FINAL REPORT

PARKERSON MILL CREEK RESTORATION FEASIBILITY STUDY

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by
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Reach A

Reach P

Reach C

Reach I

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1. INTRODUCTION

This report was prepared in response to a request by Auburn University for a feasibility study of potential restoration of Parkerson Mill Creek and its tributaries. The study site includes approximately 12,000 linear feet of perennial stream channels, surrounding vegetated buffers, and stormwater outfalls on the campus of Auburn University in Auburn, Alabama. The purpose of this feasibility study is to evaluate the stream reaches for their restoration potential and to make cost-based recommendations on stream restoration strategies, vegetated buffer enhancement, greenway installations, and stormwater management to improve the quality, function, and aesthetics of campus streams.

1.1. Project Description

Parkerson Mill Creek and its tributaries are located in Auburn, Lee County, Alabama, within the Piedmont Physiographic Province in the Lower Tallapoosa Watershed (USGS Cataloging Unit 03150110). The study site includes approximately 12,000 linear feet of perennial streams divided into 12 stream reaches for this study (Figure 1.1). The watershed at the point where it crosses under Shug Jordan Parkway is approximately 2 square miles (Figure 1.2), with an average watershed gradient of 1.5%.

The upper reaches of the Parkerson Mill Creek watershed (Reaches A, B, C, D, E, F, H, I, and K) are in heavily urbanized areas with impervious surfaces ranging from 30 to 60%. The downstream Reaches P and Q are surrounded by agricultural and forested areas. Reach R is a downstream tributary drained almost entirely by pasture areas. Future development on the Auburn University campus and surrounding areas is expected to increase runoff and potential stream impacts throughout the watershed.

Natural stream functions in the watershed have been altered by historic changes in watershed land uses, channel straightening and relocation, piping, floodplain filling, streambank armoring, stormwater discharges, and loss of riparian vegetation. The resulting stream channels are mostly incised down to bedrock with minimal active floodplains and narrow vegetated riparian corridors. Observed impacts on many of the reaches include poor aquatic habitat, sediment deposition, eroding streambanks, invasive plant species along streambanks, and degraded water quality.

Watershed development has resulted in impaired stream stability, defined as the ability of the channel to carry the water and sediment delivered by its watershed, such that over time it maintains its dimension, pattern and profile while neither aggrading nor degrading (Rosgen, 1996). Specific indications of instability in Parkerson Mill Creek include streambank erosion, sediment deposition, and streambed scouring. Three major causes of stream channel instability that may be addressed through potential restoration projects are: (1) channel incision, resulting in loss of functional floodplain; (2) channel straightening, resulting in poor riffle-pool sequence; and (3) poor riparian vegetation condition, resulting in streambank erosion and poor habitat.

This report summarizes the feasibility study and provides recommendations to meet the following objectives for the study streams:

1. Provide a stable stream that transports the water and sediment delivered by its watershed while maintaining its dimension, pattern, and profile, and neither degrading nor aggrading;
2. Improve the water quality and aquatic habitat of the stream;
3. Improve the floodplain functions of water storage and habitat;
4. Improve the riparian buffer functions of stability, habitat, and aesthetics;
5. Reduce stormwater quality and quantity impacts to the stream; and
6. Provide recreational access to the stream corridor through a multi-purpose greenway.

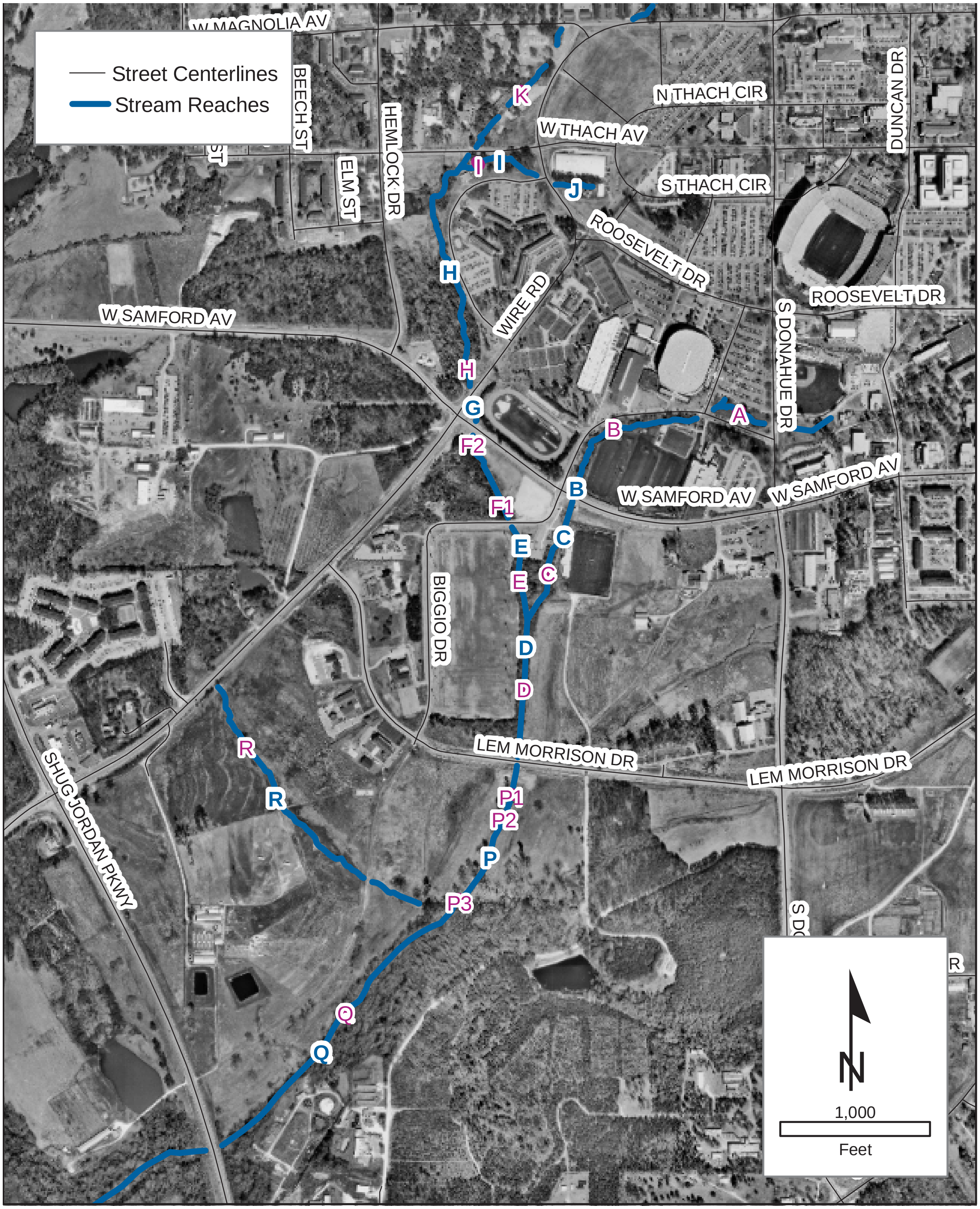


Figure 1.1. Aerial Photograph of Parkerson Mill Creek and Surrounding Area.

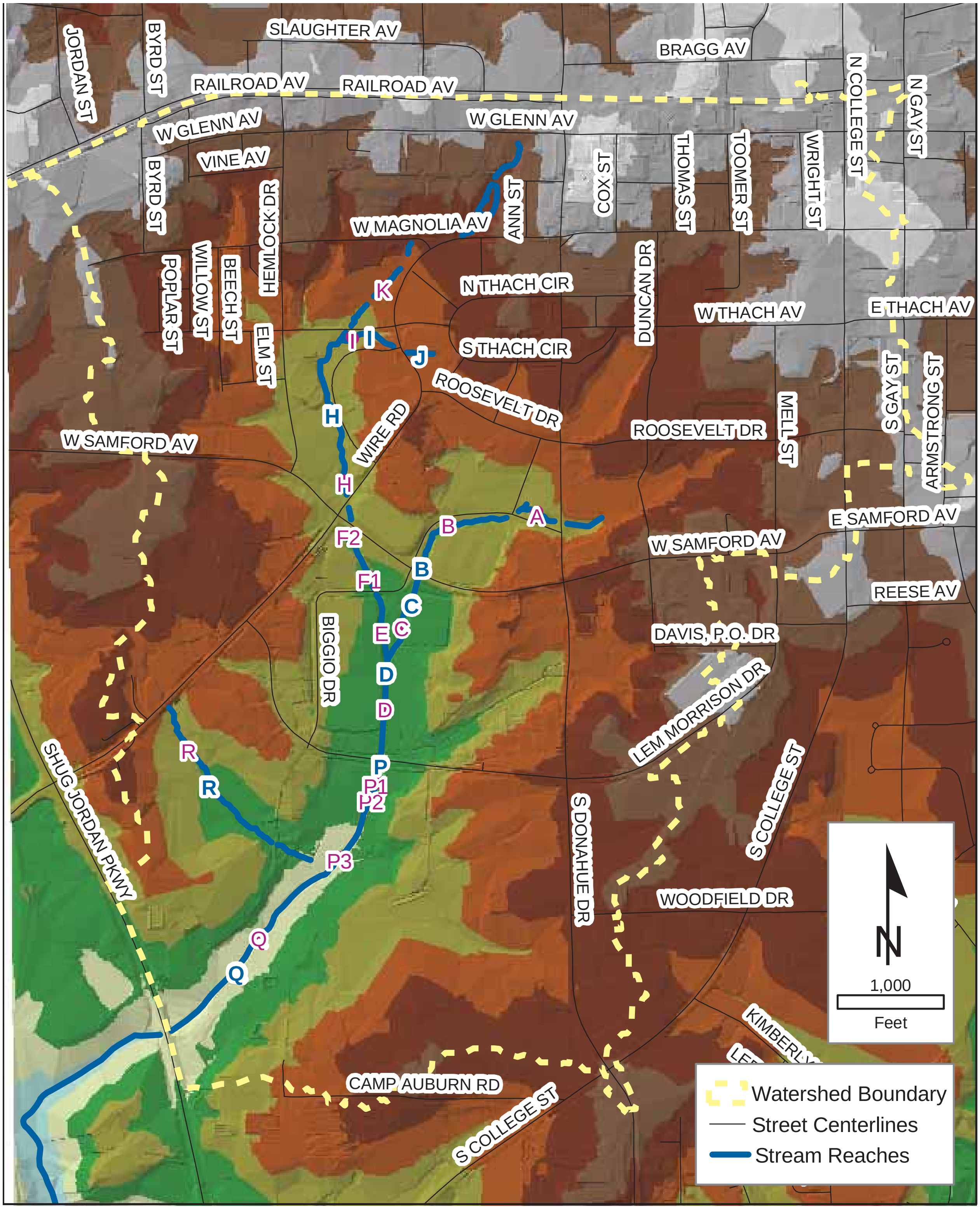


Figure 1.2. Parkerson Mill Creek Watershed Boundary and Relative Elevations.

2. EXISTING CONDITIONS

2.1. Stream Morphology

Field surveys of Parkerson Mill Creek and its tributaries were conducted in December, 2002, using techniques described by Harrelson et al (1996). These field measurements were used to classify the streams according to the Rosgen stream classification system (Rosgen, 1996) and to assess the existing stability of the stream reaches. The cross-section surveys completed in each reach are shown in Appendix A along with the calculated parameters used to classify the streams.

The Rosgen stream classification system uses five delineative criteria: entrenchment ratio, width to depth ratio, water surface slope, sinuosity, and channel bed materials. All of the streams in this study are single-thread channels, meaning that none of these streams are Rosgen class D.

The entrenchment ratio and width to depth ratio were measured at the bankfull stage. By definition, bankfull stage is the elevation of the floodplain adjacent to the active channel. If the stream is entrenched, bankfull stage is identified as a scour line, bench, or top of the point bar. If the stream is not entrenched, then bankfull stage is at or near the top of the bank. Hydraulic geometry relationships of bankfull cross sectional area as a function of watershed size (regional curves) from North Carolina Piedmont streams were used to help verify bankfull stages identified by field indicators (Figure 2.1).

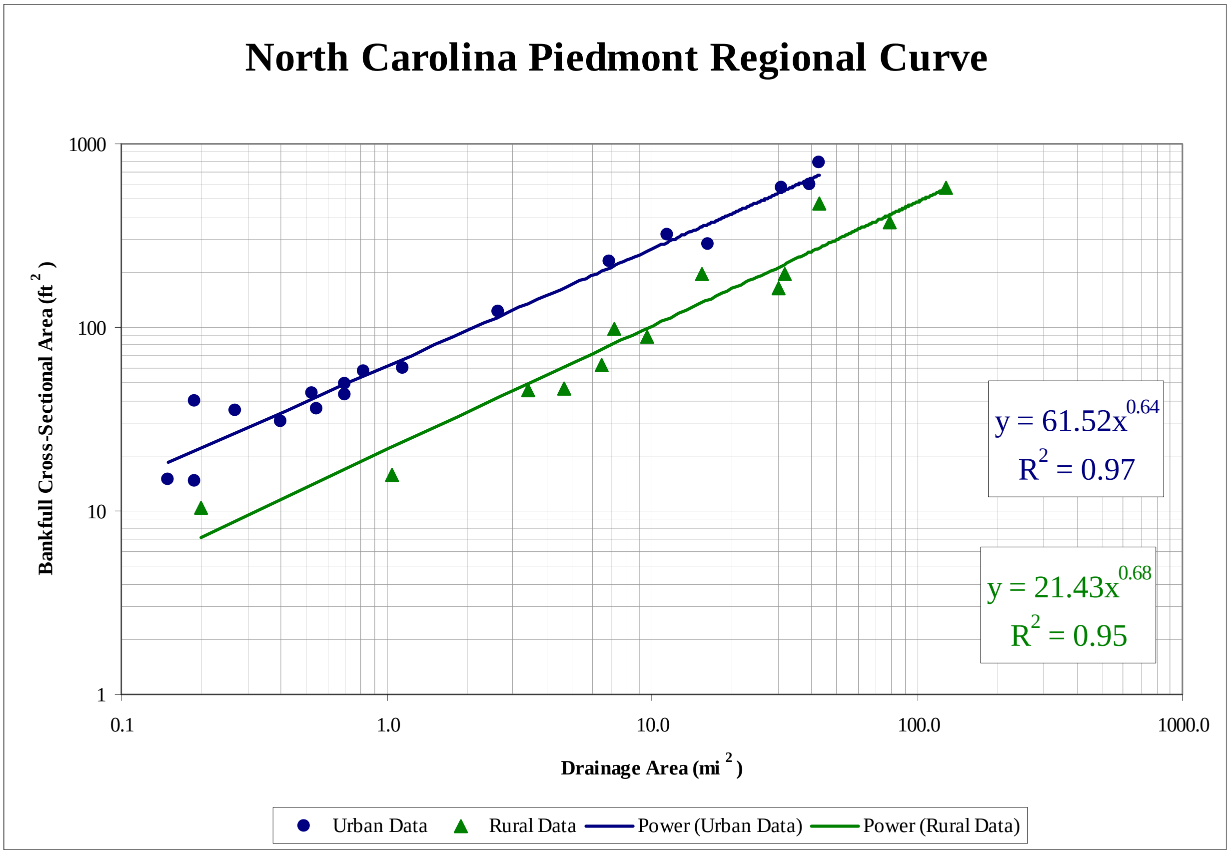


Figure 2.1. North Carolina Piedmont Regional Curves (available at http://www.ncsu.edu/sri/regional.htm)

Entrenchment Ratio is a field measurement of channel incision. Specifically, it is the flood-prone width divided by the bankfull width. The flood-prone width is measured at the elevation of twice the maximum depth at bankfull. Lower entrenchment ratios indicate channel incision. Large entrenchment ratios mean that there is a well-developed floodplain. Stream classes A, F, and G have entrenchment ratios of 1.4 or less, while stream classes C, E have entrenchment ratios of 2.2 or more. B streams have entrenchment ratios of between 1.4 and 2.2.

Width to Depth Ratio is a field measurement of the bankfull channel width divided by the mean bankfull depth. The break between stream classifications is 12, meaning that the bankfull width is 12 times greater than the mean bankfull depth. Stream classes with width to depth ratios greater than 12 are B, C, and F, while stream classes A, E, and G have width to depth ratios less than 12.

Water Surface Slope is a field measurement of the change in water surface elevation over the thalweg distance from the head of a riffle at the beginning of a reach to the head of a riffle at least 20 bankfull widths downstream. The water surface slope is representative of the average hydraulic gradient of the stream reach.

Sinuosity is a measure of a stream's "crookedness." Specifically, it is the channel thalweg length divided by a straight line valley length. Sinuosity is related to slope. Natural streams with steep slopes have low sinuosities, and streams with low slopes typically have higher sinuosities, depending on valley constraints.

Channel Bed Material is measured using a Wolman pebble count procedure to determine the median particle size (Harrelson et al, 1996). Gravel bed streams have median particle sizes ranging from 2 to 64 mm in diameter. Sand bed stream have smaller particle, while cobble bed streams are larger. All the stream reaches evaluated in this study are gravel bed streams, with varying particle sizes depending on instream erosion and sedimentation. Many of the reaches have incised down to bedrock, exposing sections of bedrock covered by thin layers of sand and gravel.

For each of the 12 reaches, at least one cross-section survey was completed. In Reaches F and P, more than one cross-section was surveyed to characterized changing channel conditions. Table 2.1 summarizes for each stream reach the field measurements taken at each cross-section survey. The table lists the observed bed feature, drainage area, Rosgen stream class, bankfull cross-section area, bankfull channel width, bankfull mean depth, width to depth ratio, maximum depth from bankfull stage, flood-prone width, entrenchment ratio, and bank height ratio.

The bank height ratio is calculated as the maximum depth from top of low bank divided by the maximum depth from bankfull stage. This is an important parameter in determining the degree of channel incision and effectiveness of the active floodplain in dissipating energy during high flows. Bank height ratios greater than 1.5 indicate potentially severe bank stability problems resulting from high shear stresses experienced during high flows, especially where streambanks are not well protected by vegetation. Most of the stream reaches evaluated had bank height ratios of 1.5 to greater than 2.0.

In addition to the existing condition measurements, Table 2.1 also lists expected values for these streams based on regional curve and reference reach data measured in North Carolina Piedmont streams. These values were used to determine the conceptual design parameters listed in Table 2.1 and shown in Appendix A for each stream reach. This information is discussed in more detail for each reach in Section 3 of this report.

Table 2.1. Cross-Section Information for Existing, Reference, and Design Channels.

Reach		Bed	DA	Class	Abkf	Wbkf	Dbkf	W/D	Dmx	Wfpa	ER	BHR
A	Exist	RUN	0.22	F	20.5	16.7	1.2	13.6	1.8	18	1.1	2.2
	RC/Ref	RIF	0.22	E	24.0	17.0	1.4	12.0	2.1	85	5.0	1.0
	Design	RIF	0.22	E	24.4	17.1	1.4	12.0	2.0	86	5.0	1.0
B	Exist	RUN	0.57	E	57.6	19.0	3.0	6.3	4.3	39	2.1	2.1
	RC/Ref	RIF	0.57	E	43.0	22.7	1.9	12.0	2.8	114	5.0	1.0
	Design	RIF	0.57	E	42.9	22.8	1.9	12.1	2.9	65	2.9	1.0
C	Exist	RUN	0.61	G	57.3	17.5	3.3	5.3	5.2	24	1.4	2.0
	RC/Ref	RIF	0.61	E	45.0	23.2	1.9	12.0	2.9	116	5.0	1.0
	Design	RIF	0.61	E	44.6	22.9	1.9	11.8	2.6	112	4.9	1.0
D	Exist	RUN	1.20	G	67.4	24.4	2.8	8.8	3.9	39	1.6	2.1
	RC/Ref	RIF	1.20	E	70.0	29.0	2.4	12.0	3.6	145	5.0	1.0
	Design	RIF	1.20	E	70.1	28.9	2.4	11.9	3.6	155	5.4	1.0
E	Exist	RUN	0.58	G	49.7	23.3	2.1	10.9	2.9	38	1.6	2.5
	RC/Ref	RIF	0.58	E	44.0	23.0	1.9	12.0	2.9	115	5.0	1.0
	Design	RIF	0.58	E	44.1	23.0	1.9	12.0	2.5	121	5.3	1.0
F1	Exist	RIF	0.56	G	46.1	29.8	1.5	19.3	2.6	34	1.1	3.3
	RC/Ref	RIF	0.56	E	43.0	22.7	1.9	12.0	2.8	114	5.0	1.0
	Design	RIF	0.56	E	42.9	22.7	1.9	12.0	2.4	92	4.1	1.0
F2	Exist	RUN	0.57	E	40.8	17.0	2.4	7.1	3.9	40	2.4	2.9
	RC/Ref	RIF	0.57	E	43.0	22.7	1.9	12.0	2.8	114	5.0	1.0
	Design	RIF	0.57	E	44.9	23.1	1.9	11.9	2.8	73	3.2	1.0
H	Exist	RUN	0.48	E	38.8	15.6	2.5	6.3	2.7	130	8.3	1.2
	RC/Ref	RIF	0.48	E	39.0	21.6	1.8	12.0	2.7	108	5.0	1.0
	Design	RIF	0.48	E	39.3	21.6	1.8	11.9	2.4	130	6.0	1.0
I	Exist	RUN	0.10	E	19.9	12.2	1.6	7.5	2.4	77	6.3	1.6
	RC/Ref	RIF	0.10	E	14.0	13.0	1.1	12.0	1.6	65	5.0	1.0
	Design	RIF	0.10	E	14.1	12.2	1.2	10.5	1.6	77	6.3	1.0
K	Exist	RUN	0.10	E	17.6	7.5	2.3	3.2	3.9	120	16.0	1.2
	RC/Ref	RIF	0.10	E	14.0	13.0	1.1	12.0	1.6	65	5.0	1.0
	Design	RIF	0.10	E	17.6	7.5	2.3	3.2	3.9	120	16.0	1.0
P1	Exist	RIF	1.53	E	80.5	29.0	2.8	10.5	3.7	120	4.1	1.7
	RC/Ref	RIF	1.53	E	81.0	31.2	2.6	12.0	3.9	156	5.0	1.0
	Design	RIF	1.53	E	81.4	30.9	2.6	11.7	3.6	170	5.5	1.0
P2	Exist	RIF	1.76	E	84.4	27.0	3.1	8.6	4.2	112	4.1	1.8
	RC/Ref	RIF	1.76	E	89.0	32.7	2.7	12.0	4.1	163	5.0	1.0
	Design	RIF	1.76	E	88.2	32.6	2.7	12.0	3.5	165	5.1	1.0
Q	Exist	RIF	1.95	E	119	30.0	4.0	7.6	5.3	200	6.7	1.3
	RC/Ref	RIF	1.95	E	100	34.6	2.9	12.0	4.3	173	5.0	1.0
	Design	RIF	1.95	E	119	30.0	4.0	7.6	5.3	200	6.7	1.3
R	Exist	RUN	0.10	E	13.0	7.8	1.7	4.7	3.3	120	15.4	1.0
	RC/Ref	RIF	0.10	E	14.0	13.0	1.1	12.0	1.6	65	5.0	1.0
	Design	RIF	0.10	E	13.0	7.8	1.7	4.7	3.3	120	15.4	1.0

DA = Watershed Drainage Area (sq mi)
Abkf = Bankfull Cross Section Area (sq ft)
Wbkf = Bankfull Width (ft)
Dbkf = Bankfull Mean Depth (ft)
W/D = Bankfull Width to Depth Ratio (ft/ft)
Dmax = Bankfull Maximimum Depth (ft)
Wfpa = Width Flood Prone Area (ft)
ER = Entrenchment Ratio, Wfpa/Wbkf (ft/ft)
BHR = Bank Height Ratio, Dtob/Dmax (ft/ft)

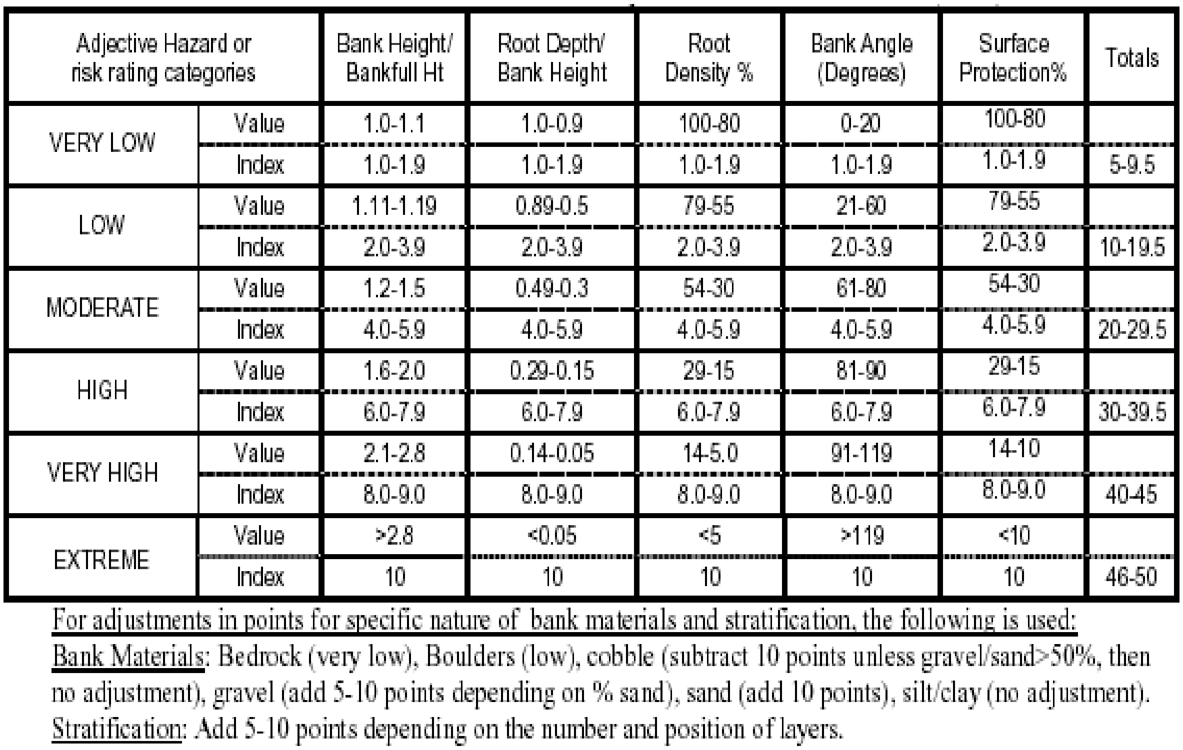
2.2 Streambank Stability

Streambank instability typically results from bank erosion along the outside bank in a meander bend. Contributing factors are high banks resulting from channel incision, lack of deep-rooted vegetation, and highly erodible soil materials in the streambank. Local instability can also occur in isolated locations as the result of channel constrictions or flow obstructions (culverts, utility crossings, debris, or other structures). Streambanks are eroded by moving water or by collapse (mass failure). Collapse typically occurs when a bank in undercut by moving water and the strength of bank materials is insufficient to resist gravitational forces. Banks that are collapsing or about to collapse are considered geotechnically unstable. Many of the streambanks observed in this study are actively eroding, contributing to downstream sedimentation and habitat degradation.

For each of the 12 stream reaches, a Bank Erosion Hazard Index (BEHI) Survey was conducted in December, 2002, to provide an estimation of stream stability and erodibility (Rosgen, 2001a). The BEHI surveys consisted of the following parameters described in Table 2.2:

- Bank height ratio
- Ratio of root depth to bank height
- Root density (in percent)
- Bank angle (with 90 degrees representing a vertical bank)
- Surface protection provided by vegetative cover, rocks, logs and other debris (in percent)
- Adjustments based on bank materials

Table 2.2. Bank Erosion Hazard Index Description (from Rosgen, 2001a).



Adjective Hazard or risk rating categories		Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%	Totals
VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80	
	Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	5-9.5
LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55	
	Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	10-19.5
MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30	
	Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	20-29.5
HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15	
	Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	30-39.5
VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10	
	Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	40-45
EXTREME	Value	>2.8	<0.05	<5	>119	<10	
	Index	10	10	10	10	10	46-50

For adjustments in points for specific nature of bank materials and stratification, the following is used:
Bank Materials: Bedrock (very low), Boulders (low), cobble (subtract 10 points unless gravel/sand>50%, then no adjustment), gravel (add 5-10 points depending on % sand), sand (add 10 points), silt/clay (no adjustment).
Stratification: Add 5-10 points depending on the number and position of layers.

Results of the BEHI evaluation are summarized in Table 2.3. The field-measured parameters were converted to a BEHI index for each reach. BEHI categories ranged from Moderate erodibility for Reaches H, K, Q, and R to Very High erodibility for Reaches A, B, C, E, and F (upstream). The remaining reaches were in the High erodibility category. This information is useful for prioritizing restoration efforts and for estimating the relative contributions of stream reaches to downstream sedimentation impacts.

Results from a study in North Carolina showed that streambanks with Moderate BEHI typically had measured erosion rates of less than 1 ft/year, while those with High to Very High BEHI had measured erosion rates ranging from 1 to greater than 10 ft/year (Patterson et al, 1999). By conservatively estimating that the typical 10-ft high unstable streambanks are eroding at 1 ft/year, the resulting total sediment load to the creek is calculated as approximately 1,000 pounds of sediment per linear foot of eroding streambank. If we assume that there are 4,000 linear feet of streambanks in the study area eroding at this rate (a conservative estimate), then the total sediment load from bank erosion would be 4 million pounds, or 2,000 tons of sediment.

Table 2.3. Bank Erosion Hazard Index Results for Each Stream Reach.

Reach	Bank Height Ratio	Root Depth Ratio	Root Density	Bank Angle	Surf Protection	Adjustment for Soil	BEHI Index	Category
A	7	8	8	6	8	5	42	Very High
B	8	7	8	7	4	7	41	Very High
C	8	8	8	6	6	6	42	Very High
D	7	5	5	6	5	6	34	High
E	8	7	8	6	6	6	41	Very High
F1	7	8	8	8	7	6	44	Very High
F2	6	6	6	7	5	6	36	High
H	3	3	4	3	5	7	25	Moderate
I	6	6	6	5	7	7	37	High
K	3	4	6	6	5	5	29	Moderate
P1	5	3	5	5	4	8	30	High
P2	6	5	5	6	5	8	35	High
P3	6	5	5	6	5	8	35	High
Q	5	5	4	4	5	5	28	Moderate
R	3	4	4	5	5	6	27	Moderate

2.3 Riparian Condition

Healthy forested riparian buffers are critical for stabilizing streambanks, filtering stormwater runoff pollutants, and providing shade and food sources for enhancing aquatic habitat. The riparian condition of the Parkerson Mill Creek stream corridor was assessed in December, 2002, to evaluate the current health of the plant community and to identify opportunities for improving natural riparian functions in the corridor. The stream corridors in the headwater reaches are mostly maintained in turf grass, providing very little benefit for streambank stabilization or aquatic habitat. The downstream reaches are primarily forested with buffer widths ranging from 10 ft to greater than 100 ft in some sections of Reach Q. The buffer in Reach R consists of pasture grasses with no limits to livestock access.

It was noted that several different types of exotic, invasive vegetation are limiting or out-competing indigenous species throughout the study area. These invasive species will continue to threaten the establishment of stable, forested plant communities unless removed. The long-term ecological success of stream restoration projects will be enhanced by encouraging indigenous plant communities and eradicating aggressive exotic species. Invasive plant species found in the Parkerson Mill Creek watershed are listed in Table 2.4.

Table 2.4. Invasive Plant Species in the Parkerson Mill Creek Watershed.

Growth Form	**Scientific Name**	**Common Name**
Tree	*Albizia julibrissin Durazz.*	mimosa
Tree	*Broussonetia papyrifera (L.) L'Her. ex Vent..*	paper mulberry
Tree	*Eleagnus angustifolia L.*	Russian olive
Tree	*Melia azedarach L.*	Chinaberry tree
Tree	*Morus alba L.*	white mulberry
Tree	*Triadica sebifera (L.) Small*	tallow tree
Shrub	*Eleagnus pungens Thunb.*	silverthorn, thorny olive
Shrub	*Eleagnus umbellate Thunb.*	autumn olive
Shrub	*Ligustrum lucidum Alt. f.*	glossy privet
Shrub	*Ligustrum sinense Lour.*	Chinese privet
Shrub	*Mahonia bealei (Fortune) Carr.*	Beale's barberry
Shrub	*Mimosa diplotnicha C. Wright ex Sauvalle*	giant sensitive plant
Shrub	*Nandina domestica Thunb.*	sacred bamboo
Shrub	*Rosa multiflora Thunb. ex Murr.*	multifora rose
Vine	*Hedera helix L.*	English ivy
Vine	*Lonicera japonica Thunb.*	Japanese honeysuckle
Vine	*Pueraria montana (Lour.) Merr.*	kudzu
Grass/Grasslike	*Lolium arundinaceum (Schreb.) S.J. Darbyshire*	tall fescue
Forb	*Lygodium japonicum (Thunb. ex Murr.) Sw.*	Japanese climbing fern

2.4 Stormwater Management

Stormwater management is a critical component of stream protection in urban watersheds. Stormwater impacts to streams include increased flooding, increased high-energy flows causing channel incision and bank erosion, local instabilities around stormwater outfalls, and water quality degradation caused by pollutant runoff. The stream corridor was assessed in December, 2002, to locate existing stormwater outfall problems and to identify potential landscape opportunities for installing stormwater best management practices (BMPs) to reduce stormwater runoff and remove pollutants. Specific BMPs recommendations are described in Section 3.3 and Appendix B.

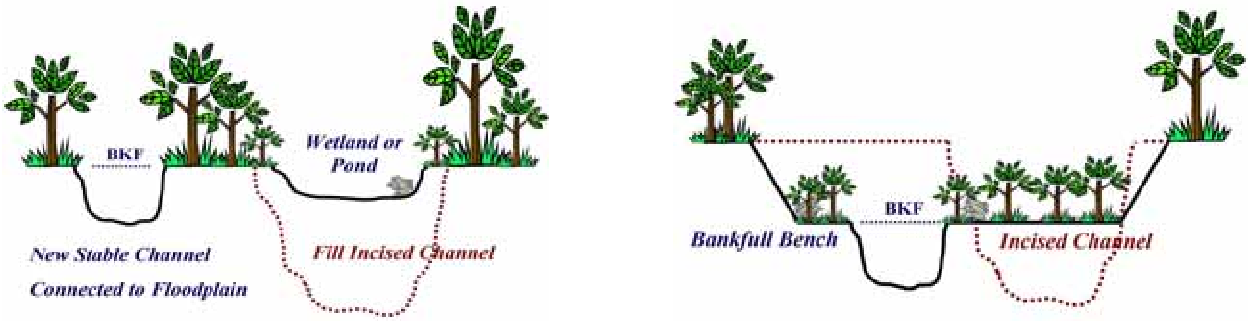
3. CONCEPTUAL PLAN

This section describes recommended approaches for stream morphology, instream structures, riparian buffers, and stormwater management to improve the natural condition and functions of the study streams. Also described are concepts for providing greenway access to the stream corridor.

3.1. Stream Morphology

This feasibility study evaluated various scenarios for stream restoration based on natural channel design methodology, taking into account constraints presented by the existing stream and surrounding land uses. The most critical aspect of stabilizing incised stream channels is to reestablish floodplain access for high flow events. Floodplains function to dissipate energy during high flows by allowing water to spread out and decrease velocity. The result is a greatly reduced shear stress in the active channel, resulting in less bed scour and streambank erosion. Rosgen (1997) described four restoration options in priority order for addressing incised alluvial streams. The options are described below and summarized in Table 3.1.

Priority 1 projects replace incised channels with new stable streams at a higher elevation (Figure 3.1). This is accomplished by excavating a new channel with the appropriate dimension, pattern, and profile based on reference reach data to fit the watershed and valley type. The new channel is typically a meandering stream with bankfull stage located at the ground surface of the original floodplain. Surrounding land uses can limit the use of a Priority 1 approach if there are concerns about increased flooding or widening the stream corridor. Priority 1 projects typically result in higher flood stages above bankfull discharge in the vicinity of the project and downstream. This approach also requires sufficient land area on one or both sides of the existing incised stream to construct the new meandering channel on the floodplain. This approach is not considered feasible for Parkerson Mill Creek due to these limitations.



Priority 1

Priority 2

Figure 3.1. Conceptual Cross Sections of Priority 1 and Priority 2 Restoration Projects.

Priority 2 projects create new stable stream channels and floodplains at or near the existing channel elevation. This is accomplished by excavating a new floodplain and stream channel (Figure 3.1). The new channel is designed with the appropriate dimension, pattern, and profile based on reference reach data to fit the watershed. The new channel is typically a meandering stream with bankfull stage located at the elevation of the newly excavated floodplain. A Priority 2 project can produce a long-term stable stream system if designed and constructed properly. Priority 2 projects can be constructed in dry conditions while streamflow continues in its original channel or is diverted (or pumped) around the construction site.

A major advantage of the Priority 2 approach is that flooding does not increase and may in some cases decrease as the floodplain is excavated at a lower elevation. Riparian wetlands in the stream corridor created by the excavation may be enhanced with this approach. Priority 2 projects typically produce more cut material than is needed to fill the old channel. This means that designers must consider the expense and logistics of managing extra soil material excavated from the floodplain. Surrounding land uses can limit the use of this approach if there are concerns about widening the stream corridor. The Priority 2 approach is the preferred design approach for restoring Parkerson Mill Creek and its tributaries.

Priority 3 projects are similar to Priority 2 with the objective of widening the floodplain at the existing channel elevation to reduce shear stresses. This is accomplished by excavating a floodplain bench on one or both sides of the existing stream channel at the elevation of the existing bankfull stage. The existing channel may be modified to enhance its dimension and profile based on reference reach data. The resulting channel is typically a relatively straight stream with bankfull stage located at the elevation of the new floodplain. A Priority 3 project can produce a moderately stable stream system but will require structural measures and maintenance attention. For these reasons, it may be more expensive and more complex to construct depending on valley conditions and structure requirements.

Priority 4 projects use of various streambank stabilization techniques to armor the bank in place, without attempting to correct problems with dimension, pattern, or profile. Projects may use rip rap, concrete, gabions, bioengineering, or combinations of structures to protect streambanks. Priority 4 projects can result in streambank stability but require inspection and maintenance to ensure long-term success.

Table 3.1. Advantages and Disadvantages of Restoration Options for Incised Streams.

Option	Advantages	Disadvantages
1	Results in long-term stable stream. Restores optimal habitat values. Enhances wetlands by raising water table. Minimal excavation required.	Increases flooding potential. Requires wide stream corridor. Unbalanced cut/fill. May disturb existing vegetation.
2	Results in long-term stable stream. Improves habitat values. Enhances wetlands in stream corridor. May decrease flooding potential.	Requires wide stream corridor. Requires extensive excavation. May disturb existing vegetation.
3	Results in moderately stable stream. Improves habitat values. May decrease flooding potential. Maintains narrow stream corridor.	May disturb existing vegetation. Does not enhance riparian wetlands. Requires structural stabilization measures. May require maintenance.
4	May stabilize streambanks. Maintains narrow stream corridor. May not disturb existing vegetation.	Does not reduce shear stress. May not improve habitat values. May require costly structural measures. May require maintenance.

The Priority 2 approach is recommended for restoring stream stability and function to Parkerson Mill Creek and its tributaries. The recommended changes to stream channel dimension, pattern, and profile are described for each stream reach below and in Appendix A. The channels will be adjusted so that the stream reaches can transport the water and sediment delivered by their watersheds, while accessing floodplains at their bankfull channel elevation.

Reach A extends approximately 384 ft from a culvert crossing under Donahue Drive to a culvert crossing under Biggio Drive. The stream corridor is confined by Biggio Drive on the left side and a parking lot on the right side. There is a stormwater outfall entering the stream near the downstream end of Reach A. Future campus stormwater modifications call for increasing the size and relocating stormwater outfall upstream. Reach A is classified as an incised class F channel with a bank height ratio greater than 2 and very high bank erodibility. This reach is a high priority for stream restoration due to its instability and large contribution to downstream sedimentation. The proposed conceptual design is shown in Appendix A. There is sufficient room for excavation of a bankfull bench approximately 80 ft wide with a meandering class E channel approximately 24 square feet in bankfull dimension.

Reach B is downstream of Reach A, extending approximately 1110 ft from a culvert crossing under Biggio Drive to a culvert crossing under West Samford Avenue. The stream corridor is confined by athletic fields on the left side and Biggio Drive on the right side. Reach B is classified as an incised class E channel with a bank height ratio greater than 2 and very high bank erodibility. This reach is a high priority for stream restoration due to its instability and large contribution to downstream sedimentation. The proposed conceptual design is shown in Appendix A. The proposed design is high-risk due to the severe limitations imposed by the land uses on both sides of the stream corridor. The width of the bankfull bench is limited to approximately 50 ft due to surrounding land uses. This limits the design entrenchment ratio for the meandering class E channel to 3 and the available belt width ratio to 2. These ratios are much lower than typically found in reference streams. Implementation of this design will require additional hardening measures such as retaining walls, rip rap, and grade control structures. To ensure long-term stability of this reach, the excavated bankfull bench should be at least 90 feet wide, requiring a minimum 50-ft encroachment on the athletic fields adjoining the left streambank.

Reach C is downstream of Reach B, extending approximately 868 ft from a culvert crossing under West Samford Avenue to the confluence of Reaches C and E. The stream corridor is confined by athletic fields on the left side and Biggio Drive and parking lots on the right side. Reach C is classified as an incised class G channel with a bank height ratio greater than 2 and very high bank erodibility. This reach is a high priority for stream restoration due to its instability and large contribution to downstream sedimentation. The proposed conceptual design is shown in Appendix A. There is sufficient room for excavation of a bankfull bench approximately 100 ft wide with a meandering class E channel approximately 45 square feet in bankfull dimension. There is a foot bridge in this reach that may limit full implementation of this design if it is not removed or replaced.

Reach D is downstream of Reach C, extending approximately 916 ft from the confluence of Reaches C and E to a culvert crossing under Lem Morrison Drive. The stream corridor is confined by athletic fields on both sides. Reach D is classified as an incised class G channel with a bank height ratio greater than 2 and high bank erodibility. This reach is a high priority for stream restoration due to its instability and large contribution to downstream sedimentation. The proposed conceptual design is shown in Appendix A. There is sufficient room for excavation of a bankfull bench approximately 130 ft wide with a meandering class E channel approximately 70 square feet in bankfull dimension.

Reach E is upstream of Reach D, extending approximately 640 ft from the confluence of Reaches C and E to a culvert crossing under Biggio Drive. The stream corridor is confined by a building on the left side and athletic fields on the right side. Reach E is classified as an incised class G channel with a bank height ratio greater than 2 and very high bank erodibility. This reach is a high priority for stream restoration due to its instability and large contribution to downstream sedimentation. The proposed conceptual design is shown in Appendix A. There is sufficient room for excavation of a bankfull bench approximately 110 ft wide with a meandering class E channel approximately 45 square feet in bankfull dimension. There is a foot bridge in this reach that may limit full implementation of this design if it is not removed or replaced.

Reach F is upstream of Reach E, extending approximately 611 ft from a culvert crossing under West Samford Avenue to a culvert crossing under Biggio Drive. Reach F is divided into two distinct sections for this study. The upstream reach (F1) extends from the culvert under West Samford Avenue downstream approximately 100 ft and is classified as an incised class G channel with a bank height ratio greater than 3 and very high bank erodibility. This reach is a high priority for stream restoration due to its instability and large contribution to downstream sedimentation. The proposed conceptual design is shown in Appendix A. There is room for excavation of a bankfull bench approximately 85 ft wide with a meandering class E channel approximately 45 square feet in bankfull dimension. This reach includes one stable meander to redirect flow coming through the culvert toward the downstream channel.

The downstream reach (F2) is classified as an incised class E channel with a bank height ratio greater than 2 and high bank erodibility. This reach is confined by recently constructed buildings and parking areas on both sides of the stream corridor that will the width of the bankfull bench to approximately 60 ft. The resulting design entrenchment ratio and belt width ratio are both approximately 3. Implementation of this design will require additional hardening measures such as retaining walls, rip rap, and grade control structures. To ensure long-term stability of this reach, the excavated bankfull bench should be at least 90 feet wide, requiring a minimum 30-ft encroachment on the athletic fields adjoining the right streambank. There is an existing foot bridge that may limit implementation of this design if not removed or replaced.

Reach H is upstream of Reach F, extending approximately 1636 ft from the confluence of Reaches I and K to a culvert crossing under Wire Road. Reach H is divided into two distinct sections for this study. The upstream reach extends from the confluence of Reaches I and K downstream approximately 700 ft. Because this stream reach is confined by utility lines and land uses on both sides of the stream corridor, it is not considered a candidate for a restoration project. No field survey data were collected on this reach.

The downstream section of Reach H extends approximately 900 ft to a culvert crossing under Wire Road. This section is classified as a slightly incised class E channel with a bank height ratio of approximately 1.2 and moderate bank erodibility. This reach is a medium priority for stream restoration due to its relative stability and minor contribution to downstream sedimentation. The proposed conceptual design is shown in Appendix A. There is sufficient room for excavation of a bankfull bench approximately 100 ft wide with a meandering class E channel approximately 39 square feet in bankfull dimension. The remeandering of this channel would support floodplain wetlands as shown in Appendix A.

Reach I is upstream of Reach H, extending approximately 573 ft from a culvert under Roosevelt Drive to the confluence of Reaches I and K. The stream corridor is confined by West Thatch Avenue on the right side. Reach I is classified as an incised class E channel with a bank height ratio of approximately 1.5 and high bank erodibility. This reach is a high priority for stream restoration due to its instability and moderate contribution to downstream sedimentation. The proposed conceptual design is shown in Appendix A. There is sufficient room for excavation of a bankfull bench approximately 60 ft wide with a meandering class E channel approximately 14 square feet in bankfull dimension.

Reach K is upstream of Reach H, extending approximately 909 ft from a culvert under Roosevelt Drive to the confluence of Reaches I and K. Reach K is classified as a slightly incised class E channel with a bank height ratio of approximately 1.2 and moderate bank erodibility. This reach is a low priority for stream restoration due to existing urban land uses along the stream corridor, including a fraternity house built over the stream channel. No conceptual design was prepared for this reach.

Reach P is downstream of Reach D, extending approximately 1049 ft from a culvert crossing under Lem Morrison Drive to the fence line, which is the beginning of Reach Q. The stream corridor is surrounded by a pasture. Reach P is classified as an incised class E channel with a bank height ratio between 1.4 and 1.8 and high bank erodibility. This reach is a high priority for stream restoration due to its instability and large contribution to downstream sedimentation. The proposed conceptual design is shown in Appendix A. Two cross sections were measured in riffles and one in a pool. There is sufficient room for excavation of a bankfull bench 150 ft wide with a meandering class E channel 85 square feet in bankfull dimension.

Reach Q is downstream of Reach P, extending approximately 2257 ft from the fence line at the end of Reach P to a culvert crossing under Shug Jordan Parkway. Reach Q is classified as a slightly incised class E channel with a bank height ratio of approximately 1.3 and moderate bank erodibility. This reach is a low priority for stream restoration due to its extensive forested stream corridor and relative stability. No conceptual design was prepared for this reach.

Reach R is a tributary to Reach Q, extending approximately 2061 ft from the culvert crossing under Wire Road to its confluence with Reach Q. The stream corridor is surrounded by a pasture. Reach R is classified as a class E channel with a bank height ratio of approximately 1.0 and moderate bank erodibility. This reach is a low priority for stream restoration due to its relative stability, but the stream quality may be greatly enhanced by fencing livestock away from the stream and installing a vegetated riparian buffer. No conceptual design was prepared for this reach.

3.2. Instream Structures

The recommended restoration plans include instream structures to provide grade control, bank stability, and enhanced habitat. Root wads (Figure 3.2), j-hook vanes (Figure 3.3), and log vanes are used along the outsides of meander bends to direct energy away from banks while deep-rooted vegetation becomes established. Boulder cross vanes (Figure 3.4) are used to provide grade control and flow direction at the heads of riffles. All of these structures enhance habitat by providing local scour holes and woody debris.

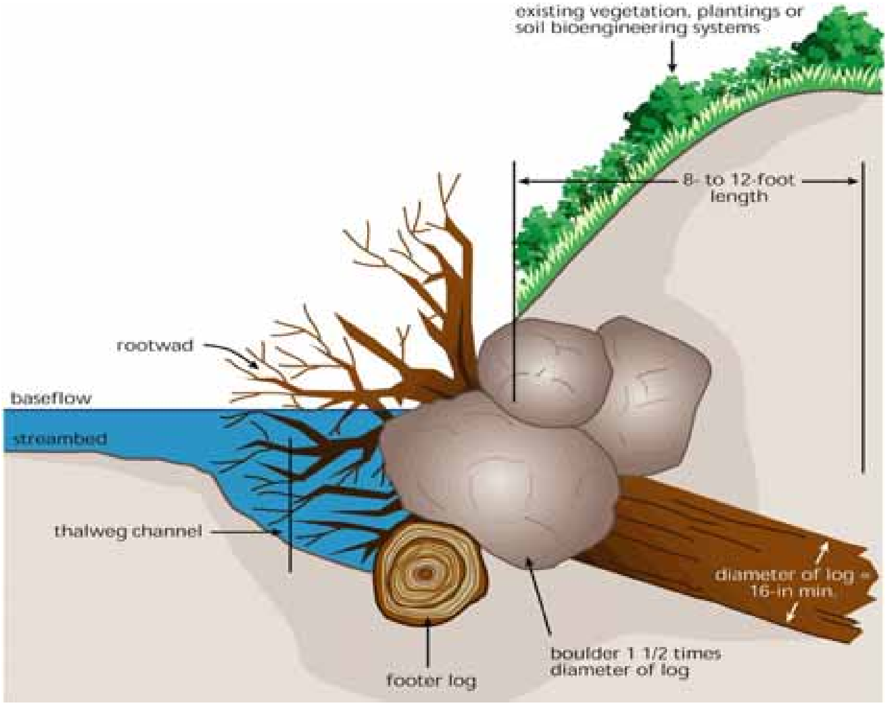


Figure 3.2. Schematic Root Wad Cross Section.

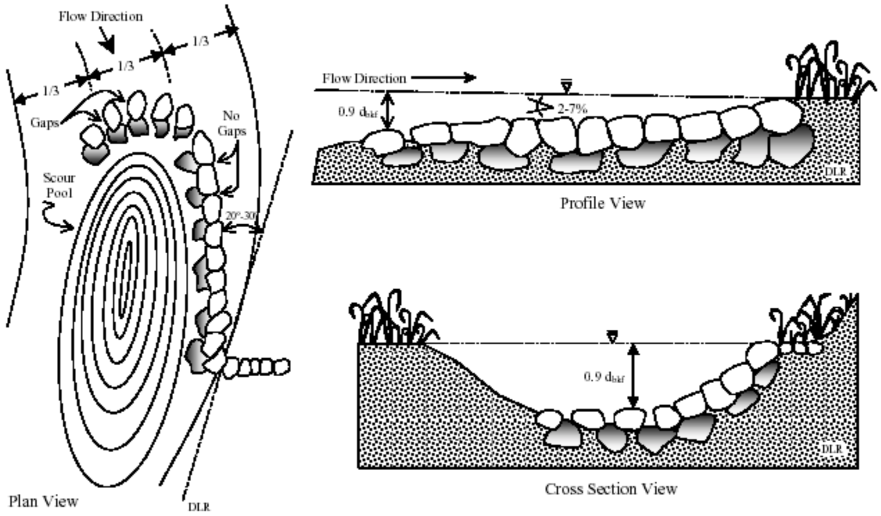


Figure 3.3. Schematic J-Hook Vane Cross Section, Profile, and Plan View (from Rosgen, 2001b).

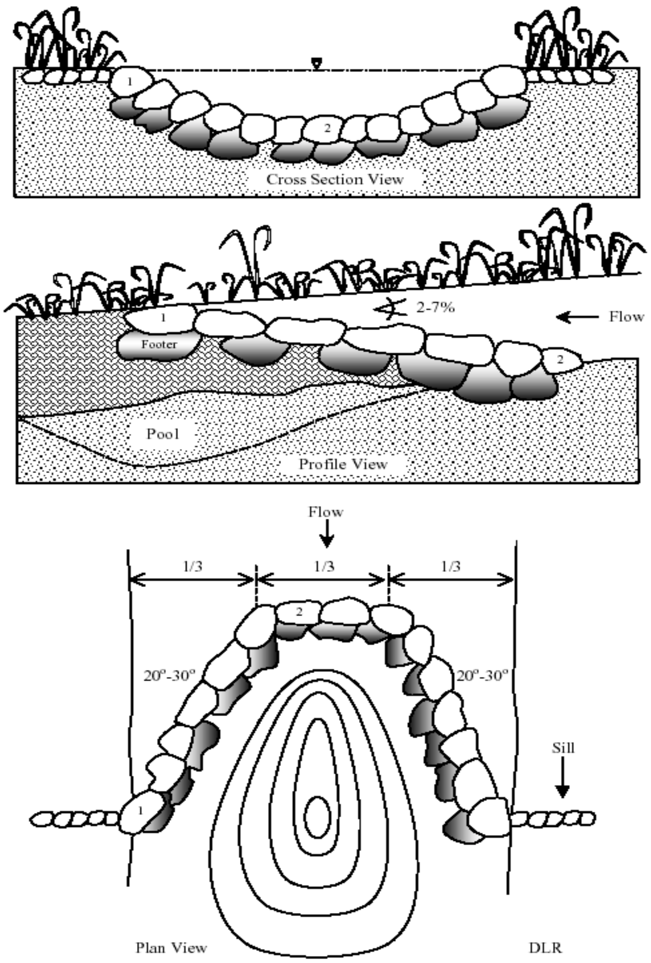


Figure 3.4. Schematic Cross Vane Cross Section, Profile, and Plan View (from Rosgen, 2001b).

3.3. Riparian Buffer

Vegetation in the riparian corridor benefits water quality and habitat by regulating temperature, adding organic matter (leaves and twigs), assisting in pollution reduction, stabilizing streambanks, and providing wildlife habitat. The most stable and effective riparian buffers include a combination of native trees, shrubs, grasses and herbs that form functional plant communities. Figure 3.5 shows components of a healthy riparian buffer.

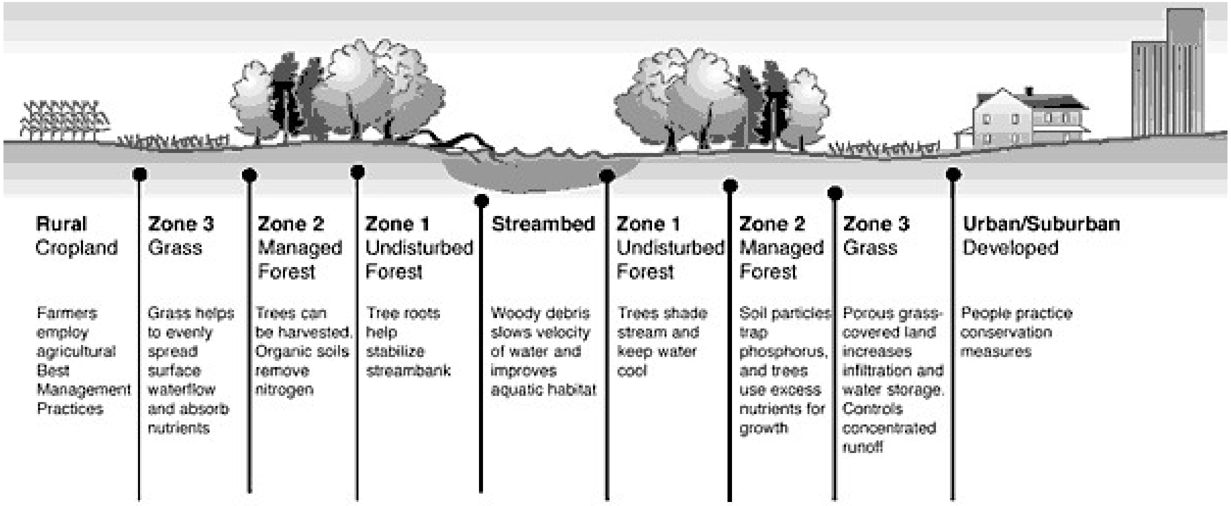


Figure 3.5. Conceptual Riparian Buffer.

In the Southeast, most plant communities will succeed into a forested landscape. An alluvial, hardwood floodplain forest is the climax community that would naturally occur at Parkerson Mill Creek. Factors including slope, aspect, soil, light, elevation, and moisture will influence plant survival. A variety of plant species should be selected to include mostly species found in the pioneering stages of ecological succession. Table 3.2 lists plants that are likely to thrive in the riparian corridors of the study area.

Many indigenous plant species used for restoration planting are already in ornamental horticulture production and commercially available. Conservation nurseries sell the less widely used plant materials. Most nurseries will offer to contract grow plant species if given enough time to produce them. Before installing any new plants, invasive exotic species should be removed to insure restoration success.

Several methods can be used to install riparian vegetation. Seeding, live staking and bare root planting are the least expensive. Containerized or ball and burlap plants are more expensive. Seeding is commonly used for temporary erosion control and also to establish the herbaceous layer. Many species of native grass and forb seed are commercially available and can be installed easily. Several vendors offer extensive lists of seed. Live staking is the process of taking a live cane cutting from a dormant plant. These canes are typically 16 to 24 inches long and approximately one inch in diameter. Canes are driven into the bank, or through erosion control fabric. Some sites may require a pilot hole for the live stake, typically done with reinforcing bar. Live stakes work well where frequent flows are anticipated because other plant material would be scoured and washed away. Bare root material is generally a plant that has a well-developed root system. These plants are usually installed with a dibble, or tree bar. Containerized and ball and burlap plants are more expensive and are pit planted. These materials also require irrigation during establishment and have higher mortality.

Table 3.2. Plants Recommended for the Parkerson Mill Creek Riparian Buffer.

Growth Form	**Scientific Name**	**Common Name**
Tree		
	Betula nigra	river birch
	Platanus occidentalis	american sycamore
	Quercus lyrata	overcup oak
	Quercus nigra	water oak
	Quercus phellos	willow oak
	Quercus shumardii	shumard's oak
Shrub		
	Cephalanthus occidentalis	common buttonbush
	Clethra alnifolia	coastal sweetpepperbush
	Cornus amomum	silky dogwood
	Cornus foemina	stiff dogwood
	Euonymus americana	strawberry bush
	Ilex decidua	possumhaw
	Ilex glabra	inkberry
	Ilex verticillata	common winterberry
	Itea virginica	Virginia sweetspire
	Rhododendron viscosum	swamp azalea
	Viburnum nudum	possumhaw
Subshrub, Shrub		
	Rudbeckia laciniata	cutleaf coneflower
	Sesbania punicea	rattlebox
	Xanthorhiza simplicissima	yellowroot
Forb/herb		
	Lobelia cardinalis	cardinalflower
	Ludwigia alternifolia	seedbox
	Macrothelypteris torresiana	swordfern
	Rhexia nashii	maid Marian
	Rudbeckia fulgida	orange coneflower
	Thelypteris dentata	downy maiden fern
	Vernonia gigantea	giant ironweed
	Woodwardia areolata	netted chainfern
Vine		
	Bignonia capreolata	crossvine
	Decumaria barbara	woodvamp
	Wisteria frutescens	American wisteria

3.3. Stormwater Management

This study evaluated potential stormwater best management practices (BMPs) to retain stormwater runoff and reduce water quality impacts to the streams. The potential BMPs are listed in Table 3.3 and shown in Appendix B. The focus of this study was on identifying existing stormwater impacts and finding possible locations to remediate impacts. Available areas for BMPs along the stream corridors are very limited by existing building, roads, and parking lots. The recommended BMPs listed in Table 3.3 take advantage of grassed or wooded areas that can be retrofitted with engineered stormwater controls to provide benefits to the streams and also serve as educational demonstrations.

Table 3.3. Recommended Stormwater Best Management Practices.

Reach	Location	BMP	Estimated Cost
A	Downstream near Biggio Drive	Bioretention	$2,000
B	Aquatic Center & Basketball Arena	Bioretention *	$60,000
B	Aquatic Center	Bioretention	$10,000
B	Track near Biggio Dr & W. Samford Av	Turf Mat & Bioretention	$18,000
C	Soccer Field near W. Samford Av	Wetland Enhancement *	$15,000
E	Biggio Dr	Enhanced Wet Swale *	$12,000
E	Biggio Dr	Wetland or Bioretention	$4,000
F	Womens Athletic Center	Level Spreader	$8,000
F	North of Womens Athletic Center	Wetland or Bioretention	$6,000
I	Roosevelt Dr & W. Thatch Av	Wetland Step Pool	$20,000
I	W. Thatch Av	Pocket Wetland or Rain Garden	$5,000
I	W. Thatch Av & Roosevelt Dr	Wetland (Conversion of Existing Dry Pond) *	$15,000

Four of the BMPs marked with * in Table 3.3 are considered highest priority based on available land, cost, potential for significant stream benefits, and demonstration value. The bioretention area in Reach B at the Aquatic Center & Basketball Arena is a priority because of the large area available to treat roof runoff and its high visibility as a demonstration site. The grassed nature of the site would be retained, but a major drawback is that the area would be off-limits to parking. Additionally, it is the most expensive BMP retrofit suggested, because of its size (1/3 acre) and the amount of fill soil that may be needed. The wetland enhancement in Reach C along West Samford Avenue is a priority because of current function of the site as a wetland and its visibility. The system could be greatly enhanced at a relatively low cost by diverting street runoff into the wetland. The wet swale in Reach E along Biggio Drive is a priority because of its existing condition as a swale, space has already been set aside for some stormwater treatment. It could be enhanced by installing check dams, curb cuts, and speed bumps to improve its function. The improvements to the roadway would account for the majority of cost. The wetland conversion of the dry pond in Reach I at West Thatch Avenues is a priority because of its existing size and the watershed that it could treat. It can accommodate more flow than it currently receives and can be easily converted to a wetland.

3.4. Greenway

This study evaluated potential greenway alignments in combination with proposed riparian restoration. Although a regional and campus greenway master plan is needed to define the logical placement of trails as transportation corridors, many of the stream reaches contain opportunities to include trails within the riparian corridor, or greenway. Potential greenway locations for many of the reaches are shown in Appendix A. A greenway trail is a continuous twelve-foot wide, paved surface designated for use by pedestrians and cyclists. Motorized vehicles are excluded. Trails within the greenway corridor provide alternative transportation choices and an enjoyable recreational amenity for students and visitors. The proposed greenway trail system will also help preserve greenspace, streams, wetlands, and wildlife corridors. The creation of greenways and trails will protect the biological diversity, air and water quality, and natural beauty of the region. Trails can also reduce crime because more eyes are on the public space and greater interaction between trail users and patrollers occurs.

Benches, interpretive signs, water fountains, and other amenities can enhance a greenway trail. Interpretive and educational signage will enlighten citizens about the importance of their natural resources. Topics could include stream restoration, stormwater practices, stream and wetland function, and natural resources stewardship. Also, having a beautiful, well-maintained greenway trail system will be a tremendous marketing tool for Auburn’s prospective students, faculty and staff.

A successful greenway trail project must be compatible with the adjacent riparian corridors and support the stormwater strategy. For example, the greenway could be used to create berms required for the stormwater wetlands and biofiltration areas. These areas would intercept and treat the potentially polluted run-off from adjacent areas before it reaches the Parkerson Mill Creek and other streams. The wetland vegetation and soil structure could filter some of the stormwater and increase infiltration.

Trails built within riparian corridors must be designed to withstand periodic flooding. This precludes using granite fines and asphalt surfaces in these areas. The surface material proposed for this trail system is concrete with a light, broomed finish. Concrete is the most durable in locations where periodic flooding is anticipated and satisfies the needs of all types of trail users. Asphalt, gravel fines, and other pervious materials will not withstand being submerged, nor are they easily cleaned and repaired after flooding. Installing asphalt trails or other, less permanent trail surfaces, would necessitate costly resurfacing and eventual replacement.

4. PROJECT CONSTRAINTS

Parkerson Mill Creek and its tributaries offer many constraints typically found in urban watersheds. These include utilities, road crossings, adjacent land uses, concerns about flooding, safety, and water quality problems. All of these were considered in the recommendations presented above. Flooding concerns are addressed through the implementation of a Priority 2 approach for channel and floodplain construction. This approach will require the excavation and removal of large quantities of soil material from the stream corridor. Each existing road crossing must be evaluated for possible changes to accommodate large flows without causing stream instabilities.

5. COST ESTIMATES

Cost estimates for stream restoration are based on typical prices for excavation, construction materials (rock, concrete, logs, plants, erosion control materials), pumping, vegetation, survey, design, construction supervision, and construction labor. Table 5.1 lists the estimated costs of excavation (based on $7 per cubic yard), minimum total costs, and maximum total costs for each reach. These costs are presented as totals and as unit costs per linear foot of restored stream channel. These estimated costs are conservative, accounting for long construction periods expected in an urban setting. Miscellaneous costs are estimated as 10% of total construction costs, and design fees are estimated as 20% of total construction costs.

Reaches A, B, C, D, E, and F are estimated to cost from $240 to $340 per linear foot. All of these reaches require extensive excavation to create functional floodplains at a lower elevation. Reaches H and I are less costly due to less excavation. Reach R costs are for livestock exclusion and vegetation to provide an enhanced riparian buffer. All of these costs are subject to change based on final design parameters.

Table 5.1. Cost Estimates for Parkerson Mill Creek Restoration.

Reach	Estimated Cost ($)								Cost ($/ft)
	Excav	**Struct**	**Eros**	**Veg**	**Survey**	**Misc**	**Design**	**Total**	
A	$41,067	$12,000	$4,800	$10,000	$2,000	$6,987	$15,371	$92,224	$240
B	$74,044	$52,000	$13,200	$28,000	$5,000	$142,000	$62,849	$377,093	$340
C	$91,962	$34,000	$5,800	$22,000	$4,000	$15,776	$34,708	$208,246	$240
D	$131,548	$36,000	$8,100	$24,000	$4,000	$20,365	$44,803	$268,816	$293
E	$87,057	$22,000	$4,600	$24,000	$4,000	$14,166	$31,164	$186,987	$292
F	$85,711	$30,000	$5,500	$18,000	$3,000	$14,221	$31,286	$187,719	$307
H	$11,667	$24,000	$3,000	$24,000	$5,000	$15,000	$16,533	$99,200	$155
I	$9,572	$12,000	$1,500	$12,000	$2,000	$3,707	$8,156	$48,935	$85
P	$93,048	$30,000	$6,500	$30,000	$4,000	$16,355	$35,981	$215,884	$206
R	$0	$0	$0	$22,000	$0	$2,200	$4,840	$29,040	$14

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