosion controls or other Best Management Practices (BMPs). The outer 30 feet of the stream setback limits may be used for purposed compatible with open space, passive recreation, wetland/channel management practices and may be credited toward meeting the landscaping buffer and pervious coverage requirements.
2) Watercourse. Any depression below the surrounding land which serves to give direction to a current of water from at least 40-acres of contributing drainage area.
3) Current Topographic Survey. Topographic survey shall be conducted by a land surveyor licensed in the State of Nebraska and shall be obtained within two years from date of submittal of documentation for approval by the local jurisdiction.
4) Ordinary High Water Mark (OHWM). The "ordinary high water mark" observed along the project stream reach as defined by the U.S. Army Corps of Engineers.
5) Top of High bank. Location where stream bank slope breaks (inflection point) and flattens to surrounding terrain.
6) 3:1 Slope Daylight point. Location where the 3:1 slope projection intersects the existing grade.
7) Future Degradation point. Future degradation shall be calculated at 200-ft intervals maximum along the stream with channel length being cumulative from the downstream grade control. The OHWM point shall be shifted directly downward by the future degradation depth to create the future degradation point. Future degradation points shall be calculated at the following locations:
    a. Upstream end of the downstream grade control structure (starting point, $L_{Channel} = 0$)
    b. Downstream end of any drainage structures within the project area
    c. Outermost edge of stream bends as indicated in the Figure 2 below:

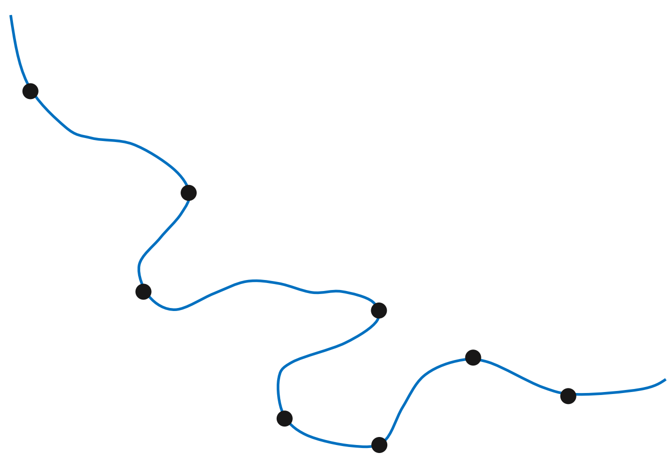


Figure 2 – Future Degradation Point Locations Example

8) Stream bed. Bottom ground surface of the stream.
9) Stream Centerline. The midway point between the ordinary high water marks on each bank.
10) Channel slope. Average slope of the channel as determined by ordinary high water marks.
11) Channel length. Distance along stream centerline.
12) Grade control. Any structure that has been designed to control stream bed degradation to a minimum depth of 10-ft below the designed downstream bed elevation.
13) Natural channel design. The application of fluvial geomorphology to create stable channels that do not aggrade or degrade over time and that maximize stream functions given site constraints.
14) Bioengineering techniques. The use of living, riparian grasses, trees, and other natural materials to stabilize stream banks.

APPENDIX A –GIS Processing Methodology

EXISTING STREAM ANALYSIS GIS PROCESS

1. Identified crossings along USGS NHD streams using ESRI and Google aerials and 2016 LiDAR
2. Used ESRI and Google aerials and 2016 LiDAR to draw the end points of each crossing
3. Drew polylines to define crossings for breaking the digital dams within the 2016 LiDAR
4. Ran “Focal statistics” on 2016 LiDAR using defaults to smooth the raster
5. Ran “DEM Conditioning” on identified crossings to create hydrologically correct surface (AgreeDEM)
    a. Buffer = 5 cells, Smooth drop = 10, Sharp drop =50
6. (South Papillion/Wehrspann watersheds) Ran “DEM Conditioning” on storm sewers (from Sarpy County GIS) to create hydrologically correct surface (AgreeDEM_02)
    a. Buffer = 5 cells, Smooth drop = 10, Sharp drop =20
7. Ran “Fill sinks” using default values (Fil)
8. Ran “Flow direction” (Fdr)
9. Ran “Flow accumulation” (Fac)
10. Ran “Stream definition” using lowest flow accumulation value at ends of NHD streams (Str)
    a. West Papio North = 62,000 cells
    b. South Papio = 13,000 cells
    c. Wehrspann = 12,500 cells
11. Ran “Stream segmentation” (StrLnk)
12. Ran “Catchment grid delineation” (Cat)
13. Ran “Catchment polygon processing” (Catchment)
14. Ran “Drainage line processing” (DrainageLine)
15. Ran “Adjoint catchment processing” (AdjointCatchment)
16. Ran “Batch Point” created at the outlet of the study area (BatchPoint)
17. “Batch Watershed Delineation” to delineate the drainage area (WatershedPoint, Watershed)
18. Select DrainageLines that coincide with Study NHD (DrainageLine_STUDY)
19. “Slope” operation with Fil as the input raster, output measurement in Percent_Rise (Slope_fil)
20. “Cost Distance” operation with the DrainageLine_STUDY layer as the input source data and the Slope_fil as the cost. Maximum distance = 50 (Cost_distance)
21. “Reclassify” the Cost_distance raster setting all non-zero values to 1 (Cost_RECLASS)
22. “Raster to Polygon” using Cost_RECLASS as the input (Cost_RASTER)
23. Using Editor, split Cost_RASTER at confluences.
24. Calculate the area for the Cost_RASTER items and length for corresponding DrainageLine_STUDY, and then determine average width of stream segments.
25. “Polyline to Raster” with DrainageLine_STUDY as the input feature, HydroID as the Value field, cell assignment type Maximum_Length, priority field as none, and cellsize as 2.5 (to match LiDAR)
26. “Channel Depth” tool from the USGS DEM Geomorphology Toolbox: (Channel_Depth)
    a. Input DEM Raster = 2016 LiDAR
    b. Input Flow Network = DrainageLine_STUDY (raster from Step #25)
    c. Input Culvert File = Crossings shapefile
    d. Neighborhood Settings = Circle, Radius = 10
27. “Raster to Points” using Channel Depth raster as the input (Channel_Depth_Points)
28. “Add Field” in the Channel_Depth_Points attribute table and use “Field Calculator” with the following expression:
    a. West Papio North = Buff_Dist = 5 + 3*(depth)
    b. South Papio = Buff_Dist = 7 + 3*(depth)
    c. Wehrspann = Buff_Dist = 6 + 3*(depth)
29. “Buffer” using Channel_Depth_Points as the input and Buff_Dist as the “Field” value (Channel_Depth_Buffer)
30. “Dissolve” the Channel_Depth_Buffer and allow Multipart features (Channel_Depth_Setback)

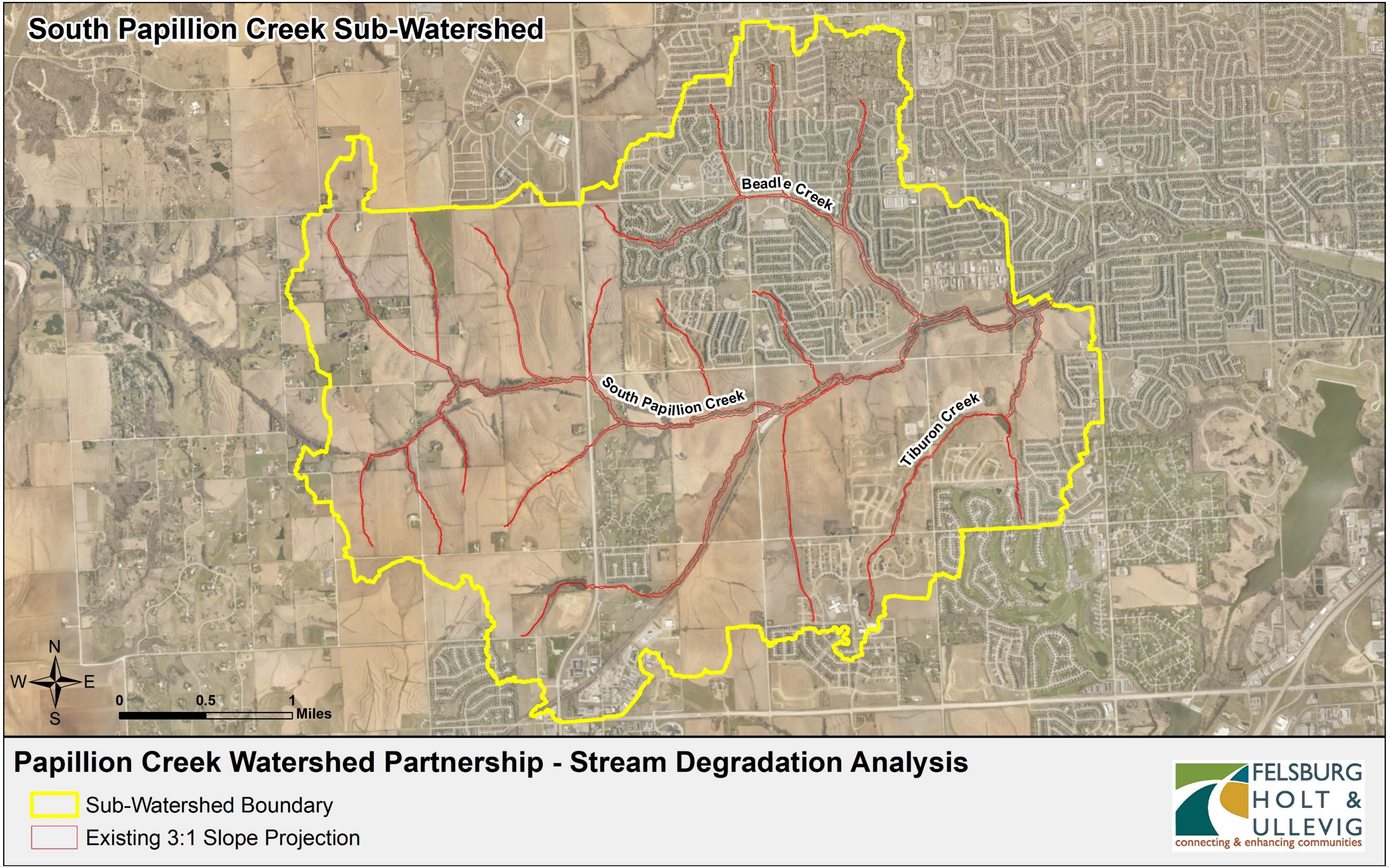
FUTURE STREAM ANALYSIS GIS PROCESS

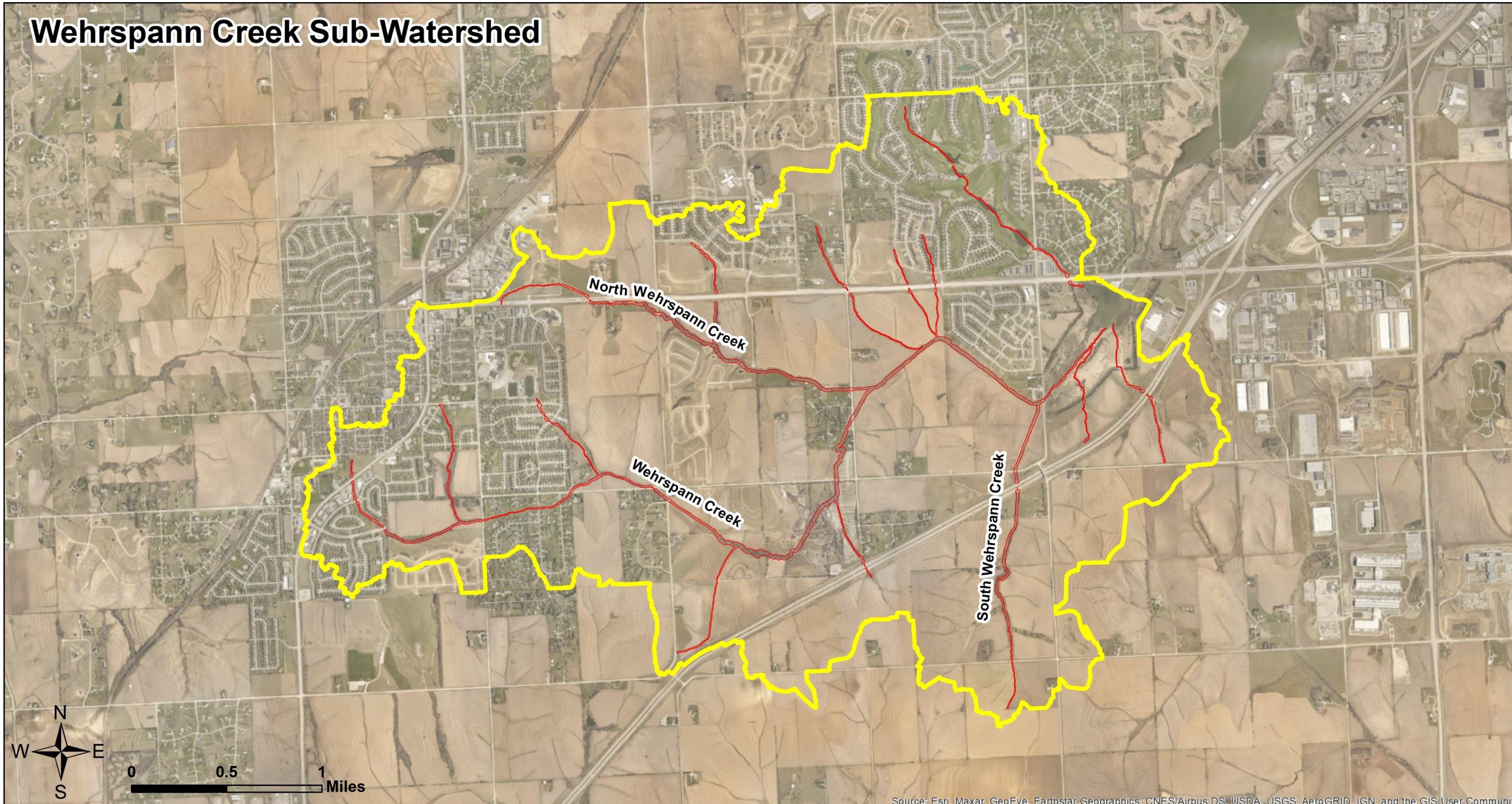
1. Ran "Flow Length" using Fdr (Step #8 of Existing Stream Analysis) as input and "Downstream" as the direction of measurement (Flow_Length)
2. Ran "Extract Value to Points" using Channel_Depth_Points shapefile (Step #29 of Existing Stream Analysis) and Flow_Length raster (Flow_Length_Points)
3. Ran "Add Field" to compute stream length from starting point by subtracting lowest stream length (StreamLength)
4. Deleted the RASTERVALU field from the attribute table.
5. Ran "Extract Value to Points" using Flow_Length_Points shapefile and 2016 LiDAR raster (Flow_Length_Elev)
6. Ran "Add Field" to compute future degradation elevations from starting point with the following formula:
    a. FutureElev = Elevation of first stream cell (distance 0) + 0.002*StreamLength
7. "Add Field" to compute the 3:1 slope projection using the following formula:
    a. FutureDegradation = 7+3*(depth+(ExistingElev-FutureElev))
8. Ran "Buffer" using Flow_Length_Elev as the input and FutureDegradation as the "Field" value (Future_Degradation_3to1)
9. Ran "Dissolve" the Future_Degradation_3to1 and allow Multipart features (Future_Degradation_Setback)

PROPOSED STREAM SETBACK POLICY GIS PROCESS

1. Ran "Flow Length" using Fdr (Step #8 of Existing Stream Analysis) as input and "Downstream" as the direction of measurement (Flow_Length)
2. Ran "Extract Value to Points" using Channel_Depth_Points shapefile (Step #29 of Existing Stream Analysis) and Flow_Length raster (Flow_Length_Points)
3. Ran "Add Field" to compute stream length from starting point by subtracting lowest stream length at the downstream grade control structure (StreamLength)
4. Deleted the RASTERVALU field from the attribute table.
5. Selected the Flow_Length_Points using the maximum 200-ft interval starting on downstream end and exported to new shapefile (Future_Degradation_Points)
6. Ran "Extract Value to Points" using Future_Degradation_Points shapefile and 2016 LiDAR raster (Flow_Length_Elev)
7. Ran "Add Field" to compute future degradation elevations from starting point with the following formula:
    a. FutureElev = Elevation of first stream cell (distance 0) + 0.015*StreamLength
8. "Add Field" to compute the 3:1 slope projection using the following formula:
    a. FutureDegradation = 7+3*(depth+(ExistingElev-FutureElev))
9. Ran "Buffer" using Flow_Length_Elev as the input and FutureDegradation as the "Field" value (Future_Degradation_3to1)
10. Ran "Buffer" using Future_Degradation_Buffer as the input and 50-feet as buffer distance (Future_Degradation_3to1plus50)
11. Drew polylines using further extents of Future_Degradation_3to1plus50 to delineation setback boundary

APPENDIX B – Stream Degradation Analysis Results

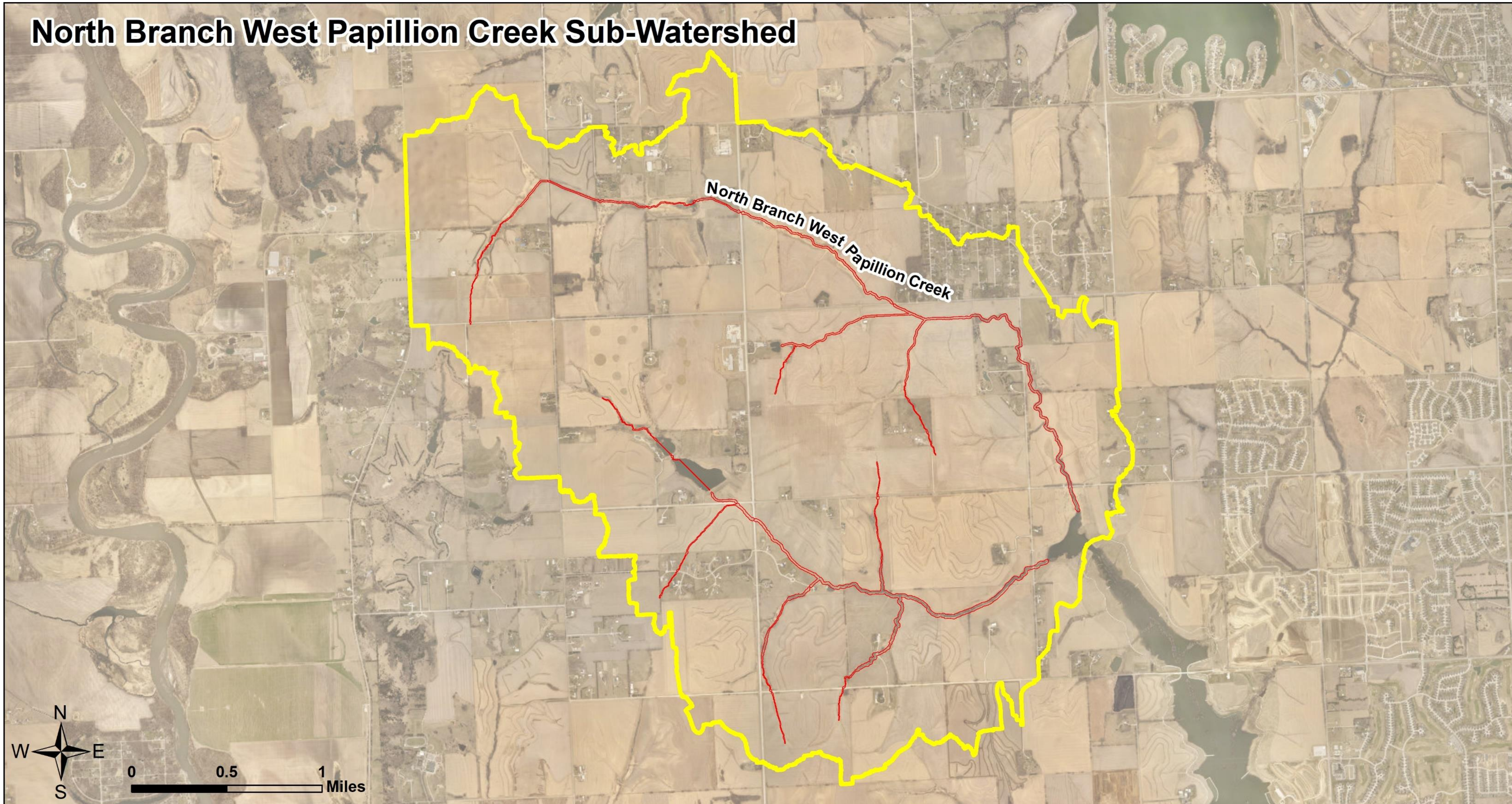

South Papillion Creek Sub-Watershed
Beadle Creek
South Papillion Creek
Tiburon Creek
N
W
E
S
0
0.5
1
Miles
Papillion Creek Watershed Partnership - Stream Degradation Analysis
Sub-Watershed Boundary
Existing 3:1 Slope Projection
FELSBURG HOLT & ULLEVIG
connecting & enhancing communities



Papillion Creek Watershed Partnership - Stream Degradation Analysis

Sub-Watershed Boundary

Existing 3:1 Slope Projection

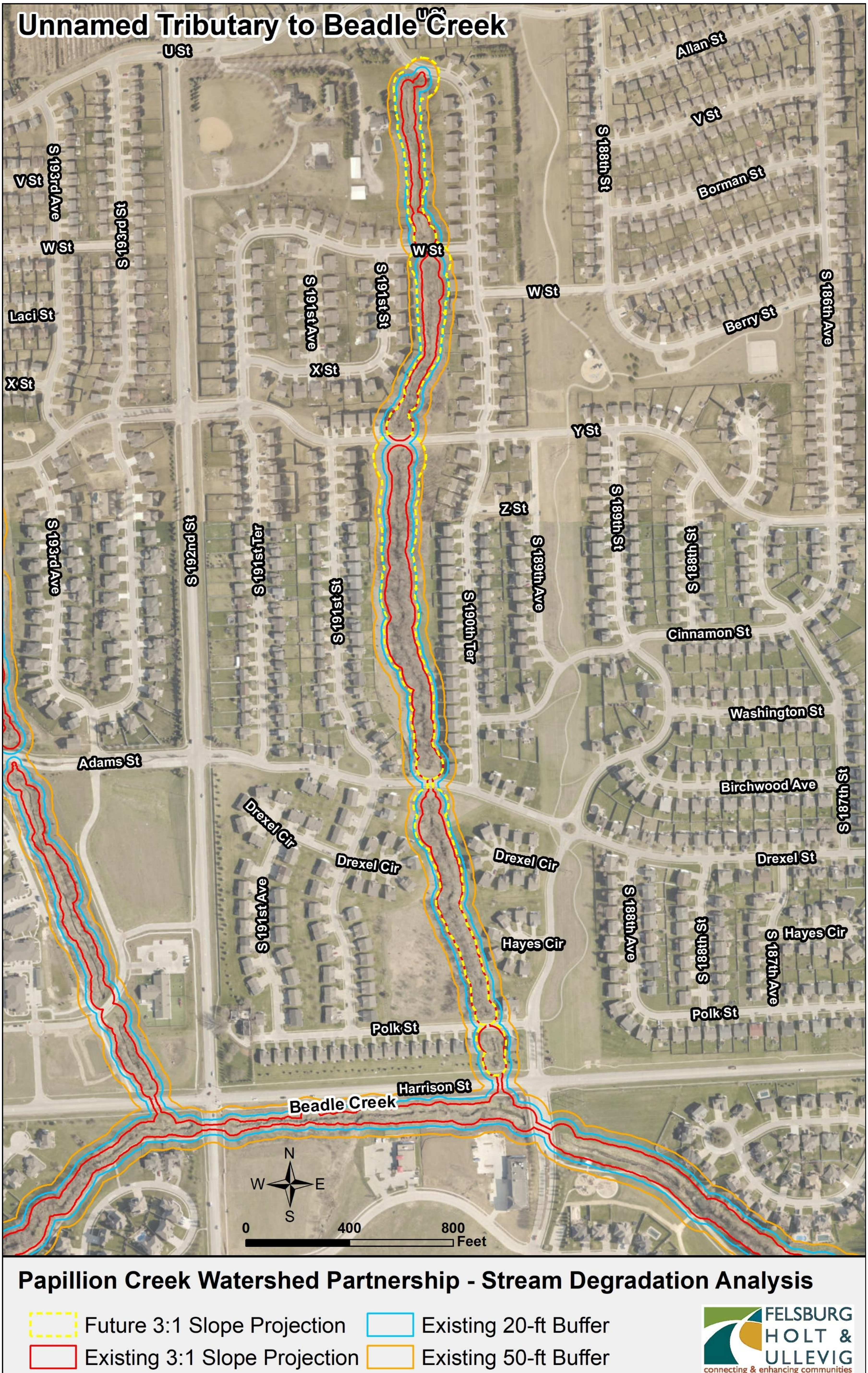


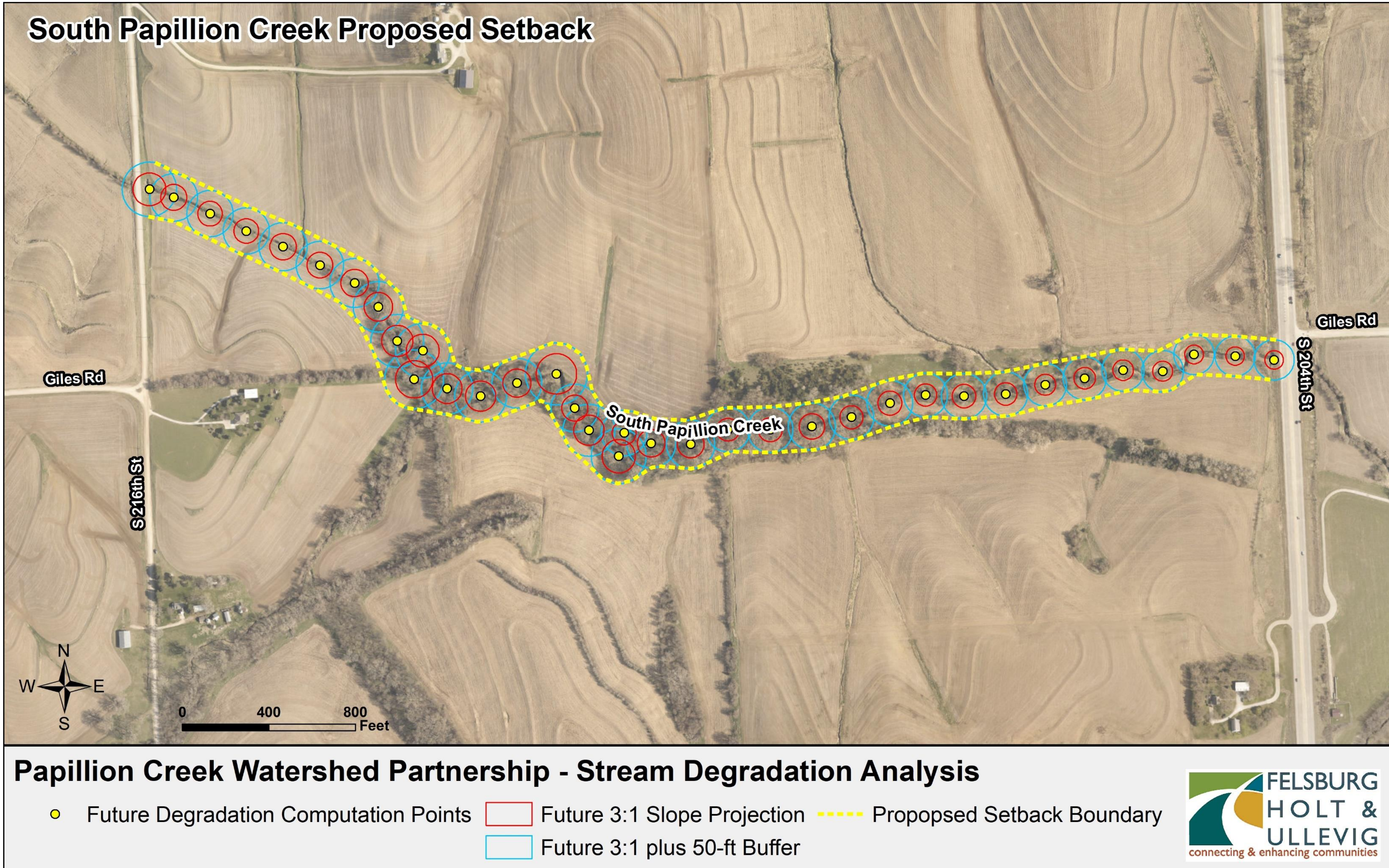
Papillion Creek Watershed Partnership - Stream Degradation Analysis

Sub-Watershed Boundary

Existing 3:1 Slope Projection

FELSBURG HOLT & ULLEVIG
connecting & enhancing communities


Unnamed Tributary to Beadle Creek
U St
Allan St
V St
S 188th St
Borman St
S 193rd Ave
S 193rd St
W St
S 191st Ave
S 191st St
S 186th Ave
Berry St
Laci St
X St
Y St
Z St
S 189th St
S 189th Ave
S 192nd St
S 191st Ter
S 190th Ter
Cinnamon St
Washington St
Adams St
Birchwood Ave
S 187th St
Drexel Cir
Drexel St
S 188th Ave
Hayes Cir
S 187th Ave
Polk St
Harrison St
Beadle Creek
N
W
E
S
0
400
800
Feet
Papillion Creek Watershed Partnership - Stream Degradation Analysis
Future 3:1 Slope Projection
Existing 3:1 Slope Projection
Existing 20-ft Buffer
Existing 50-ft Buffer
FELSBURG HOLT & ULLEVIG
connecting & enhancing communities


South Papillion Creek Proposed Setback
Giles Rd
Giles Rd
S 216th St
S 204th St
South Papillion Creek
N
W
E
S
0
400
800
Feet
Papillion Creek Watershed Partnership - Stream Degradation Analysis
Future Degradation Computation Points
Future 3:1 Slope Projection
Future 3:1 plus 50-ft Buffer
Propopsed Setback Boundary
FELSBURG HOLT & ULLEVIG
connecting & enhancing communities