U.S. Fish & Wildlife Service

Hickey Run, Washington, D.C. Watershed and Stream Assessment

CBFO-S05-01

December 2005

HICKEY RUN, WASHINGTON, D.C.
WATERSHED AND STREAM ASSESSMENT

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Stream Habitat Assessment and Restoration Program
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office

CBFO-S05-01

Prepared in cooperation with:
Government of the District of Columbia, Department of Health, Environmental Health Administration, Watershed Protection Division

Annapolis, MD
December 2005

EXECUTIVE SUMMARY

The Department of Health, Washington, D.C. (DOH) and the U.S. Fish and Wildlife Service, Chesapeake Bay Field Office (Service) entered into a Memorandum of Understanding (MOU) (Agreement 51410-1902-0172) in 2001 to implement stream and riparian habitat restoration projects within the District of Columbia's watersheds, including the Hickey Run watershed.

The Hickey Run watershed, a sub-watershed of the Anacostia River, is approximately 2.08 square miles (mi^2), all within Washington D.C. (District) and the coastal plain hydrologic region. A substantial portion of the watershed is highly urbanized, with 36 percent impervious surface (DCWQD 2002). Manufacturing/industrial (40 percent) and medium density residential (40 percent) are the primary land uses in the upper portion of the watershed. National Arboretum grounds and Anacostia Park, consisting of cultivated gardens, mowed fields, meadow areas, and lightly forested areas, represent 20 percent of the watershed.

The watershed consists of a network of stormwater pipes and natural streams. In 1861, Hickey Run had over five miles of streams consisting of fifteen tributaries and a drainage density of 2.40 mi/mi^2. Today, the watershed consists of the Hickey Run main stem and six small unnamed tributaries, totaling 2.3 miles, all on the U.S. National Arboretum (USNA) or Anacostia Park, National Park Service (NPS). Even though there is significantly less stream miles, the current drainage density is 3.82 mi/mi^2 due to the miles of stormwater pipes that drain the upper and middle portions of the watershed.

The purpose of this report is to present the findings and recommendations of the watershed and stream assessment conducted by the Service on Hickey Run. Specifically, this report documents, prioritizes, and recommends general solutions for stream problems existing on Hickey Run. The development of specific stream restoration solutions and any other specific solutions related to other problems identified in this report will occur during the design phase. The development of specific restoration solutions will be a continuous, interactive coordination effort between vested partners (DC DOH, USNA, and NPS). During that time, the vested partners will establish the restoration objectives and identify their missions. Specific assessment objectives for this report include:

- Determining the relationship between watershed land use activities and stream processes;
- Documenting stream type and stability conditions;
- Prioritizing restoration reaches;
- Developing general watershed restoration recommendations; and
- Developing preliminary design criteria for the restoration.

Methodology

The watershed assessment involved two levels of assessment: stream-based assessment and land-based assessment. The stream-based assessment involved a Rosgen Level I (Rosgen 1996) stream assessment for the tributaries of Hickey Run. The Rosgen Level I assessment describes the general geomorphic character of the stream and watershed. The land-based assessment analyzed land use/land cover patterns, soils, geology, hydrology, valley type, existing water quality and biological data, and watershed development. As part of the land-based analysis the Service also conducted a trend analysis and developed a cause and effect relationship between watershed land use activities and stream processes.

The Service conducted Rosgen Level II, III, and IV assessments to assess the Hickey Run mainstem. The Rosgen Level II assessment describes, in detail, the existing morphological character of the stream. The Service also used this information to classify the stream using the Rosgen stream classification system (Rosgen 1994). The Service used the Rosgen Level III assessment to determine the stability condition of the stream and estimate bank erosion sediment loads. The Rosgen Level IV assessment is a validation of stream stability determinations and bank erosion sediment load estimates made from the Level III assessment.

The Service grouped problem identification into two categories: process-based problems and site-specific problems. The Service identified process-based problems using the cause and effect relationship developed from the watershed and stream analyses. The Service then prioritized restoration of stream reaches and their problems relative to one another based on stability conditions, potential sediment supply, and stream type interpretations.

Findings

The majority of tributaries, except where piped, appear physically unaltered by channelization activities and free to adjust naturally. The Service delineated twenty-eight separate stream reaches, representing twelve different Rosgen stream types, based on geomorphologic character and stability conditions. Instream habitat conditions are fair to good in most tributaries with some poor areas. The riparian buffer ranges in width from 20 to 1,300 feet and consists mostly of mature woodlands with some areas consisting of woody shrubs and non-native species. Overall, the tributaries are relatively stable (72 percent vertically stable, 68 percent laterally stable), and only slightly incised (60 percent rated as low to moderate), but have a very high potential sediment supply on a majority of the tributaries (51 percent). Recovery potential of the degraded areas is poor and will only occur if the cause of the instability is corrected.

The Service partitioned the mainstem of Hickey Run into six reaches based on geomorphologic character and stability conditions and identified three Rosgen stream types. The entire main stem has been physically altered and nearly half has been hardened into place with either large rip rap or concrete. In most areas where it has not been hardened, it is actively eroding (67 percent laterally and 47 percent vertically adjusting). Fifty seven percent of the reaches are severely incised and entrenched. Instream habitat diversity and cover quality varies from poor to moderate. Water quality is impaired by urban runoff, sewer line leaks, and past petroleum leaks. The riparian buffer varies from mowed grass to wide, mature woodlands. The potential sediment supply is very high. The Service determined approximately 1,000 tons of sediment erodes from the streambanks of Hickey Run annually. The potential for Hickey Run to recover on its own, given its current condition, is poor.

Changes in the watershed and physical alterations to the Hickey Run are the primary causes for instability, poor water quality and aquatic habitat problems. High percentages of impervious surface in the watershed, along with conversion of many of the tributaries to piped or concrete-line storm drains have altered Hickey Run's natural hydrology. Base flows (groundwater derived flow) are lower than in a predominantly forested or agricultural watershed, and stormflow peaks are of greater intensity but shorter duration (flashiness). These higher flows and greater velocities have caused and are still causing stream erosion and channel incision throughout Hickey Run.

Restoration Priority

The Service determined that all, but two, of the reaches on the Hickey Run main stem have significant, widespread instability problems and considers the restoration priority as high. Although there is a discernable difference in stability between the reaches, the severity of instability of all the reaches are such that rating the restoration priority of one reach over another is not warranted. The stability conditions of the tributaries vary from stable, to localized instability, to widespread instability. However, because all the tributaries are relatively short, the Service recommends that restoration occur at a tributary level, regardless of the individual reach restoration priority.

Restoration Recommendations

The Service recommends a natural channel design approach to restoring degrading areas on Hickey Run and its tributaries. One of the more significant stream problems to address when restoring Hickey Run is the degree of incision. Based on the natural channel design methodology, restoration techniques of incised streams are divided into four major categories (Rosgen 1997).

- Create the original type stream at the original floodplain level (Priority 1)
- Create the original type stream at the current floodplain level or higher, but containing a floodprone area (Priority 2)
- Create a different type stream without an active floodplain, but containing a floodprone area (Priority 3)
- Stabilize the existing stream with structures (Priority 4)

The Service determined that a Priority 1 or 2 restoration is appropriate for most of the Hickey Run main stem and its tributaries. There are some confined areas of Hickey Run where a

Priority 1 or 2 restoration may not be feasible. For those potential areas, the Service recommends using a Priority 3 restoration. The morphology of all priority stream types generally provides good habitat potential for fish and macroinvertebrates, and reduces stream width and stream incision. The report only provides narrative descriptions of how these techniques could be applied to Hickey Run. The development of detailed restoration plans will occur during the design phase of the Hickey Run restoration project. These plans will be developed in coordination with the vested partners.

To address water quality problems in Hickey Run, DOH and USNA are currently working together to install a trash collector and if funds permit, an oil separator near New York Avenue where Hickey Run daylights from a stormwater pipe. Additionally, DOH proposes the implementation of best management practices at stormwater production sites in the upper watershed as part of their watershed implementation plan.

Storm sewer outfalls must be addressed on a case-by-case basis. The preferred alternative is to treat stormwater on site. Another alternative is to relocate outfalls to the edge of riparian corridors and install stormwater treatment and infiltration facilities. In some cases, because of space and grade limitations, this may not be possible. Where relocation is not feasible, energy dissipaters may be required to improve stream stability.

The Service derived Hickey Run restoration costs based on restoration costs developed as part the Oxon Run Stream Restoration Concept Development (Shea, et al, 2004). The restoration costs include construction costs only and are applied on a linear foot cost at the rate of $230.00. Preliminary restoration costs for Hickey Run are $1.2 million. The Service will refine the restoration costs during the design phase as details of restoration solutions and their locations are finalized.

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I. INTRODUCTION

The Department of Health, Washington, D.C. (DOH) and the U.S. Fish and Wildlife Service, Chesapeake Bay Field Office (Service) entered into a Memorandum of Understanding (MOU) (Agreement 51410-1902-0172) in 2001 to implement stream and riparian habitat restoration projects within the District of Columbia's watersheds. As part of the MOU, the Service has completed two watershed and stream assessments for Watts Branch and Oxon Run watersheds. The purpose of this report is to present the findings and recommendations of the watershed and stream assessment conducted by the Service for Hickey Run.

Hickey Run, a tributary of the Anacostia River and a tertiary tributary to Chesapeake Bay, is highly urbanized and wholly contained in the boundaries of Washington, D.C. (Figure 1). In the upper portion of the watershed, the stream and its tributaries have been piped. Approximately one mile of open channel remains, mostly on the grounds of the U.S. National Arboretum (USNA). A portion, approximately 20 percent, flows through Anacostia Park, which is owned by the U.S. National Park Service (NPS). Watershed changes due to urbanization are widely recognized to be a major contributor to stream destabilization, aquatic and riparian habitat degradation, and increased sediment loading (Gregory 1987; Allen 1995). All are occurring in the Hickey Run watershed.

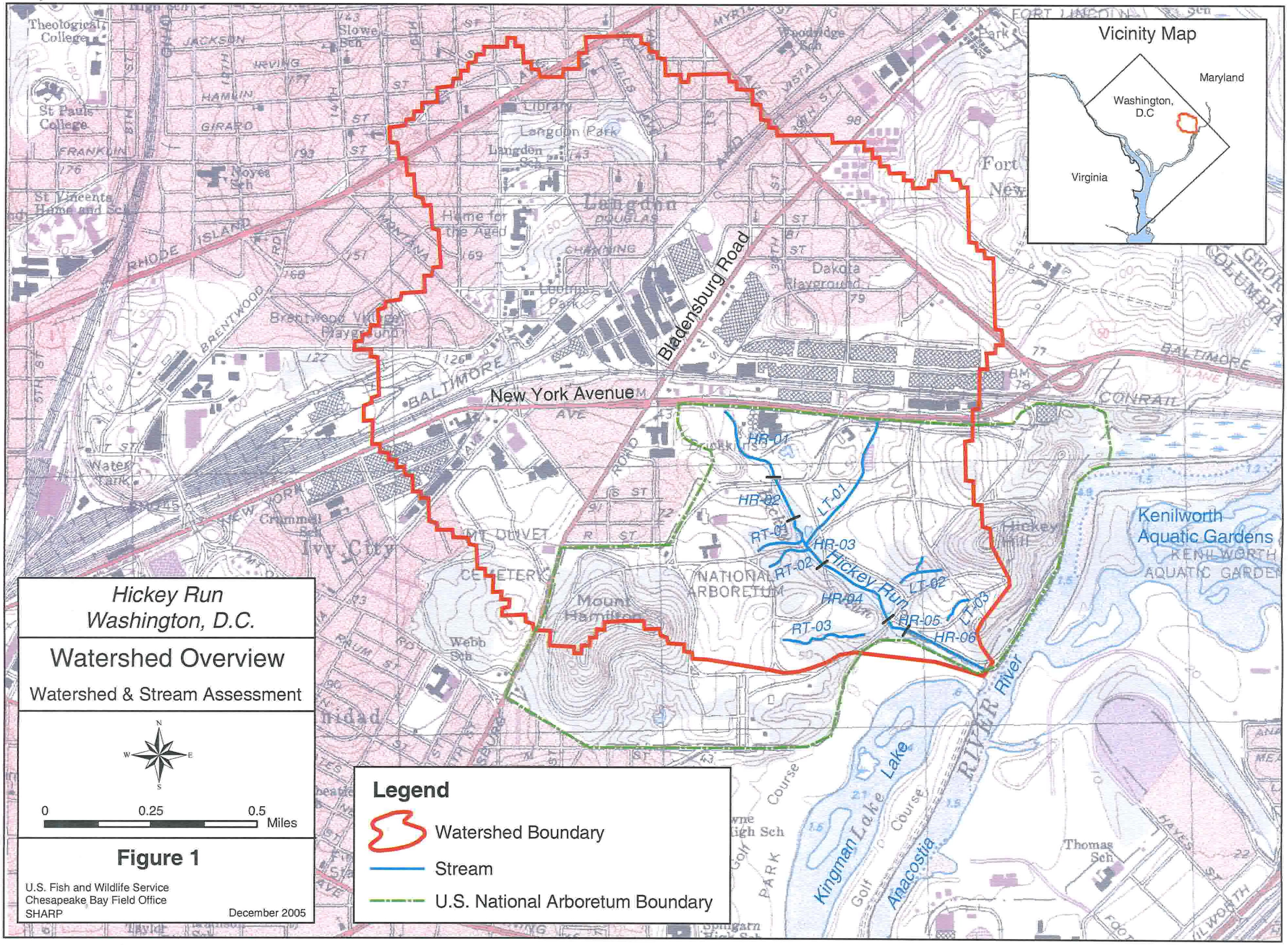
The purpose of this report is to document, prioritize, and recommend general solutions for stream problems existing on Hickey Run. The development of specific stream restoration solutions and any other specific solutions related to other problems identified in this report will occur during the design phase. The development of specific restoration solutions will be a continuous, interactive coordination effort between vested partners (DC DOH, USNA, and NPS). During that time, the vested partners will establish the restoration objectives and identify their missions. For example, *the USNA serves and supports the ornamental horticultural industries, landscape design and construction industries, and floral industries in the United States. The use of suitable plants in well designed landscape settings are important to use, particularly when the USNA can show different examples of landscape treatments.* The incorporation of partners' missions into the restoration solutions is critical to the success Hickey Run restoration.

This report contains the assessment methodologies used by the Service, a watershed characterization; reach specific stream characterization and stability condition descriptions; problem identification and restoration prioritization; restoration recommendations; and preliminary design criteria and construction costs.

II. ASSESSMENT OBJECTIVES

The watershed and stream assessment provides baseline information necessary to develop stream restoration solutions. Specific objectives for this assessment include:

- Determining the relationship between watershed land use activities and stream processes;
- Documenting stream type and stability conditions;


Hickey Run
Washington, D.C.
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Miles
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U.S. Fish and Wildlife Service
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Stream
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New York Avenue
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HR-04
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HR-06
LT-01
LT-02
LT-03
RT-01
RT-02
RT-03
Kenilworth
Aquatic Gardens
Kingman Lake
Anacostia
RIVER
River
NATIONAL
ARBORETUM

- Prioritizing restoration reaches;
- Developing general watershed restoration recommendations; and
- Developing preliminary design criteria for the restoration.

III. METHODOLOGY

A brief summary of methods used by the Service to assess the watershed and stream condition is presented; however, a more detailed description of the methods used by the Service is described in the Hickey Run Scope of Work. The only change in methodology was the substrate sampling technique. Instead of pebble counts, bulk samples were collected due to a water quality advisory recommending no human contact. Particle distribution was determined by sieving the bulk samples in the laboratory.

The methods used by the Service focused on characterizing and determining the stability condition of Hickey Run and its tributaries. Therefore, the most detailed and intensive field surveys and data analyses were conducted on the fluvial geomorphic physical features and stream processes. The Service used existing information and limited field surveys of other data such as riparian vegetation, soils, geology, land use, land cover, water quality, historic maps and aerials, and topography to develop an understanding of the processes associated with these resources in relation to stream processes.

A. Watershed Assessment

The watershed assessment involved two levels of assessment: stream-based assessment and land-based assessment. The stream-based assessment involved a Rosgen Level I (Rosgen 1996) stream assessment for the tributaries of Hickey Run. The Rosgen Level I assessment describes the general geomorphic character of the stream and watershed. Service personnel walked the tributaries to characterize fluvial geomorphic conditions, instream habitat, and riparian habitat. Most of the data collected was based on observations, but did include some minimal measurements of channel dimensions and riparian buffer widths. Each assessed reach was photographed and all photographs are in Appendix A. The fluvial geomorphic conditions observed included channel dimensions, pattern, profile, and substrate material, vertical and lateral stability, sediment supply potential, debris jams, utility crossings, outfall locations, Rosgen stream type, and channel evolution. The instream habitat observed included water quality, large woody debris, aquatic vegetation, fish blockages, bed features, velocity and depth variations, and cover and shelter. The riparian habitat observed included vegetation species composition, diversity, density, and condition, floodplain and riparian buffer width, nutrient uptake potential, type of overland flow, and stream proximity to hill slope.

The land-based assessment analyzed land use/land cover patterns, soils, geology, hydrology, valley type, existing water quality and biological data, and watershed development. The assessment was predominatly an office exercise with field verification. As part of the land-based analysis the Service also conducted a trend analysis, using historical maps and aerial photos, to develop an understanding of how the stream responded to land use changes overtime and how the stream may have been directly altered by man. The Service used the stream-based data, land-based data, and the trend analysis to develop a cause and effect relationship between watershed land use activities and stream processes. The Service then used the cause and effect relationship in the problem identification phase of the assessment to identify those areas and/or land use activities that have a negative or positive impact to Hickey Run and its tributaries.

B. Stream Assessment

The Service conducted Rosgen Level II, III, and IV assessments to assess the Hickey Run mainstem. The Rosgen Level II assessment describes, in detail, the existing morphological character of the stream. The Service also used this information to classify the stream using the Rosgen stream classification system (Rosgen 1994). The Rosgen stream classification system uses physical features of a stream such as width, depth, pattern, and bed material, to group streams into a "type" denoted by alphanumeric codes. The Service used the Rosgen Level III assessment to determine the stability condition of the stream and estimate bank erosion sediment loads. A Rosgen Level III assessment compares the stream of interest to a stable (reference) stream and quantifies the deviation from optimum condition (of the stable stream). The Service used C4 and C5 streams from the Western Coastal Plain (McCandless 2003) as the reference since they could not find a suitable reference reach within the project area. As part of the Level III assessment, the Service assessed channel parameters (incision, entrenchment, with/depth ratio, and confinement), bank erodability potential, near bank stress, depositional pattern, meander pattern, critical shear stress, channel evolution, sediment capacity, and Pfankuch assessment. The Rosgen Level IV assessment is a validation of stream stability determinations and bank erosion sediment load estimates made from the Level III assessment. The Service installed representative monumented erosion cross sections to validate the actual amount of lateral and vertical adjustment. The Service resurveyed the erosion cross sections in summer 2004 and has validated its bank erosion estimates. Upon completion of the analysis, the Service will validate and adjust, if necessary, the bank erosion sediment loads predicted in this report.

C. Bankfull Determination

The bankfull discharge is the discharge (or range of discharges) which is responsible for the formation and maintenance of the stream channel dimensions, planform patterns and longitudinal profile. The stream typically develops bankfull indicator(s), such as a significant slope break and floodplain feature, along the stream banks at the bankfull stage. An accurate determination of the bankfull indicator(s) is one of the most critical aspects of assessing a stream because surveyors will base the entire survey and assessment on its determination. To insure an accurate determination of the bankfull discharge, the Service verified the bankfull discharge with the regional discharge relationships documented in the report *Maryland stream survey: Bankfull discharge and channel characteristics in the Coastal Plain hydrologic region* (McCandless 2003) and based on the bankfull determinations made as part of the Watts Branch Watershed and Stream Assessment (Eng 2002) and the Oxon Run Watershed and Stream Assessment (Doelling-Brown 2003), both conducted by the Service.

D. Problem Identification and Restoration Priority

The Service grouped problem identification into two categories: process-based problems and site-specific problems. The Service identified process-based problems using the cause and effect relationship developed from the watershed and stream analyses. The Service describes the specific processes associated with the variety of natural and man-made features within the watershed (i.e., stream, sediment, urban infrastructure, water quality, riparian buffer, and instream habitat) and their interaction with one another to identify where processes are not functioning to their fullest potential or are impacting other processes. This process-based problem identification is a critical step towards identifying and prioritizing restoration sites. If a problem area is degrading (the effect) as a result of some other activity or process (the cause), then remediation of the activity or process causing the problem must occur prior to or at the same time the degraded area is restored for the restoration to be successful.

The Service identified site-specific problems for each reach surveyed on the Hickey Run main stem. The information is displayed in a table format so that reviewers can visualize reach specific problems relative to one another. The actual location of the each specific problem is documented on the geomorphic maps the Service produced as part of the data collection effort.

The Service prioritized restoration of stream reaches relative to one another based on stability conditions, potential sediment supply, and stream type interpretations. The Service obtained reach stability conditions from the overall lateral and vertical stability conditions predicted as part of the Rosgen Level III assessment. The potential sediment supply came from two sources: a prediction, as part of the Rosgen Level III assessment, of potential sediment supply, and an estimate of potential sediment, in tons per year, from stream bank erosion. The interpretations of various stream types (Rosgen 1996) consider the response of streams to such parameters as sensitivity to disturbance, recovery potential, and sediment supply. Sensitivity to disturbance is a measure of a stream's tolerance to changes in watershed conditions; including sediment output, peak discharge, and response timing. Recovery potential relates to the stream's ability to recover once the cause of disturbance is removed. Sediment supply is a relative (i.e., low, moderate, or high) estimate on the potential amount of sediment that a specific stream type could contribute to the overall sediment load of a stream system.

IV. EXISTING CONDITIONS

The section presents the findings of existing and past watershed character, trend analysis, and stream character and stability condition.

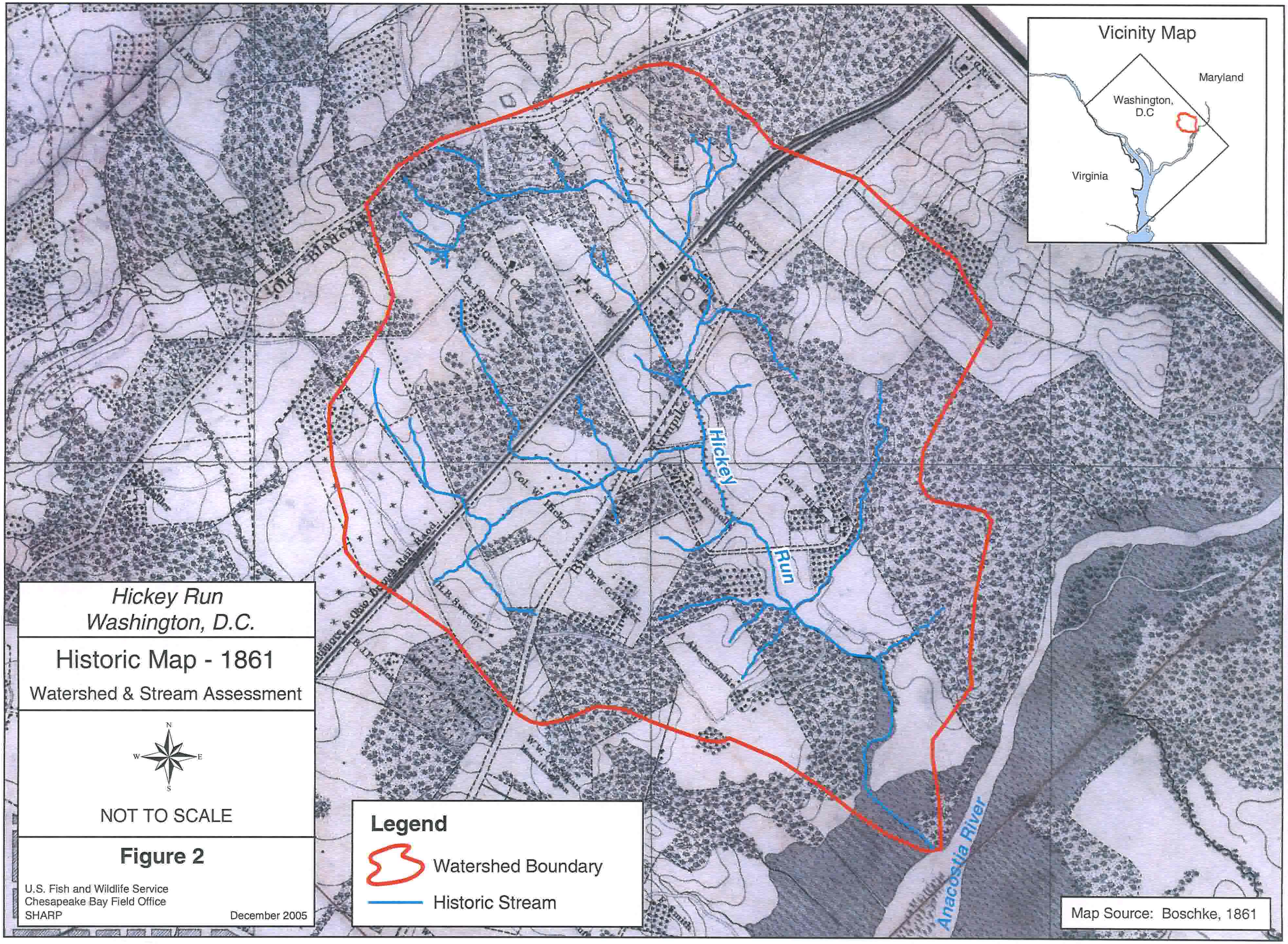
A. Watershed Characterization

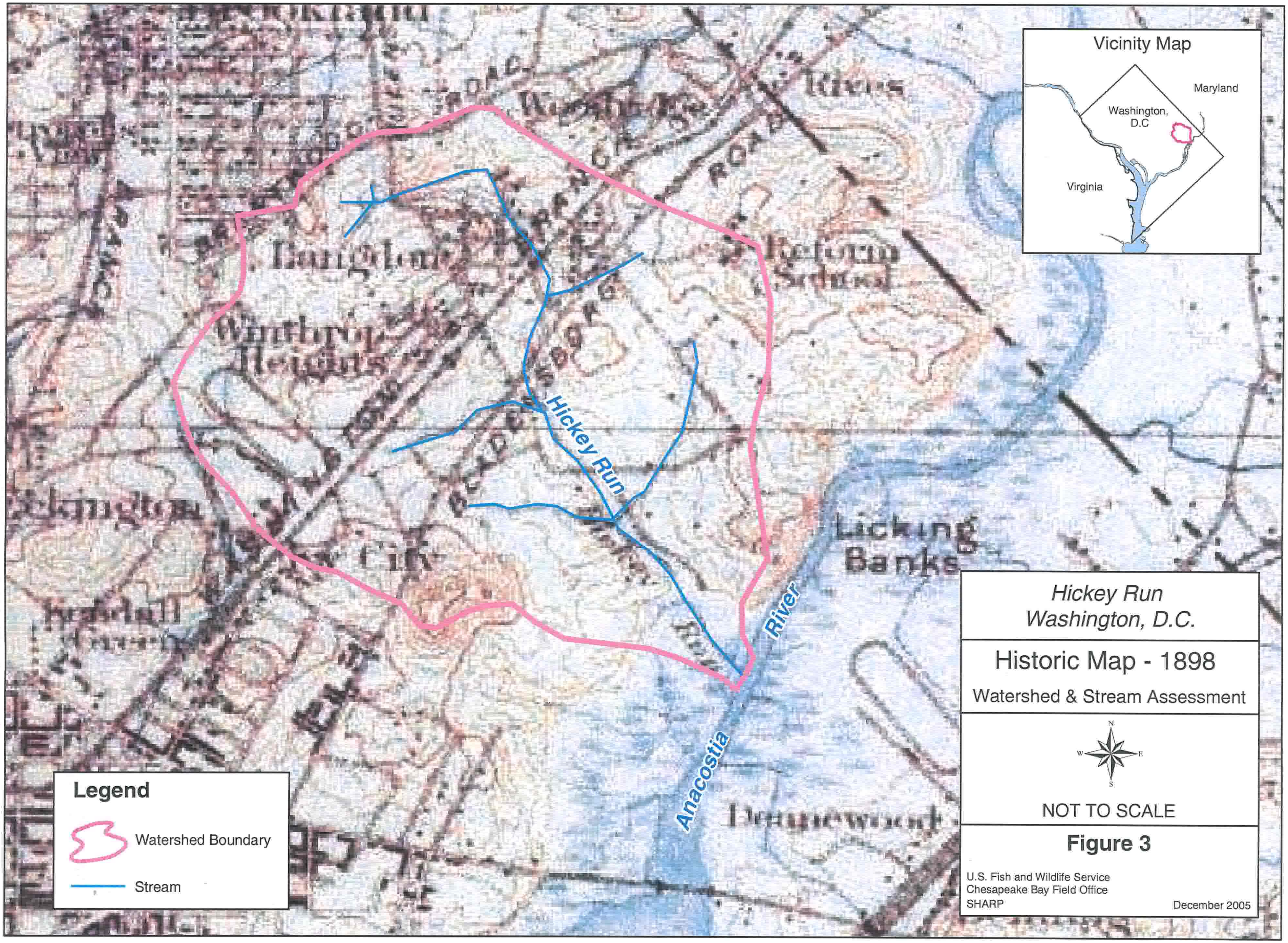
The Hickey Run watershed is a sub-watershed of the Anacostia River, and is comprised of Hickey Run, six small unnamed tributaries, and stormwater drainage from the upper portion of the watershed. The watershed is approximately 2.08 square miles (mi^2), all within theDistrict, and is in the coastal plain hydrologic region (Schmidt, Jr. 1993). All open channel reaches of the stream are on the grounds of the U.S. National Arboretum and Anacostia Park. The valley type, as defined by Rosgen (1996) is a valley type VIII; a wide, gentle valley slope with a well developed floodplain adjacent to the river. Valley slope of the mainstem (measured from headwaters near Brickkilns) is 0.3 percent, and basin relief (measured from the top of the historic watershed in Langdon Park), is 1.9 percent.

1. Historical Overview

The current Hickey Run watershed is entirely within the District boundary, although in the earliest map located (1822) (not shown) portions were located outside the city limits and undeveloped, in an area known at that time as Washington County. In 1822, the stream consisted of the main stem and one major tributary. The three major tributaries, shown on subsequent maps, most likely existed in 1822 but were not recorded on the map. The main stem originated near what is now Langdon Park, and the tributary originated near Bladensburg Road. The confluence of these two was joined just east of the Baltimore Turnpike Road. The 1861 map is the oldest documentation the Service found that probably best represents the hydrology of Hickey Run (Figure 2). The main stem alignment is similar to the 1822 map, but the 1861 map shows Hickey Run had over five miles of stream consisting of fifteen tributaries with one of the tributaries having five sub-tributaries of its own; a total of approximately five miles of streams in the Hickey Run watershed. The other notable piece of information shown in the 1861 map is that over half of the forested areas within the watershed had been cleared. By 1891 (map not shown), the housing areas of Avalon Heights and Winthrop Heights had been built in the upper part of the watershed, west of Bladensburg Road. There was no development east of Bladensburg Road, towards the Anacostia River. Extensive tidal wetlands still existed along the river, and the map shows Hickey Run terminating in the wetland rather than draining into the Anacostia. By 1898 (Figure 3), the Anacostia River both up and downstream of Hickey Run had been channelized, potentially initiating bed level adjustments on Hickey Run. This map shows only four tributaries: one originating above Bladensburg Road on the east side of Hickey Run, one originating above Bladensburg Road on the west side of Hickey Run, one originating north of Hickey Hill on the east side of Hickey Run, and one above the wetland area west of Hickey Run. Whether some of the tributaries shown in the 1861 map were not recorded on the 1898 map or possibly filled in for development is unknown. A 1917 map (Figure 4) shows one road with scattered houses east of Bladensburg Road, but the lower portion of the watershed is still largely undeveloped.

In the 1940s, there were significant changes in the watershed. By 1942 (map not shown), several neighborhoods had been built east of Bladensburg Road. Two more of the original tributaries are not shown on the map, and an instream pond (now referred to as Springhouse Pond) had been constructed on one of the remaining tributaries. A 1948 aerial photo (Figure 5) shows a stream configuration similar to what now exists, although the straightness of the channel suggests the entire stream had recently been ditched. There is another pond shown adjacent to Hickey Run (now referred to as Heart Pond), to the east, located near Crabtree Road. The two tributaries originating near Bladensburg Road have been entirely piped and only


Vicinity Map
Maryland
Washington, D.C
Virginia
Hickey
Run
Anacostia River
Hickey Run
Washington, D.C.
Historic Map - 1861
Watershed & Stream Assessment
NOT TO SCALE
Figure 2
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
SHARP
December 2005
Legend
Watershed Boundary
Historic Stream
Map Source: Boschke, 1861


Vicinity Map
Maryland
Washington, D.C
Virginia
Hickey Run
River
Anacostia
Licking Banks
Legend
Watershed Boundary
Stream
Hickey Run
Washington, D.C.
Historic Map - 1898
Watershed & Stream Assessment
NOT TO SCALE
Figure 3
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
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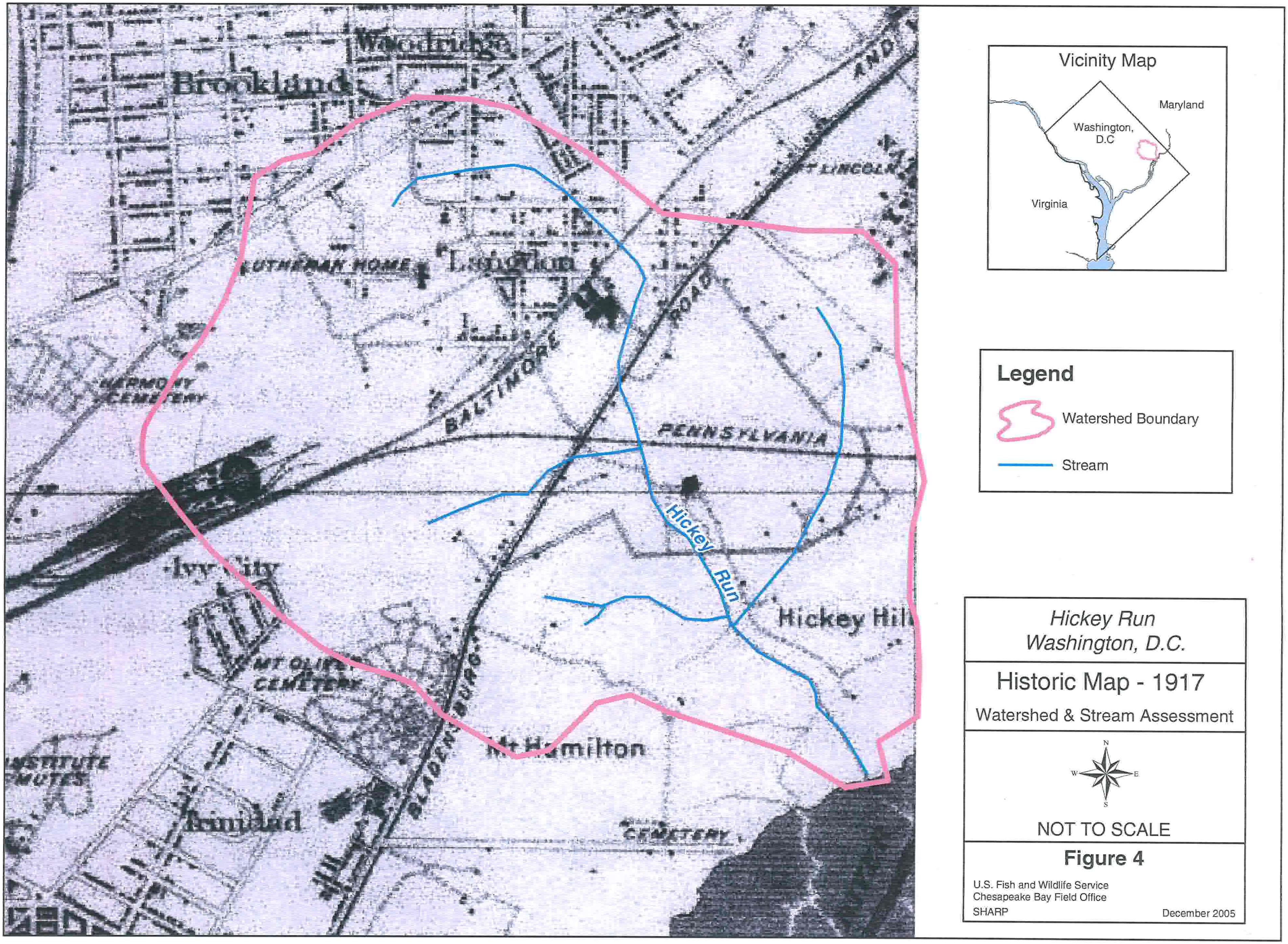

Brookland
Woodridge
Langdon
Lutheran Home
Harmony Cemetery
Baltimore
Road
And
Ft Lincoln
Pennsylvania
Hickey Run
Hickey Hill
Ivy City
Mt Olivet Cemetery
Bladensburg
Mt Hamilton
Cemetery
Trinidad
Institute Mutes
Vicinity Map
Maryland
Washington, D.C
Virginia
Legend
Watershed Boundary
Stream
Hickey Run
Washington, D.C.
Historic Map - 1917
Watershed & Stream Assessment
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NOT TO SCALE
Figure 4
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
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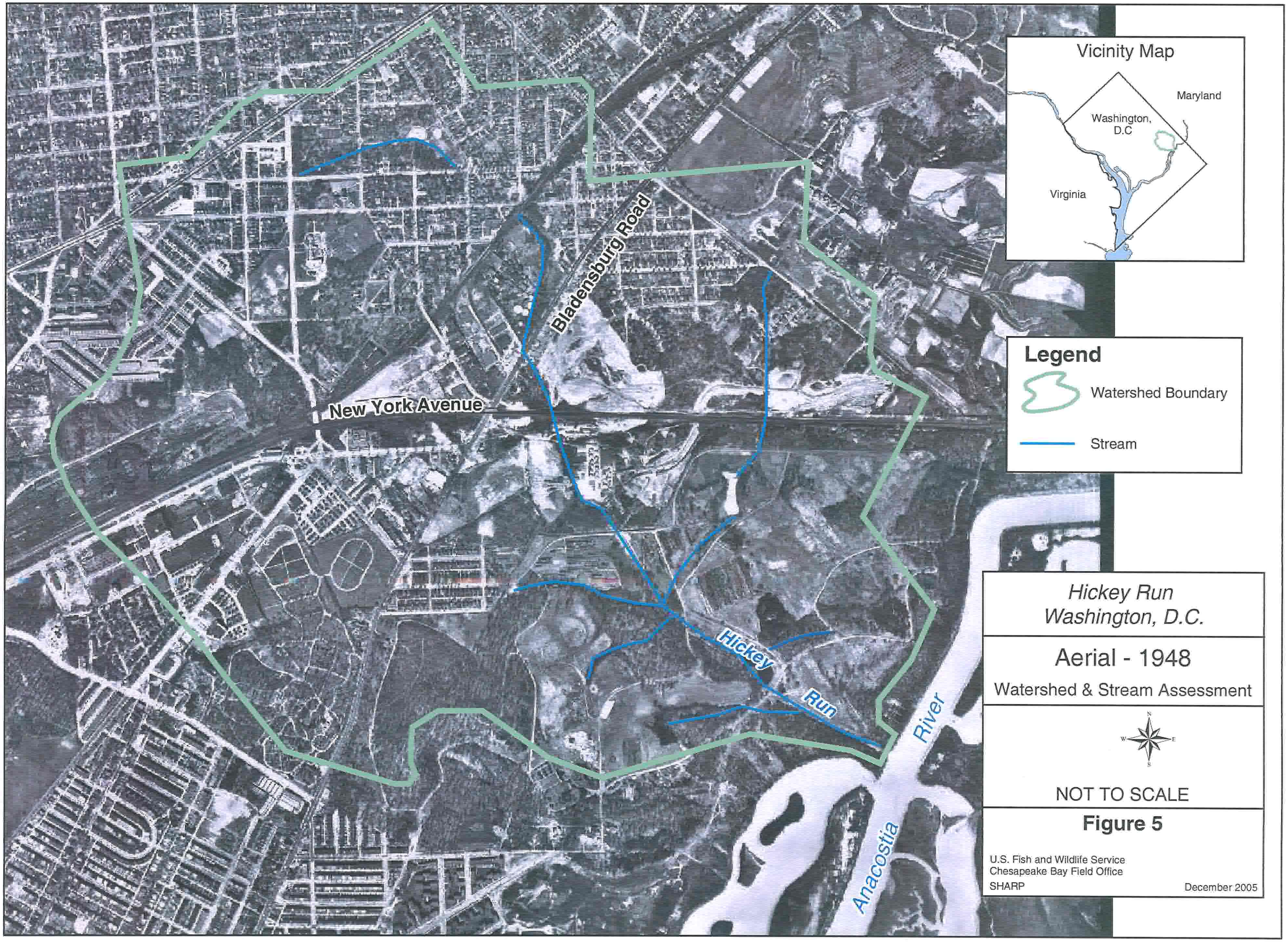

Vicinity Map
Maryland
Washington, D.C
Virginia
Legend
Watershed Boundary
Stream
New York Avenue
Bladensburg Road
Hickey Run
Anacostia River
Hickey Run
Washington, D.C.
Aerial - 1948
Watershed & Stream Assessment
NOT TO SCALE
Figure 5
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
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four of the original tributaries exist. However, one new tributary is shown west of Hickey Run, approximately 1000 feet upstream of the confluence with the Anacostia River. The formation of this tributary is most likely a result of concentrated runoff and piped storm flow associated with development within the watershed. The aerial also shows a section of Hickey Run main stem, near the headwaters, had been piped.

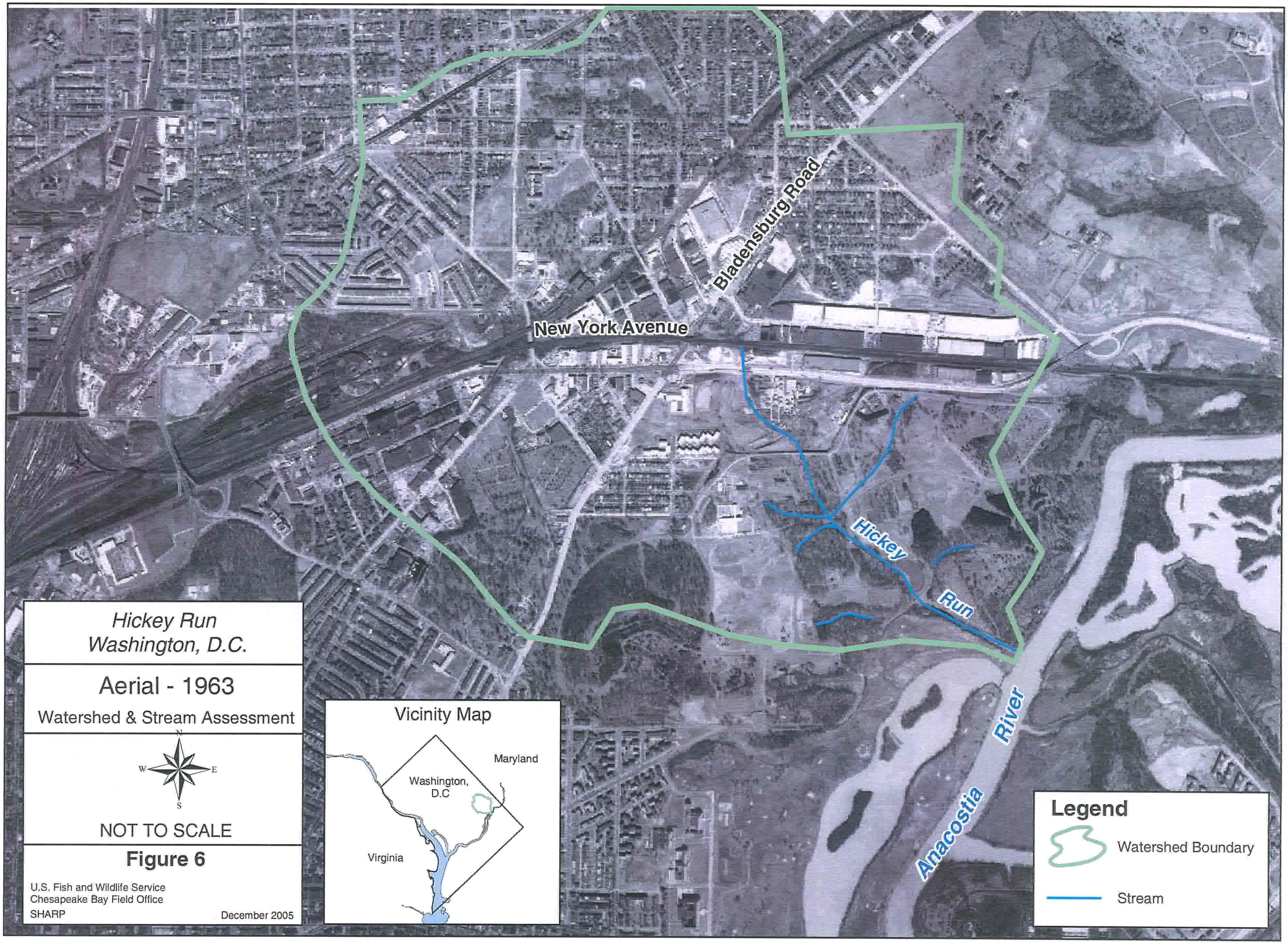
More recent aerial photos (Figure 6 -1963 and Figure 7 -1971) show development in the watershed similar to what exists today. The Route 50 connection to New York Avenue had been constructed, as have the industrial areas along those roads. The only open stream channels are the ones on the National Arboretum and NPS premises. The two tributaries west of Hickey Run still exist. A new tributary, located west of Hickey Run approximately 1000 feet upstream from the confluence with the Anacostia River, is shown on the 1963 aerial. The downstream section of this tributary, where it enters Hickey Run, is shown as piped. The east tributary (Springhouse Run) still runs through the instream pond (Springhouse Pond), although sometime between 1971 and 2000, it was rerouted around the pond. Another new tributary appeared between 1971 and 2000; east of Hickey Run. The downstream section of this tributary is piped before entering Hickey Run. By 2000 (Figure 8), the only land in the watershed not highly urbanized are the grounds of the Arboretum, Anacostia Park, Langdon Park, and Mt. Olivet Cemetery.

2. Geology and Soils

Geology of the Hickey Run watershed is predominatly Patapsco Formation and Arundel Clay (Figure 9), which consists of a maroon clay over-layer and a dark-gray clay underlayer. In the tidal area of the stream the geology is Pamlico Formation and recent alluvium, a mixture of gravel, sand, and silt. Dominant soil types in the watershed are urban land and the urban land-Christiana-Sunnyside association (Figure 10). A small portion of the watershed is udorthents, a classification describing cuts, fills, and otherwise disturbed land. The urban land-Christiana-Sunnyside group are well-drained soils underlain by unstable clayey sediment. When undisturbed, soils typically found in this area are permeable and moderately well-drained. Modification of the soils by development, in combination with the high percentage of impervious surface (36 percent) in the watershed, increases the volume and rate of stormwater runoff. In undisturbed areas, the naturally occurring alluvial sediment is highly erodible.

3. Land use/land cover

A substantial portion of the watershed is highly urbanized (Figure 11), with 36 percent impervious surface (DCWQD 2002). Manufacturing/industrial (40 percent) and medium density residential (40 percent) are the primary land uses in the upper portion of the watershed. Natural areas (20 percent) consist primarily within the National Arboretum grounds and Anacostia Park. While both of these areas are highly managed, they generally consist of cultivated gardens, mowed fields, meadow areas, and lightly forested areas. A more detailed land cover and land use description of the Arboretum and Anacostia Park can be found in their perspective master plans. In the heavily developed upper portion of the watershed, there are no open channels.



Bladensburg Road
New York Avenue
Hickey Run
Anacostia River
Hickey Run
Washington, D.C.
Aerial - 1963
Watershed & Stream Assessment
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Figure 6
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
SHARP
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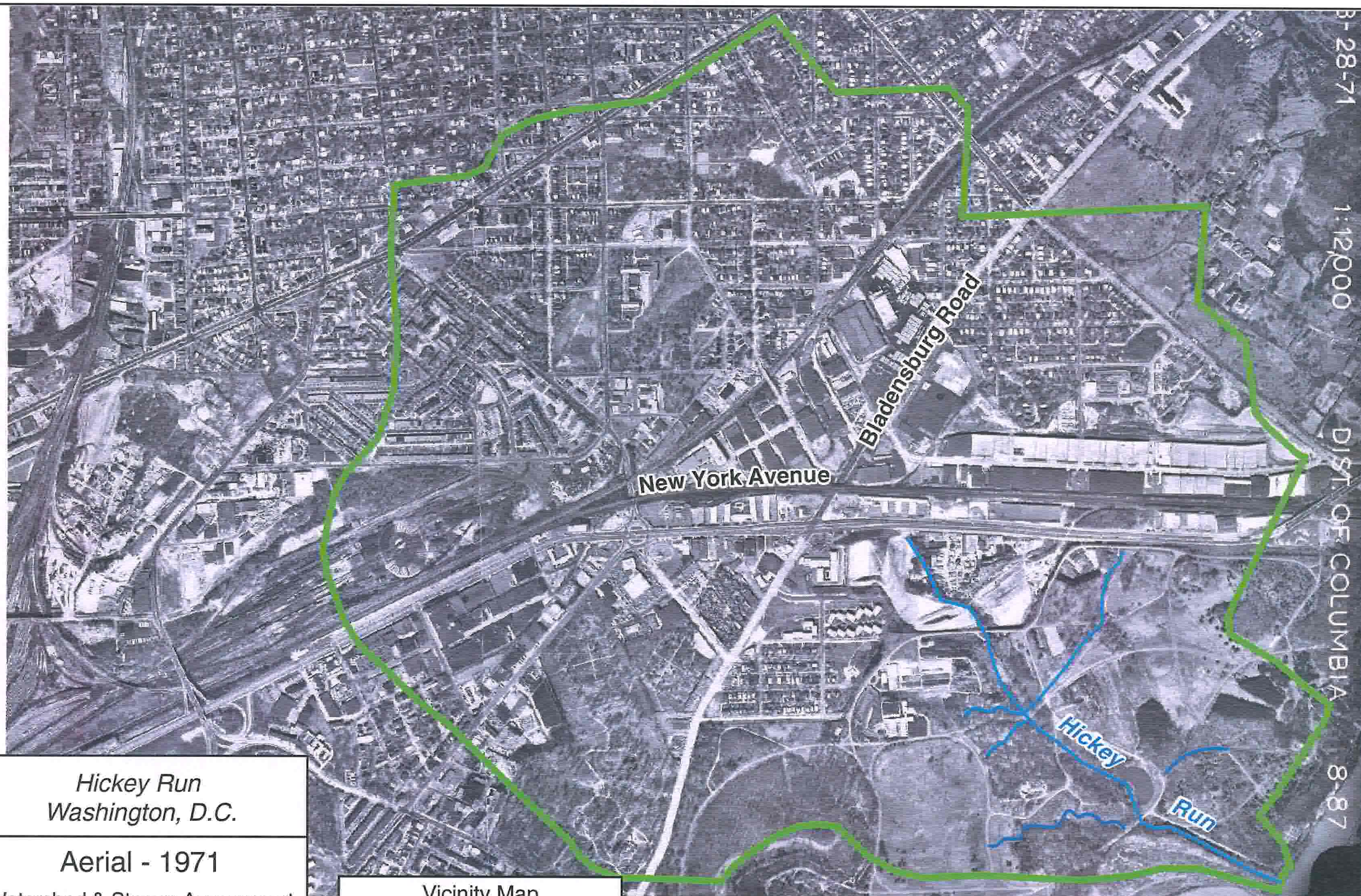
Vicinity Map
Maryland
Washington, D.C
Virginia
Legend
Watershed Boundary
Stream



Legend

Watershed Boundary

Stream

Hickey Run
Washington, D.C.

Aerial - 1971

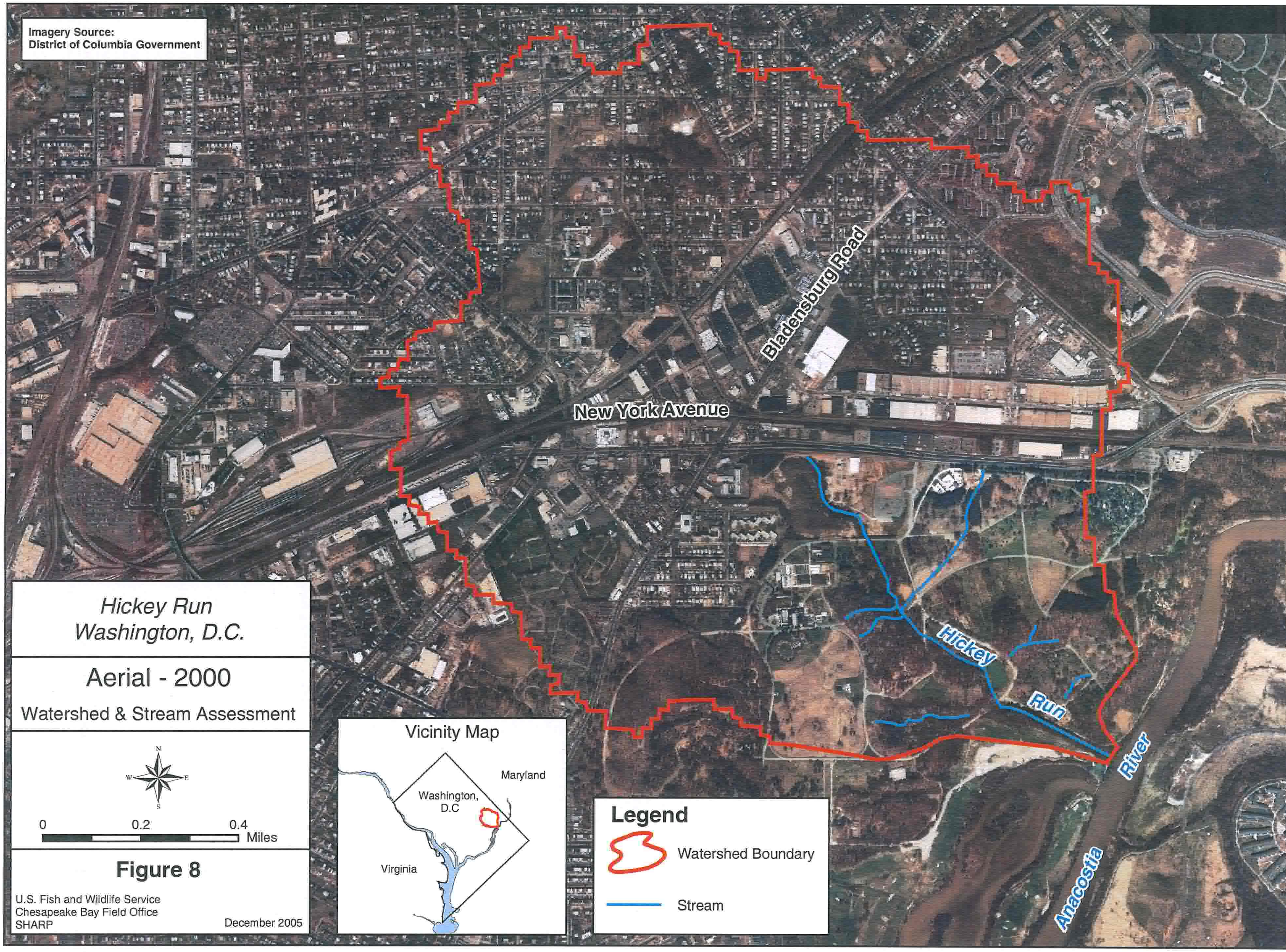
Watershed & Stream Assessment

NOT TO SCALE

Figure 7

U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
SHARP

December 2005


Imagery Source:
District of Columbia Government
Bladensburg Road
New York Avenue
Hickey Run
Anacostia River
Hickey Run
Washington, D.C.
Aerial - 2000
Watershed & Stream Assessment
N
W
E
S
0
0.2
0.4
Miles
Figure 8
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
SHARP
December 2005
Vicinity Map
Maryland
Washington, D.C
Virginia
Legend
Watershed Boundary
Stream

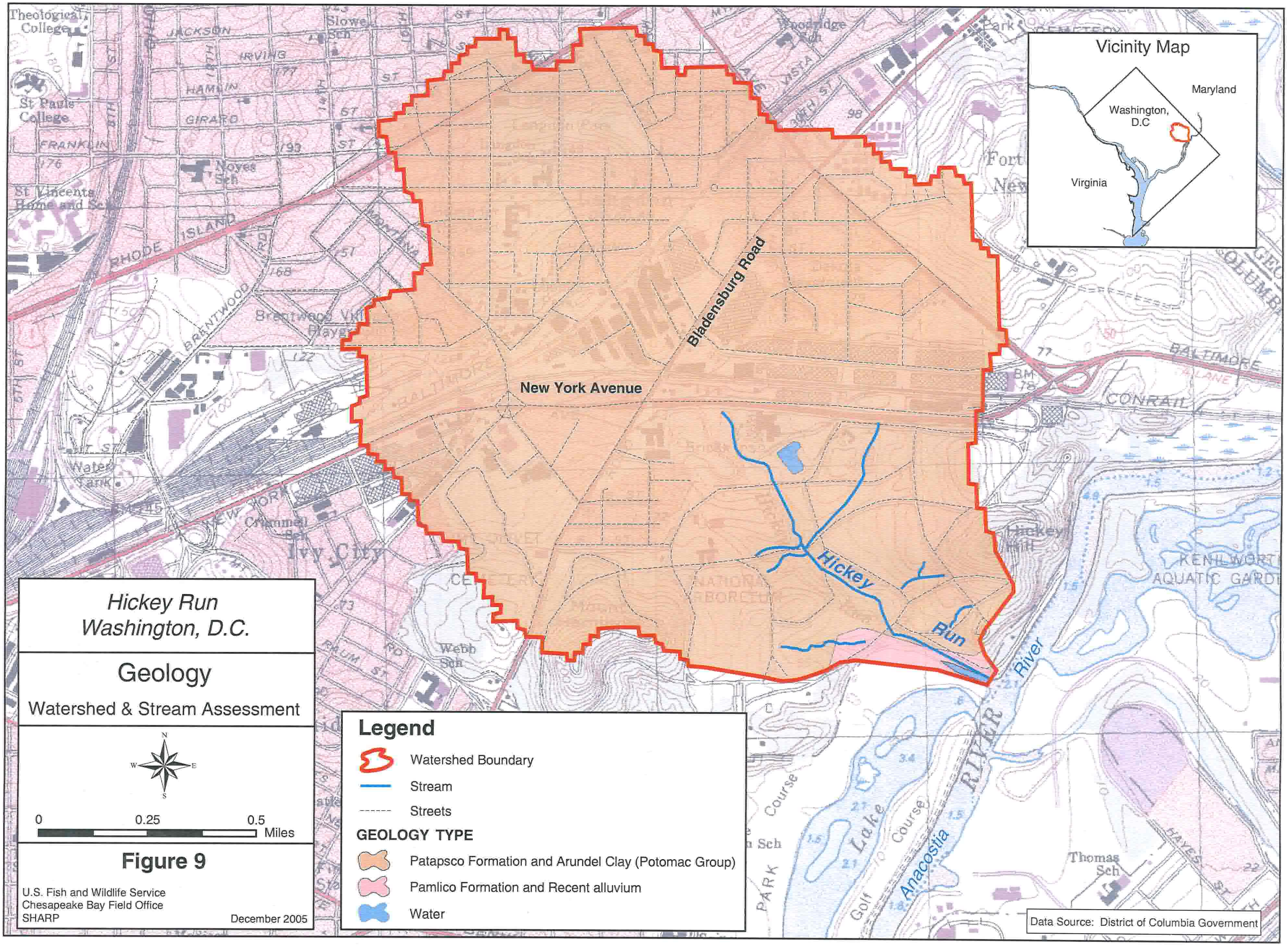


Figure 9

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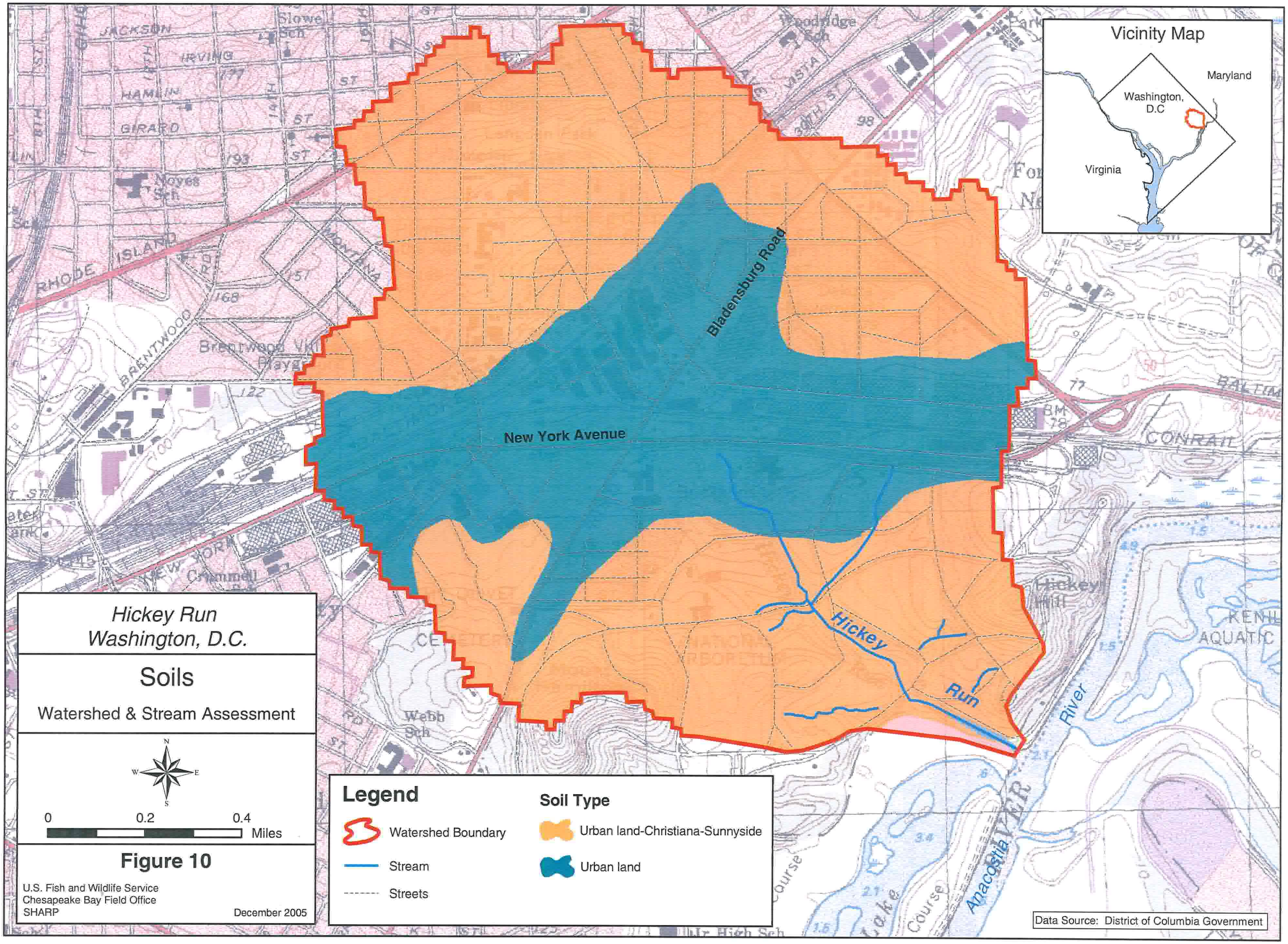
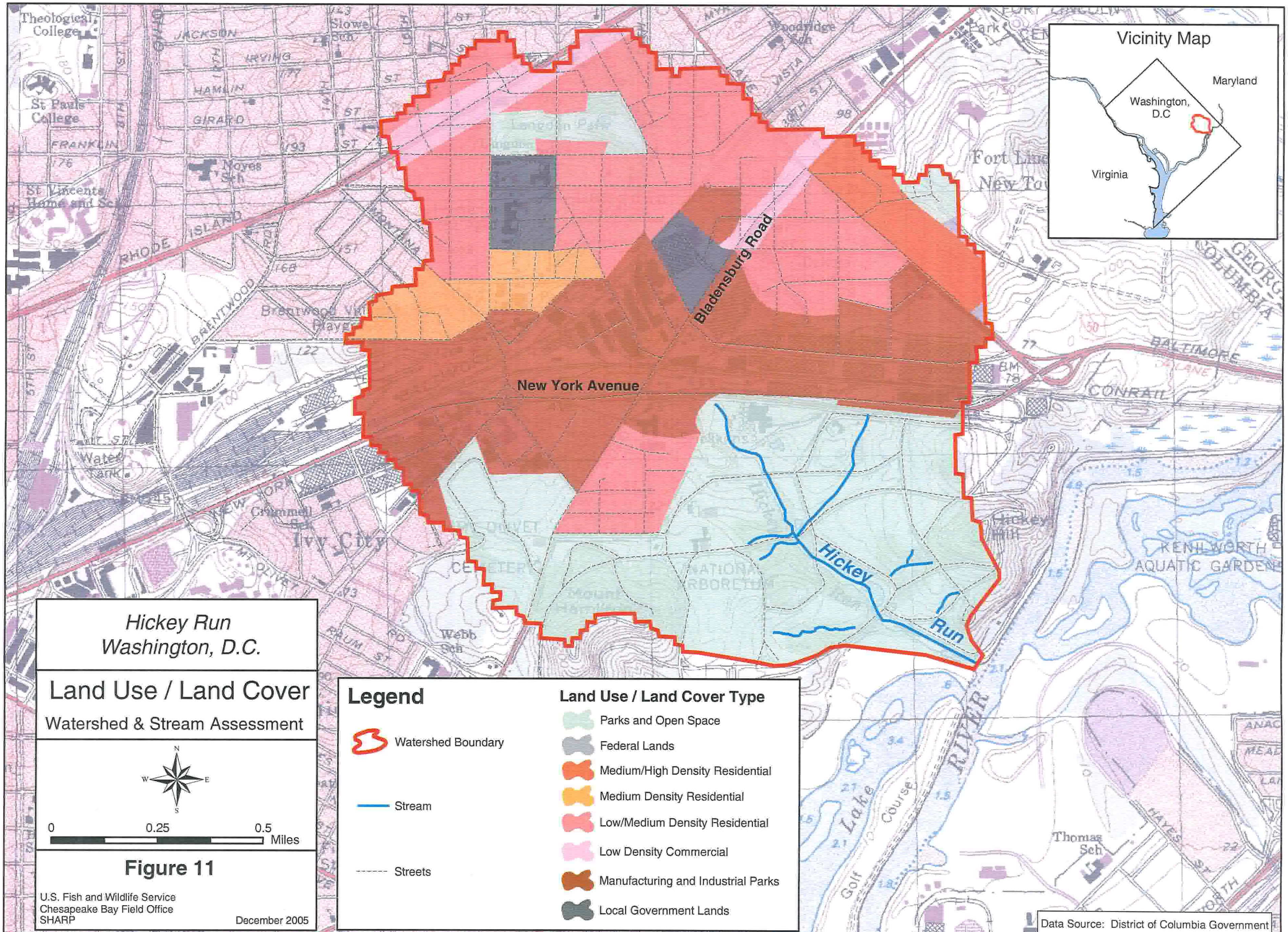
December 2005


Vicinity Map
Maryland
Washington, D.C
Virginia
New York Avenue
Bladensburg Road
Hickey Run
Legend
Watershed Boundary
Stream
Streets
Soil Type
Urban land-Christiana-Sunnyside
Urban land
Data Source: District of Columbia Government
Hickey Run
Washington, D.C.
Soils
Watershed & Stream Assessment
0
0.2
0.4
Miles
Figure 10
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
SHARP
December 2005



Hickey Run
Washington, D.C.

Land Use / Land Cover

Watershed & Stream Assessment

Figure 11

U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
SHARP

December 2005

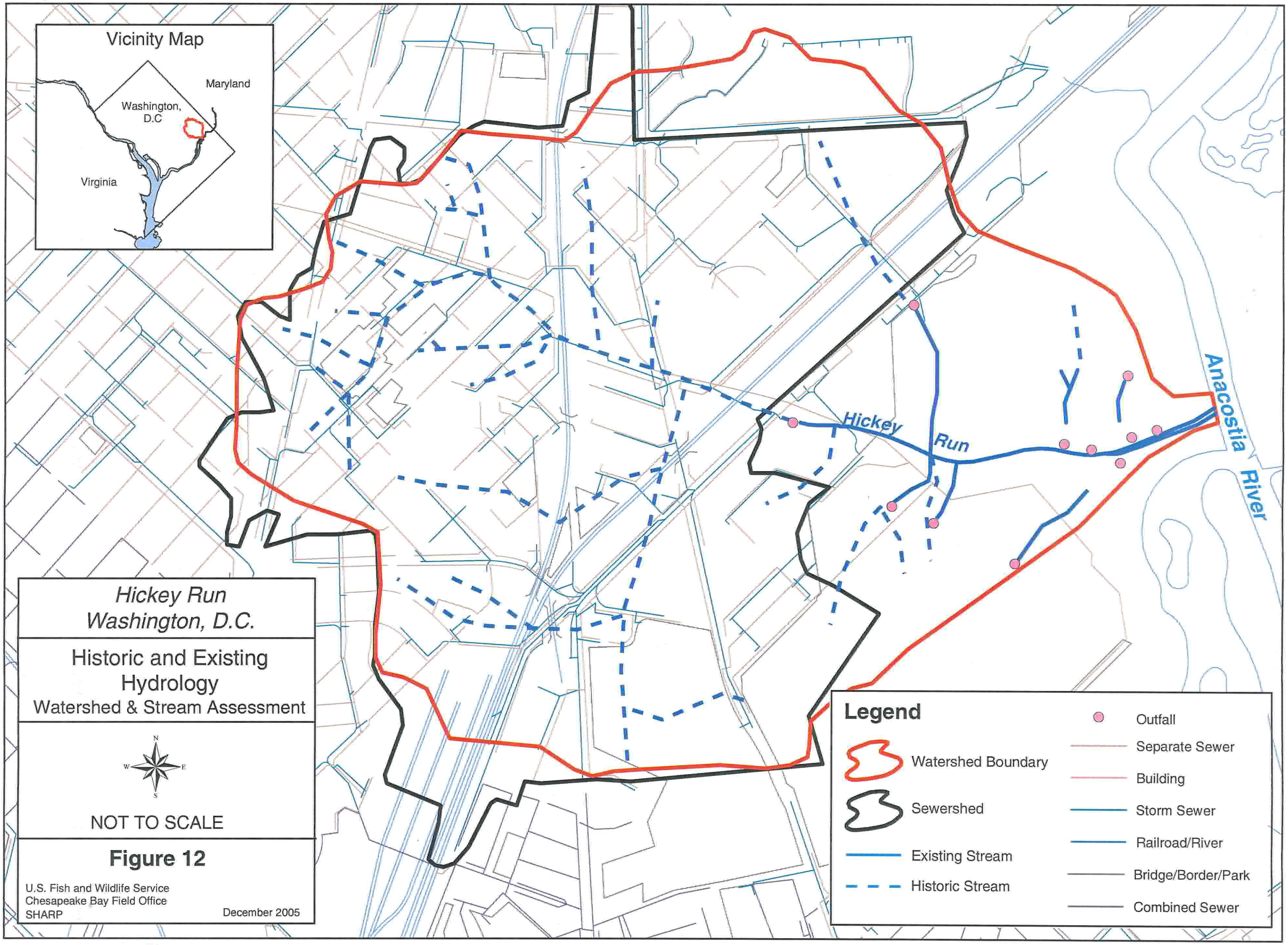
4. Hydrology

The Hickey Run watershed consists of a network of stormwater pipes and some open channel natural bed material streams. Within the watershed, there are 2.3 miles of natural channel, approximately 46 percent less stream miles than existed in 1861. However, due to changes in the land cover, new tributaries have developed in several locations in the USNA and Anacostia Park to handle the increased runoff. Drainage density was 2.40 mi/mi^2 in the 1861 watershed. Currently, when miles of stormwater drains are included, the drainage density is 3.82 mi/mi^2. Figure 12 shows the existing hydrology and storm drain network overlaid by the 1861 hydrology. Higher drainage densities are associated with higher flood peaks (Dunne and Leopold 1978). In an undeveloped watershed, the stream channel and adjacent wetlands provide storage for runoff. Loss of this storage capacity creates a "flashy" flow regime, with peak flows exhibiting a rapid response to runoff events. Additionally, the lower roughness and increased hydraulic efficiency associated with piping increases the velocity and erosive force of the water entering the stream and causes stream erosion. Streambank and bed erosion increases sediment loading.

5. Riparian Vegetation

The riparian buffer is an integral part of the stream ecosystem, providing bank stability and nutrient uptake, serving as a food source for aquatic organisms, and providing terrestrial habitat and migration corridors for various types of wildlife, including migratory neotropical songbirds. Shading provided by the buffer moderates stream temperature and prevents excessive algal growth. Large woody debris derived from the buffer is an important component of aquatic habitat. The Service evaluated quality of the riparian buffer based on buffer width, vegetation diversity, and vegetation density.

Buffer width, species composition and density are described for each of the stream reaches in the appropriate section. Generally, the buffer for the main stem and tributaries ranges from 20-1,300 feet (width includes buffer on both banks) in the locations where the stream is not piped or lined with concrete. In almost all cases, the buffer is of low to moderate density and low to moderate diversity. In some locations, the stream is bordered on one or both banks by mature forested floodplain. Vegetation in the buffer area is a deciduous overstory of tulip poplar *(Liriodendron tulipifera),* red and silver maple *(Acer rubrum* and *Acer saccharinum),* Virginia pine *(Pinus virginiana)*, sycamore *(Platanus occidentalis),* box elder *(Acer negundo),* sweetgum *(Liquidambar styraciflua)*, pignut hickory *(Carya glabra)*, blackgum, *(Nyssa sylvatica)*, mockernut hickory *(Carya tomentosa)*, sassafras *(Sassafras albidum)*, American beech *(Fagus sylvatica)*, American holly *(Ilex opaca)*, hemlock *(Tsuga sp.)*, and a variety of oak species *(Quercus spp.).* Understory plants include spicebush *(Lindera benzoin)*, jewelweed *(Impatiens capensis),* dogwood (*(Cornus florida)*, mountain laurel *(Kalmia latifolia)*, rhododebdron *(Rhododendron sp.)*, low blueberry *(Vaccinium vacillans)*, serviceberry *(Amelanchier sp.)*, arrowwood *(Viburnum dentatum)*, and deerberry *(Vaccinium stamineum).*


Vicinity Map
Maryland
Washington, D.C
Virginia
Anacostia River
Hickey Run
Hickey Run
Washington, D.C.
Historic and Existing Hydrology
Watershed & Stream Assessment
N
W
E
S
NOT TO SCALE
Figure 12
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
SHARP
December 2005
Legend
Watershed Boundary
Sewershed
Existing Stream
Historic Stream
Outfall
Separate Sewer
Building
Storm Sewer
Railroad/River
Bridge/Border/Park
Combined Sewer

Several exotic plant species exists in several locations with the stream corridor and include grape sp.*(Vitis sp.)*, English Ivy (Hedera helix), Asian tear-thumb (Polygonum perfoliatum), Japanese Stilt Grass (Microstegium vimineum), Exotic Bush and Vine Honeysuckles (Lonicera sp.), Porcelainberry (Ampelopsis brevipedunculata), Mimosa Tree (Albizia julibrissin), Poison Ivy (Rhus radicans), Bradford Pear (Pyrus calleryania), Multiflora Rose (Rosa multiflora), Black Lotcus (Robinia pseudo-acacia), Japanesse Knotweed (Polugonum cuspidatum), Tree of Heaven (Ailanthus altissima), Purple Loosestrife (Lythrum salicaria), and Kudzu (Pueraria Montana). Many of these exotic species are considered invasive species as well. They grow rapidly, creating a monoculture, and choking out native vegetation. These invasive monocultures are generally poor quality wildlife habitat, providing little in the way of food and cover.

B. Stream Geomorphology

1. Bankfull Determination

Bankfull discharge characterizes the range of discharges that is effective in shaping and maintaining a stream. Over time, geomorphic processes adjust the stream capacity and shape to accommodate the bankfull discharge within the stream. Bankfull discharge is strongly correlated to many important stream morphological features (*e.g.,* bankfull width, drainage area, etc.) and is the critical parameter used by the Service in assessing Hickey Run. Bankfull discharge is also used in natural channel design procedures as a scale factor to convert morphological parameters from a stable reach of one size to a disturbed reach of another size. This section describes the in-depth analysis the Service conducted to ensure that the correct bankfull determination was made for Hickey Run.

a. Field Determination of Bankfull Stage

During the Hickey Run assessment, the Service identified bankfull stages using physical indicators of bankfull stage described by McCandless and Everett (2002). Indicators found to be significant in Maryland are depicted in Illustration 1. Based on these indicators, the Service identified three sets of consistent geomorphic features at Hickey Run: a low, mid, and high geomorhic feature. The low geomorphic feature was typically the inflection point above the active channel. The mid geomorphic feature typically consisted of the first dominant slope break located above the low geomorphic feature. The high geomorphic feature consisted of a dominant slope break above the middle indicator, but was sometimes obscured by scour.

The Service assessed two other streams, Watts Branch (Eng 2002) and Oxon Run (Brown et al., 2003) within the District prior to the assessment of Hickey Run. The assessment of both of these streams also identified three sets of consistent geomorphic features similar to those found in Hickey Run. The features for Oxon Run were formed mostly by depositional processes while for Hickey Run and Watts Branch; they were formed more by shear stresses which tend to strip the channel of depositional features.

The Service believes, based on monitoring results, that all three of these geomorphic features are actively formed and maintained by the streams. The Service observed lateral migration of Oxon Run as a result of the frequent, high flows generated by record precipitation in calendar year 2003. Even though the stream shifted location, it reformed the three sets of indicators at approximately the same stages. The Service concludes that the low and middle indicators are not remnant features, but are active indicators. The Service believes that the low feature represents a feature called the "inner berm", which generates a discharge associated with the active stream portion of the bankfull channel. The presence of two indicators above the active channel may indicate seasonal variation in bankfull discharge or an effect of urbanization. Woodyer (1968) noted similar multiple benches in survey of streams in developing areas of New South Wales, Australia.

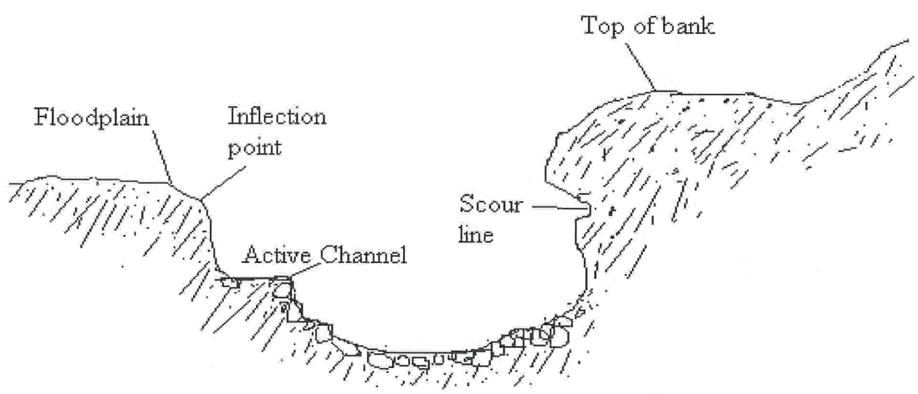


Illustration 1: Typical bankfull indicators (McCandless, 2003)

The exact geomorphic processes forming the three separate indicators are not completely understood and are a subject for further study. However, the Service determined that the multiple field indicators are consistent in all three streams surveyed and the relative stages and discharges of the indicators are also consistent. Therefore, the Service concluded that all three features indicate important features that should be incorporated in the assessment and restoration design of Hickey Run.

b. Bankfull Discharge Determination

The Service estimated bankfull discharges for the three geomorphic features found at Hickey Run using several methods:

- gage calibration using recorded stream stages from the U.S. Geological Survey USGS) Watts Branch stream gage;
- regional relationships between drainage area and bankfull discharge (McCandless and Everett 2002 and McCandless 2003); and
- relationships between channel characteristics and channel roughness (Leopold 1994, Limerinos 1970, and Rosgen 1996).

Each of these methods was also applied to the Watts Branch and Oxon Run assessments and the Service compared their results to the Hickey Run estimated bankfull discharges.

Gage Calibration

The Service calibrated discharges for the three features at the USGS Watts Branch stream gage (01651800) to develop roughness (Manning's "n") values so bankfull discharges could be computed at Hickey Run. Even though the computed values of roughness at the Watts Branch gage are not directly applicable to estimating the bankfull discharges at the Hickey Run, because of differences in stream characteristics, they do provide indications of the range of Manning's "n" values found in District streams. The Manning's "n" values computed for Watts Branch ranged from 0.032 to 0.043 (Shea et al, 2004).

The Service also used the gage calibration to determine the frequency of discharges associated with the three features. Analysis of gage data showed that the discharge associated with the high feature alone is exceeded on average about five times a year, with a return frequency of less than 1 year (Shea et al., 2004).

Regional Relationships

The Service compared the bankfull discharges, bankfull cross section areas, mean bankfull depths and bankfull widths of Hickey Run to the regional relationships of the same parameters developed for the Maryland Coastal Plain (McCandless, 2003) physiographic regions. The District streams are located close to (but below) the Fall Line that separates the Piedmont from the Coastal Plain.

The bankfull cross section area and bankfull width for all three sets of bankfull indicators for the District streams are generally larger than the Maryland Coastal Plain relationship. The larger cross sectional areas of District streams are likely due to the high degree of urbanization of the District streams. The Coastal Plain regional relationships developed by McCandless (2003) were based on gaging stations located in predominantly rural watersheds where as the District watersheds have high percentages of impervious surfaces. Hammer (1972) suggests stream channels may enlarge by a factor of 2.5-3 times the original channel following urbanization.

Because the District streams have larger bankfull cross sectional areas than the Maryland Coastal Plain streams, it is likely that bankfull discharges per drainage area are greater in the District streams than in the Maryland Coastal Plain. Because the land use and hydraulic geometry of the District's streams are different from the streams used to prepare the Maryland Coastal Plain relationship, the Maryland Coastal Plain relationship for bankfull discharge does not provide a reliable means of estimating bankfull discharge for the Hickey Run sites.

Resistance Relationships

Several methods are commonly used to estimate channel roughness and bankfull velocity for ungaged streams. The Service used Leopold (1994) and Limerinos (1970) to estimate bankfull velocity for Hickey Run. Leopold and Limerinos use the relationships between friction factor and relative roughness to estimate velocities. Relative roughness is the ratio of flow depth to the representative substrate particle size.

Comparison of the range of Manning's "n" values calibrated for the Watts Branch gage (0.032 – 0.043) to the values produced by Leopold's (1994) relationship (0.027 – 0.028) indicate that, at least for the Watts Branch gage, the Leopold (1994) under-predicts roughness and over-predicts discharge and velocity. While the Watts Branch stream gage is only one data point, comparison of the predicted bankfull discharges for Hickey Run reaches HR-01 and HR-03 suggests that the Leopold (1994) relationship may provide accurate estimates of channel roughness. The Manning's "n" values of reaches HR-01 (0.069) and HR-03 (0.039) are comparable to the Manning's "n" values of the Watts Branch gage. The predicted Manning's "n" value for HR-04, 0.024, is low because the relative roughness is high[1] and Leopold's relationship is more appropriate for streams with low relative roughness.

Discussion

Accurate estimates of bankfull discharge for Hickey Run, under existing conditions, require additional stream gaging at or near bankfull flows. Use of regional relationships for the Maryland Coastal Plain established by McCandless (2003) is not appropriate because of apparent differences in District streams and the data set used to develop the Maryland Coastal Plain relationship. Use of resistance relationships appears to reflect the influence of form drag and vegetation on discharge best for reaches HR-01 and HR-03. At this time, an approximate range of bankfull discharges may be estimated for assessment assuming a range of likely values of Manning's "n". It appears that Manning's "n" values vary from 0.024 to 0.069 and are appropriate based on the varying existing reach conditions of Hickey Run. Furthermore, using these Manning's "n" values to calculate bankfull discharge, results in a reasonable range of

---

[1] Relative roughness is the ratio of particle size to depth of stream. A low relative roughness means that a particle has greater influence on stream velocities because its size does greatly protrude into the water column.

discharges (172 to 218 cfs) associated with the high indicator. This estimate may be altered if more gaging information is obtained.

2. Tributaries

a. General Characterization

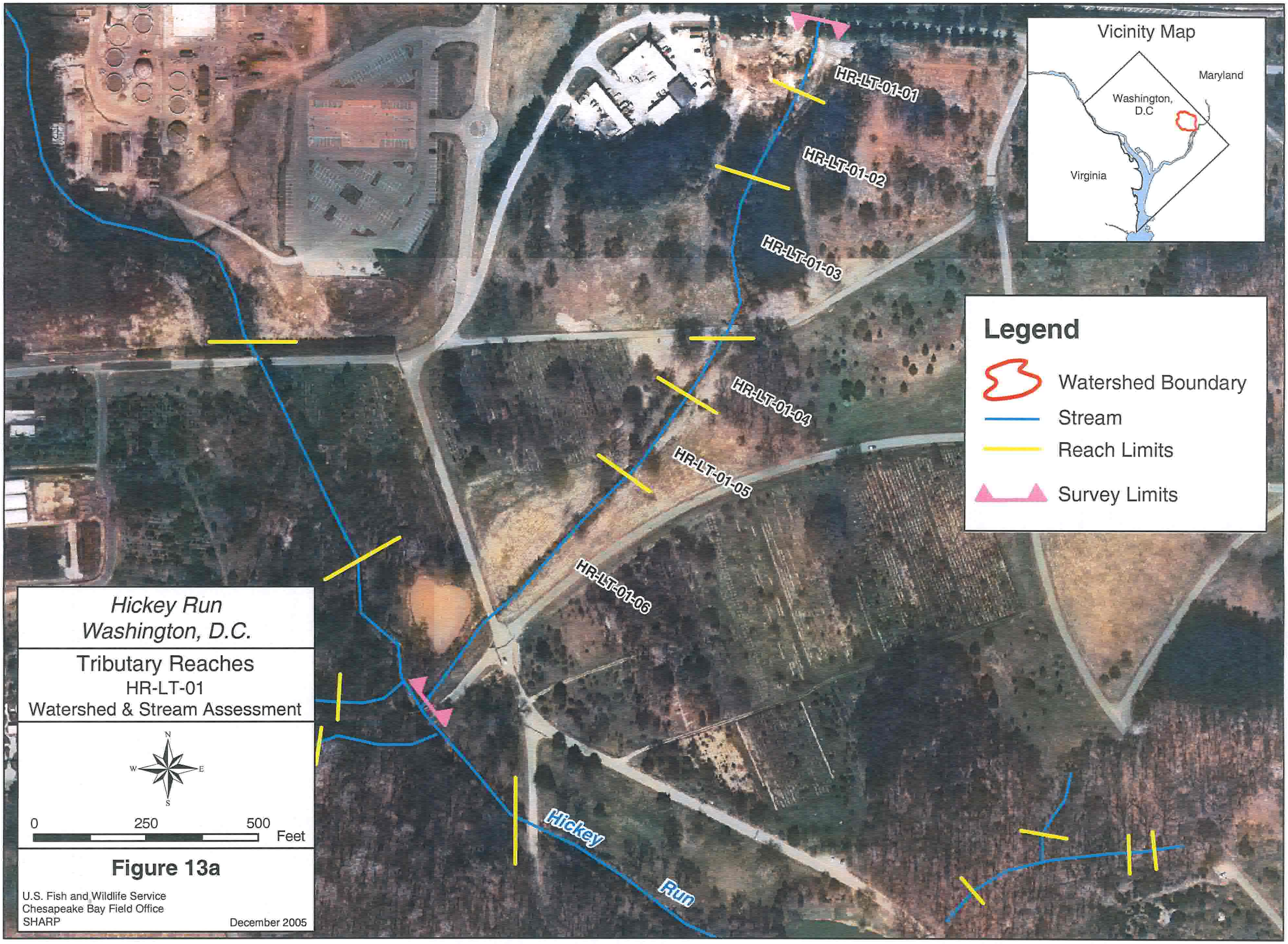
Streams within a watershed form a drainage network that is often dendritic in appearance, with tributary streams joining both one another and the main stem of the stream (Gordon et al, 1992). Drainage from the top of the watershed may occur in swales or intermittant streams that flow only during rain events. Perennial streams occur when the groundwater is high enough to provide baseflow into the stream even during dry weather. In an undeveloped watershed, tributary streams have been estimated to drain approximately 50 percent of the watershed (Gordon et al, 1992). In urban situations, many of the smaller tributaries are eliminated, either by grading, or by conversion of the stream to drainage pipes, thus there may be a significant loss of stream miles (Dunne and Leopold 1978).

Hickey Run has six small tributaries; all located on Arboretum property (Table 1 and Figures 13a – 13d). Total stream length of the tributaries is approximately 5,700 linear feet. Three of the tributaries (HR-LT-01, HR-LT-02, and HR-RT-01) were part of the stream network in the unaltered watershed in 1861, but the other three (HR-LT-03, HR-RT-02, and HR-RT-03) are either man-made or developed due to increased runoff after land use changes. Three tributaries (HR-LT-02, HR-LT-03 and HR-RT-03) connect to the main stem via pipes. All the tributaries, except where piped and HR-LT-01 and HR-RT-03, appear physically unaltered by channelization activities and are free to adjust naturally. HR-LT-01 has had extensive channelization activities in the past and HR-RT-03 has a significant amount of bank and bed stabilization structures throughout the tributary as well as an inline pond. Instream habitat conditions are fair to good in most tributaries, but poor in others. The riparian buffer ranges in width from 20 to 1,300 feet and consists mostly of mature woodlands with some areas of woody shrubs and non-native species. Overall, the tributaries are relatively stable (72 percent vertically stable, 68 percent laterally stable), and only slightly incised (60 percent rated as low to moderate), but a majority (51 percent) have a very high potential sediment supply. Recovery potential of the degraded areas is poor and will only occur if the cause of the instability is corrected.

The Service delineated 28 separate stream reaches, representing twelve different Rosgen stream types, within the six tributaries based on geomorphologic character and stability conditions. The twelve Rosgen stream types include A4, A5, B4, B5, C4, C5, E4, E5, F4, F5, G4, and G5. Rosgen A stream types are steep, entrenched and confined channels that are highly sensitive to disturbance and have a poor recovery potential (Photograph 1) (Note: All photographs are located in Appendix A). Entrenchment is the vertical containment of a stream and the degree of incision into the valley floor. A stream that is highly entrenched has a narrow floodplain width

Table 1. Hickey Run Tributary Characterization and Stability Summary

Hickey Run Tributaries		Rosgen Stream Type	Reach Length (ft)	Bankfull Width (ft)	Riparian Buffer Width (Range, ft)	Instream Habitat	Bank Height (Range, ft)	Incision	Vertical Stability	Lateral Stability	Sediment Supply	Disturbance Sensitivity	Recovery Potential
HR-LT-01	HR-LT-01-01	B4	248	12	+/- 50	Fair	4 - 5	Moderat	Stable	Stable	Moderate	Moderate	Excellent
	HR-LT-01-02	C4	185	13	+/- 100	Fair	2 - 3	Low	Stable	Stable	High	Very high	Good
	HR-LT-01-03	F4	340	11	+/- 50	Fair	2 - 3	Low	Stable	Stable	Very high	Extreme	Poor
	HR-LT-01-04	F4	207	10	+/- 20	Poor	4 - 6	High	Degrading	Unstable	Very high	Extreme	Poor
	HR-LT-01-05	F4	190	10	+/- 20	Poor	3 - 5	High	Stable	Unstable	Very high	Extreme	Poor
	HR-LT-01-06	F4	655	7	+/- 20	Fair	3 - 6	High	Stable	Localized instability	Very high	Extreme	Poor
	Reach Total		1,170										
HR-LT-02	HR-LT-02-01	A5	50	2	+/- 350	Fair	1 - 2	Low	Stable	Stable	Very high	Extreme	Very poor
	HR-LT-02-02	Pipe	30	N/A	+/- 350	Poor	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	HR-LT-02-03	B5	320	3	350 - 1300	Fair	1 - 5	Low	Stable	Stable	Moderate	Moderate	Excellent
	HR-LT-02-04	C5	200	10	+/- 1300	Fair	1 - 3	Low	Stable	Stable	Very high	Very high	Fair
	Reach Total		600										
	HR-LT-02 RT-01-01	E5	150	2	+/- 740	Poor	0.5 - 2	Low	Stable	Stable	Moderate	Very high	Good
	HR-LT-02 RT-01-02	G5	50	3	+/- 740	Poor	2 - 4	High	Degrading	Unstable	Very high	Extreme	Very poor
	Reach Total		200										
HR-LT-03	HR-LT-03-01	G5	43	3	+/- 560	Poor	2 - 3	High	Degrading	Unstable	Very high	Extreme	Very poor
	HR-LT-03-02	E5	230	3 - 4	+/- 560	Poor	0.5 - 1	Low	Stable	Stable	Moderate	Very high	Good
	HR-LT-03-03	G4	45	2 - 3	+/- 560	Poor	0.5 - 3	High	Degrading	Unstable	Very high	Extreme	Very poor
	HR-LT-03-04	A4	140	3 - 4	+/- 560	Poor	2 - 3	High	Stable	Stable	Very high	Extreme	Very poor
	Reach Total		458										
HR-RT-01	HR-RT-01-01	G5	182	+/- 6	+/- 1100	Poor	6 - 8	High	Degrading	Unstable	Very high	Extreme	Very poor
	HR-RT-01-02	F4	378	+/- 7	+/- 1100	Poor	3 - 5	High	Degrading	Unstable	Very high	Very high	Poor
	HR-RT-01-03	F5	70	+/- 10	+/- 1100	Fair	6 - 8	High	Stable	Unstable	Very high	Very high	Poor
	Reach Total		630										
HR-RT-02	HR-RT-02-01	B4	190	3 - 5	+/- 1100	Fair	8 - 12	Low	Degrading	Unstable	Moderate	Moderate	Excellent
	HR-RT-02-02	C4	145	3 - 5	+/- 1100	Fair	1 - 3	Low	Stable	Localized instability	High	Very high	Good
	HR-RT-02-03	G4	245	4 - 6	+/- 1100	Poor	6 - 12	High	Degrading	Unstable	Very high	Extreme	Very Poor
	Reach Total		580										
HR-RT-03 (Fern Valley)	HR-RT-03-01	Swale	109	2.5	200 - 550	Poor	0.5 - 1	Low	Stable	Stable	N/A	N/A	N/A
	HR-RT-03-02	Piped	116	N/A	200 - 550	Poor	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	HR-RT-03-03	B4	406	7	200 - 550	Fair	2.5 - 8	Low	Stable	Stable	Moderate	Moderate	Excellent
	HR-RT-03-04	C4	277	9	200 - 550	Fair	2.5 - 8	Low	Stable	Stable	High	Very high	Good
	HR-RT-03-05	E5	127	6	200 - 550	Poor	2.5	Low	Stable	Stable	Moderate	Very high	Good
	HR-RT-03-06	E4	313	7	200 - 550	Fair	2.5	Low	Stable	Stable	Moderate	Very high	Good
	Reach Total		1,348										


Vicinity Map
Washington, D.C
Maryland
Virginia
Legend
Watershed Boundary
Stream
Reach Limits
Survey Limits
HR-LT-01-01
HR-LT-01-02
HR-LT-01-03
HR-LT-01-04
HR-LT-01-05
HR-LT-01-06
Hickey
Run
Hickey Run
Washington, D.C.
Tributary Reaches
HR-LT-01
Watershed & Stream Assessment
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W
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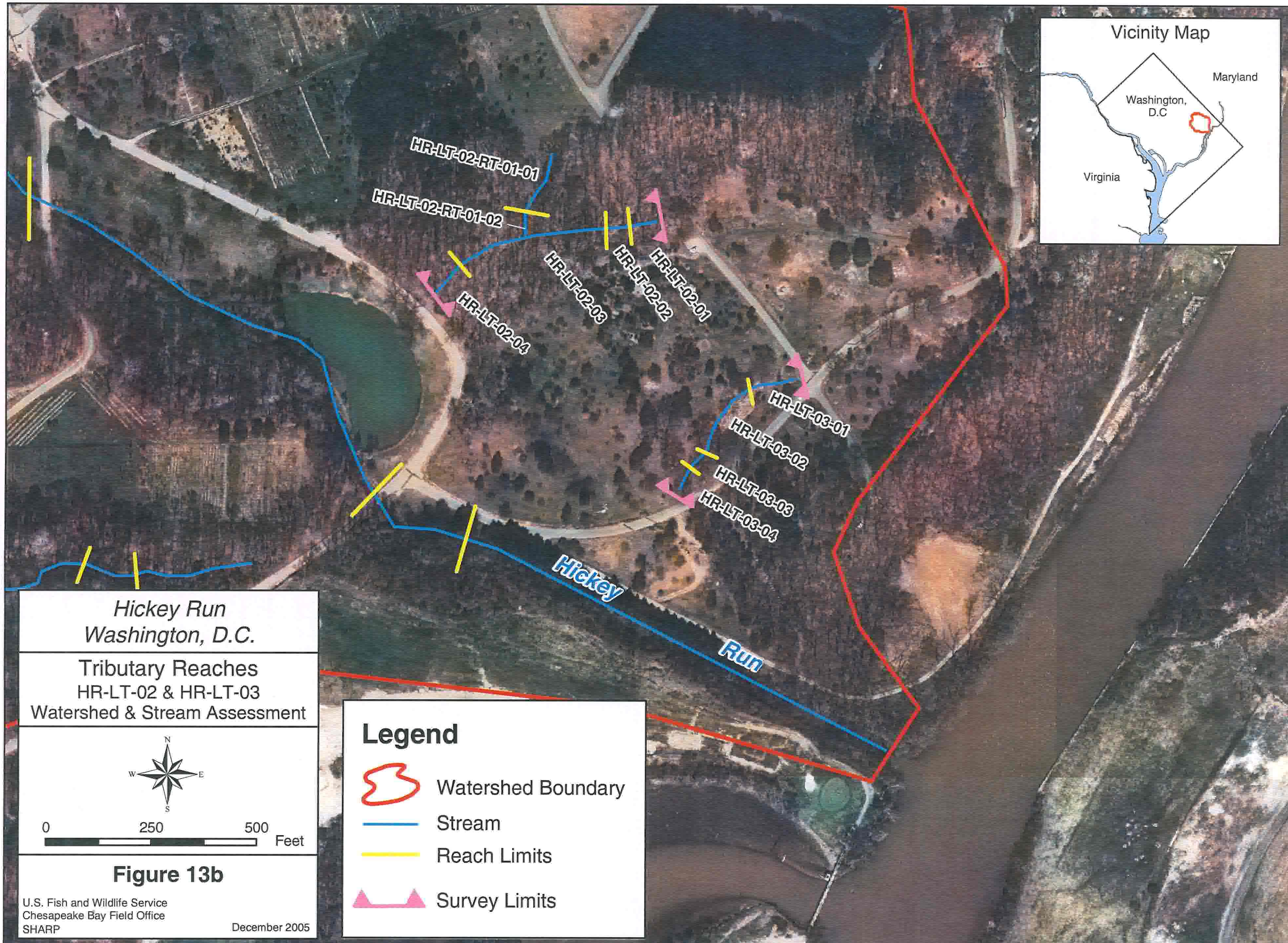
250
500
Feet
Figure 13a
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
SHARP
December 2005


Vicinity Map
Maryland
Washington, D.C
Virginia
HR-LT-02-RT-01-01
HR-LT-02-RT-01-02
HR-LT-02-01
HR-LT-02-02
HR-LT-02-03
HR-LT-02-04
HR-LT-03-01
HR-LT-03-02
HR-LT-03-03
HR-LT-03-04
Hickey Run
Hickey Run
Washington, D.C.
Tributary Reaches
HR-LT-02 & HR-LT-03
Watershed & Stream Assessment
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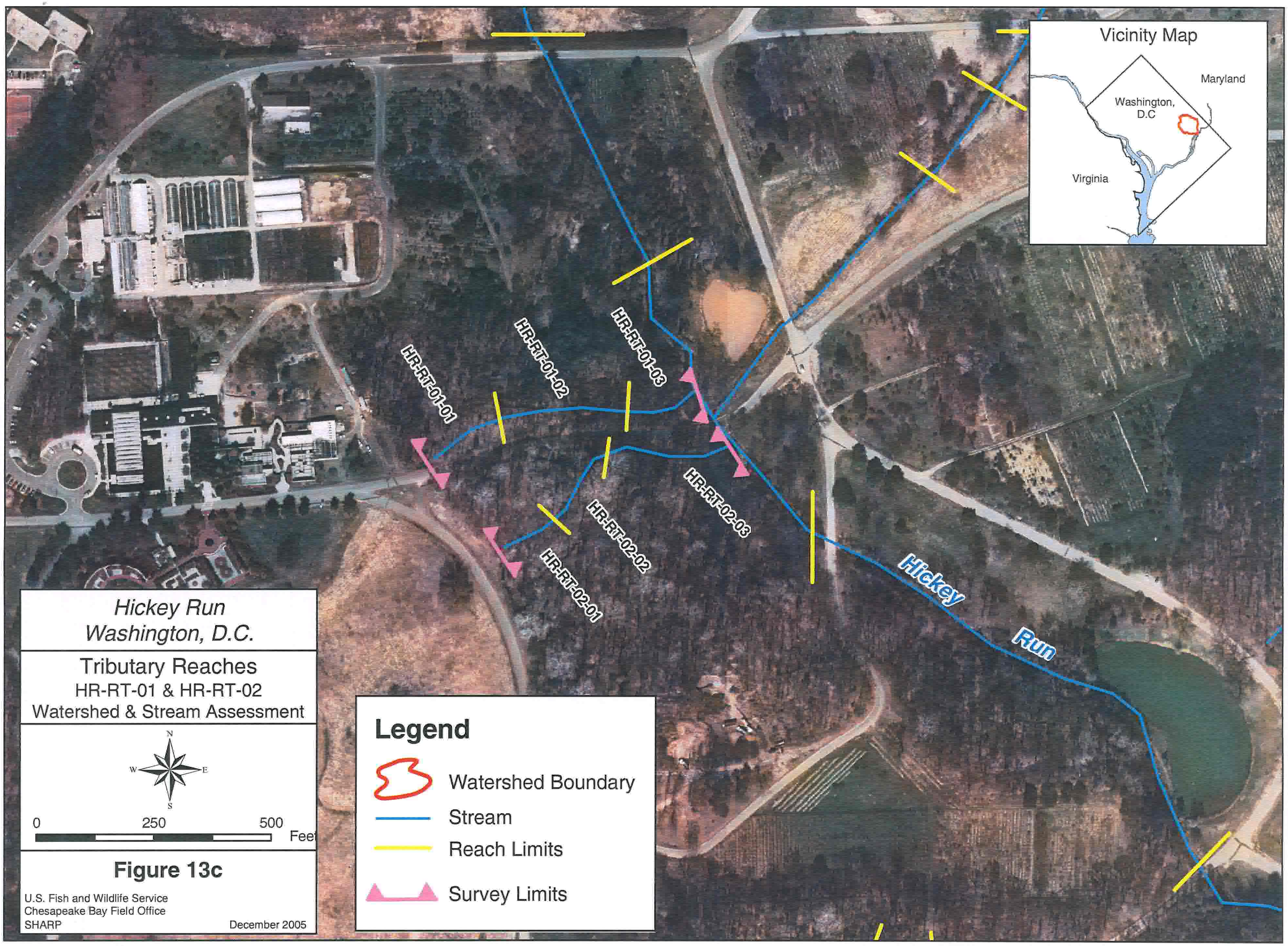
Watershed Boundary
Stream
Reach Limits
Survey Limits
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
SHARP
December 2005
Figure 13b


Vicinity Map
Maryland
Washington, D.C
Virginia
HR-RT-01-01
HR-RT-01-02
HR-RT-01-03
HR-RT-02-01
HR-RT-02-02
HR-RT-02-03
Hickey Run
Hickey Run
Washington, D.C.
Tributary Reaches
HR-RT-01 & HR-RT-02
Watershed & Stream Assessment
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250
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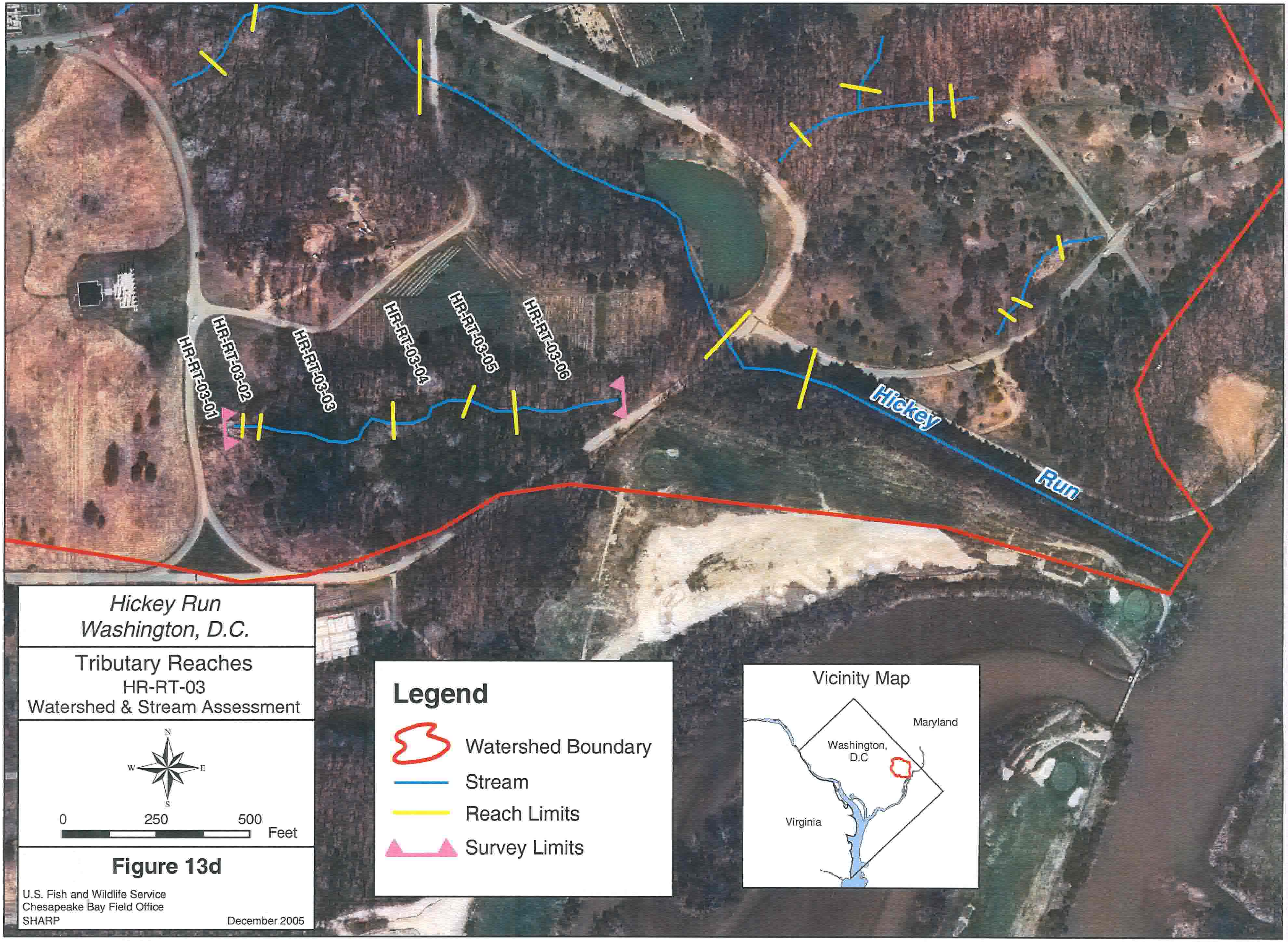
Feet
Figure 13c
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
SHARP
December 2005
Legend
Watershed Boundary
Stream
Reach Limits
Survey Limits


HR-RT-03-01
HR-RT-03-02
HR-RT-03-03
HR-RT-03-04
HR-RT-03-05
HR-RT-03-06
Hickey Run
Hickey Run
Washington, D.C.
Tributary Reaches
HR-RT-03
Watershed & Stream Assessment
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250
500
Feet
Figure 13d
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
SHARP
December 2005
Legend
Watershed Boundary
Stream
Reach Limits
Survey Limits
Vicinity Map
Maryland
Washington, D.C
Virginia

as opposed to a stream that is slightly entrenched which has a large floodplain width. These stream types generally exist in the headwater areas of the tributaries with slopes of typically four percent or greater.

Rosgen B stream types are moderately entrenched, low sinuosity channels with a slope of two to four percent, are moderately sensitive to change, and have an excellent recovery potential (Photograph 2). Sinuosity is the ratio of the stream length to valley length. A stream with high sinuosity has many meandering bends and a stream with low sinuosity is nearly straight. These stream types also generally exist in headwater areas of the tributaries.

Rosgen C stream types are slightly entrenched, low gradient, meandering riffle/pool channels with a well developed floodplain that are highly sensitive to disturbance but have a good recovery potential (Photograph 3). These stream types generally exist where there are low valley slopes and relatively large floodplain areas.

Rosgen E stream types are slightly entrenched, low gradient, meandering channels with low width/depth ratios and well developed floodplains. These stream types are highly sensitive to disturbance but have good recovery potential (Photograph 4). Width/depth ratio is the ratio of the bankfull surface width to the mean depth of the bankfull channel. Streams with high width/depth ratios are wide and shallow and streams with low width/depth ratios are narrow and deep. These E type reaches also generally exist where there are flat valley slopes and relatively large floodplain areas.

Rosgen F stream types are highly entrenched, low gradient, and incised channels that are highly sensitive to disturbance and have a poor recovery potential (Photograph 5). Incision is the ratio of the bankfull height to the top of bank height. Streams with a large elevation difference between bankfull and top of bank height have a high incision ratio and streams with a small elevation distance between bankfull and top of bank height have a low incision ratio. They are also typically considered unstable, transitional streams that were once a Rosgen A, B, C, or E stream type. These stream types generally exist throughout the watershed where there has been some type of disturbance.

Rosgen G streams are highly entrenched, moderately steep, incised channels that are highly sensitive to disturbance and have a very poor recovery potential (Photograph 6). They are similar to Rosgen F stream types in that they are typically considered unstable, transitional streams that generally exist throughout the watershed where there has been some type of disturbance.

b. Reach Characterizations

<u>HR-LT-01</u> - The HR-LT-01 tributary (Springhouse Run) is a remnant of one of the original tributaries that originates from a 60-inch diameter outfall south of New York Avenue. The Service identified six stream reaches within this tributary consisting of three Rosgen stream types (F4, C4, and B4), with the F4 stream type representing the majority of the tributary.

Bankfull widths range from 7 to 13 feet, bank heights range from 2 to 6 feet, channel incision is low to high, riparian buffer widths (consisting primarily of invasive exotics) range from 20 to 100 feet, pools and riffles are poorly to moderately defined, and instream habitat is mostly fair with some poor sections (Photograph 7).

The majority of the tributary is stable (80 percent laterally and 90 percent vertically stable) although highly altered and armored, in most areas. Since the majority of the HR-LT-01 tributary is an entrenched, Rosgen F4 stream type, large flood flows are contained within the stream resulting in a very high erosion potential, extreme sensitivity to disturbance, and a poor recovery potential. The armoring and dense riparian vegetation are currently resisting the erosive energy of the large flood flows, but if compromised, which is possible and starting to occur in some areas, widespread stream instability will occur resulting in severe instream habitat degradation and significant increases in sediment supply.

There is one short reach, HR-LT-01-02, that is stable transition reach, with respect to morphology (Photograph 8). The reach is a Rosgen C4 stream type that is connected to its floodplain, has well-defined pools and riffles and good instream habitat. While this reach exists within the natural setting of the USNA, its headwaters are highly developed and is an excellent example of a stable stream existing within a predominantly urban watershed.

<u>HR-LT-02</u> - The HR-LT-02 tributary is also a remnant of one of the original tributaries that originates from a 24-inch diameter outfall, with a portion of the stream's base flow coming from spring water, and connects to Hickey Run via a pipe. The Service identified four stream reaches within this tributary consisting of three Rosgen stream types (A5, B5, and C5) and one small reach, near the headwaters that is piped. Bankfull widths range from 2 to 10 feet, bank heights range from 1 to 5 feet, channel incision is low, riparian buffer widths (consisting primarily native mature hardwoods) range from 350 to 1300 feet, pools and riffles are moderately defined and instream habitat is mostly fair with some poor sections (Photograph 9). The tributary is stable, but has a moderate to high erosion potential, very high to extreme sensitivity to disturbance and very poor to fair recovery potential. As long as the mature hardwood riparian buffer remains and no physical alterations occur to the stream, this tributary should remain healthy and stable.

<u>HR-LT-02-RT-01 and 02</u> – The HR-LT-02-RT-01-01 and 02 are reaches to an ephemeral tributary of HR-LT-02 approximately 200 feet upstream of Valley Road. The existence of this tributary is recent, most likely because of broken drain tiles, and therefore cutting a new channel into the valley floor (Photograph 10). HR-LT-02-RT-01-02 is an unstable Rogen G5 stream type and HR-LT-02-RT-01-01 is a stable Rosgen E5 stream type both 2 to 3 feet wide. HR-LT-02-RT-01-02 has three major headcuts (totaling 7 to 8 feet in vertical height) actively eroding upstream into HR-LT-02-RT-01-01 (Photograph 11). The head cuts probably formed as the stream's energy increased where the flows drop over the steep valley slopes before entering HR-LT-02. Even though it is a small stream, there are significant impacts to the downstream reaches on HR-LT-02 because of the sediment produced from the eroding headcuts. If not addressed, the headcuts will continue to move upstream farther, degrading HR-LT-02-RT-01 and impacting the HR-LT-02 reaches downstream of HR-LT-02-RT-01.

HR-LT-03 - The HR-LT-03 is not one of the original tributaries and originates from one 18-inch and two 12-inch diameter outfalls below Holly Spring Road and connects to Hickey Run via a pipe. The Service identified four stream reaches within this tributary consisting of four Rosgen stream types (A4, E5, G4, and G5). The tributary is ephemeral, bankfull widths range from 2 to 3 feet, bank heights range from 0.5 to 3 feet, channel incision is low to high, riparian buffer widths (consisting of mowed grass and landscaped planting bed with perennials and woody shrubs) range from 500 to 600 feet, pools and riffles are poorly defined and instream habitat is poor (Photograph 12).

HR-LT-01-04 (the farthest downstream reach) formed before the other three reaches. HR-LT-03-01, HR-LT-03-02, and HR-LT-03-03 formed within the last three to five years, most likely because of a recently broken stormwater pipe. The stormwater runoff that originally flowed through the broken pipe, now flows across the ground and has formed a new open channel. Only 18 percent of the tributary is vertically and laterally unstable. However, the instability is significant because it is associated with three actively eroding headcuts. One headcut (2 to 3 foot vertical height) exists at the downstream end of HR-LT-03-03 (Photograph 13). . The other two headcuts (1 to 2 foot vertical height) are on HR-LT-03-01 (Photographs 14 and 15). If these headcuts are not addressed, there will be wide spread instability throughout the majority of the tributary. The tributary has a moderate to very high erosion potential, very high to extreme sensitivity to disturbance and mostly a very poor recovery potential.

HR-RT-01 - The HR-RT-01 is a remnant of the original tributaries, which had a drainage area that included a portion of Mt.Olive cemetery and the neighborhood around 24th Street. Now the headwaters are a stormwater mangament pond near the main USNA building complex, which flows through a pipe under Meadow Road, daylighting out of an 18-inch outfall. Two other stormwater outfalls empty into this tributary: one (24 inches in diameter) near the confluence with Hickey Run and the other (36 inches in diameter) at the downstream end of Reach 1. The Service identified three stream reaches within this tributary consisting of three Rosgen stream types (G5, F4, and F5). Bankfull widths range from 6 to 10 feet, bank heights range from 3 to 8 feet, channel incision is high, riparian buffer width (consisting of native and non-native woody shrubs and canopy trees) is approximately 1,100 feet, pools and riffles are poorly defined and instream habitat is poor (Photograph 16).

The entire tributary is unstable and has a very high erosion potential, very high to extreme sensitivity to disturbance and poor to very poor recovery potential. The widespread instability is a direct result of urbanization, piping of stormwater flows, and the downcutting of Hickey Run main stem. There is a 10-foot vertically high headcut actively eroding at the start of the tributary caused by the 18-inch outfall, which is now failing (Photograph 16). There are two utility line crossings acting as vertical grade control. The larger one is the District of Columbia, Water and Sewer Authority (WASA) Eastside Interceptor sewer line, which is 72 inches in diameter and encased in concrete. There is a 10 to 12 foot streambed vertical elevation difference between the upstream side of the sewer line to the downstream side.

The USNA is currently constructing a new stormwater management pond, as part of a new trail and walkway area, to replace the existing stormwater pond. The new pond would transfer all stormwater flows from HR-RT-01 to HR-RT-02. This reduction of stormwater flows to HR-RT-01 will reduce erosive forces, but the tributary has such severe instability problems that self-recovery is unlikely.

HR-RT-02 - The HR-RT-02 tributary may have actually been a tributary to HR-RT-01, but when Meadow Road was constructed, the tributary may have been re-routed to confluence with Hickey Run. It also originates from the same stormwater management pond as HR-RT-01 and is piped under Ellipse Road, daylighting out of a 24-inch diameter outfall perched 2.5 feet above the streambed. The Service identified three stream reaches within this tributary consisting of three Rosgen stream types (B4, C4, and G4). Bankfull widths range from 3 to 6 feet, bank heights range from 1 to 12 feet, channel incision is low to high, riparian buffer width (consisting of native and non-native woody shrubs and canopy trees) is approximately 1,100 feet, pools and riffles are poorly to moderately defined and instream habitat is poor to fair (Photograph 17).

Seventy five percent of the tributary is unstable and has a very high erosion potential, very high to extreme sensitivity to disturbance and poor to very poor recovery potential. In HR-RT-02-01 streambanks are eroding at the toe and experiencing slope failure. There are three headcuts actively eroding: two (12 and 18 inches in vertical height) on HR-RT-02-01 and the third one (48 inches in vertical height) is on HR-RT-02-03 near the upstream end of the reach (Photographs 18, 19, and 20). The widespread instability is also a direct result of urbanization, piping of stormwater flows, and the downcutting of Hickey Run main stem. The only stable section of the tributary (HR-RT-02-02) is a result of the Eastside Inceptor sewer line, which also crosses this tributary, acting as grade control and not allowing the reach to downcut. Below the crossing, the bed of reach HR-RT-02-03 is 7 feet lower than the bed upstream of the crossing.

The Service is unable to predict the effects of increasing stormwater flows from the new stormwater pond, currently under construction, to HR-RT-02 because existing flow data was not available to compare to the proposed new flows. Typically, increased stream flows cause stream adjustments and instability problems. However, the Service does not know how the proposed stormwater pond will alter stream flows.

HR-RT-03 - The HR-RT-03 (Fern Valley) tributary is not one of the original tributaries and connects to Hickey Run via a pipe. The headwaters are a grassy swale (HR-RT-03-01) that drains into a 6-inch pipe (HR-RT-03-02) and daylights out into HR-RT-03-03. The Service identified six stream reaches within this tributary consisting of four Rosgen stream types (B4, C4, E4, and E5). Bankfull widths range from 6 to 9 feet, bank heights range from 0.5 to 8 feet, channel incision is low, riparian buffer widths (consisting of native and non-native woody shrubs and canopy trees) range from 200 to 500 feet, pools and riffles are moderately to well defined and instream habitat is poor to fair (Photograph 21).

The entire tributary is stable, with some localized erosion, and has a moderate to high erosion potential, moderate to very high sensitivity to disturbance and good to excellent recovery potential. Although the tributary is currently stable, there is a potential for widespread instability to occur if the existing bank protection and grade control structures fail. There is a variety of bank armoring and grade control methods existing throughout this tributary that include dry stacked stonewalls, mortared stonewalls, timber cribbing, concrete, and large rip rap. Some of the bank armoring and grade control structures appear to be structurally sound and effective in providing bank and bed protection. However, some other armored banks and grade control structures are beginning to show signs of potential failure.

At the upstream end of HR-RT-03-03, where the stream daylights from a pipe, there is a 6-foot headcut that large rip rap was used to stop the erosion. The rip rap does not appear to have any footers and there is a potential for the stream to under cut the rip rap and continue eroding upstream is moderate to high. If the rip rap is able to dissipate the energy of the flows coming from the pipe, then the upward movement of the headcut may be halted. Farther downstream on HR-RT-03-03 there is timber cribbing and a concrete check dam that have the potential to fail and no longer provide bank and bed protection because of current stream undermining (Photograph 22).

On HR-RT-03-04 there are mortared stonewalls and a concrete check dam that also have the potential to fail because of stream undermining. This reach also has some localized bank erosion occurring on the left bank at the upstream end of the reach. The eroding bank is approximately 40 feet long and 5 to 6 feet high and if not addressed will continue to erode until stabilized (Photograph 23).

On HR-RT-03-05 there is an instream pond and a log check dam. The pond has a 6 to 7-foot high mortared stone dam and appears to be structurally sound. The log check dam was recently installed by the USNA to help reduce the bank erosion occurring around the stonewalls upstream. However, this method will not address that problem and is already causing localized bank erosion as the stream flows around the check dam. This check dam should be removed in order to prevent any further streambank erosion.

3. Mainstem

a. General Characterization

The only remaining portion of Hickey Run main stem that is not piped, approximately 5,200 linear feet, exists solely on the USNA and NPS properties. The Service partitioned the mainstem of Hickey Run into six reaches based on geomorphologic character and stability conditions and designated the reaches HR-01 through HR-06 (Figure 14, Tables 2 and 3). The Service assessed the stability conditions of all six reaches and conducted detailed characterization surveys of reaches HR-01, HR-03, HR-04, and HR-06. The Service did not conduct a detail characterization survey of reaches HR-02 and HR-05 because HR-02 is a concrete lined channel and HR-05 is a short transition reach between HR-04 and HR-06. The Service identified three Rosgen stream types: HR-01 as a G3c, HR-03 as a B4c, and HR-04 as a F5. The Rosgen

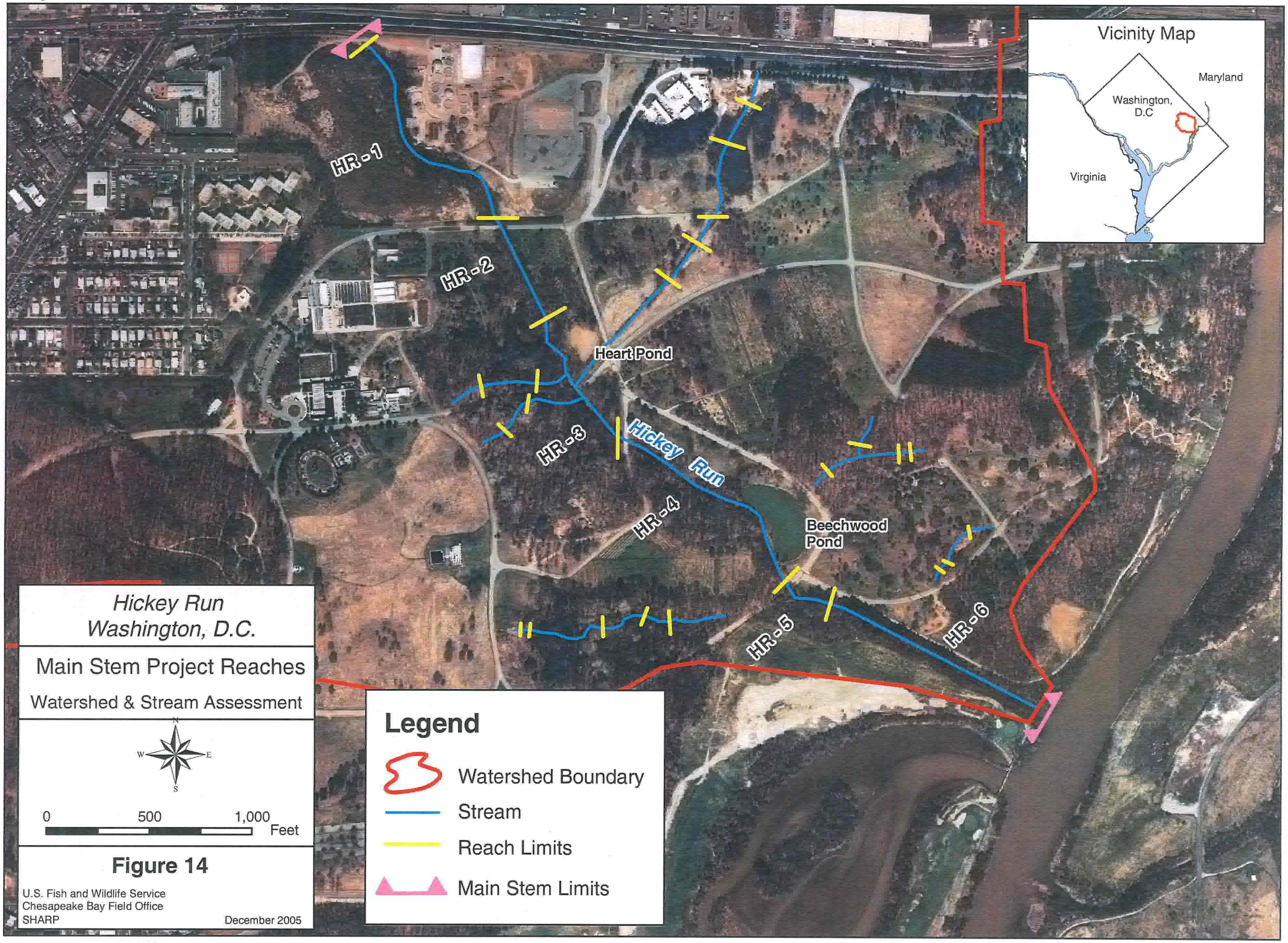
Vicinity Map
Maryland
Washington, D.C
Virginia
HR-1
HR-2
HR-3
HR-4
HR-5
HR-6
Heart Pond
Hickey Run
Beechwood Pond
Hickey Run
Washington, D.C.
Main Stem Project Reaches
Watershed & Stream Assessment
N
W
E
S
0
500
1,000
Feet
Figure 14
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
SHARP
December 2005
Legend
Watershed Boundary
Stream
Reach Limits
Main Stem Limits

Table 2. Hickey Run Classification Summary

Reach	Reach Length (ft)	Rosgen Stream Type	Cross Sectional Area (ft^2)	Bankfull Width (ft)	Mean Bankfull Depth (ft)	Width/ Depth Ratio	Entrenchment Ratio	Sinuosity	Stream Slope (ft/ft)	Bankfull Discharge (cfs)	Riparian Buffer Width (ft)	
											Left Bank	Right Bank
HR-01	1170	G3c	53.51	19.48	2.75	7.09	1.63	1.10	0.0070	188	30-70	430
HR-02	544	N/A[1]									50-250	430
HR-03	762	B4c	60.55	34.00	1.78	19.09	1.65	1.08	0.0046	218	0-100	710
HR-04	1186	F5	45.89	23.28	11.81	26.70	1.15	1.05	0.0019	172	10-70	300
HR-05	268	N/A[1]									20-100	270
HR-06	1206	N/A[1]									10-350	100-270

N/A[1] - HR02 is a concrete lined channel, HR05 is a transition reach, and HR06 is tidally influenced; none of which apply to the Rosgen classification system.

Table 3. Hickey Run Stability and Erosion Summary

Reach	Pfankuch Channel Stability	Vertical Stability	Lateral Stability	Enlargement Potential	Sediment Supply	Predicted Erosion		Disturbance Sensitivity	Recovery Potential
						Tons/yr	Tons/yr/ft		
HR-01	Stable	Stable	Stable	Stable	Low	43	0.04	Low	Poor
HR-02	N/A[1]	Stable	Stable	Stable	Stable	N/A[2]	N/A[2]	N/A[1]	N/A[1]
HR-03	Poor	Stable	Unstable	Slight Increase	High	190	0.25	Very High	Good[3]
HR-04	Poor	Degrading	Unstable	Moderate Increase	Very High	329	0.28	Very High	Poor
HR-05	Poor	Stable	Unstable	Stable	High	83	0.31	N/A[1]	N/A[1]
HR-06	N/A[1]	Degrading	Unstable	Moderate Increase	Very High	454	0.38	N/A[1]	N/A[1]

N/A[1] – Pfankuch, disturbance sensitivity, recovery potential are based on Rosgen stream type and HR02 is a concrete lined channel, HR05 is a transition reach, and HR06 is tidally influenced; none of which apply to the Rosgen classification system.
N/A[2] – HR-02 is a concrete lined channel.
Good – Recovery Potential[3] - HR-03 is actively adjusting, therefore the recovery potential is based on what the stream is adjusting to: a C4 stream type.

classification did not apply to HR-02 because it is a concrete lined channel and HR-06 since it is tidally influenced. The entire main stem has been physically altered and nearly half of it has been hardened into place with either large rip rap or concrete. In most areas where it has not been hardened, it is actively eroding (67 percent laterally and 47 percent vertically adjusting).

Fifty seven percent of the reaches are severely incised and entrenched. Instream habitat diversity and cover is poor to moderate. Water quality is impaired by urban runoff, sewer line leaks, and past petroleum leaks. The riparian buffer varies from mowed grass to wide, mature woodlands. The potential sediment supply is very high. The Service determined approximately 1,000 tons of sediment erodes from the streambanks of Hickey Run annually. The potential for Hickey Run to recover on its own, given its current condition, is poor.

b. Reach Characterizations

HR-01 - Reach HR-01 originates from a stormwater pipe emerging from below New York Avenue (Route 50). It flows along the western side of the old brick kiln area, and terminates at Hickey Lane. This reach is a Rosgen type stream G3c (Photograph 24). The stream has a bankfull width of 20 feet, a bankfull depth of 2.7 feet, a cross-sectional area of 54 square feet, bank heights range from 7.5 to 10.5 feet, channel incision is low, and instream habitat is fair with moderately well defined pools and riffles. Riparian buffer width ranges from 30 to 430 feet and consist of new growth forest (5 to 15 years old) with understory shrubs.

A stream with a Rosgen G3c stream classification is typically unstable. However, HR-01 is stable, with some localized bank erosion, because of large riprap that armors the channel bed and banks. The stream was probably eroding severely sometime in the past, which would explain the G3c classification, and riprap was used to stop the erosion and in this case, it was effective. The streambanks also have added stability because of the woody vegetation that has established throughout the riprap. All banks have a low to moderate potential for erosion. The potential for sediment supply is low, but the stream has a very high sensitivity to disturbance. The only infrastructure in this area is the remains of a abandoned bridge. The reach is likely to remain stable under the current watershed conditions and flow regime. However, since the stream has a poor recovery potential, those few areas of localized erosion should be stabilized and instream habitat should be improved.

HR-02 - Reach HR-02 begins just upstream of Hickey Lane, and is a concrete lined channel. The channel was constructed during two different time periods, and the cross-sections differ significantly. In the upstream portion of the reach, the walls are vertical and 7 feet high with a channel width of 14 feet (Photograph 25). Although the bottom of the channel is also concrete, some gravel has accumulated on the bed. This reach is structurally sound and will most likely continue to provide stability, but lacks instream habitat.

The downstream section of the concrete lined channel appears to be older than the one upstream. It is 10 feet wide, has vertical concrete walls 3 feet high, and the upper section of the bank is laid back at a 45 degree angle covered with mortared riprap and some annual vegetation (Photograph 26). The stream is eroding behind the wall in various sections. There have been attempts to repair the failing sections, with grout and additional rocks, but erosion continues and will most likely continue, resulting in significant sediment input to the stream.

The current Eastside Interceptor sewer line crosses Hickey Run at the downstream end of this reach (Photograph 27). The sewer line crosses the stream at 45-degree angle, is elevated approximately 5 to 6 feet above the stream, and is currently restricting flood flows.

<u>HR-03</u> - Reach HR-03 begins downstream of the sewer line crossing and ends at the Beechwood Road bridge. Three tributaries, HR-RT-01, HR-RT-02, and HR-LT-01 flow into Hickey Run at the downstream end of this reach. The reach is a Rosgen stream type B4c that is adjusting to a C4 (Photograph 28). It has a bankfull width of 34 feet, a bankfull depth of 1.78 feet, and a cross-sectional area of 61 square feet. Banks are generally 6 to 7 feet in height, but range from 3.5 to 20 feet and channel incision is low. Instream habitat is fair with moderately well defined pools and riffles, but there are a significant number of bricks in the bed material that originate from a historic brick making company. Riparian buffer width generally ranges from 0 to 710 feet consisting of mature forest, but there is a section of the reach, near Heart Pond, that has mowed grass.

This reach is vertically stable, but has widespread lateral instability. The stream is attempting to rebuild a floodplain and increase sinuosity within the remnant Rosgen F4 stream type. Forty-one percent of the banks have a moderate or greater potential for erosion. One of the most significant areas of lateral erosion is on the left bank near Heart Pond (Photograph 29). The potential for sediment supply is high and disturbance sensitivity is very high. Although the reach has a good recovery potential, significant adjustments need to occur for the stream to reach a stable channel dimension, pattern and profile. During that adjustment period, significant inputs of sediment will occur with adverse impacts to aquatic species and instream habitat.

<u>HR-04</u> - Reach HR-04 extends from Beechwood Road bridge to Crabtree Road bridge, running alongside Beech Spring Pond at the downstream end of the reach. This reach is a Rosgen stream type F5 (Photograph 30). Bankfull width is 34 feet, bankfull depth is 1.9 feet, and cross-sectional area is 63 square feet. Bank heights range from 6 to 8.5 feet and channel incision is high. Instream habitat is poor with poorly defined pools and riffles. Riparian buffer width ranges from 10 to 300 feet and consists of woody shrubs on the left bank and a mature woodland forest on the right bank.

Reach HR-04 is laterally and vertically unstable. The stream is severely incised and nearly straight, most likely because of past channelization activities. Because of its severe incision, large flood flows are contained within the channel and is the primary cause of stream instability. Eighty-six percent of the banks have a moderate or greater potential for erosion. However, the right bank adjacent to Beech Spring Pond is armored with large riprap and stable. There is also a significant fish barrier at the downstream edge of the Crabtree Road bridge. The bridge culvert is perched two feet above the base flow because of active bed erosion. This reach has a very high sediment load potential, very high disturbance sensitivity, and poor recovery potential.

HR-05 – Reach HR-05 a short transitional reach between HR-04 and the tidally influenced HR-06. It begins just downstream of Crabtree Road bridge and ends just upstream of the large concrete wall on the left bank of HR-06. It is very similar to the geomorphic character and stability condition of HR-03(Photograph 31). The approximate stream dimensions are 38 feet wide and 1.5 feet deep. Bank heights range from 7 to 10 feet and channel incision is low. Instream habitat is fair with moderately well defined pools and riffles. The riparian buffer width ranges from 20 to 270 feet and consists of a mature woodland forest.

HR-05 is vertically stable, but laterally unstable. It is attempting to increase its sinuosity and rebuild a flood plain by actively eroding its banks. Seventy-six percent of the banks have a moderate or greater potential for erosion. This reach has a high sediment supply potential and very high sensitivity to disturbance. Like HR-03, it has a good recovery potential, but significant adjustments are needed for the stream to reach a stable channel dimension, pattern and profile.

HR-06 - HR-06 is a tidally influenced reach that confluences with the Anacostia River. Based on surveyed channel dimensions, it has the characteristics of a Rosgen F5 stream type although the Rosgen classification system is not applicable to tidal areas (Photograph 32). The approximate stream width is 32 to 42 feet. Tidally driven changes in the water level are around 3 feet. Bank heights range from 7 to 10 feet and channel incision is high. Instream habitat is fair with moderately well defined pools and riffles. The riparian buffer width ranges from 10 to 1,000 feet and mostly consists of a mature woodland forest. The farthest upstream, left bank is lined with large mature hemlocks for approximately 550 feet.

HR-06 is both vertically and laterally unstable. Most of this reach is severely incised and nearly straight. It was probably ditched at some point in time, although the stream is attempting to recreate some meander by developing alternating lateral gravel bars and eroding its banks. Seventy-five percent of the banks have a moderate or greater potential for erosion. A 6 to 10 foot concrete retaining wall, along the left bank, is present for about half the reach length, starting at the upstream end. A portion of the wall has collapsed into the stream, and the remaining sections are threatened by bank erosion (Photograph 33). Approximately, halfway down its length, an outfall empties into HR-06, from the left bank. This is likely the confluence of HR-LT-03, which is piped under Hickey Hill Road. This reach has a very high sediment load potential, very high disturbance sensitivity, and poor recovery potential.

V. Problem Identification

The Problem Identification section describes the cause and effect relationship between watershed and stream processes and lists site specific problems associated with each main stem reach. The discussion of the cause and effect relationships is grouped by specific processes and addresses their impacts to Hickey Run.

A. Watershed Processes

Changes in the watershed have direct influence on stream morphology, stability, water quality and aquatic habitat. High percentages of impervious surface in the watershed, along with conversion of many of the tributaries to piped or concrete lined storm drains have altered the natural hydrology. Base flow (groundwater derived flow) is lower than in a predominantly forested or agricultural watershed, and stormflow peaks are of greater intensity but shorter duration (flashiness). These higher flows and greater velocities cause bed and bank erosion. Stormwater also carries contaminants, nutrients, and trash into the stream. These hydrological changes affect the entire Hickey Run watershed. The entire upper portion of the watershed has been piped. The lower portion of the watershed, located on the Arboretum grounds and NPS property, has also been significantly altered. Stormwater inputs and channel alterations accelerate stream adjustment through the process of erosion and deposition. Hickey Run continues to adjust to changes in water and sediment supply. Incision and lateral migration and potential damage to nearby infrastructure will continue on Hickey Run unless stormwater controls are implemented.

B. Stream Morphology Processes

The morphology of the stream is affected by stream processes, changes in sediment transport, urban infrastructure, and the quality of the riparian buffer. These factors also influence water quality and stream habitat.

1. Stream Processes

Many of the streams in the Hickey Run watershed have incised, although whether it was due to ditching, bed erosion, or some combination of the two is difficult to ascertain. In some areas, the streams have widened or are in the process of widening. Specific examples of these processes are in Reaches HR-04 and HR-06 (Photograph 34), which are incising; and in Reach HR-03 and HR-05, which are widening (Photograph 35). In the highly erodible materials found in the coastal plain, the stream will continue to incise and/or migrate laterally until it encounters a more resistant material, either a different geological layer, or vegetation, or an anthropogenic structure such as a wall, road, or utility crossing. Streams dissipate energy in a high flow situation by overtopping the stream banks, and spreading across the floodplain. As the stream incises, it loses access to the floodplain, and higher flows are contained in the channel, increasing erosive forces on the banks and beds. Eventually, the abandoned floodplain becomes a low terrace, and the stream will create a new floodplain within the incised channel. Responses in an incised stream and one that has been channelized are similar. Reaches HR-03, HR-05, and HR-06(Photograph 36), with their alternating point bars, are examples of a stream attempting to create a stable channel dimension, meander pattern, and floodplain.

2. Departure from Potential

The Service conducted a departure from potential analysis to determine the extent of stream instability problems occurring within Hickey Run. A departure from potential analysis compares a channel's dimension, pattern, and profile of a stable (reference) stream to those of the study stream. The primary requirement of a reference reach is that the stream reach is stable. Reference reaches are not required to be in a natural, undisturbed state. A suitable reference reach and the restored reach must possess similar hydrologic, geologic, and physiographic characteristics.

The shape of a particular stream represents the balance between erosive forces applied to a stream by water flowing down a slope and the resistive forces supplied by stream substrate and streambanks. Streams formed in differing types of alluvium or rock respond differently to the same hydrology. Likewise, streams of the same lithology and geology exhibit different forms if subjected to different hydrologies. Streams in developed versus undeveloped watersheds, even in the same hydrophysiographic region, will respond based on flow timing and volume (flashiness) and differences in boundary conditions (*i.e.*, stream flow, vegetation, geology, and lithology). It is important to select a reference reach with similar hydrophysiographic characteristics. Generally, this would be a stream located in the same general area, but streams from remote locations may be used for reference reaches if there is close similarity in boundary conditions (Hey, in press).

The Service was unable to identify a suitable reference reach for urban streams in the District. Finding a suitable reference reach is unlikely, as most streams in the region have been relocated or straightened. The imposition of urban infrastructure such as bridges, culverts, and sewer systems has created structural controls that obscure natural stream characteristics or otherwise preclude their use as reference reaches.

The hydrologic responses of drainage basins in and around the District have been altered by development. Stream flow typically consists of a regime of flashy stormflow and very low base flow. Suitable reference reaches must have similar hydrology. As urbanization impacts are still developing, no suitable reaches have been identified that have adjusted to stable conditions, possess good habitat features, and whose shape is not controlled or influenced by urban infrastructure. Given the lack of identified reference reaches and the low potential for suitable reference reaches to be identified in the future, other methods are used employed to identify geomorphic design parameters for restoration of urban streams in the District.

The Service developed comparison parameters for the Hickey Run departure from potential analysis using a set of characteristic geomorphic data from C4 streams with similar physiographic settings in the Western Maryland Coastal Plain[2] and Maryland Piedmont physiographic provinces (Table 4). Characteristic data was obtained from a comprehensive survey of streams in Maryland that the Service collected to develop regional relationships between bankfull discharge, bankfull width, bankfull mean depth, and drainage area (McCandless and Everett 2002 and McCandless 2003).

The survey data contain many of the relationships that are required to conduct a departure from potential analysis. The Service selected survey data that were most similar to the District streams, however, there are several caveats that must be considered when employing the survey data to conduct a departure from potential analysis for the District:

- The selected streams are from rural areas with much lower rates of watershed imperviousness.
- They may not possess the same hydrologic, geologic, and physiographic characteristics as streams in the District.
- Streams in the Maryland Stream Survey are not necessarily representative of reference reach conditions. Streams were not evaluated for habitat quality.

The Service also used C4 reference data generated by Rosgen (1996). Although the dataset comes from western United States streams, the data is similar to the Maryland data and is useful for comparison purposes.

A comparison of the existing Hickey Run geometry data (meander width, meander length, radius of curvature, and sinuosity) to the reference reach data supports the lateral instability predications made by the Service. The ratios[3] of the existing Hickey Run geometry data are typical of a straightened stream. Sinuosity and meander width ratios are lower than or slightly within the range of the reference reach ratios and the meander length ratios and radius of curvature ratios are significantly larger than the reference reach ratios. Essentially, the data shows that Hickey Run in nearly straight as represented by its slight radius of curvatures, few meanders, and low sinuosity. The lack of meanders and an adequate sinuosity limits the ability of Hickey Run to reduce erosive flows that cause lateral erosion. Low gradient, stable streams dissipate stream energy by meandering through the landscape. Meanders typically contain deep pools and have very shallow slopes and slow moving water. As high energy water enters a meander, the deep pools and shallow slopes dissipate the energy in the bed of the stream and

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[2] The District lies along the border between the Piedmont and Western (Chesapeake Bay) Coastal Plain. Review of streams in the Western Coastal Plain portion of the District found that the discharge relationships fell between the two physiographic provinces rather than matching the Western Coastal Plain. This may be the result of urbanization or it may reflect that the District is in a transition zone. Regardless, both Western Coastal Plain and Piedmont Streams were used to develop a characteristic data set of C4 streams.

[3] Ratios of the channel data are created to allow comparison between similar streams even though they may have different watershed sizes and streams sizes. Ratios are developed by dividing channel variables by the bankfull values of the same feature (i.e., channel cross section features divided by bankfull width and depth; plan form features divided by bankfull width; and profile features divided by bankfull slope and riffle depth.

reduce bank erosion potential. This process is also critical for maintaining deep water habitat. The way deep pools help dissipate energy is through scouring. Instead of eroding the banks, the high energy scours out the pools and maintains depths critical for habitat.

Table 4. Hickey Run Departure from Potential Summary

Variable		Existing Conditions Hickey Run HR-01	HR-03	HR-04	Rosgen Colorado C4 Streams	Maryland Characteristic C4 Streams
Width depth ratio	Mean	7.09	19.09	26.70	15	14.3
	Range				12 - 25	9.56 - 27.0
Low bank height to max bankfull depth ratio	Mean	1.00	1.00	2.41	N/A	N/A
	Range					
Entrenchment Ratio	Mean	1.63	1.65	1.15	5.26	12.7
	Range				2.7 - 31.65	2.86 - 36.5
Ratio of meander length to bankfull width	Mean	39.5	4.3	24.4		13.0
	Range	39.5	3.41-5.09	24.4	9 - 14	5.7 - 27.2
Ratio: Radius of curvature to bankfull width	Mean	12.68	1.74	7.75		2.3
	Range	11.30-14.06	1.24-2.24	7.75	2.5 - 3.5	1.4 - 3.3
Meander width ratio	Mean	7.76	1.8	6.3	11.4	2.8
	Range	6.13-9.39	1.8	6.3	4 - 20	0.97 - 4.52
Sinuosity	Mean	1.10	1.08	1.16	1.9	1.39
	Range	1.10	1.08	1.16	1.43 - 2.80	1.26 - 1.47
Pool WS slope / Average WS slope	Mean	0.230	0.08	0.4		N/A
	Range	0.06-0.0046	0.0-0.18	0.13-1.47	0.20 - 0.30	
Riffle WS slope / Average WS slope	Mean	3.4	6.3	3.7		N/A
	Range	1.71-7.71	1.67-10.43	1.68-5.79	1.5 - 2.0	
Max Riffle depth/ Mean riffle depth	Mean	1.49	1.61	1.23		1.36
	Range				1.2 - 1.5	1.18 - 1.65
Ratio of max pool depth to average bankfull depth	Mean	0.75	2.60	1.80	3.0	2.26
	Range	0.48-1.49	2.32-3.11	1.61-2.03	2.5 - 3.5	1.68 - 3.10
Ratio of pool to pool spacing to bankfull width	Mean	4.83	4.82	5.50		N/A
	Range	2.05-8.21	3.50-6.79	3.35-7.73	5 - 7	

The entrenchment, incision, and riffle water surface slope ratios document vertical instability. Hickey Run entrenchment ratios are two to twenty times less than the range of ratios for the reference reaches. Lower entrenchment ratios indicate that Hickey Run contains large flood flows within the channel due to insufficient floodplain and flood prone areas to attenuate flood flows and reduce instream erosive flows. More than half of Hickey Run has high incision ratios that further indicates lack of a connection to the floodplain and actively downcutting. The riffle water surface slope ratios are up to five times higher than the reference reach ratios, which imply that Hickey Run has steeply sloped riffles. Steeply sloped riffles are another indicator of active stream downcutting.

Pool depth and pool to spacing ratios confirm that the instream habitat of Hickey Run does not have optimum diversity. Most of the Hickey Run pool ratios fall within the range of the reference reach ratios, but the frequency and depth of the pool should be greater.

3. Sediment Processes

Stream instability influences both sediment supply and sediment transport. An unstable stream often increases the amount of sediment available to the stream, as significant amounts of material are eroded from the banks and bed of the stream. In many coastal plains streams the bed is sand or fine to medium gravel (McCandless 2003). The stream bed materials in the Hickey Run watershed range from cobble to silt. Changes in slope and width/depth ratios affect sediment routing. Sediment scours in steep and/or narrow reaches, and deposit in flat and/or wide reaches. Increased runoff and concentrated flows typically causes channel enlargement and instability, degrades instream habitat and water quality, and increases sediment loads. The Service estimated streambank erosion for Hickey Run based on a Bank Erosion Hazard Index (BEHI) and a Near Bank Stress (NBS) rating (Rosgen 2002b). While this bank erosion estimation method is very accurate, estimate amounts are spatially and temporally influenced. Variability in annual precipitation and time of bank erosion rate monitoring will result in some variance of erosion estimates. The streambank erosion estimates presented in this report are based on one year of monitoring and future monitoring may result in slightly different erosion estimates

In 2004, the Service predicted an annual streambank erosion of 1,100 tons/year (Table 5). In 2005, the Service resurveyed the cross sections to validated predicted erosion rates in 2004. The 2005 measured annual erosion from the streambanks is 1,031 tons/year (Table 5), a 14 percent difference from the 2004 predicted annual erosion. HR-01 had the biggest difference between the predicted and measured bank erosion rates. This is because the bank erosion rate curved, used by the Service, predicted a higher erosion rate for the BEHI/NBS rating of Low/Low than what the Service actually measured. For all of the other Hickey Run BEHI/NBS bank ratings, the predicted curved matched reasonably well with the actual measurements. Reaches HR-04 and HR-06 contribute the most sediment from bank erosion. This is consistent with the stability assessment which indicated that HR-04 and HR-06 have the most widespread instability problems and that HR-01 and HR-02 are the most stable.

Table 5. Hickey Run Annual Streambank Erosion Prediction				
Reach	**2004 Predicted Erosion (tons/yr)**	**2004 Predicted Erosion (tons/yr/ft)**	**2005 Measured Erosion (tons/yr)**	**2005 Measured Erosion (tons/yr/ft)**
HR-01	44	0.04	17	0.01
HR-02	0	0.0	0	0.0
HR-03	190	0.25	267	0.36
HR-04	329	0.28	280	0.24
HR-05	83	0.31	70	0.26
HR-06	454	0.38	397	0.33
Total	**1100**		**1031**	

4. Urban Infrastructure

Urban drainage infrastructure (*i.e.,*stormwater pipes and outfalls) is an important factor in the degradation of Hickey Run and its tributaries. Piping of all the tributaries upstream of New York Avenue (Route 50) significantly increases the volume and velocity of water delivered to the stream (Photograph 37). While most of the stormwater delivered to Hickey Run enters at the upstream ends of HR-01 and HR-LT-01, other smaller outfalls found on HR-01, HR-06, HR-RT-01, HR-RT-02, HR-LT-02, HR-LT-03 cause localized vertical and lateral erosion and carry additional water to the stream. Several of the tributaries (HR-LT-02, HR-LT-03 and HR-RT-03) join the mainstem via a piped segment and an outfall, which has the same effect as direct stormwater input. Pollutants carried in urban runoff degrade water quality. Several types of contaminants, including polycyclic aromatic hydrocarbons (PAHs), semi-volatile organic compounds (SVOCs), heavy metals, and diesel range organics (DRO) have been identified in the sediments and water of the stream (RKK 2002).

Although only one sanitary sewer (Eastside Interceptor) crosses the mainstem of Hickey Run, and does not appear to have a significant impact on the geomorphology of the stream (the crossing is elevated). The deteriorating structure of the sewer has created failing manhole covers and cracks in the crown of the pipe that allow the contents of the sewer to leak into the stream (RKK 2002). The evaluation report recommended immediate relocation and repair of the sewer line. This same sewer line also crosses HR-RT-01 and HR-RT-02, where it is serving as a temporary grade control. It may be leaking in these locations as well, although field crews noted no specific evidence of leaks.

5. Water Quality

Hickey Run is listed as an impaired waterway under Section 305 (b), primarily for oil and grease, a source of polynuclear aromatic hydrocarbons (PAHs); and pathogens (WQD 2002). When surveying the stream, field crews repeatedly noted a petroleum odor in both the water and the sediment. Sufficient petroleum products are present in the sediment that disturbing it causes visible oil slicks to form on the surface of the water. Several sources have contributed, including inputs from industrial and municipal point sources, urban runoff, leaking storage tanks, and spills. The specific source, age, and amount of the oil products in the sediment are unknown. Runoff from the storm sewer upstream, which drains both residential and industrial areas, also contains petroleum products (Marshall, Tyler, Rausch 1999). The specific source, type, timing, and quantity of these inputs is not well documented. The Washington Area Metropolitan Transit Authority (WMATA) maintains an oil boom at the New York Avenue outfall (Marshall, Tyler, Rausch 1999).

A preliminary assessment (Apex Environmental 1991) and site investigation (Entech 2000) were conducted to determine if the Arboretum qualified for listing under the Comprehensive Environmental Response, Compensation, and Liability Act and Superfund Amendments and Reauthorization Act (CERCLA/SARA).[4] Although the final recommendation of the investigation was No Further Response Action Planned (NFRAP), the assessment identified ten sites potentially containing CERCLA hazardous substances. Of the ten sites, six are located within the Hickey Run watershed. Three of these sites have surface water drainage pathways into Hickey Run and may contribute some contaminants to the stream, primarily metals and pesticide residues.

The D.C. Water Quality Division monitors a station on Hickey Run (directly upstream of Crabtree Road) on a monthly basis, measuring parameters such as pH, dissolved oxygen (DO), nitrogen, phosphorus, turbidity, and fecal coliforms. The pH ranges from 6.8 to 8.2 and dissolved oxygen is always greater than 4.0 milligrams/Liter (mg/L). These parameters are within acceptable ranges for aquatic biota. Typically, nitrate concentrations in forested catchments are 0.1 mg/L (Dunne and Leopold 1978) and the U.S. Environmental Protection Agency Water Quality Criterion for nitrate is 10 mg/L. In 2001 (no data were available for 2002) nitrate concentrations ranged from 0.2 mg/L to 1.8 mg/L, with an average of 1.0 mg/L (DCWQD, unpublished data, Contact C. Jarman). Concentrations from other years are similar. Fecal coliform concentrations measured in 2002 ranged from 20 mpn/100mL to 5000 mpn/100mL, with an average of 840 mpn/100mL. The USEPA standard for recreational use is 200 mpm/100mL (USEPA 1986). Coliform concentrations in Hickey Run regularly exceed this level.

6. Aquatic Biota

The stream was evaluated using rapid bioassessment protocols (RBPs), first in 1993 by Banta (Banta 1993) and more recently by D.C. Fisheries (D.C. Fisheries 2003). Banta used the benthic macro invertebrate assemblage to evaluate one site on Hickey Run and concluded it was

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[4] Petroleum products derived from spills and underground storage tanks are specifically excluded under CERCLA/SARA.

moderately impaired. He did note, however, that the sampling may have inadvertently been conducted in the tidally influenced area, which could bias the results. D.C. Fisheries sampled Hickey Run in 2002 and again in 2003, evaluating both the benthic macroinvertebrate and the fish communities. Currently, there are no reference streams in D.C., but comparisons with the Maryland reference streams ranked Hickey Run as very poor for benthos, and fair for fish (R. Hansen, D.C. Fisheries, personal communication). Fish collected were primarily pollution tolerant species. Invertebrate species found in 2002 were also pollution tolerant species, and in 2003 no benthic macroinvertebrates were present in the sampling area.

7. Riparian Buffer

The riparian buffer serves several important functions by slowing the overland flow of water, providing nutrient uptake, and serving as a filter to settle excessive sediment and pollutants. When stormwater is piped into a stream, these important functions are bypassed. The riparian zone serves as a structural component, reinforcing the banks, and the shading provided by canopy trees moderates the water temperature. Mowed lawn directly adjacent to stream, while preferable to pavement, does not provide the structural support and shading that a denser vegetated riparian buffer provides. The riparian buffer also serves as habitat and a food source for both terrestrial and aquatic biota. Detritus and fallen leaves are an important part of the energy budget of streams.

The riparian buffer for Hickey Run varies in composition and width. Where the bank lacks a wide, heavily vegetated buffer, which is most of Hickey Run's left bank and tributaries HR-LT-01 and HR-LT-03, there is significant bank erosion. The lack of well-rooted vegetation is not the sole cause of the bank erosion, but it is a contributing cause. Where the banks have a well-vegetated, substantial buffer width, which is most of Hickey Run's right bank and the remaining tributaries, erosion is less but still occurs because of stream incision. There is adequate riparian buffer to serve as a food source and provide shading for the aquatic biota of Hickey Run. There is even adequate buffer width to filter nutrients of stormwater runoff, but only within the USNA and NPS property boundaries. Unfortunately, too much of the watershed upstream of the USNA is piped and the water quality impacts associated with the piping far exceed the benefits achieved by the riparian buffers on the USNA and NPS.

8. Instream Habitat

Overall, the instream habitat is poor to fair for Hickey Run and its tributaries. On the mainstem, Reaches HR-01, HR-03, HR-05, and HR-06 have moderate to well-defined pools and riffles. These bed features are poorly defined in Reach HR-04 and non-existent in Reach 2 (the concrete channel). A diversity of habitats is necessary for healthy aquatic biota. Riffles provide cover for many of the benthic macroinvertebrates serving as the base of the food chain in such streams, as well as some species of fishes. Pools provide habitat for some of the larger fishes as well as refugia for others when water levels are low. As a whole, Hickey Run is deficient in instream cover, usually provided in coastal plain streams by large woody debris and overhanging banks.

Degraded water quality, resulting from pollutants, the leaking sanitary sewer, and high load of suspended sediment during runoff conditions further decreases the quality of the habitat.

9. Specific Problems

Table 6 shows the specific problems associated with each reach. It also shows the level of problems for each reach relative to one another and the level of occurrence for each problem relative to one another. For example, reach HR-04 has more specific problems than any other reach and stream confinement is the most prevalent problem among all the reaches.

VI. Priority Rating

The Service used quantitative and qualitative data to rate the restoration priority of Hickey Run and its tributaries. The quantitative data focused on the severity of instability and included such data as channel shear stress, bank erodibility, predicted annual streambank sediment load, enlargement potential, evolutionary trend of stream stability, width/depth ratio, definition of facet streambed features, and stream entrenchment and incision. The qualitative data focused on the stream's sensitivity characteristics; a management interpretation of various stream types developed by Rosgen (1996). This interpretation evaluates a stream's sensitivity to disturbance, recovery potential, and sediment supply potential based on Rosgen stream types. The Service also combined the quantitative and qualitative data to develop cause and effect relationships, between watershed and stream processes, to assist in the restoration priority ratings.

A. Hickey Run Main Stem

The Service determined that all of the reaches on the Hickey Run main stem, except HR-01 and HR-02, have significant, widespread instability problems. Although there is a discernable difference in stability between the reaches, the severity of instability of all the reaches are such that rating the restoration priority of one reach over another is not warranted. HR-02, while stable, is a concrete lined channel and therefore lacks instream habitat. The Service considers the restoration priority for reaches HR-02 through HR-06 as high due to the severe, widespread instability.

Reach HR-01, although not typical of a coastal plain stream because of the existing large riprap, meets the objective of stream stability, and does not require total restoration. There are some localized streambank erosion problems and some areas with poor to moderate instream habitat, but HR-01 is a low priority in comparison to other Hickey Run reaches. Even though HR-01 has a low restoration priority, restoration implement should start on HR-01 since it is the farthest upstream reach. Logistically and functionally, the best way to restore a stream is from upstream to downstream, thus avoiding instream impacts to restored sections of stream.

Table 6. Hickey Run Specific Problem Identification

Category	Specific Problem	Reaches												
		Main Stem						Tributaries						
		HR-01	HR-02	HR-03	HR-04	HR-05	HR-06	HR-LT-01	HR-LT-02	HR-LT-02 - RT-01	HR-LT-03	HR-RT-01	HR-RT-02	HR-RT-03 (Fern Valley)
Watershed Processes	No. Stormwater Outfalls	1					1	1	1		1	2	1	2
	Floodplain Loss	X	X	X	X	X	X	X		X		X	X	
	Stream Confinement	X	X	X	X	X	X	X		X	X	X	X	X
Stream Processes	Channelization/Alteration	X	X	X	X	X	X	X			X			X
	Revetment - Single Bank				X			X						X
	Revetment - Both Banks							X						X
	Revetment – Bed and Banks	X	X					X						
	Lateral Instability			X	X	X	X	X		X	X	X	X	X
	Vertical Degradation				X		X			X	X	X	X	
	Vertical Aggradation													
	Channel Enlargement Potential			X	X		X	X		X	X	X	X	X
Sediment Processes	Sediment Supply Potential			X	X	X	X	X	X	X	X	X	X	X
	Sediment Competency				X									
Urban Infrastructure	Piped Channel								X		X	X	X	X
	Utility Lines and Crossings			X										
Water Quality	Poor Water Quality	X	X	X	X	X	X	X				X	X	
	Sanitary Sewer Leaks	X	X	X	X	X	X					X	X	
	Contaminant Input Sources	X						X						
	Urban Debris and Trash	X	X	X	X	X	X	X						
Riparian Buffer	Lack of Forested Buffer			X	X						X			
	Poor Quality Buffer	X	X	X	X	X	X	X			X			
Instream Habitat	Poorly Developed Bed Features		X	X	X		X	X		X	X	X	X	
	Insufficent Cover		X		X		X	X		X	X	X	X	
	Fish Passage Barriers	X	X									X	X	

B. Hickey Run Tributaries

The stability conditions of the tributaries vary from stable to localized instability to widespread instability. The Service initially rated restoration priority between all the reaches, relative to one another. However, because all the tributaries are relatively short, the Service recommends that restoration occur at a tributary level, regardless of the individual reach restoration priority, versus restoring individual reaches sequentially based on their restoration priority rating. Table 7 lists the order of restoration priority for the tributaries.

The Service rates HR-LT-03 and HR-LT-02-RT-01 as the highest restoration priority due to unstable reaches within these tributaries, which continue to degrade, and adversely impact the stable reaches. Both of these tributaries have significant headcuts that are actively eroding and must be stabilized.

HR-LT-01 and HR-RT-01 have the next highest restoration priority. Both of the tributaries have widespread instability throughout and no stable reaches that would be adversely impact by the degrading reaches. HR-RT-02 follows since it also has widespread instability, but only at various locations throughout. HR-RT-03 would be the last tributary to restore since it has relative minor, localized instability problems that do not significantly impact other reaches on the tributary. However, some of the localized instability problems are associated with some of the existing stabilization structures. These erosion problems should be monitored closely and if failure of a structure appears to be imminent in the future, they should be addressed quickly before the entire structure fails and causes significant adverse impacts. HR-LT-02 is entirely stable and needs no restoration at this time, except for HR-LT-02-02, which is piped. The pipe should be removed and the stream restored

Table 7. Hickey Run Tributary Restoration Priority Rating

Reach	**Priority Rating**
HR-LT-03	Highest
HR-LT-02-RT-01	Highest
HR-LT-01	High
HR-RT-01	High
HR-RT-02	High
HR-RT-03	Moderate
HR-LT-02	Low

VII. General Restoration Recommendations

The restoration recommendations are comprehensive and based on watershed and stream processes and the techniques used to restore these processes. There are only narrative descriptions of how these techniques could be applied to Hickey Run. The development of restoration plans will occur during the next phase (design phase) of the Hickey Run restoration project. The Service has already developed a scope of work (SOW) for the design phase and coordinated it with DOH, USNA, NPS. The SOW proposes to developed detailed restoration plans for three demonstration sites on tributaries to Hickey Run and conceptual plans for the main stem of Hickey Run. This report has no conceptual or detailed restoration plans.

Table 8 presents a summary of potential restoration alternatives to the watershed and stream process problems identified in Hickey Run. Following Table 9, there is narrative describing how these alternatives could be applied to Hickey Run.

There are four other projects underway in the Hickey Run watershed: the development of a watershed implementation plan by DOH, the implementation of a trash collector and a potential oil separator by USNA and DOH, the implementation of the Arboretum master plan by USNA, and the development of a revised Anacostia Park master plan by NPS. The watershed implementation plan will include low impact development (LID), and other stormwater retrofit measures to address quality and quantity control of stormwater runoff. The trash collector and potential oil separator are proposed downstream of New York Avenue just as Hickey Run daylights from a large outfall. The Arboretum master plan is a comprehensive plan that describes management procedures and improvement projects for the Arboretum. The Anacostia Park master plan is a comprehensive plan that describes management procedures and improvement projects for the Anacostia Park and surrounding NPS parks. The Service will work closely with USNA, NPS, and DOH on project coordination with the development of Hickey Run restoration plans during the design phase.

A. Stream Stability

The Service recommends a natural channel design approach to restoring degrading areas on Hickey Run and its tributaries. The goal of the natural channel design approach is to adjust stream planform, cross-section, and profile such that restored streams accommodate their regimes of flows and sediment supply without creating erosion or deposition impacts within, upstream, or downstream of restored reaches. Natural channel design methodology employs geomorphic measurements from stable, natural streams as a template for designing the restored stream. Measurements from stable streams are scaled by ratios of bankfull mean depth, bankfull width, and bankfull discharge to develop planform, cross section, and vertical profiles for restored streams.

One of the more significant stream problems occurring in Hickey Run is the degree of incision. Based on the natural channel design methodology, restoration techniques of incised streams are divided into four major categories (Rosgen 1997).

- Create the original type stream at the original base level (Priority 1)
- Create the original type stream at the current base level or higher, but containing a floodprone area (Priority 2)

Table 8. Hickey Run Problems and General Restoration Recommendations

	Problem	Restoration Alternatives
Stream Stability	Unstable stream dimension, pattern, and longitudinal profile	1) Create a stable meandering stream in the historic floodplain. 2) Establish stream and floodplain within the existing stream. 3) Establish stream and floodprone area within the existing stream. 4) Stabilize stream in place.
Water Quality	Heavy metals, PAH's, PCB's, and pesticides	1) Divert and treat road runoff 2) Relocate stormwater outfalls away from stream 3) Remove urban debris 4) Create wetlands and ephemeral ponds
	Sewage Leaks	1) Locate and repair leaks and breaks
	Sediment	1) Develop a stable dimension, pattern, and longitudinal profile 2) Use physical restoration techniques which reduce bank stress
	High Water Temperature	1) Establish riparian buffers 2) Develop a stable stream dimension, pattern, and longitudinal profile with a lower width/depth ratio
Infrastructure	Stormwater Outfall	1) Relocate outfall 2) Retrofit outfalls to attenuate stormwater flows 3) Install energy dissapators
	Exposed sanitary sewers in stream channel	1) Relocate sanitary sewers 2) Encase sanitary sewers 3) Use grade control structures to protect utility crossings and restore fish passage
	Stream Crossings	1) Avoid modifications to bridge crossings
Riparian Habitat and Riparian Buffer	Water Quality	1) Address contaminant, nutrient, sediment, and temperature problems
	Stream Stability	1) Develop a stable stream dimension, pattern, and longitudinal profile
	Instream Cover	1) Incorporate instream cover with the restoration techniques 2) Establish bank vegetation 3) Employ large woody debris in stream restoration
	Fish Passage	1) Use restoration structures (e.g., j-hooks and cross vanes) to allow fish passage
	Reforestation and Riparian Enhancement	1) Establish or expand riparian buffer 2) Improve diversity of buffer 3) Plant native vegetation and remove non-native vegetation

Table 9. Comparison of Priority 1, 2, and 3 Stream Restoration Adapted from Rosgen 1997		
Description	**Advantages**	**Disadvantages**
Priority 1: Creation of the original type stream at the original base level	1) Establishes a stable and dynamic stream condition 2) Reduces bank height 3) Reduces stream erosion 4) Improves aquatic and terrestrial habitats 5) Improves natural aesthetics	1) May require extensive excavation 2) May require filling of existing stream 3) May result in loss of existing land use(s) 4) May require grade control at the downstream limit of project to prevent headcutting
Priority 2: Creation of the original type stream at the current base level or higher, but not at the original base level	1) Decreases bank heights 2) Decreases stream erosion 3) Reduces land loss 4) Improves aquatic habitat 5) Prevents wide-scale flooding of adjacent land	1) Stream may experience higher flow velocities and bank stress due to narrower floodplain 2) Requires grading and stabilization of the upper streambanks to reduce erosion during higher flows 3) May require grade control at the downstream limit of project to prevent headcutting
Priority 3: Establishment of a stream with an increased flood prone area within the existing degraded stream	1) Reduces land needed to establish a stable stream 2) Structures next to the stream do not need to be relocated 3) Improves aquatic habitat	1) Increases in material costs 2) Limits the creation of a diverse aquatic habitat

- Create a different type stream without an active floodplain, but containing a floodprone area (Priority 3)
- Stabilize the existing stream with structures (Priority 4)

These priorities are ordered in terms of preferred alternatives. If feasible, Priority 1 is the preferred alternative, as it restores a stream to its pre-disturbance state and has the greatest chance of success. Priority 4 is the least desirable, as it is an attempt to stabilize the stream in a disturbed state, is costly, and has the greatest chance of failure.

Descriptions of the advantages and disadvantages of the various types of restorations are shown in Table 9. A Priority 1 restoration creates a stable, meandering stream in the existing or historic floodplain. This alternative establishes a stable and self-maintaining stream with the highest potential for success. It may use a relic stream, or may require excavation of a new stream and filling of the existing stream. A Priority 2 stream restoration establishes a floodplain and stream dimension, pattern and longitudinal profile within the existing degraded stream. Excavation of the existing degraded stream may be required to create the proper meander pattern. Either the floodplain is created at the existing grade, or the elevation of the streambed is raised to allow access to an abandoned floodplain. Although the floodplain is narrower than in the previous alternative the presence of a floodplain still attenuates flow velocities and bank and bed shear stresses during higher flows. It relies more on bank vegetation to stabilize the stream, but may require structures as well. The Priority 3 restoration establishes a stream and floodprone area within the existing degraded stream. The benefit of a Priority 3 restoration is that it reduces the land required to establish a stable stream as the stream has minimal access to the floodplain and relies more on the flood prone area to reduce stream energy at high flows. The tradeoffs are increased construction costs (because more structures are required), less diverse aquatic habitat, greater maintenance requirements, and a lower success rate than the first two alternatives. A Priority 4 restoration stabilizes the stream in place by armoring the banks and bed. The Service does not recommend this option because it is costly, has a high risk of failure, and does little to improve aquatic habitat or aesthetics.

As part the Hickey Run assessment, the Service determined that a Rosgen C4 stream type (Priority 1 or 2) would be appropriate for most of the Hickey Run main stem and its tributaries; given their location within the Western Coastal Plain, stream order, the characteristics of the valley, valley slope, sediment load, and discharge. There are some confined areas of Hickey Run where a Priority 1 or 2 restoration may not be feasible. For those potential areas, the Service recommends restoring the stream to a Rosgen B4c (Priority 3) stream type. The morphology of both Rosgen stream types generally provides good habitat potential for fish and macroinvertebrates, and reduces stream width and stream incision. Less stream incision will decrease erosive stresses during major flow events.

A Rosgen C stream type is a meandering, alluvial stream, well connected with its floodplain. The "4" indicates that the median size of stream materials is gravel; typical of the materials currently in place in the natural stream reaches of Hickey Run. The selection of a Rosgen C4 stream type indicates that the restored stream reaches will be slightly entrenched, possess moderate to high width depth ratios, and have moderate to high sinuosity. The bed features include a well-developed pool-riffle sequence and dissipation of stream energy occurs as the flows move through the meanders.

A Rosgen B stream type is slightly meandering, alluvial stream, with a narrow floodplain. The selection of a Rosgen B4c stream type indicates that the restored stream reaches will be moderatley entrenched, possess moderate to high width depth ratios, and have low sinuosity. The bed features include a well-developed pool/step pool-riffle sequence and dissipation of stream energy occurs in the bed of the stream as the flows plunge over the steps into a pool.

B. Water Quality

Several different sources contribute to the degraded water quality in Hickey Run. Urban stormwater from the upper portion of the watershed is one source. As mentioned earlier in the report, DOH and USNA are working to install a trash collector and a potential oil separator at the headwaters pipe on the main stem of Hickey Run which will assist in improving water quality.

Furthermore, the Service supports the implementation of best management practices (BMPs), at stormwater production sites in the upper watershed, by DOH in their watershed implementation plan. The implementation of BMP's is an important part of the overall strategy to improving water quality.

For other areas of point source runoff (i.e., outfalls) within USNA and NPS property, the Service recommends the creation of wetlands and ephemeral ponds to treat stormwater runoff. Wetlands and ephemeral ponds naturally filter stormwater as it percolates into the soil. The wetlands and ephemeral ponds should be constructed within the riparian corridor and stormwater outfalls relocated to the edges of the riparian corridor for best resluts.

There is the potential that soils contaminated with petroleum based substances to exist in certain areas on the USNA. Contaminates from soil can enter into the stream several different ways: through groundwater or subsurface flow; surface runoff flows; and bank erosion. The Service recommends a contaminants assessment of the stream channel, streambanks, and adjacent flood plains to identify potentially contaminated soils and to develop specific remediation alternatives, if necessary.

C. Infrastructure

1. Stormwater

Storm sewers discharge into the headwaters of the mainstem and tributary HR-LT-01, as well as several other locations. These discharges, which have no treatment or energy dissipation measures, create several types of problems.

- Poor water quality from untreated stormwater
- Trash and debris are delivered directly to the stream
- Stormwater jets disrupt normal flow hydraulics and create stream stability problems by creating "hard-points" on streambanks
- Spills and unregulated discharges into storm sewer systems are delivered directly to the stream
- Storm sewers can capture sanitary sewer overflows and leaks

Storm sewer outfalls must be addressed on a case-by-case basis. The preferred alternative is to treat stormwater on site. Another alternative is to relocate outfalls to the edge of riparian corridors and install stormwater treatment and infiltration facilities. In some cases, because of space and grade limitations, this may not be possible. Where relocation is not feasible, energy dissipaters may be required to improve stream stability.

2. Utility Crossings

Utility crossings are of concern in the Hickey Run mainstem (downstream end of HR-02), and in the HR-RT-01 and HR-RT-02 tributaries. A major sewer trunk line, the Eastside Interceptor, crosses the stream in these locations. The section of the Interceptor that crosses the mainstem is elevated above the stream. The pipe is cracked and leaking in this area, and WASA has begun the planning process for replacement of a portion of the pipe. (RKK 2002). The alternative currently under consideration is to construct a new sewer trunk line upstream of the existing structure. The original designs specified the new sewer trunk line to have a clear span of 30 feet, and a clearance of 6 feet above the invert of the existing concrete channel (RKK 2004). The 30 foot clear span would not provide adequate room for the stream restoration. The Service recommended the opening (measured perpendicular to the current stream) be at least 45 feet for Hickey Run to convey most flood flows without a channel constriction at the crossing and to promote effective stream stability. The Service also recommended that DCWASA locate the footings for the two piers immediately adjacent to Hickey Run at an elevation that is below the current channel invert depth of Hickey Run. RKK engineers stated that implementing the Service's recommendations is feasible and would not increase implementation costs. Therefore, DCWASA has incorporated the Service's recommendations into their designs.

Where the sewer line crosses the tributaries, it is acting as a grade control, and there is a significant elevation difference between the up- and downstream sides of the pipe. Apparently there was no evaluation as to the structural integrity of this portion of the pipe. The Service recommends this portion of the pipe be evaluated and if any repairs or realignment is required, that it be performed concurrent with the relocation of the other crossing. A second utility line crosses HR-RT-01 just upstream of the Interceptor. It does not appear compromised, and is not acting as a grade control.

3. Stream Crossings

Stream crossings consist of roadway bridges, all located on USNA property. Replacement of roadway bridges is generally cost prohibitive. The Service will accommodate the existing crossings when developing the restoration plans, unless the USNA is proposing any bridge replacement to accommodate a potential increase in visitors. If the USNA is not proposing any bridge replacement, this will require controlled stream alignment at bridges similar to current alignments and evaluation of potential changes in vertical grade and flood stages. Currently, there are road crossings in Reach HR-02, HR-04, HR-05 and HR-LT-01.

D. Aquatic Habitat

Addressing the water quality and stream stability problems will resolve many of the aquatic habitat concerns, with the possible exception of instream cover and fish passage. Many of the restoration structures (*e.g.*, J-hooks and cross-vanes) provide instream cover by design. However, the Service may recommend incorporating additional instream cover alternatives. The riparian planting plan will provide a source for large woody debris and overhead cover along the streambank.

E. Riparian Buffer

Although the USNA contains many exotic plant species, the stream buffers are not intensively managed, and many native plant species exist, as described in Section IV.A.5. Riparian Vegetation. However, field crews noted invasive exotic species in several locations within the stream corridor. The Service recommends eradication of invasive species and a replanting and invasive management plan that satisfies the Arboretum's mission of showcasing botanical species.

VIII. Preliminary Design and Construction Costs

The Service estimated Hickey Run restoration costs for the main stem based on restoration costs developed as part the Oxon Run Stream Restoration Concept Development (Shea, et al, 2004). The restoration costs include construction costs only and are applied on a linear foot cost at the rate of $230.00. Preliminary restoration costs for Hickey Run are presented in Table 10. The Service will refine the restoration costs during the design phase as details of restoration solutions and their locations are finalized.

Table 10. Hickey Run Construction Cost Estimate

Reach		Linear Cost	Cost
Identification	**Length (ft)**		
HR-01	1170	$230	$269,100
HR-02	544	$230	$125,120
HR-03	762	$230	$175,260
HR-04	1186	$230	$272,780
HR-05	268	$230	$61,640
HR-06	1206	$230	$277,380
Total	5136		$1,181,280

IX. Additional Recommendations

To optimize the restoration and ensure the greatest potential for success, the Service recommends an expanded contaminants assessment and development of an invasive species management plan.

A. Perform an Expanded Contaminants Assessment

Hickey Run contains various types of contaminants, including fuel derived compounds and persistent accumulative pesticides, such as chlordane and DDT. The Service recommends an expanded contaminants assessment to address three elements: in-situ contamination of bed sediment, banks, and the floodplain; source input from the upper (piped) portion of the watershed; and groundwater contamination. The overwhelming problem in the stream is the contamination with oil products, thus the assessment should characterize the contamination pattern in order for the development of remediation alternatives for the contaminated sediment. CERCLA investigation (Entech 2000b) characterizes potential contaminant sources on the grounds of the Arboretum, but inputs from the upstream portion of the watershed should be evaluated in terms of compounds, associations with flow conditions, and form (*i.e.,* dissolved phase, particulate phase, surface layer or emulsion). Identification and control of upstream sources at the site of contamination is critical to reducing the toxics loadings to Hickey Run. Groundwater may be an important source of pollutants, and efforts should be made to coordinate with the on-going Lower Anacostia watershed groundwater evaluation being conducted by USGS (Miller and Klohe 2003).

B. Develop an Invasive Plant Species Management Plan

During surveys, field crews noted several species of invasive plants. These plants generally degrade the quality of wildlife habitat by creating a monoculture, and crowding out native species that have greater value as habitat and food sources for wildlife. An invasive species management plan should document location, extent, and severity of these infestations, and recommend removal and replanting strategies that satisfies the Arboretum's mission of showcasing botanical species.

C. Investigate Potential Influence of Remnant Bricks from Old Brick Yard

A brick manufacturing business operated adjacent to Hickey Run for several decades, from the late 1800s to the mid 1900s. Over that period, tens of thousands of bricks were produced. Today several of the kilns and other structures still exist within the USNA property near New York Avenue. Also what remains are several thousand bricks and brick fragments which are littered throughout the stream bottom of Hickey Run. The largest concentrations of bricks are in HR-01, HR-03, HR-04. The USNA has attempted, in the past, to clean out all of the bricks from Hickey Run, but with the next storm event, bricks were once again littered the stream bottom. The exact location of unexposed bricks and their impacts are not known. The Service recommends that a study be conducted, by those most familiar with the history of the Arboretum, to locate all bricks, exposed and unexposed, and develop solutions to halt their introduction into Hickey Run.

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APPENDIX A
ASSESSMENT PHOTOGRAPHS

LIST OF PHOTOGRAPHS

Photograph 1. HR-LT-02, example of a Rosgen A stream type.

Photograph 2. HR-RT-02, example of a Rosgen B stream type.

Photograph 3. HR-RT-02, example of a Rosgen C stream type.

Photograph 4. HR-RT-03, example of a Rosgen E stream type


Photograph 5. HR-RT-01, example of a Rosgen F stream type


Photograph 6. HR-RT-02, example of a Rosgen G stream type.


Photograph 7. Typical HR-LT-01 stream character.


Photograph 8. Typical HR-LT-01-05 C4 reference condition stream character.


Photograph 9. Typical HR-LT-02 stream character.


Photograph 10. Typical HR-LT-02-RT-01-02 stream character


Photograph 11. Typical HR-LT-02-RT-01 headcut.


Photograph 12. Typical HR-LT-03-01 stream character


Photograph 13. Headcut on HR-LT-03-02.


Photograph 14. Upstream headcut on HR-LT-03-04.

Photograph 15. Downstream headcut on HR-LT-03-04.

Photograph 16. Typical HR-RT-01 stream character.


Photograph 17. Typical HR-RT-02 stream character.


Photograph 18. Headcut on HR-RT-02-03.

Photograph 19. Downstream headcut on HR-RT-02-01

Photograph 20. Upstream headcut on HR-RT-02-03

Photograph 21. Typical HR-RT-03 stream character.

Photograph 22. Undermining erosion of crib wall bank protection on HR-RT-03.

Photograph 23. Localized erosion on HR-RT-03.

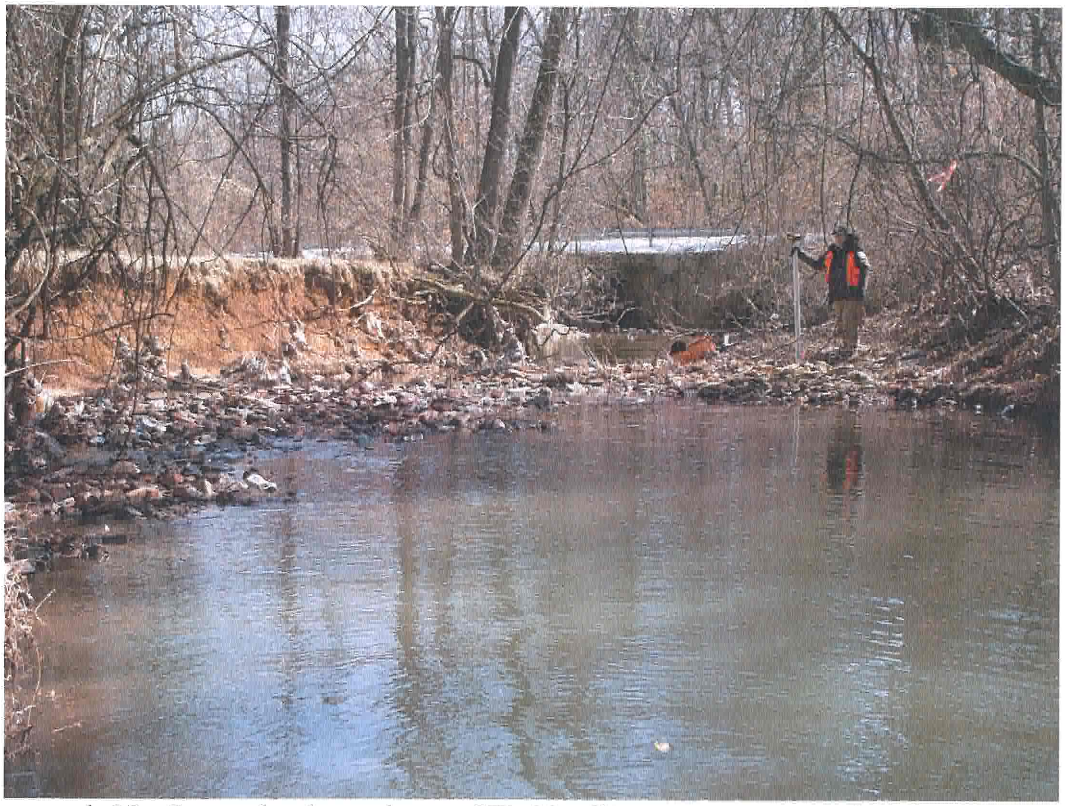
Photograph 24. Typical HR-01 stream character.


Photograph 25. HR-02 upstream concrete section.


Photograph 26. HR-02 downstream concrete section.


Photograph 27. Eastside Interceptor sewer line.


Photograph 28. Typical HR-03 stream character.



Photograph 29. Severe bank erosion on HR-03 adjacent to Heart Pond.

Photograph 30. Typical HR-04 stream character.

Photograph 31. Typical HR-05 stream character.

Photograph 32. Typical HR-06 stream character.

Photograph 33. Failing wall on HR-06.

Photograph 34. Example of channel incision (HR-04).


Photograph 35. Example of channel widening (HR-03).


Photograph 36. Example of lateral bar development (HR-06).

Photograph 37. Outfall where Hickey Run daylights (HR-01).