PRINCE WILLIAM COUNTY, VA
DEPARTMENT OF PUBLIC WORKS

Bull Run Watershed Study

Whitman, Requardt & Associates, LLP
Engineers • Architects • Planners
9030 Stony Point Parkway, Suite 220
Richmond, Virginia 23235

March 2010

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (cont)

LIST OF FIGURES

APPENDICES

SUPPLEMENTAL

I. EXECUTIVE SUMMARY

The Watershed Management Branch of the Prince William County Public Works Department - Environmental Services Division, investigated the condition of stream channels and storm water management facilities within representative subwatersheds of the Bull Run Watershed. Bull Run is a tributary of the Occoquan Reservoir and drains approximately 186 square miles of Loudoun, Prince William, and Fairfax Counties, as well as the Cities of Fairfax, Manassas and Manassas Park. The reach of Bull Run between Cub Run and Popes Head Creek is listed by Virginia Department of Environmental Quality as benthically impaired. The completed Total Maximum Daily Load (TMDL) study for this reach indicates that excessive sediment is the leading stressor of the benthos. This watershed assessment identified opportunities to address sources of sediment and other pollutants that may be contributing to the listing of this segment of Bull Run as impaired.

This watershed study involved inspection of existing stormwater facilities, assessment of the condition of stream channels, inventorying problem areas along stream channels, and identification of potential watershed management Capital Improvement Projects (CIP). Due to the large size of the Bull Run watershed, this study was narrowed to three primary subwatersheds which are representative of conditions found throughout the Bull Run watershed:

- Buckhall (194) subwatershed is less densely developed, with limited stormwater facilities.
- Yorkshire (186) subwatershed is characteristic of older development with minimal stormwater facilities. A small subwatershed (100) which drains directly into Bull Run was included in this subwatershed.
- Linden (166) subwatershed is characterized by relatively recent, dense commercial and residential development, much of which has some level of stormwater management.

Stormwater Facilities Condition and Recommendations

This study targeted 15 out of the 33 existing wet and dry ponds in the County inventory for inspection. During field work 5 existing stormwater facilities which were not listed in the county inventory were identified. A total of 20 facilities were evaluated: four in Buckhall, four in Yorkshire, and twelve in the Linden subwatershed.

There were minimal safety issues at the existing stormwater facilities. Sites on the County's inventory tended to be well maintained, while those not on the inventory were poorly maintained. However, several of the sites on the County inventory appeared to have no visible evidence of recent maintenance. Based on the field inspections the following projects were recommended:

- One out of the 20 sites (5%) inspected requires repairs to address significant safety issues.
- Three out of the 20 sites (15%) are good candidates for retrofitting existing dry basins for improved water quality treatment. Retrofitting these sites would provide water quality treatment for over 33.3 acres of impervious surface not currently being treated.
- Six out of the 20 sites (30%) require repairs to address existing functional issues.

- Ten sites, or 50% of those inspected, had no issues or only require minor repairs or maintenance

The estimated design, construction, and contingency costs for the proposed improvements, repairs and water quality retrofits ranges from $600,000 to $800,000. The three water quality retrofit projects would cost approximately $300,000, or about $9,000 per impervious acre.

Stream Channel Condition and Recommendations

There are 171,473 linear feet of stream channel within the three subwatersheds. Approximately 15 percent (21,969 linear feet) was identified for field assessments. Most of the streams received assessment scores that indicated they were either in good or fair condition. The magnitude and severity of channel erosion was not as great as has been seen on other watersheds within the county. Of the 25 stream reaches investigated, seven (28%) reaches were identified a high priorities for restoration, stabilization, or enhancement.

The five recommended stream and riparian buffer projects would address deficiencies and degradation along over 3,000 linear feet of stream channel at an estimated cost of $360,000. Costs per linear foot range from $50 to $330 depending on the complexity of the project. Three additional stream reaches would be improved as part of proposed stormwater facility projects.

Outfall Retrofits Recommendations

Increasing the amount of runoff treated in a developed watershed is difficult due to the limited amount of land available for new stormwater facilities. Retrofitting an existing outfall to provide water quality treatment is a space efficient approach to improving the stormwater management in a developed watershed. As an outcome of the stream inventory, 5 stormwater outfalls were identified which are recommended for water quality retrofitting. The proposed outfall retrofits would provide water quality treatment for over 15 acres of impervious surface not currently being treated. The estimated total costs for the 5 outfall retrofits ranges from $300,000 to $500,000, or approximately $20,000 to $33,000 per impervious acre being treated.

Programmatic Recommendations

Within the three subwatersheds in the Bull Run watershed, a capital outlay budget of approximately $1.3-1.4 M would be required to address all of the high and moderate priority projects identified in this study. These costs do not include potential needs in the other Bull Run subwatersheds, which were not studied. Based on the results of the stormwater facility inspections, the following are recommendations to improve the existing Stormwater Management Program:

- Conduct office and field reconnaissance to identify existing stormwater facilities that are not included in the County’s inventory so that these facilities will be subjected to annual inspections and maintenance.
- The use of GPS enabled cameras during inspections would help document when inspections occur and provide a long-term record of the condition of the sites.

- The County’s stormwater facilities database should be updated based on annual inspections and any modifications to the original design of the facilities. Some of the data in the County’s database does not appear to accurately reflect as-built conditions or recent modifications to the facilities.

These recommendations would help insure that all existing stormwater facilities are routinely inspected, are functioning properly, and that GIS databases accurately reflect the full inventory of stormwater treatment efforts in the County.

II. PROJECT DESCRIPTION

The Prince William County, Public Works Department, Environmental Services Division, Watershed Management Branch investigated the condition of stream channels and storm water management facilities within representative subwatersheds of the Bull Run Watershed, and identified potential watershed management Capital Improvement Projects (CIP). Bull Run is a tributary of the Occoquan Reservoir and drains approximately 186 square miles of Loudoun, Prince William, and Fairfax Counties, as well as the Cities of Fairfax, Manassas and Manassas Park. The dominant land use across the Bull Run watershed include developed land (39%), forest (34%), and agricultural (23%). The portion of the Bull Run watershed within Prince William County is approximately 85.5 square miles or 44% of the total watershed. Within Prince William County the proportion of the watershed that is developed is higher than 40% and the proportion that is forested or agricultural is lower than the watershed-wide statistics.

The 4.8 mile long reach of Bull Run (VAN-A23R-01) between Cub Run and Popes Head Creek is listed by Virginia Department of Environmental Quality as benthically impaired (Figure 1). The Total Maximum Daily Load (TMDL) study completed for this segment indicated that excessive sediment is the leading stressor of the benthos. TMDL studies often select sediment as a stressor because it takes into account the impacts of sedimentation, altered urban hydrology, and degraded habitat. Sediment loads come from urban stormwater runoff, stream bank erosion and channel incision. Improvements in the benthic community are dependent on reducing sediment loadings through stormwater control, stream restoration and riparian buffer improvements. This watershed study will identify opportunities to address sources of sediment, other pollutants and stream degradation that may be contributing to the listing of the Bull Run as impaired. Based on the results of the study, potential watershed management CIPs will be identified. This initial inventory will lead, in future phases, to more detailed studies or surveys of each potential watershed management project, and eventually to final design and construction.

This watershed study involved inspecting existing stormwater facilities, assessing the condition of stream channels, inventorying problem areas along stream channels, and identifying opportunities to retrofit stormwater management where it is currently lacking. Due to the large size of the Bull Run watershed with Prince William County, this study was narrowed to three primary subwatersheds which are representative of conditions found throughout the Bull Run watershed (Figure 2). This subset of subwatersheds covers 6.7 square miles or approximately 8% of the watershed within the County. The character of each subwatershed can be summarized as follows:

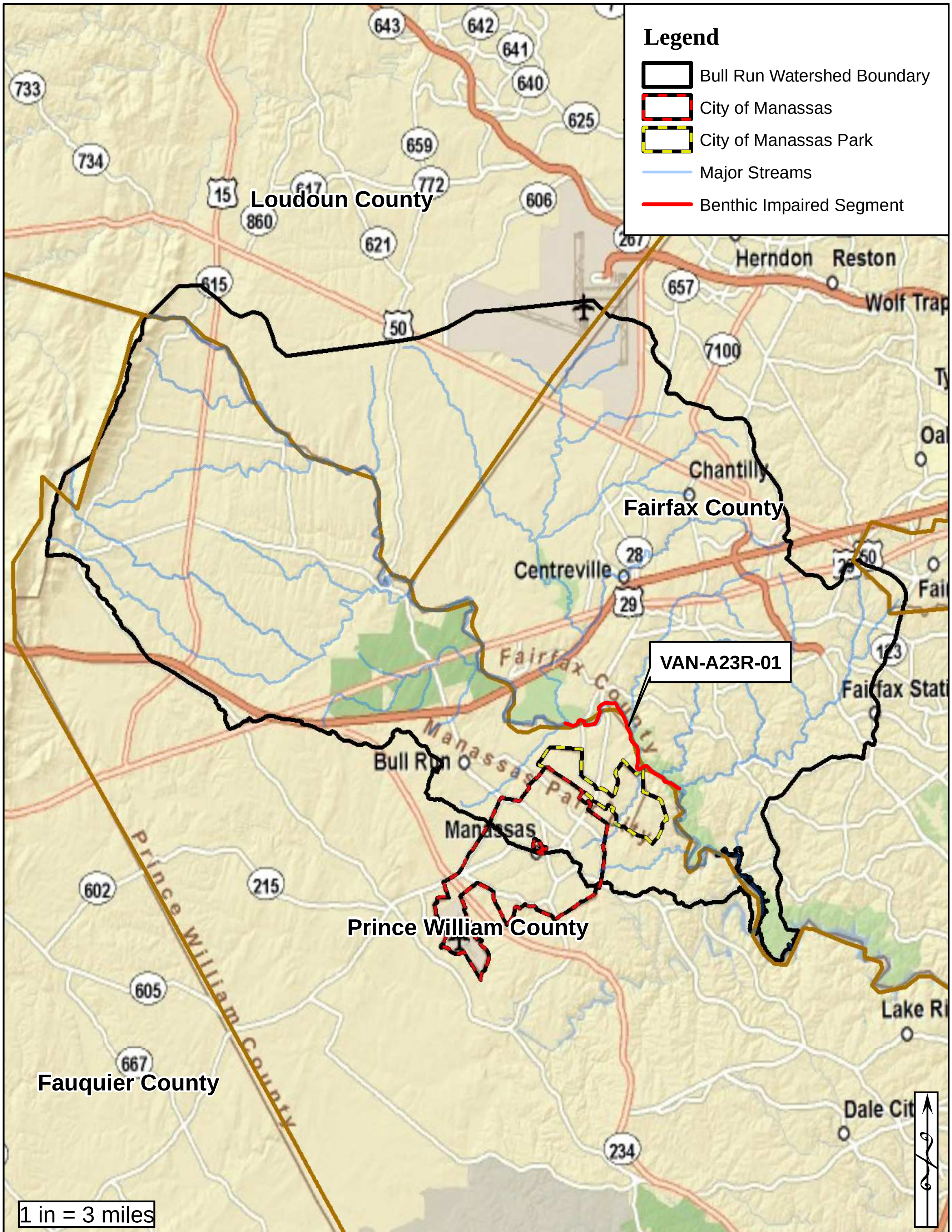
- **Buckhall Branch** (194) subwatershed is less densely developed with limited stormwater management. It drains 1,924 acres, contains 16 stormwater facilities, and 100,746 linear feet (lf) of streams.
- **Yorkshire** (186 + 100) subwatershed is characteristic of older development with minimal stormwater management. A smaller subwatershed (100) which abuts subwatershed 186 and drains directly to Bull Run was included in the Yorkshire subwatershed. The Yorkshire subwatershed drains 1,083 acres, contains 6 stormwater facilities, and 29,432 lf of streams.

- **Linden** (166) subwatershed is characterized by relatively recent, dense residential and commercial development, much of which has some level of stormwater management. It drains 1,230 acres, contains 20 stormwater facilities, and 41,432 lf of streams.

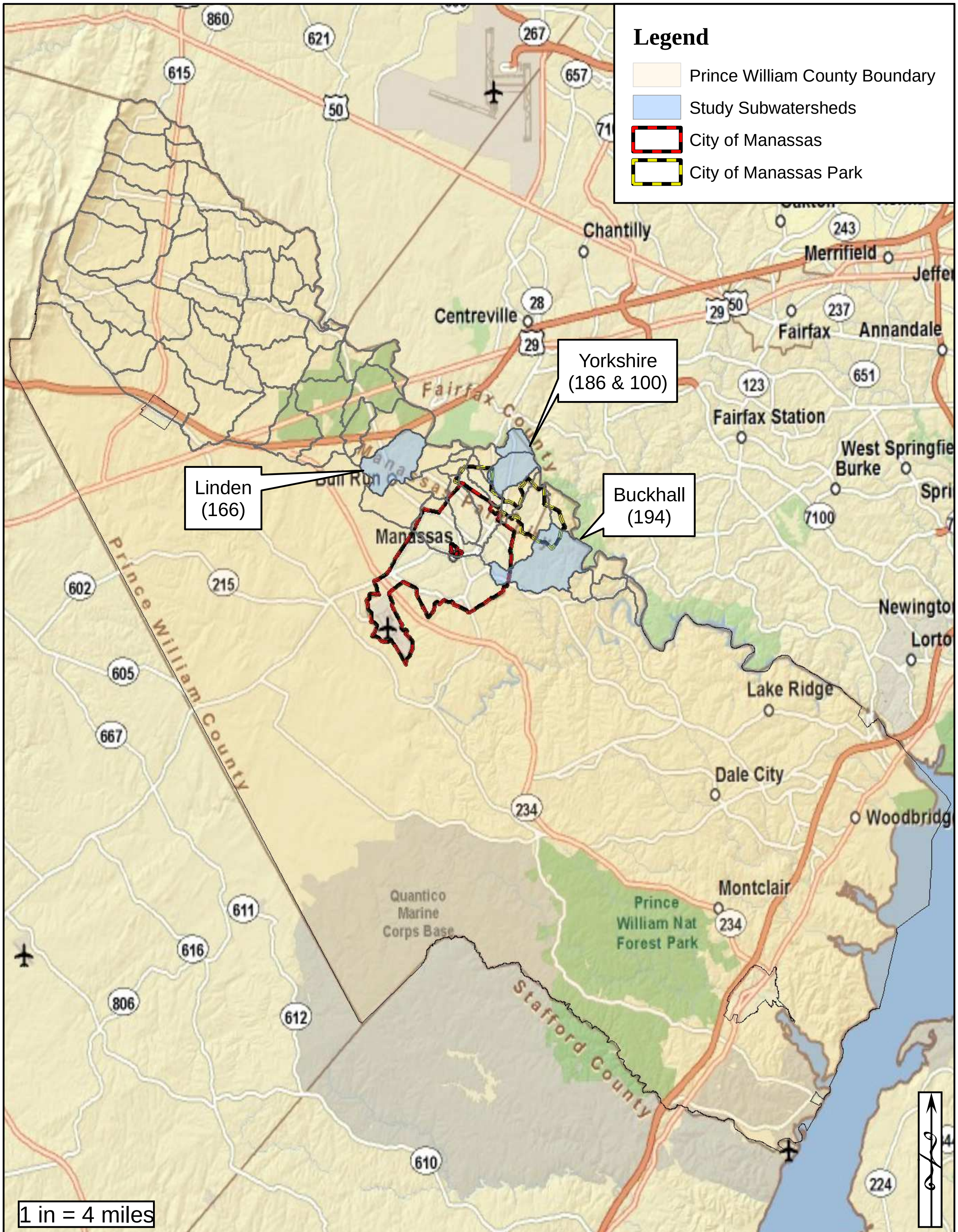
Even though the scope of the study was narrowed to three primary subwatersheds, there are extensive amount of stream channel, stormwater facilities, and outfalls included in these subwatersheds. For both the stormwater inventory and the stream assessment, additional steps were taken to screen the existing facilities and stream channels to identify those sites where degradation was most likely and where a watershed improvement project would be compatible with the existing land use and ownership.

Based on the results of the stream assessments and stormwater inventory the sites were prioritized and ranked within each subwatershed and across the entire study area. Based on the prioritization and ranking, specific projects were carried forward into conceptual design. Design narratives and cost estimates were developed for each project.

The step in the study process is detailed in the following chapters and supported by detailed data provided in the Appendices.



Source:	Title:	Figure:
Prince William County GIS, USGS	**Bull Run TMDL Study Watershed**	1



Source:

Prince William County GIS, Esri World Street Map

Title:

Bull Run Watershed Location Map

Figure:

2

III. STORMWATER INVENTORY APPROACH AND RESULTS

To help guide the stormwater portion of this study, the first five steps in an eight step process described in the *Manual 3: Urban Stormwater Retrofit Practices Manual (Center of Watershed Protection)* were completed. Traditionally, this process focuses on identification of stormwater retrofit opportunities. However, this study included consideration of existing stormwater facility condition and any need for repairs to address existing deficiencies as well as addressing the potential for water quality retrofits. The five steps in evaluating stormwater facilities were:

1. **Stormwater Scoping** – The study approach was refined to meet local watershed objectives and stormwater management requirements.
2. **Desktop Analysis** –Existing stormwater facilities were screened using existing GIS data and aerial photography.
3. **Stormwater Facility Reconnaissance Investigation** – Each stormwater facility identified in the desktop analysis was evaluated in the field, noting the existing condition, deficiencies, and retrofit feasibility.
4. **Stormwater Facility Evaluation and Ranking**– Each facility was prioritized (i.e. high, moderate, low) and assigned a numerical ranking. The high and moderate priority sites were selected to carry forward into conceptual design development.
5. **Development of Conceptual Design** – For each stormwater site, conceptual designs were developed to address the identified deficiencies or to improve water quality treatment.

Completion of these steps will allow the County to progress into the later phases of watershed management, including subwatershed treatment analysis, final design, and construction.

3.1. Stormwater Scoping Process

In order to clearly articulate the goals of the stormwater inventory and the development of proposed repair and retrofit projects, the following guiding principles were defined:

- Core Stormwater Objectives
- Minimum Performance Criteria
- Preferred Retrofit Treatment Options

Core Stormwater Objectives - The projects identified in this watershed study focused on addressing sources of watershed impairments such as stream sedimentation, channel erosion, nutrient enrichment, toxic pollutants, and disrupted watershed hydrology. However, the projects addressed other objectives as well, including:

- Correcting any safety issues
- Insuring that stormwater facilities are functioning as intended (i.e., address deficiencies in design or maintenance)
- Improving water quality function of existing facilities (i.e., retrofit for water quality)
- Improving protection of downstream channels (i.e., address outfall scour)
- Improving ease of maintenance

Minimum Performance Criteria -The two primary performance criteria of concern in this study were to provide control of the water quality volume and the channel protection volume where practicable when considering retrofits or repairs. The two performance criteria were:

- **Water Quality Volume (WQv**): Target the rainfall events that generate the majority of stormwater pollutants in a year by providing 100% control of first 0.5 inch of runoff from impervious surface.
- **Channel Protection Volume (CPv**): Target storms that generate bankfull or sub-bankfull floods that cause stream channel erosion, which would typically require 60% control of the 1 year, 24-hour storm event (2.4 inch event).

Preferred Retrofit Treatment Options - The study focused on improvements that could be made at the subwatershed scale to address water quality and channel protection. The treatment options most applicable to a subwatershed scale are storage retrofits. Storage retrofits are more cost effective than on-site retrofits due to the economies of scale. Storage retrofit projects usually treat 5 to 500 acres, are generally constructed on public lands, and typically rely on extended detention, wet ponds, and constructed wetlands to meet water quality and channel protection controls.

On-site retrofits typically target individual rooftops, parking lots, streets, stormwater hotspots, and other small projects. While on-site projects may cumulatively contribute to improvements in water quality and quantity, the potential sites within this large watershed are too numerous to address at the subwatershed scale and were not addressed in this study. On-site retrofits are typically addressed in a catchment or neighborhood scale study.

The initial watershed management strategies for storage retrofit opportunities included:

- **Retrofit of existing dry ponds** to constructed wetlands.
- **Retrofit of existing wet ponds** to add or increase water quality volume storage, add wetlands, or modify detention.
- **Adding new storage below existing outfalls** – Limited to outfalls less than 36 inches, this option includes creation of off line bioretention basins or wetlands within open land between the outfall and the receiving stream.

3.2. Desktop Analysis

The desktop analysis consisted of compiling existing GIS mapping layers, databases, and aerial photography, and screening each subwatershed for stormwater facilities suitable for evaluation in the field. The following screening criteria were used to narrow the selection of stormwater facilities to individual sites to carry forward into the Stormwater Facilities Reconnaissance Inventory:

- Dry basins were preferred over other types of stormwater facilities because they are good candidates for water quality retrofitting.

- Sites located on public lands, home owner associations (HOAs), and institutional land (i.e. churches, schools, etc.) are preferred over private residential or commercial property.
- Sites treating greater than 5 acres but less than 500 acres

The desktop analysis initially identified 33 existing dry or wet ponds within the study's subwatersheds (Table 1). From this initial set of facilities, 15 sites were identified for field evaluations based on the screening criteria.

3.3. Stormwater Facilities Reconnaissance Inventory

A Stormwater Facilities Reconnaissance Inventory was conducted of the sites identified in the desktop analysis. Field data sheets and GPS-located photographs were completed for each site inspection. The field inventory included an inspection of existing stormwater facilities and documentation of any problems which have arisen due to a delay in or lack of maintenance. The retrofit potential of the existing facility was assessed, and potential retrofit sites were evaluated to determine appropriateness of a retrofit and to identify any existing constraints.

Initially, the selected stormwater facilities were labeled using the County Facility ID number from the County stormwater database. During field work 5 additional facilities were identified which appear to be stormwater facilities but were not listed in the county stormwater database. There are a number of valid reasons why these facilities may not have been included in the listing of County facilities that were used in this study.

- Recently built facilities are not added to the inventory until as-built surveys are approved and bonds are released.
- A facility may belong to another jurisdiction (VDOT, City, etc.) and is not part of the County system.
- A facility may not be intended to treat stormwater.
- A facility may not be accepted into the County system due to deficiencies, or other issues.

The field identified facilities were included in the reconnaissance inventory, resulting in a total of 20 facilities evaluated: four sites in the Buckhall subwatershed, four sites in the Yorkshire subwatershed and 12 sites in the Linden subwatershed. The results of the field inspections are summarized in Table 2. The location of the evaluated stormwater facilities in each subwatershed are presented in Figures 3 through 5. As facilities which were not on the County inventory were identified in the field, new identification codes were developed. At the completion of the inventory, Site IDs were reassigned to all of the facilities using the Subwatershed code (i.e. 166-1, 166-2, etc.).

The results of the field inspections identified the following:

- One out of the 20 sites (5%) inspected requires repairs to address significant safety issues.
- Six out of the 20 sites (30%) require repairs to address existing functional issues.

- Three out of the 20 sites (15%) are good candidates for retrofitting existing dry basins for improved water quality treatment. These sites would also require repair or extensive maintenance if not retrofitted.
- Ten sites, or 50% of those inspected, had no issues or only require minor repairs or maintenance

TABLE 1
PWC Stormwater Management Facility Inventory Database

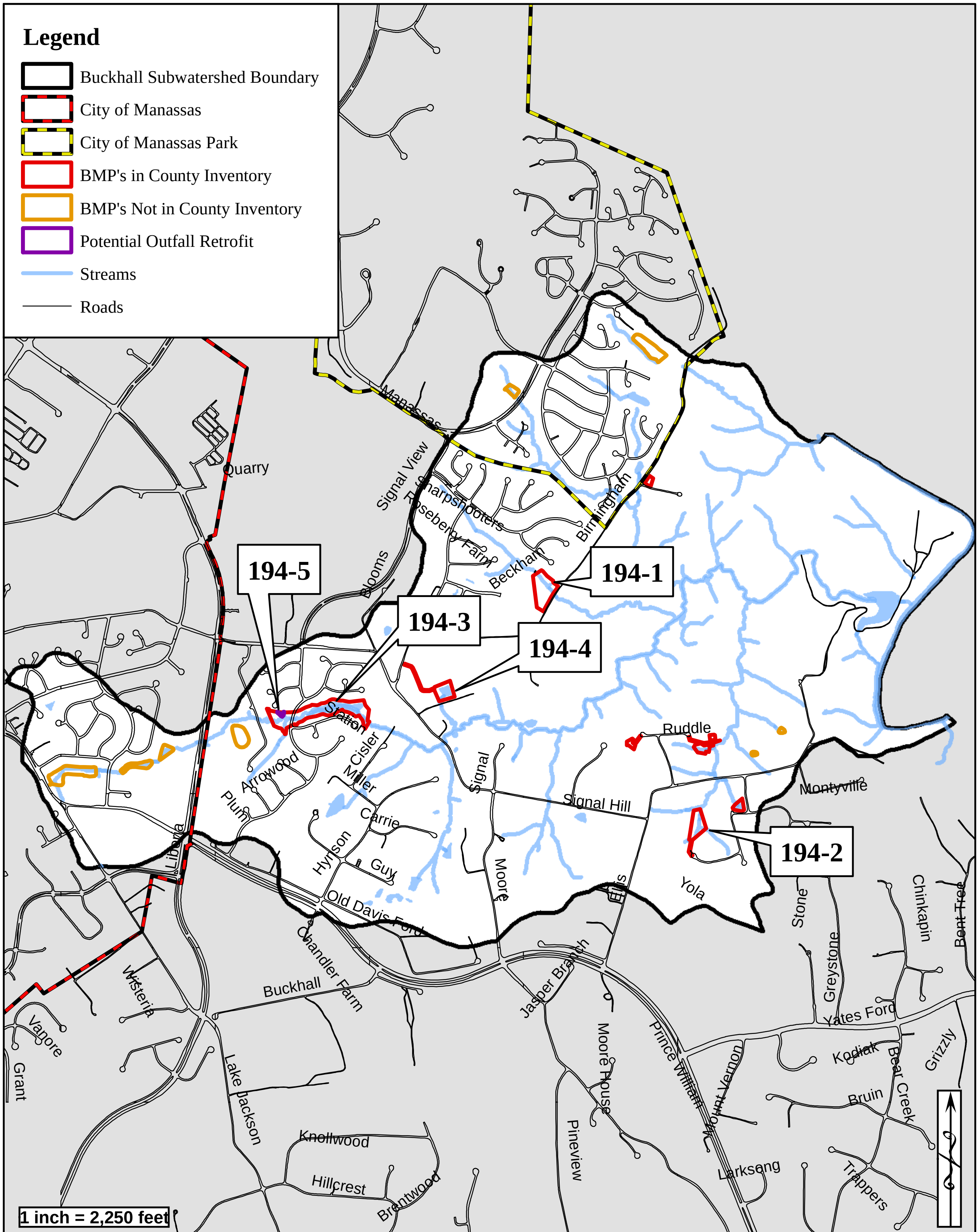
Facility ID	Facility Type	Included in Field Inspections	Facility Description	Riser Present	Rise Diameter	Type of Outlet Structure	Inv. In	Invert Out	Spillway Present	Dam Height	Drainage Area (ac)	Date Added to Inventory	Maintenance Provided by
Buckhall	**Subwatershed 194**												
76	SWMP	N	W	N	0	--	0.00	0.00	--	7	0	12/1/1992	HOA
77	SWMP	Y	D	N	0	CMP	252.43	251.24	Y	10	0	12/1/1992	Private
106	SWMP/BMP	Y	D	N	0	RCP	259.33	258.20	Y	8	53	3/1/1992	Private
416	SWMP/BMP	Y	D	Y	72	RCP	232.56	230.74	Y	12	0	11/1/2002	Private
485	SWMP	N	D	N	0	CMP	0.00	0.00	N	0	0	7/1/1997	Private
486	SWMP	N	D	N	0	CMP	0.00	0.00	--	0	0	7/1/1997	Private
487	SWMP	N	D	N	0	CMP	0.00	0.00	--	0	0	7/1/1997	Private
5282	CSWMP/BMP	Y	D	Y	48	RCP	259.81	262.14	Y	13	0	7/1/2001	County
9004	--	N	--	N	0	--	0.00	0.00	N	0	0	3/1/2005	Private
Yorkshire	**Subwatershed 186 + 100**												
105	SWMP/BMP	Y	D	Y	672	RCP	170.50	169.35	N	18	24	3/1/1993	Private
5206	CSWMP	N	D	N	0	--	0.00	0.00	N	2	0	10/1/1999	County
164	SWMP/BMP	Y	D	Y	36	RCP	249.01	248.53	Y	12	0	3/1/1996	Private
311	SWMP/BMP	N	D	Y	48	RCP	174.54	174.21	N	4	0	9/1/2000	Private
5097	CSWMP/BMP	Y	D	Y	4	RCP	252.35	211.07	Y	0	0	1/1/2001	County
5152	CSWMP	N	D	Y	24	RCP	210.55	207.10	Y	14	0	6/1/1997	County
5280	CSWMP/BMP	N	D	Y	48	RCP	172.30	171.87	Y	5	1	10/1/2005	County
5296	CSWMP/BMP	N	D	Y	60	RCP	191.11	191.04	N	3	1	9/1/2001	County
Linden	**Subwatershed 166**												
61	SWMP/BMP	Y	D	N	0	RCP	207.00	206.85	N	7	0	1/1/1995	Private
91	SWMP/BMP	Y	D	Y	81	RCP	185.30	181.60	N	10	1	4/1/2004	Private
99	SWMP	Y	D	N	0	RCP	233.50	231.81	Y	10	0	11/1/1995	Private
162	SWMP	N	D	N	0	--	0.00	0.00	N	0	0	12/1/2000	Private
196	SWMP/BMP	N	D	Y	0	RCP	283.75	283.50	Y	5	0	8/1/1997	Private
209	BMP	Y	B	N	0	RCP	209.45	208.73	Y	2	0	12/1/1997	Private
386	SWMP/BMP	N	D	Y	48	RCP	245.75	243.65	Y	11	24	6/1/2002	Private
412	SWMP/BMP	Y	D	Y	48	RCP	212.00	211.66	N	7	0	10/1/2002	Private
492	SWMP/BMP	Y	W	Y	108	RCP	240.04	235.58	Y	17	0	7/1/2000	Private
5007	CSWMP/BMP	N	W	Y	54	RCP	241.60	241.31	Y	11	7	10/1/2004	County
5148	CSWMP/BMP	N	W	Y	144	RCP	183.35	181.90	N	28	0	4/1/1997	County
5177	CSWMP	N	D	Y	18	RCP	195.40	195.20	N	5	0	9/1/1997	County
5212	CSWMP/BMP	N	W	Y	84	RCP	218.80	217.39	Y	19	0	1/1/2000	County
5233	CSWMP/BMP	Y	D	Y	36	RCP	236.29	235.50	Y	8	5	7/1/2000	County
5302	CSWMP/BMP	N	D	N	0	PVC	198.93	198.70	Y	7	1	10/1/2001	County
5331	CSWMP/BMP	Y	W	Y	48	RCP	216.79	216.30	N	10	0	3/1/2002	County

Note: W=Wet Pond; D= Dry Pond; B=Bioretention; N= No, Y=Yes; -- = no data

TABLE 2
Stormwater Management Facility Field Inspection Results

Watershed Name and ID	Site ID	PWC BMP Inventory	Design of Facility	Drainage Condition	Safety Issues	Maintenance	Repair	Investigation
Buckhall (194)	194-1	416	Dry	Wet	No	Removal of debris from orifice	No	No
	194-2	77	Dry	Dry w/ low flow channel	No	No	No	Evaluate design of riser structure and stream erosion
	194-3	106	Dry	Wet	No	Removal of debris from inflow pipes	Stabilize incised inflow channel	Evaluate design of riser structure
	194-4	5282	Dry	Dry	No	Removal of brush from spillway	No	No
Yorkshire (186 & 100)	186-1	NOI	Dry	Wet	No fence	Removal of sediment at inflow pipes and outlet structure	No	Redesign riser structure and provide fence
	186-2	105	Dry	Some seeps	No	No	No	No
	186-3	164	Dry	Dry	No	No	Minor slope erosion	No
	186-4	5097	Wet	Wet	No	No	No	No
Linden (166)	166-1	5233	Dry	Wet	Apparent overtopping	Removal of debris	Berm	Evaluate design, potential for full re-design
	166-2	NOI	Wet	Wet	No	Removal of debris and dead trees	No	Full redesign to functional and efficient stormwater facility
	166-3	5331	Wet	Minor ponding	No fence	No	No	Provide fence
	166-4	NOI	In line	NA	No	No	No	No
	166-5	NOI	Dry	Dry	No fence	No	Structure	Evaluate Design to determine if stormwater facility is needed
	166-6	99	Dry	Wet bottom	No	No	No	Evaluation design of riser and trash rack
	166-7	91	Dry	Wet	No	Removal of debris from orifice	Stabilize erosion under inlet pipe	Evaluation design of riser and orifice
	166-8	492	Wet	Wet	No	Removal of debris from trash rack	No	Investigate water quality to determine if aeration is needed
	166-9	209	Bioretention	Dry	No	Removal of debris from inflow pipes	No	Possible future investigation
	166-10	61	Dry	Dry	No	Removal of minor sediment in front of orifice	No	No
	166-11	NOI	Wetland	Marsh	No	No	No	No
	166-12	412	Dry	Dry	No	No	No	No

NOI = Not in County inventory



Source:

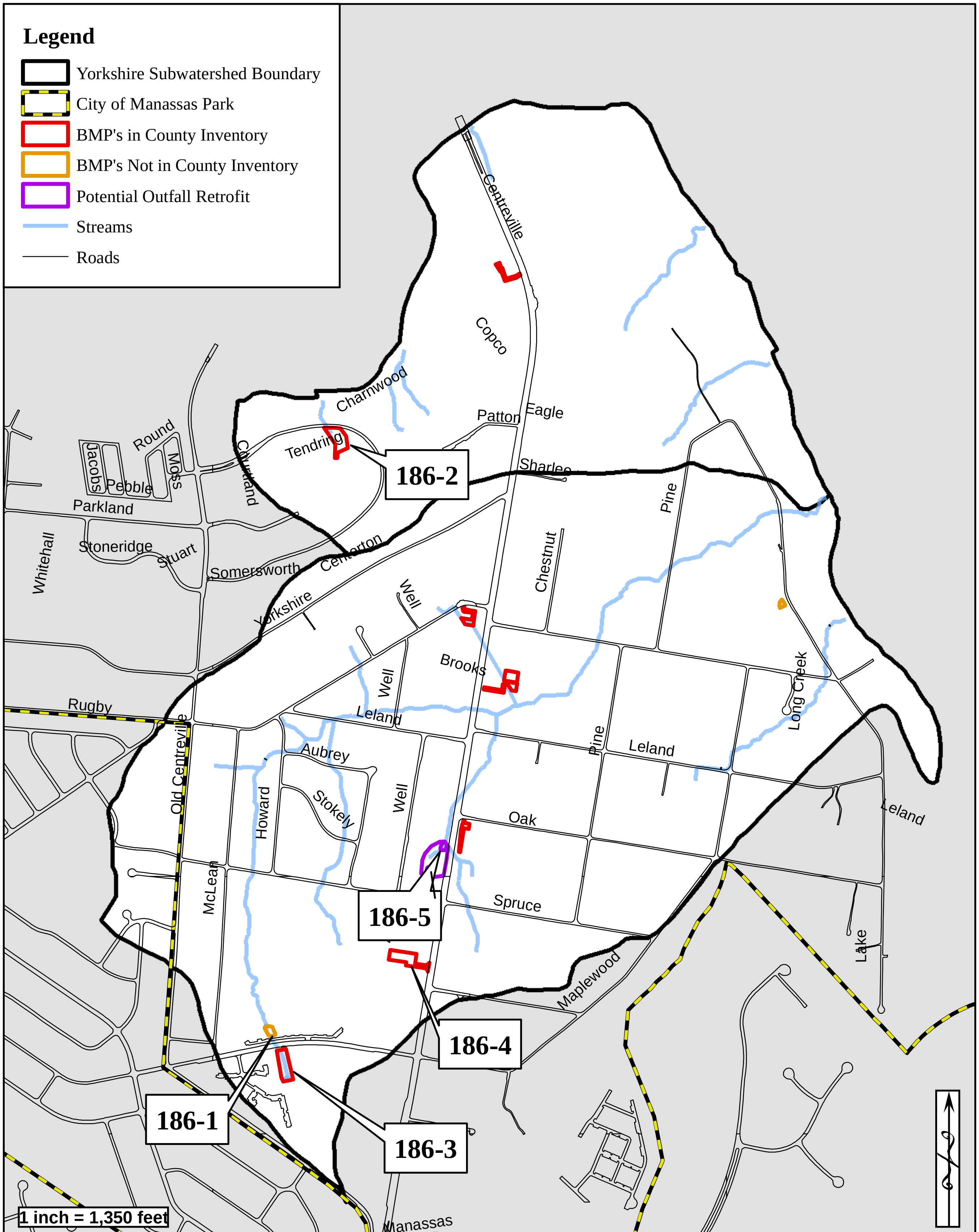
Prince William County GIS

Title:

Stormwater Facility Reconnaissance Inventory Buckhall (194) Subwatershed

Figure:

3



Source:

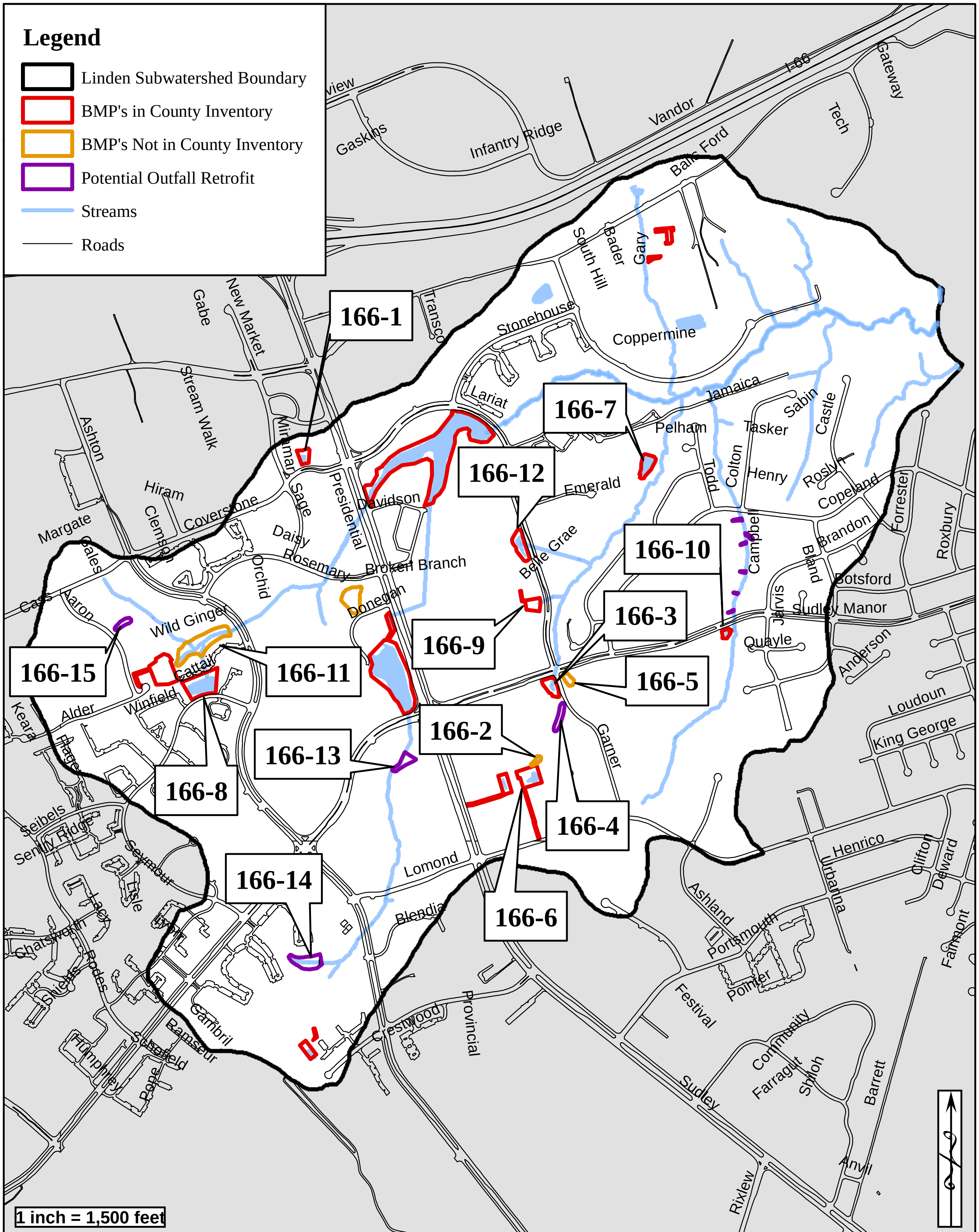
Prince William County GIS

Title:

Stormwater Facility Reconnaissance Inventory Yorkshire (186 & 100) Subwatershed

Figure :

4



Source:	Title:	Figure:
Prince William County GIS	Stormwater Facility Reconnaissance Inventory Linden (166) Subwatershed	5

3.4. Stormwater Repair and Retrofit Prioritization and Ranking

The stormwater facilities inspected in the reconnaissance inventory were assigned a priority based on how well the site was functioning, and the potential to improve function with water quality retrofits. Priorities were assigned based on the following guidance:

Priority	Reasons
High	Safety issues or site completely failing to perform as designed
Moderate	Site is functional, but may not be fully performing as designed; or where a retrofit could improve functions, such as adding water quality control
Low	Requires only minor repairs or maintenance
None	Well maintained sites, fully functional

The assigned priorities are listed in Table 3. There were two high priority sites, seven assigned moderate priority, and eleven with low or no priority. Site 166-1 was assigned high priority due to safety issues, while site 166-2 was assigned high priority due to the very poor water quality conditions and poor functioning of the facility.

Within each subwatershed, the individual sites with a priority of high or moderate were ranked to facilitate the selection of projects to move forward into implementation. In addition, the individual sites were ranked across the three subwatersheds so that projects could be prioritized between the subwatersheds. The Linden subwatershed included the two highest ranked projects.

3.5. Stormwater Conceptual Design Projects

A conceptual design was developed for each of the sites assigned a high or moderate priority, resulting in the eight projects summarized in Table 4 (some sites were combined into a single project). A full description of each project is presented in the conceptual design narrative included in Appendixes A-C, organized by subwatershed. Each appendix includes a map with the location of each project. Each design narrative includes the location, problem description, project description, potential benefits, design considerations, and a summary of cost estimate. Each design narrative also includes a location map with ADC map page references, ground level photos of existing conditions, and aerial photos of either existing conditions or proposed conceptual plan. Each project is identified by subwatershed, site ID, County facility ID if available, GPIN Ownership, and GPS coordinates. Drainage calculations used in the evaluation of the effectiveness of the conceptual designs are provided in Appendix D. The proposed projects would provide the following:

- One major reconstruction to address a significant safety issue.
- Retrofitting three sites which would provide water quality treatment for over 33.3 acres of impervious surface not currently being treated.
- Repairs or improvements to three sites which would address existing functional issues.
- One stormwater study which would improve functioning across 5 sites

TABLE 3
Stormwater Management Facility Improvement and Retrofit Recommendations

Watershed Name and ID	Site ID	PWC BMP Number	Priority	Ranking within Subwatershed	Study Ranking	Recommendations	Reasoning for Ranking
Buckhall (194)	194-1	416	Moderate	1	5	Convert to Wetland BMP	Good Candidate for WQ Retrofit on HOA land, combined with stream project
	194-2	77	Moderate	2	6	Install Rise, Stabilize stream	BMP is destabilizing downstream channel
	194-3	106	Moderate	3	7	Install Rise, Stabilize outfall	Site is generally functioning well, but lacks a adequate riser
	194-4	5282	Low	4		None	Well maintained dry pond
Yorkshire (186 & 100)	186-1	NOI	Moderate	1	3	Rebuild riser, WQ	Existing Facility, not maintained
	186-2	105	Low	2		None	Well maintained dry pond
	186-3	164	Low	3		None	Well maintained dry pond
	186-4	5097	None	4		None	Well maintained wet pond
Linden (166)	166-1	5233	High	1	1	Redesign to address Safety issues	Significant safety issues and lack of adequate riser
	166-2	NOI	High	*2	2	Redesign required to provide BMP functions	unmaintained wet basin with very poor water quality
	166-3	5331	None	*	2	Include in regional study	Well maintained dry pond
	166-4	NOI	Low	*	2	Include in regional study	Potential BMP retrofit site
	166-5	NOI	Low	*	2	Include in regional study	Abandoned dry basin
	166-6	99	Moderate	*5	2	Potentially replace riser, include in regional study	Generally functional dry basin with wet basin floor
	166-7	91	Moderate	3	4	Replace riser and convert to Wetland BMP	Ponded dry basin good WQ retrofit candidate
	166-8	492	Moderate	4	8	Aeration and possible riser modifications for storage	Wet pond with high algae content, would benefit from aeration
	166-9	209	Low			None	Functional bioretention basin
	166-10	61	Low			None	Well maintained dry pond
	166-11	NOI	None			None	Well maintained dry pond
	166-12	412	None			None	Well maintained dry pond

*Group166-2 to 166-6 in to a single study of effectiveness and design
NOI =Not on County Inventory

TABLE 4

Stormwater Management Facility Repair and Retrofit Recommendations

Project Name	Site ID	Priority	Study Ranking	Recommendations
Linden 166-1 Stormwater Facility Safety Improvements	166-1	High	1	Redesign the existing SWM facility to address overtopping, inadequate riser, and lack of maintenance access.
Linden Stormwater Management Study Area (166-2)	166-2, 166-3,166-4, 166-5, 166-6	High	2	Conduct regional study to determine how best to correct the failing facility (166-2) and other identified deficiencies in this headwater.
Yorkshire 186-1 Stormwater Facility Water Quality Retrofit	186-1	Moderate	3	Water quality retrofit to an existing unmaintained facility, including modification to riser, adding forebays, and fencing.
Linden 166-7 Stormwater Facility Water Quality Retrofit	166-7	Moderate	4	Convert dry basin to wetland system and replace existing low flow riser.
Buckhall 194-1 Water Quality Retrofit and Stream Stabilization	194-1	Moderate	5	Combine this large scale water quality retrofit with stream stabilization and buffer management.
Buckhall 194-2 Stormwater Facility Improvements and Stream Stabilization	194-2	Moderate	6	Design riser to provide channel protection, and stabilize downstream channel. Consider providing stormwater controls closer to roadway and eliminating this facility.
Buckhall 194-3 Stormwater Facility Improvements	194-3	Moderate	7	Determine current hydrological functioning, design and install a riser, remove accumulated sediment and stabilize one inlet.
Linden 166-8 Stormwater Facility Water Quality Investigation and Retrofit	166-8	Moderate	8	Monitor wet pond for nutrient, algal and oxygen levels to determine if stratification or oxygen depletion is occurring. Install aeration to improve water quality and possible riser modifications for improved storage.

3.6 Outfall Retrofit Recommendations

One of the preferred stormwater retrofit options is to add new storage below existing outfalls that lack stormwater management. These outfall retrofits would include bioretention basins to capture and treat a portion of the first flush, thereby providing water quality improvements, and some limited water quantity controls. Retrofitting an existing outfall to provide water quality treatment is a space efficient approach to improving stormwater treatment in a developed watershed. Potential outfall retrofit sites were difficult to identify during the stormwater desktop analysis. As an outcome of the stream inventory, 5 stormwater outfalls were identified which are recommended for water quality retrofitting (Table 5). A full description of each outfall retrofit project is presented in the conceptual design narratives included in Appendixes A-C. The proposed outfall retrofits would provide water quality treatment for over 15 acres of impervious surface not currently being treated.

TABLE 5
Recommended Outfall Retrofits

Watershed	Site ID	Study Ranking	Reasoning	Retrofit Recommendations
Buckhall (194)	194-5	5	Good outfall retrofit site located on HOA property to provide water quality measures for runoff from single family neighborhood which is not currently being treated	The addition of a Bioretention facility to provide water quality treatment and some quantity storage between the two outfalls
Yorkshire (186 & 100)	186-5	2	Good outfall retrofit site on Church School property to provide water quality treatment for currently untreated runoff from large parking lot	The addition of a Bioretention facility to treat parking lot runoff, Enhanced Extended Detention basin to treat pipe discharge & drainage from road and restore riparian buffer
Linden (166)	166-13	1	Good outfall retrofit site on commercial property to provide water quality treatment for currently untreated runoff from highly impervious area commercial property	The addition of an offline Bioretention facility would treat the runoff for water quality and provide some quantity measures and provide a stable connection from the outfall to the receiving channel
	166-14	3	Good outfall retrofit site located on both PWC Park Authority& Private property to provide water quality measures for runoff from multifamily neighborhood which is not currently being treated	The addition of an offline Bioretention facility would treat the runoff for water quality and provide some quantity measures
	166-15	4	Good outfall retrofit site located on PWC Park Authority property to provide water quality measures for runoff from multifamily neighborhood which is not currently being treated	The addition of an offline Bioretention facility to treat runoff to provide water quality treatment

IV. STREAM INVENTORY APPROACH AND RESULTS

Due to the large amount of stream channels within the subwatersheds, this study evaluated streams through a two phase process. Initially a Desktop Site Selection Analysis was conducted to identify potential stream and riparian restoration opportunities from existing data and mapping. A stream reconnaissance inventory was conducted in the field to evaluate the initially identified stream or buffer restoration sites. Conceptual narratives were developed for those sites with the greatest restoration opportunities. The individual stream projects were prioritized and ranked to aid in the selection of projects to move forward into implementation.

4.1. Developing a GIS Stream Layer

A basic requirement of this study is a well defined stream GIS layer. The existing County GIS stream layers did not completely identify all perennial and intermittent open channels within the study area. A revised GIS stream layer was developed using the existing County GIS stream layers, aerial photography, and topographic layers to identify all open channels and generate one continuous layer illustrating the open channel network to be studied. The initial identification of open stream channels was verified in the field and the GIS stream layer updated. Based on the revised GIS stream layer, the subwatersheds in this study contain the following length of stream channels:

Buckhall	19.0 miles
Yorkshire	5.6 miles
Linden	7.8 miles
Total	**32.4 miles**

4.2. Desktop Site Selection Analysis

The Desktop Site Selection Analysis consisted of compiling existing GIS mapping layers and photography, and searching each subwatershed for potential stream or riparian buffer restoration sites. The County's Stream Assessment data were used to assist in the location of potential projects. A set of screening criteria was developed to focus field efforts on those stream reaches which had characteristics most compatible with restoration. The screening criteria included the following:

Screening Criteria	Most Preferred	Least Preferred
Drainage Area	> 500 acres	< 50 acres
Length of Channel	>1,000 lf	< 300 lf
Riparian Buffer	No forested buffer	Forested buffer >50 feet wide
Adjacent Land Uses	Undeveloped, lawn	Developed, commercial, or industrial
Ownership	County, HOAs, Institutional	Private residential or business

Stream reach identification numbers were assigned based on the first letter of the subwatershed name (i.e., B of Buckhall), and then a sequential number assigned to a particular reach during the desktop analysis (i.e., B-4). If a stream reach identified during the desktop analysis warranted division into several separate reaches due to highly variable conditions during the field investigations, then an alphabetic subscript was added to the initial reach ID (i.e., B-6C).

4.3. Stream Reconnaissance Inventory

Each site identified by the Desktop Site Selection Analysis was walked in the field. Streamside infrastructure was identified, problem areas assessed, geomorphic and habitat assessments completed, and potential restoration projects considered. Within each reach, GPS located photographs were taken of representative stream conditions and of each infrastructure element identified.

Review of Stream Assessment Methods

A review of at least 40 various stream assessment protocols and methods as reported in "*Physical Stream Assessment: A Review of Selected Protocols for Use in the Clean Water Act Section 404 Program (March 2004)*", came to the following conclusions:

- A preferred method should be objective, collect quantitative data, and have a fluvial geomorphology emphasis
- Flow dependant variables are often imprecise
- Visual quantification of stream features have a low precision
- Presence / absence data has moderate to high precision
- Rapid Bioassessment Protocol (RBP) habitat scores for streams in the Mid-Atlantic are imprecise and highly variable

A quote from the above referenced study highlights an important element of any assessment protocol used in a watershed restoration program:

> *"Stream assessments undertaken to prioritize watersheds or stream reaches for management or aid the design of stream enhancement or restoration projects should be based on fluvial geomorphic principles".*

Historically the RBP protocol has been used to evaluate stream condition as part of water quality programs. It is intended to be used to augment the findings of a benthic macro-invertebrate or fisheries study by considering observable habitat and water quality parameters which may help explain the results of a biological survey. It was never designed to identify stream reaches suitable for geomorphic restoration.

Selection of Stream Assessment Methods for this Study

In considering which stream assessment method to use in this study the following criteria were considered:

- Methods with a strong fluvial geomorphology emphasis more effectively identify potential stream restoration sites than water quality or habitat focused methods.

- Methods that are influenced by flow or growing season make it difficult to accurately compare between sites or over time.
- Compatibility with the existing County Stream Inventory would be desirable.

Three field methods of assessing stream condition were considered for this study:

CH2MHill Modified RBP method – This method is the approach upon which the existing County Stream Inventory is based. The County has historical data based on studies by CH2MHill which used a modified Rapid Biomonitoring Protocol (RBP) method.

Unified Stream Method (USM) – This method was jointly developed by the Virginia Department of Environmental Quality and the U.S. Army Corps of Engineers to assess the condition of stream channels for determining mitigation requirements. This method assesses the condition of the channel, riparian buffer, and in-stream habitat as well as the level of channel alterations (i.e. riprap, etc.).

Rapid Stream Assessment Technique (RSAT) was developed by the Washington Metropolitan Council of Governments for assessment of stream conditions in Northern Virginia, D.C., and Maryland, specifically to identify stream reaches suitable for restoration. It has a strong geomorphology emphasis, as well as water quality and benthos evaluations. It provides the flexibility to generate subscores for bank stability, channel stability, riparian buffer condition, water quality, and benthos.

All three methods have been used in Virginia and for urban streams. A comparison of the three methods is provided in Table 6. The USM and RSAT methods were specifically developed and tested in the Mid-Atlantic for targeting restoration projects. The RBP method was developed to reflect conditions applicable across the entire range of stream conditions in the continental U.S., with an emphasis on identification of streams impacted by pollution. When used in urban or developing watersheds, this method tends to result in the lumping of a majority of streams into a single category, usually suboptional or marginal. RBP tends not to provide the resolution needed to identify the most physically degraded streams for restoration efforts.

Table 6
Comparison of Stream Assessment Methods

Parameter	CH2MHill RBP Method	RSAT	USM
Stream Condition	Yes	Yes	Yes
Geomorphic Emphasis	No	Yes	Yes
Includes Water Quality and Benthic	No	Yes	No
Provides Sub-scores	No	Yes	Yes
Focused on Identification of Restoration Sites	No	Yes	Yes

Because this study is specifically focused on identification of stream restoration projects as part of a watershed management program, the RSAT method was selected. It provides the data most suitable for targeting restoration projects. The standard RSAT scoring matrix was modified to further increase its sensitivity to fluvial geomorphic conditions. This method is also less affected than RBP by seasonal and flow variability. This method generates a score for a wide range of metrics, allowing watershed managers to more specifically compare reaches to determine the types of degradation present and suitability for restoration.

The Modified RSAT evaluation categories and parameters are summarized in Table 7 and the complete data sheets are included in Appendix E.

Table 7
Modified Rapid Stream Assessment Technique

Evaluation Category	Parameters
Channel Stability	Shape, incision, deposition, exposed utilities
Bank Stability	Slumping, height, angle, material, tree falls, vegetation
Riparian Habitat	Buffer width, type of vegetation, shading
Water Quality	Benthic diversity, pollution sensitive benthos, litter, fouling, odors
Aquatic Habitat	Channel modifications, riffle substrate, embeddeness, pool depth, fish cover

Within each category, there are 3 to 6 specific parameters which are scored individually. These scores are averaged to produce a score for each evaluation category. The total of the score for each of the five evaluation categories provides an overall stream condition score.

Channel stability is given twice the weight of the other variables to reflect the importance of channel stability, particularly incision, in selection of stream restoration projects (Table 8). Bank stability, riparian buffer, and water quality are equally weighted. Aquatic habitat is given lower weighting due to the difficultly in visually assessing aquatic habitat accurately.

Table 8
Rapid Stream Assessment Technique Rating Table

Evaluation Category	Excellent	Good	Fair	Poor
Channel Stability	18-20	12-16	6-10	0-4
Bank Stability	9-10	6-8	3-5	0-2
Riparian Habitat	9-10	6-8	3-5	0-2
Water Quality	9-10	6-8	3-5	0-2
Aquatic Habitat	7-8	5-6	3-4	0-1
Reach Scoring Ranges	52-58	35-46	18-29	<11

Note: Some sites may fall between the scoring ranges. In these cases, the site can be assigned a narrative descriptor indicating a border line condition (i.e. good/fair for a score of 31).

Inventory of Streamside Infrastructure and Assessment of Problem Areas

The inventorying of streamside infrastructure and the assessment of potential problem areas is a critical element of a stream assessment conducted for restoration purposes. This type of data tends to be related to a specific point along the stream instead of representing an entire reach. For this study, the following streamside infrastructure inventory methods were considered:

CH2MHill Method - The County's existing stream inventory includes a streamside infrastructure inventory. The CH2MHill inventory method uses codes entered on a single line of a data form for each element located in the field. The CH2MHill method does not address site access or restoration options.

Unified Stream Assessment (USA) – This method was developed by the Center for Watershed Protection to inventory streamside infrastructure and assess problem areas in urban streams. USA method datasheets relies on check boxes instead of codes for recording observations. The scoring in the USA method differs considerably from the existing County inventory method. This method includes a database for entry of field data. This method addresses site access and restoration opportunities.

Stream Corridor Assessment Survey (SCA) – This method was developed by the Maryland Department of Natural Resources to identify observable environmental problems (i.e. problem areas), determine the severity of the problem, assist in prioritization of problems, and provide the ability to compare conditions between streams. This method has been used in many large scale watershed assessments in Maryland. The SCA method is not designed for database or GIS applications. This method addresses site access and restoration opportunities.

For this study, field data forms were designed based on the USM method, which includes evaluation of access and restoration potential. Scoring of the problem areas is compatible with the existing county database (i.e. CH2MHill method). Each streamside infrastructure element was located with GPS, photographed, and documented on a field data form. The field protocols identify the following types of problems:

- Pipe Outfall / Ditch
- Exposed Utility
- Fish Barrier / Obstruction / Head cuts
- Dump Sites
- Culvert Crossings
- Unusual conditions

All streamside infrastructure elements identified in the field were assigned an ID based on the reach ID (i.e., Y6), the type of infrastructure and the number of each infrastructure elements assessed (i.e., Y6-U2). The abbreviations for each of the infrastructure types are as follows:

- Pipe or Culvert Outfall = P
- Ditch Outfall= D
- Exposed Utility = U
- Fish Barrier = B
- Obstruction = O
- Head cuts = H
- Dump / Trash Sites = T

4.4. Stream Assessments Results

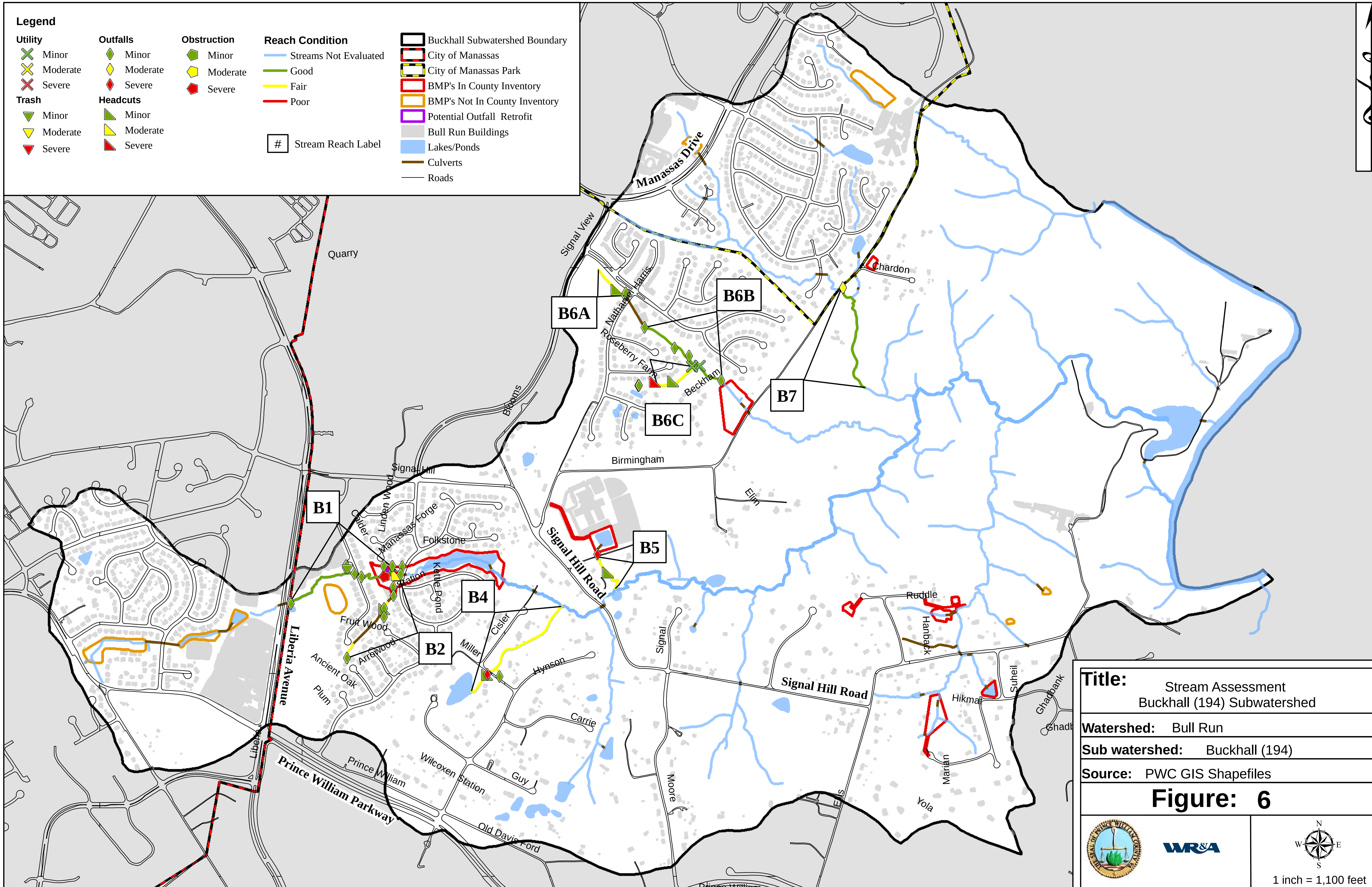
The desktop site selection analysis identified 29 stream reaches to be assessed in the field. During the field assessments, four of the 29 reaches were determined to be drainage ditches or ephemeral channels and were dropped from further consideration. The GIS stream layer was revised to reflect these field results.

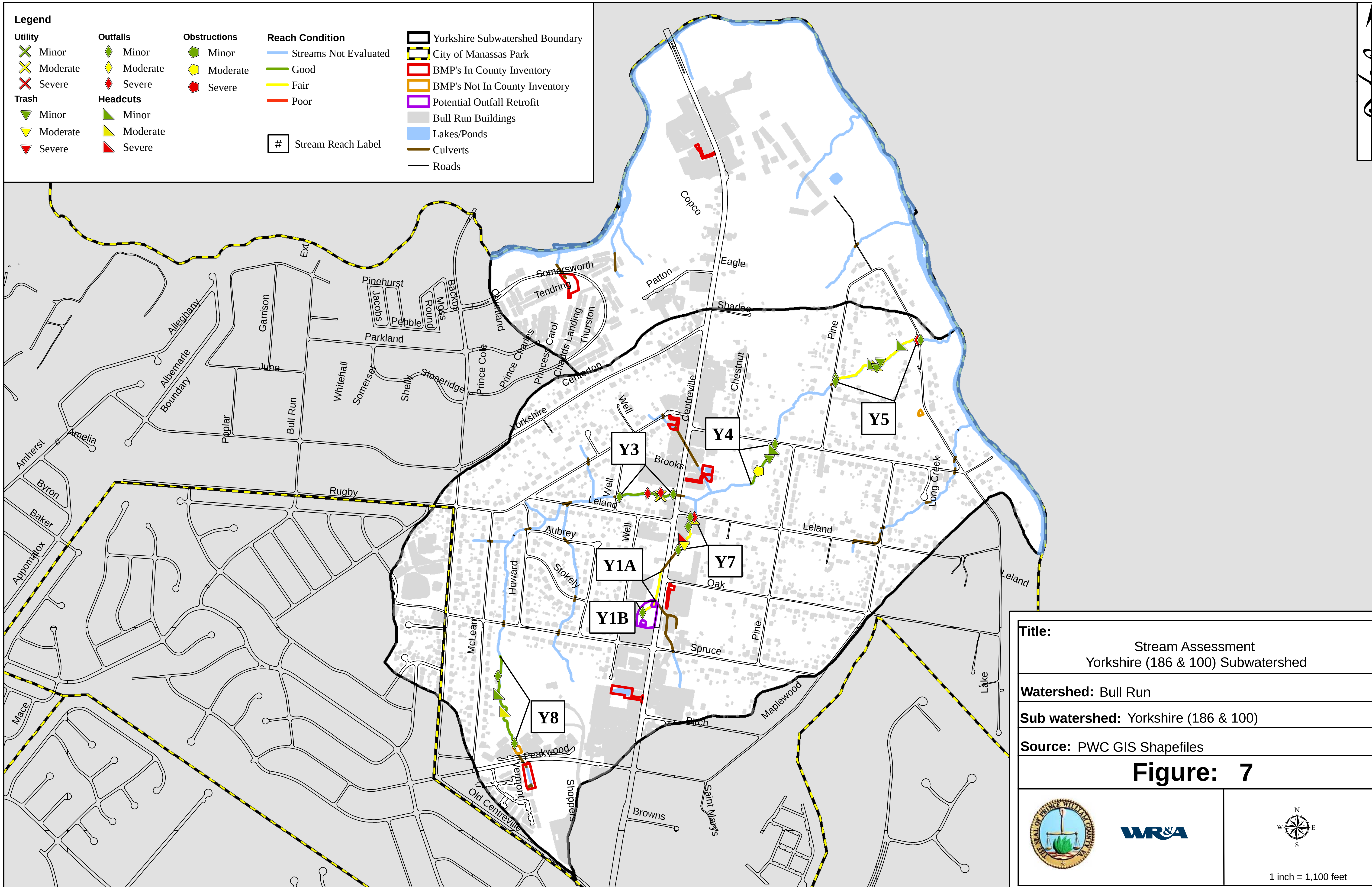
The 25 stream reaches that were assessed represent a total of 21,969 linear feet of stream channel, out of an estimated total of 171,610 linear feet of channel within the three subwatersheds. This assessment evaluated approximately 13% of the existing stream channels within the study's subwatersheds. The location of each stream reach within its subwatershed is presented in Figures 6 through 8. The overall condition score is indicated by color coding.

The majority of the streams scored either good or fair condition overall (Table 9 & 10). Water quality and aquatic habitat tended to score fair over most of the streams. General observations of the results of the stream assessment include:

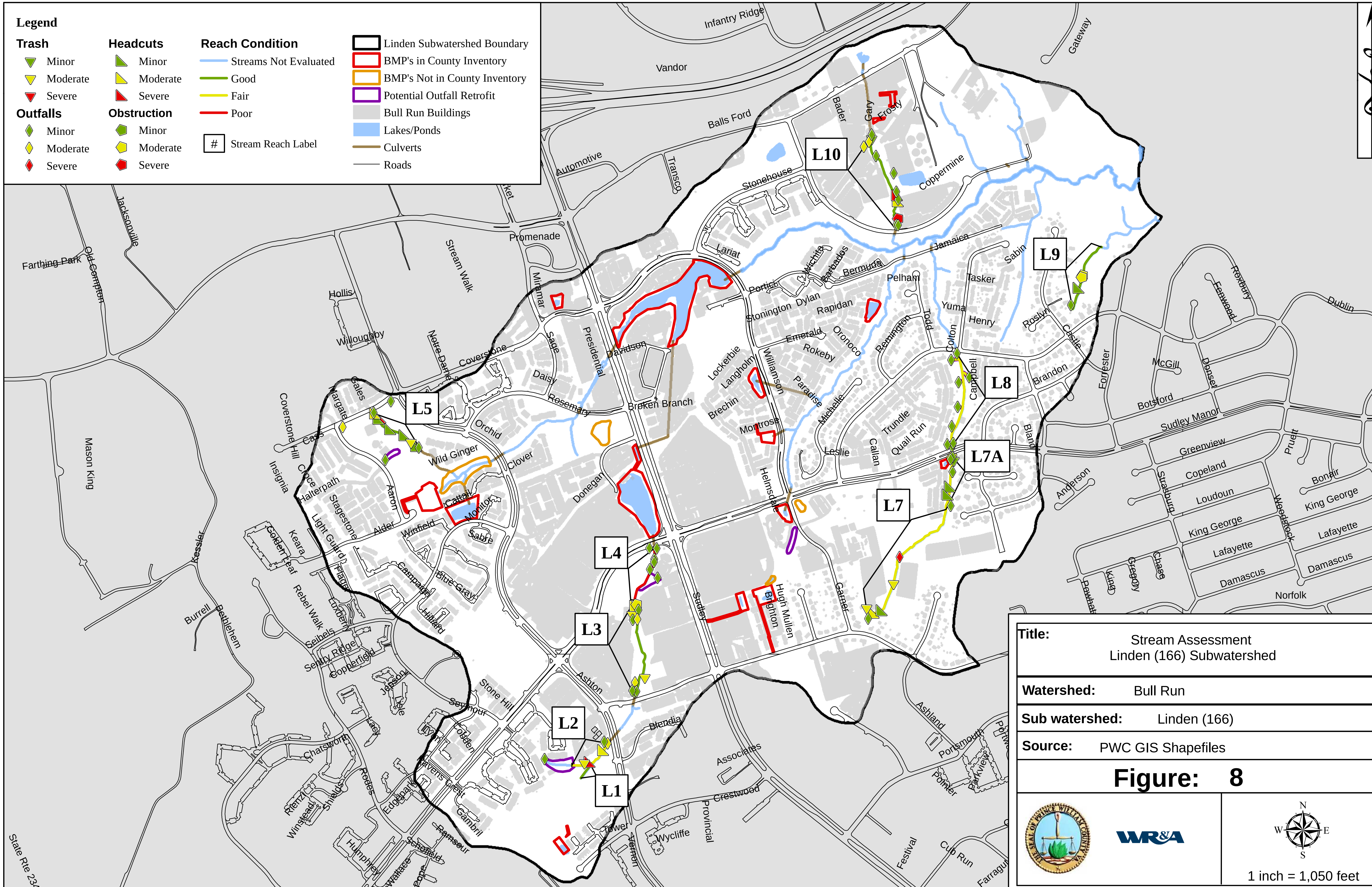
- The majority of reaches scored good for channel stability
- The overwhelming majority of reaches scored good or better for bank stability
- Scores for riparian habitat were evenly split between good and fair, but this result is due in part to screening out sites with excellent buffers during the desktop analysis.
- Only three reaches scored good for water quality, which is based primarily on benthic invertebrates.
- In contrast to the scores of good for channel stability and bank stability, the majority of streams scored fair for aquatic habitat.
- The streams in this study appear to be relatively stable, but have degraded water quality and habitat.

Channel stability, bank stability, and riparian habitat tended to score good across the majority of the stream reaches. Water quality and aquatic habitat appeared to be in a more degraded condition than the riparian buffers or the stability of the channels. ***In contrast to the findings of the Bull Run TMDL study, this stream assessment does not appear to indicate a wide spread problem with erosion, sedimentation and subsequent export of that sediment to Bull Run.***


Legend
Utility
Minor
Moderate
Severe
Trash
Minor
Moderate
Severe
Outfalls
Minor
Moderate
Severe
Headcuts
Minor
Moderate
Severe
Obstruction
Minor
Moderate
Severe
Reach Condition
Streams Not Evaluated
Good
Fair
Poor
Stream Reach Label
Buckhall Subwatershed Boundary
City of Manassas
City of Manassas Park
BMP's In County Inventory
BMP's Not In County Inventory
Potential Outfall Retrofit
Bull Run Buildings
Lakes/Ponds
Culverts
Roads
B1
B2
B4
B5
B6A
B6B
B6C
B7
Manassas Drive
Signal View
Quarry
Nathaniel Harris
Roseberry Farm
Beckham
Chardon
Birmingham
Elm
Signal Hill
Linden Wood
Manassas Forge
Folkstone
Station
Kettle Pond
Fruit Wood
Arrowood
Ancient Oak
Plum
Miller
Cisler
Hynson
Carrie
Guy
Wilcoxen Station
Signal Hill Road
Signal
Moore
Ruddle
Hanback
Hikmat
Suheil
Marian
Yola
Liberia Avenue
Liberia
Prince William Parkway
Prince William
Old Davis Ford
Title: Stream Assessment
Buckhall (194) Subwatershed
Watershed: Bull Run
Sub watershed: Buckhall (194)
Source: PWC GIS Shapefiles
Figure: 6
WR&A
N
W
E
S
1 inch = 1,100 feet



Legend
Utility
Minor
Moderate
Severe
Trash
Minor
Moderate
Severe
Outfalls
Minor
Moderate
Severe
Headcuts
Minor
Moderate
Severe
Obstructions
Minor
Moderate
Severe
Reach Condition
Streams Not Evaluated
Good
Fair
Poor
Stream Reach Label
Yorkshire Subwatershed Boundary
City of Manassas Park
BMP's In County Inventory
BMP's Not In County Inventory
Potential Outfall Retrofit
Bull Run Buildings
Lakes/Ponds
Culverts
Roads
Y1A
Y1B
Y3
Y4
Y5
Y7
Y8
Copco
Eagle
Patton
Somersworth
Tendring
Sharloe
Pine
Chestnut
Centreville
Well
Brooks
Leland
Aubrey
Stokely
Howard
McLean
Oak
Spruce
Long Creek
Maplewood
Birch
Peakwood
Vermont
Old Centreville
Shoppers
Browns
Saint Marys
Lake
Yorkshire
Centerton
Thurston
Childs Landing
Carol
Princess
Prince Charles
Prince Cole
Churchland
Backus
Moss
Round
Pebble
Jacobs
Pinehurst
Parkland
Stoneridge
Shelly
Somerset
Whitehall
Bull Run
June
Garrison
Poplar
Rugby
Alleghany
Albemarle
Boundary
Amelia
Amherst
Byron
Baker
Appomattox
Mace
Ext
Title:
Stream Assessment
Yorkshire (186 & 100) Subwatershed
Watershed: Bull Run
Sub watershed: Yorkshire (186 & 100)
Source: PWC GIS Shapefiles
Figure: 7
WR&A
N
S
E
W
1 inch = 1,100 feet



Legend
Trash
Minor
Moderate
Severe
Headcuts
Minor
Moderate
Severe
Reach Condition
Streams Not Evaluated
Good
Fair
Poor
Outfalls
Minor
Moderate
Severe
Obstruction
Minor
Moderate
Severe
#
Stream Reach Label
Linden Subwatershed Boundary
BMP's in County Inventory
BMP's Not in County Inventory
Potential Outfall Retrofit
Bull Run Buildings
Lakes/Ponds
Culverts
Roads
L10
L9
L8
L7A
L7
L5
L4
L3
L2
L1
Title:
Stream Assessment
Linden (166) Subwatershed
Watershed: Bull Run
Sub watershed: Linden (166)
Source: PWC GIS Shapefiles
Figure: 8
N
W
E
S
1 inch = 1,050 feet

Table 9
Numerical Stream Condition Scores

Watershed	Site ID	Channel Stability	Bank Stability	Riparian Habitat	Water Quality	Aquatic Habitat	Numerical Score	Narrative Score
Buckhall 194	B1	14.67	6.00	5.30	3.80	2.80	32.60	Good
	B2	10.00	6.00	4.33	3.40	3.00	26.73	Fair
	B4	8.67	6.50	3.67	3.80	2.20	24.83	Fair
	B5	8.67	5.33	7.67	6.80	3.40	31.87	Fair
	B6A	10.00	6.20	7.00	4.33	2.40	29.93	Fair
	B6B	11.50	5.50	7.67	5.33	3.60	33.60	Good
	B6C	4.67	4.83	6.67	5.00	3.80	24.97	Fair
	B7	13.33	4.33	6.67	5.00	5.00	34.33	Good
Yorkshire 186&100	Y1A	8.00	5.2	5.33	6.83	1.80	27.17	Fair
	Y1B	8.67	3.2	3.67	5.40	2.00	22.93	Fair
	Y3	13.33	5.83	6.00	3.20	4.00	32.37	Good
	Y4	14.67	4.17	7.00	4.60	4.20	34.63	Good
	Y5	12.67	5.33	4.67	3.00	2.80	28.47	Fair
	Y7	7.33	6.17	5.67	4.20	1.60	24.97	Fair
	Y8	14.50	6.17	8.00	6.67	3.00	38.33	Good
Linden 166	L1	13.33	6.50	10.00	5.00	2.40	37.23	Good
	L2	8.67	6.60	6.33	3.00	1.80	26.40	Fair
	L3	16.00	5.83	8.33	4.83	4.80	39.80	Good
	L4	2.67	4.20	1.00	2.75	1.80	12.42	Poor
	L5	14.67	6.83	8.00	3.60	4.20	37.30	Good
	L7	11.33	6.67	5.00	4.00	3.20	30.20	Fair
	L7A	11.33	6.50	4.67	4.40	3.40	30.30	Fair
	L8	12.00	7.83	3.00	5.40	3.60	31.83	Fair
	L9	13.00	7.50	7.33	3.80	4.0	35.63	Good
	L10	12.50	7.00	6.67	3.20	3.40	32.77	Good

B3, Y2, Y6, and L6 were determined during field assessments to not be perennial or intermittent streams

Table 10
Narrative Stream Condition Scores

Watershed	Site ID	Channel Stability	Bank Stability	Riparian Habitat	Water Quality	Aquatic Habitat	Narrative Score
Buckhall 194	B1	Good	Good	Fair/Good	Fair	Fair	Good
	B2	Fair	Good	Fair	Fair	Fair	Fair
	B4	Fair	Good	Fair	Fair	Fair	Fair
	B5	Fair	Fair/Good	Good	Good	Fair	Fair
	B6A	Fair	Good	Good	Fair	Fair	Fair
	B6B	Fair/Good	Fair/Good	Good	Fair/Good	Fair	Good
	B6C	Poor/Fair	Fair	Good	Fair	Fair	Fair
	B7	Good	Fair	Good	Fair	Good	Good
Yorkshire 186 & 100	Y1A	Fair	Fair/Good	Fair/Good	Good	Poor	Fair
	Y1B	Fair	Fair	Fair	Fair/Good	Poor	Fair
	Y3	Good	Fair/Good	Good	Fair	Fair	Good
	Y4	Good	Fair	Good	Fair	Fair	Good
	Y5	Good	Fair/Good	Fair	Fair	Fair	Fair
	Y7	Fair	Good	Fair/Good	Fair	Poor	Fair
	Y8	Good	Good	Good	Good	Fair	Good
Linden 166	L1	Good	Good	Excellent	Fair	Fair	Good
	L2	Fair/Good	Good	Good	Fair	Poor	Fair
	L3	Good	Fair/Good	Good/Ex	Fair	Good	Good
	L4	Poor	Fair	Poor	Poor/Fair	Poor	Poor
	L5	Good	Good	Good	Fair	Fair	Good
	L7	Good	Good	Fair	Fair	Fair	Fair
	L7A	Good	Good	Fair	Fair	Fair	Fair
	L8	Good	Good/Ex	Fair	Fair/Good	Fair	Fair
	L9	Good	Good/Ex	Good	Fair	Fair	Good
	L10	Good	Good/Ex	Good	Fair	Fair	Good

B3, Y2, Y6, and L6 were determined during field assessments to not be perennial or intermittent streams

Of the stream reaches investigated, 11 scored good and 13 scored fair with only one scoring poor (Table 11). When stream length is considered, the length of stream channel that scored good or fair were nearly equal, with only 3% scoring poor (Table 12).

Table 11
Summary of Channel Condition by Number of Reaches

Evaluation Category	Excellent	Good	Fair	Poor
Channel Stability	0	15	8	2
Bank Stability	0	16	9	0
Riparian Habitat	0	15	9	1
Water Quality	0	3	22	0
Aquatic Habitat	0	2	19	4
Reach Scoring Ranges	**0**	**11**	**13**	**1**

Table 12
Summary of Channel Condition by Length
(Linear Feet)

Condition	Buckhall	Yorkshire	Linden	Total Length	Percentage
Excellent	0	0	0	0	0%
Good	4,151	2,561	4,143	10,855	52%
Fair	3,299	2,306	3,567	9,172	44%
Poor	0	0	681	681	3%
Total	**7,450**	**4,867**	**8,391**	**20,708**	

4.5. Problem Area Identification (Infrastructure Inventory)

During field assessments of stream conditions, the field crew identified any "problem areas" that may have an impact on the condition of the stream channel or buffer. Problem area identification is essentially an inventory of streamside infrastructure such as outfalls, road crossings, utility crossings as well a site specific as opposed to reach specific issues, including debris dumps, head cuts or fish blockages. During the stream assessments, a considerable number of potential problem areas were identified and evaluated (Table 13). The general location of the problem areas are illustrated in Figures 6-8, for each of the subwatersheds. Due to the large number of points, individual labeling was not included in the report graphics. However, this information is available in the GIS data provided to the County. In addition, the detailed summary tables give specific site identification numbers in order to retrieve the data from the GIS.

Table 13
Summary of Problem Area Inventory

Problem Area	Total Recorded	Total Severe Condition
Debris Dumps	14	4
Exposed Utilities	4	1
Outfalls	101	5
Head Cut, Obstruction, Fish Barrier	43	9

Debris Dumps / Trash

Fourteen areas along streams which were surveyed in this study were identified with some level of debris or trash (Table 14). The majority of trash dumps were considered minor and consisted of paper, plastic, and glass.

TABLE 14
Trash Dumping/Debris Summary Table

Watershed	Site ID	General Description	Severity	Removal/Size
Buckhall 194	B1-T1	Plastic, paper, glass	1	Volunteers (pickup load)
	B2-T1	Plastic, paper, glass	1	Volunteers (less than pickup load)
Yorkshire 186 &100	Y3-T1	Lawn debris, plastic, paper, glass	1	Volunteers (pickup/dump truck load)
	Y4-T1	Plastic, paper, glass	1	Volunteers (pickup load)
	Y5-T1	Automotive, plastic, paper	1	Volunteers (pickup/dump truck load)
	Y7-T1	Appliances, automotive, furniture	5	Volunteers or county (dump truck/many loads)
Linden 166	L2-T1	Food/garbage, plastic, paper, glass	5	Volunteers or county (dump truck)
	L3-T2	Trash and carts from COSTCO	5	Volunteers or COSTCO (dump truck)
	L5-T1	Plastic, paper, glass	1	Volunteers or county (pickup/dump truck)
	L7-T1	Lawn debris, plastic, paper, glass	5	Volunteers or county (dump truck)
	L7A-T1	Plastic, paper, glass	1	Volunteers (pickup)
	L8-T1	Plastic, paper, glass	1	Volunteers (pickup)
	L9-T1	Paper, plastic, glass, automotive	1	Volunteers (pickup)
	L10-T1	Plastic, paper, glass	1	Volunteers (pickup)

Note: Most severity scores of 1 = general litter in floodplain and not concentrated dump site

The Linden sub-watershed has three areas of moderate debris accumulation (L2-T1, L3-T2, and L7-T1). L3-T2 is an active dumpsite on commercial property (Costco Corporation). Access could be difficult due to a vertical retaining wall along the edge of the developed property. The Yorkshire subwatershed has one area with moderate trash accumulation. Site Y7-T1 is an inactive dump site for automotive debris and appliances. This area is within the riparian buffer of Reach Y7, making removal difficult.

Exposed Utilities

Only four exposed utility stream crossings were catalogued during stream field assessments (Table 15). The majority of the utility crossings appear to be well below the streambed. All of the assessed utility crossings are perpendicular to the stream channel. Only one utility crossing was considered moderately exposed and none were severely exposed. Two of the inventoried utility crossings were identified for stabilization or protection:

- Utility crossing Y3-U1 is an exposed concrete encased pipe which scored moderate due to bank erosion, pool scour, and restriction of upstream fish migration
- Utility crossing B6C-U2 is a stable crossing. However, downstream is a four to five foot head cut (B6C-H2) which is migrating upstream to the utility crossing

Table 15
Utility Summary Table

Watershed	Site ID	General Description	Severity	Recommendations
Buckhall 194	B6B-U1	Sewer pipe embedded in substrate	0	None
	B6C-U1	Sewer pipe embedded in substrate	0	None
	B6C-U2	Sewer pipe embedded in substrate	0	Stabilize head cut downstream from migrating
Yorkshire 186	Y3-U1	Concrete encased pipe causing scour hole	7	Scour pool downstream with moderate erosion potential riffle retrofit

Outfalls (pipes, ditches and culverts)

Sixty-four stormwater pipes and ditches were evaluated during field assessments. Twenty-seven stream crossings (i.e. road culverts) were also examined during stream assessments. The majority of stormwater outfalls are structurally and functionally stable. Minor sediment removal and maintenance was the most common issue. Relatively few stormwater outfalls or ditches were in poor or failing condition (Table 16). Only four outfalls were identified as eroding or failing, and recommended for repair.

- L3-P5 Stabilize rip rap at receiving channel
- L3-P6 Stabilize trapezoidal concrete ditch
- L5-P3 Stabilize roadside stormwater ditch at confluence with receiving channel
- Y3-D1 Establish adequate outfall channel with receiving channel

Three corrugated metal (B4-P1, B5-P1, and Y7-P1), and one plastic (L7-P2) culverts, are severely degraded and are in need of repair. In some cases the CMP has rusted completely through the bottom of the culvert allowing stream flow to pass under the culvert. Failure of the culvert can lead to failure of the roadway.

Only two outfalls (L7-P1 & Y3-P2) were observed with dry weather flows. L7-P1 is a stormwater outfall that was flowing during dry weather. Stormwater flow increased significantly throughout the duration of the evaluation and did not recede. Y3-P2 is a small pipe of unknown origin directly discharging to the stream. No color, odor, or visual characteristics were observed.

Head cuts, Fish Barriers and Flow Obstructions

Head cuts (i.e., areas of vertical bed erosion), fish barriers, or obstructions that restrict stream discharge were evaluated and assigned a score of minor, moderate, or severe (Table 17). The instability of these areas has caused both the substrate and stream bank to erode. Six severe head cuts greater than two vertical feet were documented during our evaluation. They are as follows: B6B-H2, B6C-H2, L2-H1, L5-H4, L10-H2, and Y7-H2. Subwatershed Linden, the most developed watershed, contains the largest number of severe head cuts. Most of these larger head cuts are in headwater streams. The most serious of the head cuts is B6C-H2 which is located immediately downstream of a utility crossing. This head cut is proposed for stabilization as part of a larger stream enhancement and stormwater facility retrofit.

Table 16
Outfall Summary Table

Watershed	Site ID	General Description	Severity	Recommendations
Buckhall 194	B1-P1	Stream Crossing	0	None
	B1-P2	Stormwater	0	None
	B1-P3	Stormwater	0	Sediment Removal / Minor Maintenance
	B1-P4	Stormwater	2	Stabilize area near top of pipe
	B1-P5	Stream Crossing	0	None
	B1-P6	Stormwater	0	None
	B1-P7	Stormwater	0	None
	B1-P8	Stormwater	2	Stabilize outfall channel
	B1-P9	Stormwater	0	Sediment Removal / Minor Maintenance
	B1-P10	Stormwater	0	None
	B1-P11	Stream Crossing	0	None
	B2-P1	Stormwater	0	None
	B2-P2	Stream Crossing	0	None
	B2-P3	Stormwater	0	None
	B2-P4	Stormwater	0	None
	B2-P5	Stormwater	0	None
	B4-P1	Stream Crossing	10	Replace rusted out CMP at road crossing
	B4-P2	Stormwater	0	None
	B5-P1	Stream Crossing	10	Replace rusted out CMP at road crossing
	B6A-P1	Stream Crossing	0	None
	B6A-P2	Stormwater	2	Stabilize outfall ditch
	B6B-P3	Stormwater	0	None
	B6B-P4	Stormwater	0	None
	B6B-P5	Stream Crossing	0	None
	B6C-P1	Stormwater	0	Sediment Removal / Minor Maintenance
	B6C-P2	Stormwater	2	Sediment Removal / Minor Maintenance
	B6C-P3	Stormwater	0	Minor debris removal
	B7-P1	Stream Crossing	5	Replace rusted out CMP at road crossing
Yorkshire 186 & 100	Y3-D1	Ditch	7	Repair stream channel erosion due to ditch
	Y3-P1	Stream Crossing	2	Sediment removal / Minor maintenance
	Y3-P2	Poss. Illicit	10	Investigation of black pipe with small discharge
	Y3-P3	Stream Crossing	0	None
	Y4-P1	Stream Crossing	0	Sediment removal / Minor maintenance
	Y5-P1	Stream Crossing	2	Sediment removal / Minor maintenance
	Y5-P2	Stormwater	0	None
	Y5-P3	Stream Crossing	0	None
	Y7-P1	Stream Crossing	10	Replace rusted out CMP
	Y7-P2	Stormwater	0	Sediment removal / Minor maintenance
	Y7-P3	Stormwater	0	None
	Y7-P4	Stream Crossing	2	Stabilize minor erosion, scour pool
	Y8-P1	Stormwater	0	None
	Y8-D1	Stormwater	2	Reconnect ditch with channel
Linden 166	L2-P1	Stream Crossing	5	Grout is failing around stream crossing pipe
	L2-P2	Stormwater	2	Stabilization and clean sediment
	L2-P3	Stormwater	0	Retrofit stormwater bio retention downstream
	L3-P1	Stream Crossing	0	None

Watershed	Site ID	General Description	Severity	Recommendations
Linden 166	L3-P2	Stormwater	0	None
	L3-P3	Stream Crossing	0	None
	L3-P4	Stormwater	2	Stabilization
	L3-P5	Stormwater	5	Reconstruct outfall to main channel
	L3-P6	Stormwater	5	Remove concrete and stabilize outfall
	L3-P7	Stormwater	0	None
	L3-P8	Stormwater	0	None
	L4-P1	Stormwater	2	Stabilization and clean sediment
	L4-P2	Stormwater	0	None
	L4-P3	Stormwater	0	None
	L4-P4	Stormwater	2	Stabilize erosion behind headwall
	L4-P5	Stormwater	0	None
	L4-P6	Stormwater	2	Potentially outfall retrofit BMP
	L5-P1	Stream Crossing	0	None
	L5-P2	Stream Crossing	0	None
	L5-P3	Stormwater	5	stream/ditch needs stabilization, stabilization at confluence (large head cut is forming)
	L5-P4	Stormwater	2	Headwall grout erosion (not urgent), not well defined channel some trash and organic debris in area)
	L5-P5	Stormwater	0	Sediment removal / Minor maintenance
	L7A-P1	Stream Crossing	0	None
	L7A-P2	Stormwater	0	None
	L7A-P3	Stormwater	0	None
	L7A-P4	Stormwater	0	Sediment removal / Minor maintenance
	L7-P1	Stormwater/Poss. Illicit	2	Discharge Investigation - Possibly sump pump
	L7-P2	Stream Crossing	10	Replace crushed corrugated plastic pipe
	L8-P1	Stream Crossing	0	None
	L8-P2	Stormwater	2	Stabilization of ditch
	L8-P3	Stormwater	2	Minor stabilization
	L8-P4	Stormwater	0	None
	L8-P5	Stormwater	0	None
	L8-P6	Stormwater	0	None
	L8-P7	Stormwater	2	Sediment removal / Minor maintenance
	L8-P8	Stormwater	0	None
	L8-P9	Stream Crossing	0	None
	L9-P1	Stormwater	0	Sediment removal / Minor maintenance
	L10-P1	Stream Crossing	0	None
	L10-P2	Stormwater	0	None
	L10-P3	Stormwater	0	None
	L10-P4	unknown	2	Red hydrant with sediment control bag (hole in bag)
	L10-P5	unknown	2	Black metal pipe
	L10-P6	Stormwater	0	None
	L10-P7	Stormwater	5	Sediment removal / Minor maintenance
	L10-P8	Stream Crossing	2	Sediment removal / Minor maintenance
	L10-D1	Stormwater	2	Stabilize minor erosion
	L10-D2	Stormwater	2	Stabilization of ditch
	L10-D3	Stormwater	0	None

Table 17
Obstruction / Fish Barrier / Head Cut Summary Table

Watershed	Site ID	General Description	Severity	Recommendations
Buckhall 194	B1-O1	Flow obstruction	10	Remove large tree fall
	B2-H1	Head cut	3	None
	B2-O1	Flow obstruction	10	Remove flow obstruction
	B2-H2	Head cut/tree 2'	5	Stabilize head cut
	B4-H1	Head cut <.5'	1	None
	B5-H1	Head cut 1'	3	None
	B6A-H1	Head cut 1'	3	None
	B6B-O1	Head cut/flow obstruction	5	Remove flow obstruction
	B6B-H1	Head cut 1'	3	None
	B6B-H2	Head cut >2'	10	Stabilize head cut
	B6B-H3	Head cut 2'	3	None
	B6C-H1	Head cut 1'	3	None
	B6C-H2	Head cut >2'	10	Stabilize head cut
Yorkshire 186 &100	Y4-O1	Obstruction	5	Remove flow obstruction
	Y4-H1	Head cut	3	Stabilize head cut
	Y5-H1	Head cut	3	None
	Y5-H2	Several small head cuts with woody debris	5	Stabilize head cut
	Y5-H3	Head cut	3	None
	Y5-B1	Fish Barrier	10	None (> 2' Weir wall box culvert to block back flooding)
	Y7-H1	Large head cut approx. 2'	5	Stabilize head cut
	Y7-H2	Large head cut approx. greater than 2'	10	Stabilize head cut
	Y8-H1	Head cut 1'	3	None
	Y8-H2	Head cut 1'	5	Stabilize head cut and meander
Linden 166	L2-H1	Fish barrier/head cut >2'	10	Stabilize head cut
	L2-H2	Fish barrier/head cut 2'	5	Stabilize head cut
	L3-B1	Stormwater outfalls creating series of head cuts	5	Stabilize head cut
	L3-O1	Head cut/trees 2' blocking channel	5	Stabilize head cut
	L5-H1	Head cut/trees 1'	3	None
	L5-H2	Head cut/debris 1'	3	None
	L5-H3	Head cut/fish barrier 1'	3	None
	L5-H4	Head cut/fish barrier >2'	10	Stabilize head cut
	L5-H5	Head cut/fish barrier 1'	3	Fish barrier during low water conditions
	L7-O1	Flow obstruction <0.5'	3	Remove flow obstruction (board across stream forms obstruction)
	L7-H1	Head cut/trees 1'	5	Stabilize head cut (tree roots form part of head cut/grade control)
	L7-H2	Head cut <0.5'	3	None
	L7A-H1	Head cut<0.5'	3	None
	L7A-H2	Head cut 1'	3	Stabilize head cut
	L7A-O1	Flow obstruction 1'	5	Remove flow obstruction (roots, leaves trash about 1.5' high)

Watershed	Site ID	General Description	Severity	Recommendations
	L9-O1	Flow obstruction 2'	5	Down tree (roots from tree causing blockage)
Linden 166	L9-H1	Head cut 1'	3	None
	L10-O1	Flow obstruction >2'	10	Remove beaver dam
	L10-H1	Head cut 1'	5	Stabilize head cut (woody debris in dam head cut)
	L10-H2	Head cut 2'	10	Stabilize head cut (plunge pool, tree roots part of head cut)

Other than head cuts, the number of structural fish barriers were minimal. In most urban watersheds, culverts can create fish barriers when there is a significant elevation difference between the outlet of the culvert and the stream channel. Within the study reaches only one structure was identified as a fish barrier. A box culvert (Y5-B1) located near the mouth of Reach Y5, an unnamed tributary to Bull Run, is the only permanent fish barrier. This structure has a five foot weir wall to block back flooding from Bull Run, which also prohibits fish movement from Bull Run into the tributary.

Ten flow obstructions were identified during the field assessments. Most are tree falls and/or root wads, which are blocking flow and causing bank erosion.

4.6. Stream and Buffer Prioritization and Ranking

The stream reaches assessed in the reconnaissance inventory were assigned a priority based on the following characteristics:

- Low RSAT Scores, particular for channel and bank stability
- Lack of woody riparian buffer
- Sufficient length to make a project warranted
- Ownership and land use that is compatible with project
- Ease of construction access
- Presence of head cuts, exposed utilities, or failing outfalls
- Reach’s impact on downstream stormwater facilities

The assigned priorities are listed in Table 18. There were seven high priority sites; eleven assigned moderate priority, and seven with low priority. Within each subwatershed, the individual reaches with a priority of high were ranked to facilitate the selection of projects to move forward into implementation. In addition, the individual sites were ranked across the three subwatersheds so that projects could be prioritized between the three subwatersheds. The Linden subwatershed contained the most high priority stream reaches.

4.7. Conceptual Design for Stream and Buffer Projects

There are a wide range of stream and riparian buffer restoration projects that could be considered in a large watershed. The range of stream and riparian buffer restoration projects that were considered included:

- **Riparian Zone Restoration or Enhancement –** Riparian buffer projects were limited to where a relatively stable channel would benefit from increased buffer protection and the buffer would be compatible with the existing land use.
- **Stream Restoration / Enhancement / Stabilization -** Projects considered ranged from partial stabilization where infrastructure is being threatened, to larger functional restoration, to strategic stabilization of individual head cuts.

In many cases, stream or riparian buffer projects were combined with an adjacent or downstream stormwater facility project to generate a more holistic solution to a watershed catchment scale problem.

A proposed project was developed for each of the seven stream reaches assigned a high priority. The projects are summarized in Table 19. A full description of each project is presented in the conceptual design narrative included in Appendixes A-C, organized by subwatershed. Each appendix includes a map with the location of each project. Each design narrative includes the location, problem description, project description, potential benefits, design considerations, and a summary of cost estimate. Each design narrative also includes a location map with ADC map page references, ground level photos of existing conditions, and aerial photos of either existing conditions or proposed conceptual plan. Each project is identified by subwatershed, site ID, County facility ID if available, GPIN Ownership, and GPS coordinates.

The results of the field inspections and the development of conceptual design narratives resulted in the following:

- Over 3,000 linear feet of stream channel and buffer are proposed for restoration, stabilization or enhancement.
- The conceptual designs for four of the reaches were combined with a stormwater facility retrofit or outfall retrofit.
- Five out of the seven reaches have a specific water quality improvement component related to treating runoff.
- The proposed projects would improve over 3 acres of urban riparian buffer.

Table 18

Ranking and Prioritization of Stream Reaches with Recommendations

Watershed	Site ID	RSAT	Stream Length	Priority	Ranking within Sub-watershed	Study Ranking	Ownership	Buffer and Channel Recommendations
Buckhall 194	B6B	Good	1218	High	1	1	HOA	Repair head cuts, improve management of buffer
	B6C	Fair	568	High	1	1	HOA	Combine with B6B stabilization and stormwater quality retrofit
	B1	Good	1666	Moderate	2	9	HOA	Retrofit water quality BMP (B1-P8 and B1-P9), Remove flow obstruction B1-O1)
	B7	Good	1267	Moderate	3	15	Residential	Riparian Buffer expansion and bank stabilization
	B2	Fair	150	Moderate	4	12	HOA	Establish Riparian Buffer, Remove blockage, Stabilize head cuts
	B6A	Fair	466	Low	5	-	HOA, Town of Manassas Park	Work with HOA to develop a riparian buffer management plan, Stabilize outfall B6A-P2 ditch
	B5	Fair	542	Low	6	-	Residential	Work with residents to improve riparian buffer along one side
	B4	Fair	1573	Low	7	-	Residential	Only recommending replacement of collapsing culvert pipe B4-P1 (county was contacted)
Linden 166	L2	Fair	555	High	1	3	Apartment Complex	Retrofit Water Quality BMP, Restore Channel, and Stabilize head cuts
	L8	Fair	1153	High	2	4	HOA	Enhance Riparian Buffer, Water Quality Retrofit (L8-P2 thru L8-P8)
	L7	Fair	550	High	3	5	School Board	Riparian buffer enhancement and wetland enhancement,
	L4	Poor	681	Moderate	4	7	Commercial	Remove concrete channel, install riparian buffer enhancement, combine with Outfall retrofit (L4-P6)
	L5	Good	699	Moderate	5	8	Park Authority	Outfall Retrofit at L5-P4, stabilize head cut (L5-H4), Remove trash from floodplain
	L10	Good	1202	Moderate	6	14	Industrial	Some stabilization along channel, Investigate L10-P4 hydrant
	L3	Good	1197	Moderate	7	13	Commercial	Stabilize Outfall L3-P5 and L3-P6, Remove debris dump
	L7A	Fair	1309	Low	8	.	HOA	Stabilize a series of head cuts, Remove obstruction, Remove sediment from outfall
	L1	Good	200	Low	9	.	Park Authority	None
	L9	Good	845	Low	10	.	Park Authority	None

	Site ID	RSAT	Stream Length	Priority	Ranking within Sub-watershed	Study Ranking	Ownership	Buffer and Channel Recommendations
Yorkshire 186 & 100	Y1B	Fair	219	High	1	2	Church School	Stabilize as part of Outfall Retrofit, Riparian Buffer Enhancement
	Y7	Fair	489	High	2	6	Commercial	Stabilize head cuts, Replace pipe (Y7-P1), Remove Debris Dump
	Y3	Good	778	Moderate	3	10	Residential	Utility stabilization, Riparian Buffer Enhancement, Investigate illicit discharge
	Y4	Good	587	Moderate	4	16	Residential	Bank stabilization and riparian buffer extension
	Y8	Good	1196	Moderate	5	17	Park Authority & Apartment	Stabilize banks
	Y1A	Fair	367	Moderate	6	11	Church School	Riparian Buffer Restoration (remove invasives, plantings, management)
	Y5	Fair	1231	Low	7		Residential	None

Table 19
Summary of Proposed Stream and Buffer Projects

Site ID	Stream Length(linear feet)	Priority	Study Ranking	Ownership	Proposed Stream and Buffer Projects	Justification
B6B & B6C	1,786	High	1	HOA	Repair head cuts, improve management of buffer. Combine with WQ retrofit (194-1)	Stabilize 4' Head cut (B6B-H3) migrating upstream into utility crossing (B6C-U2). Protect downstream stormwater facility (194-1) from erosion
Y1B	219	High	2	Church School	Stabilize channel and enhance riparian buffer as part of outfall retrofit (186-1)	Channel in fair condition with eroding banks and poor riparian buffer, easy access
L2	134	High	3	Apartment Complex, Park	Restore channel and stabilize head cuts as part of an outfall water quality retrofit (166-14)	Moderate trash accumulation (L2-T1), Stream instability (L2-H1 >2' head cut and L2-H2 2' head cut), Impervious concrete lined channel
L8	1,137	High	4	HOA	Enhance riparian buffer and retrofit 7 ditches for water quality retrofit	Fair channel with good access, but lacking riparian buffer; has 7 ditch discharges (L8-P2 thru L8-P8)
L7	530	High	5	School Board	Riparian buffer and wetland enhancement	Fair channel lacking a riparian buffer. Moderate trash accumulation (L7-T1), Failing corrugated plastic pipe blocking stream flow (L7-P2)
Y7	489	High	6	Commercial	Stabilize head cuts, replace pipe (Y7-P1), remove debris dump	Fair channel with moderate trash accumulation (Y7-T1), poor riparian buffer, stream instability (Head cuts >2' Y7-H1 and Y7-H2), and failing corrugated metal pipe (Y7-P1)
L4	421	Moderate	7	Commercial	Remove concrete channel, install riparian buffer enhancement, combine with Outfall retrofit (L4-P6)	Impervious concrete lined channel, No defined hydrologic connection to receiving channel (L4-P6)
Y3	161	Moderate	10	Commercial	Remove concrete channel, install riparian buffer enhancement, combine with Outfall retrofit (L4-P6)	Impervious concrete lined channel, No defined hydrologic connection to receiving channel (L4-P6)

V. COST ESTIMATES

The costs for construction and design of the proposed projects were estimated several different ways to provide a range of possible costs to the County. By reviewing the range of costs, the County can develop a list of funding priorities, and an estimated capitol cost to address those projects selected for funding. The cost is summarized in the Conceptual Design Narratives in Appendixes A-C, and the detailed cost estimates are provided in Appendix F. The methods used to estimate costs included the following:

Center for Watershed Protection (CWP)

For different types of stormwater facility construction, the CWP has developed a range of construction costs based on the acres of impervious surface treated (Table 20). These costs would not include the site specific factors identified in this study which may affect costs. The cost estimates for new facilities is significantly lower than retrofitting existing facilities. These costs are only for construction and do not include design or contingency costs.

Table 20
Center for Watershed Protection Construction Costs
(Per Impervious Acre Treated)

Type of BMP	Low Cost	Median Cost	High Cost
New Wetland Construction	$2,000	$2,900	$9,600
New Extended Detention	$2,200	$3,800	$7,500
Pond Water Quality Retrofit	$3,600	$11,100	$37,100
Bioretention Retrofit	$19,900	$25,400	$41,750

Generalized Construction and Design Costs

Generalized unit construction costs were developed for created wetlands and bioretention facilities (Table 21). These estimates do not take into account factors that might increase or decrease costs at a specific site. The assumptions used to generate the generalized cost estimates are available in Appendix F. Design costs were assumed to be 30% of the estimated construction costs, and an additional 20% contingency was added to the design and construction costs.

Table 21
Generalized Construction Costs Per 1,000 sf of Facility

Type of BMP	Construction Cost	Design (30%)	Contingency (20%)	Total Cost
Created Wetland	$5,687	$1,706	$1,137	$8,530
Bioretention	$14,171	$4,251	$2,834	$22,106

The generalized construction costs for bioretention matched well with the median range estimated from the CWP. The generalized construction estimate for a created wetland was similar to the high estimate from the CWP.

Site Specific Costs

Based on the proposed conceptual design narratives, assumed unit costs, and an initial rough estimate of quantities, this study developed planning level construction costs that are specific to each of the proposed projects. These estimates take into account factors that might increase or decrease costs at a specific site. Individual cost estimates for each project are available in Appendix F. Design costs were assumed to be 30% of the estimated construction costs. An additional 20% contingency was applied to the construction and design costs resulting in the total costs. The site specific costs are summarized below:

Stormwater Facility Repair and Retrofit Cost Estimates - For the eight proposed stormwater facility repairs and retrofits, the estimates of total construction costs range between $310,000 and $360,000 (Table 22). The total costs including design, construction, and contingency, ranges between $350,000 and $483,000 for the eight proposed stormwater repair and retrofit projects.

Table 22
Site Specific Cost Estimate for Each Facility

Watershed	Site ID	Construction Cost	Design Cost	Contingency (20%)	Total	WQ Retrofit $/Imp. Acre
Buckhall 194	194-1	$117,265	$35,180	$30,489	$182,933	$8,167
	194-2	$21,450	$6,435	$5,577	$33,462	
	194-3	$44,839	$13,452	$11,658	$69,949	
Yorkshire 186&100	186-1	$27,770	$8,331	$7,220	$43,320	$18,050
Linden 166	166-1	$57,369	$17,211	$14,916	$89,495	
	166-2	NA	$100,000	NA	$100,000	
	166-7	$44,232	$13,270	$11,500	$69,001	$8,166
	166-8	$16,830	$5,049	$4,376	$26,255	
	Total	**$329,754**	**$198,926**	**$85,736**	**$614,417**	

Outfall Retrofit Cost Estimates - The estimate of construction costs for the six proposed outfall retrofits projects range between $241,000 and $360,000 (Table 23). The total costs including design, construction, and contingency, ranges between $350,000 and $483,000 for the six proposed outfall retrofits (Table 24). The total costs per acre of impervious surface treated typically range from approximately $20,000 to $35,000 per acre.

Table 23
Comparison Construction Cost Estimates
for Six Proposed Outfall Retrofits

Outfall Retrofits	CWP Median Construction Cost	Generalized Unit Costs	Site Specific Cost Estimate
Construction Costs	$356,128	$241,546	$310,115
Cost Per Impervious Acre	$22,871	$15,500	$ 19,900

TABLE 24
Total Cost Estimates for Each Proposed Outfall Retrofit

Watershed	Site ID	Construction Cost	Design Cost	Contingency (20%)	Total Cost	Cost per Imp. Acre
Buckhall 194	194-5	$35,400	$10,620	$9,204	$55,224	$27,612
Yorkshire 186&100	186-5	$40,910	$12,273	$10,637	$63,820	$31,910
	186-5	$23,588	$7,077	$6,133	$36,798	$21,027
Linden 166	166-13	$56,608	$16,982	$14,718	$88,309	$35,324
	166-14	$114,260	$34,278	$29,708	$178,246	$97,884
	166-15	$39,348	$11,804	$10,231	$61,383	$20,461
	Total	**$310,115**	**$93,035**	**$80,630**	**$483,780**	

Note: 166-14 cost includes stream restoration and stabilization costs

Stream and Buffer Enhancement and Stabilization Cost Estimates - For stream and buffer projects, the estimated total cost is approximately $360,000 for the five proposed sites, including design, construction, and contingency (Table 25). This cost estimate results in an average per linear foot cost of $122. This estimated cost is well within the typical planning range of costs of $100-$200 per linear foot for stream stabilization. Full stream restoration in urban watersheds typically would cost upward of $400 per linear foot, depending on the design approach.

TABLE 25
Total Cost Estimates for Each Proposed Stream or Buffer Project

Watershed	Site ID	Const. Cost	Design Cost	Contingency (20%)	Total Cost	Cost Per Linear Foot
Yorkshire 186	Y3	$13,563	$4,069	$3,526	$21,158	$131
	Y7	$13,090	$3,927	$3,403	$20,420	$102
Linden 166	L4	$83,738	$25,121	$21,772	$130,631	$327
	L7	$26,840	$8,052	$6,978	$41,870	$76
	L8	$85,371	$25,611	$22,196	$133,179	$117
	Total	**$191,334**	**$57,400**	**$49,747**	**$298,481**	**$122**

Cost Summary

Based on the individual cost estimates prepared for each concept design narrative, the total program cost to implement the projects identified within this study would be $1.3-1.4M (Table 26). The prioritization and ranking provides the County with the ability to limit the implementation of projects to those that are most needed, or the most cost effective.

TABLE 26
Summary of Costs for Proposed Projects

	Construction	Design	Contingency	Total
Stormwater Improvements and Retrofits	$329,754	$198,926	$85,736	$614,417
Outfall Retrofits	$310,115	$93,035	$80,630	$483,780
Stream Stabilization and Buffer Enhancements	$191,334	$57,400	$49,747	$298,481
Subtotals	**$831,203**	**$349,361**	**$216,113**	**$1,396,678**

This study did not identify all possible projects or all high priority projects which may exist in the Bull Run watershed. This study evaluated only 4 subwatersheds out of 61 total subwatersheds within the Bull Run watershed, representing approximately 8% of the total area of Bull Run watershed in the county.

The stream assessments screened all streams within the study subwatersheds but only field evaluated 13% of the total length of streams within the three subwatersheds. Those reaches which were assessed in the field were those reaches where the potential for problems were the highest, and the compatibility of restoration with adjacent land use and ownership were the greatest. The two step approach to identification of stream projects (i.e., screening and field assessments) should result in the majority of existing stream problems being identified within these subwatersheds. The stream conditions in the other subwatersheds may vary from those found in the subwatersheds in this study.

The stormwater inventory provides a sampling of existing conditions which could be used to project costs across the entire Bull Run watershed within the County. Based on the results of the stormwater facility inventory conducted for this study, the following assumptions could be made:

- Based on the results of this study, approximately 30% of the dry and wet ponds in the County's inventory may require repairs or modifications to address existing deficiencies. The County stormwater inventory used in this study had 4 bioretention basins, 7 wet ponds and 58 dry ponds within the Bull Run watershed. Based on the 69 bioretention basins, dry ponds, and wet ponds reported to be in the Bull Run watershed within the county, 15-17 of those facilities may require repairs to correct existing deficiencies.
- The majority of the stormwater facilities in the Bull Run watershed are dry ponds. Based on this study, 15% of the remaining BMPs, or 7-9 additional sites, may make good candidates for water quality retrofits.
- In this study, stormwater facilities not on the County inventory accounted for 25% of the sites inspected. Based on 69 wet ponds, dry ponds and bioretention sites within the Bull Run watershed, there may be an additional 10-12 facilities not currently included in the County inventory. Those facilities not included in the County inventory may not be routinely inspected or maintained.

WHITMAN, REQUARDT & ASSOCIATES, LLP

Engineers • Architects • Planners

Baltimore Office
801 South Caroline Street
Baltimore, Maryland 21231
Office: (410) 235-3450

Richmond Office
9030 Stony Point Parkway, Suite 220
Richmond, Virginia 23235
Office: (804) 272-8700
Fax: (804) 272-8897

Blacksburg Office
1700 Kraft Drive, Suite 1200
Blacksburg, Virginia 24060
Office: (540) 951-3727
Fax: (540) 951-3741

Fairfax Office
3701 Pender Drive, Suite 210
Fairfax, Virginia 22030
Office: (703) 293-9717
Fax: (703) 273-6773

Newport News Office
11870 Merchants Walk, Suite 100
Newport News, Virginia 23606
Office: (757) 599-5101
Fax: (757) 599-5320

Pittsburgh Office
300 Seven Fields Boulevard, Suite 130
Seven Fields, Pennsylvania 16046
Office: (724) 779-7940
Fax: (724) 779-7943

York Office
224 St. Charles Way, Suite 140
York, Pennsylvania 17402
Office: (717) 741-5057
Fax: (717) 741-5124

Wilmington Office
Three Mill Road, Suite 309
Wilmington, Delaware 19803
Office: (302) 571-9001
Fax: (302) 571-9011