WEST CUDDIHY WATERSHED: STREAM ASSESSMENT

Patuxent River Naval Air Station,
St. Mary's County, Maryland

Final Report

U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
177 Admiral Cochrane Drive
Annapolis, Maryland 21401

Prepared By
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EXECUTIVE SUMMARY

Patuxent River Naval Air Station (PRNAS) is located in the Patuxent River watershed, with extensive shoreline coverage along the Chesapeake Bay. It is near the town of Lexington Park, Maryland, approximately 70 miles southeast of Washington D.C. PRNAS is an active naval research, development, test and evaluation, engineering, and fleet support center for air platforms. In 1995, PRNAS was the fastest growing military base in the nation. At present, there are approximately 15,000 support personnel employed at PRNAS.

Construction of new buildings at the PRNAS has increased the impervious surface areas (such as new roads, rooftops, walkways, and parking lots) resulting in higher surface water runoff volumes entering streams during precipitation events. The use of stormwater best management practices is intended to control this runoff. If the stormwater is not effectively managed, the increase in surface water runoff results in flashy, high stream flows, impacting the fluvial geomorphologic and biologic components of the receiving streams.

In 1997, the U.S. Fish and Wildlife Service (Service) and PRNAS signed a Cooperative Agreement to conduct stream and riparian habitat restoration projects. Specifically, the Service and PRNAS would conduct watershed level stream assessments, identify sources of stormwater runoff which degrade stream and riparian habitats, target and prioritize stream reaches and riparian areas for restoration or protection, and design and implement stream and riparian restoration projects in high priority reaches. The Service selected the West Cuddihy watershed as the pilot for testing watershed-level assessment protocols because the watershed represented a variety of stream and riparian habitat conditions existing at PRNAS.

The West Cuddihy watershed has a drainage area of 188 acres with one mile of mainstem channel draining directly to the Patuxent River. The watershed is relatively long with steep slopes, deep V-shaped ravines and narrow, and shallow gradient floodplains. The upper half of the watershed above Buse Road is primarily residential and commercial with some forest areas. The lower half of the watershed is mostly forest with two major power-line crossings, an old clear-cut area, and a small portion of a residential area.

Methodology

The Service surveyed twenty-four reaches in the watershed and identified but did not survey six other reaches. The Service collected quantitative and descriptive data to characterize stream condition, classify reaches using the Rosgen classification system, and assess stream stability. The Service initially surveyed the watershed in 1997. In 2000, the Service resurveyed one monumented cross-section per reach to validate estimates of stream stability.

The Service analyzed stream sensitivity based on the management interpretations of various Rosgen stream types presented in Rosgen (1996). The stream sensitivity analysis evaluated such parameters as sensitivity to disturbance, recovery potential, and sediment supply. The Service compiled the data into one table for qualitative evaluation of restoration priority for each reach. The Service also identified significant site-specific problem areas and potential stormwater retrofit and conversion opportunities based on field conditions.

Report Findings

Existing Conditions:

The Service identified nine general Rosgen stream types in the watershed. The overall condition of the streams within the watershed varies. Both natural processes and human activities have and continue to influence the evolution and condition of streams. Beaver activity, debris jams, vegetation density, storm events, mass wasting, vegetation clearing, housing and commercial developments, permanent and temporary road crossings, and stormwater management facilities have resulted in varying spatial and temporal stream impacts. These activities combined with the flashy flow regime and sensitivity of the streams have resulted in an overall stream system that is continually adjusting at variable rates. The stream types that are less sensitive to disturbance (approximately 50 to 70 percent) are generally stable and adjusting at a naturally occurring rate while those streams more sensitive to disturbance (approximately 30 to 40 percent) are unstable and adjusting at rate too rapid to sustain biological resources.

The Service's Contaminants Branch conducted a rapid bioassessment of the West Cuddihy watershed. They assessed 3 sites within the watershed: 1) WCA, located in the upper one-third of watershed, 2) WCB, located in the middle one-third of the watershed, and 3) WCC, located in the lower one-third of the watershed. The results of their assessment indicated that the overall bioassessment scores, based on percent comparability to a reference, were highest at WCA, which were assessed as non-impaired and the other two sites were only slightly impaired.

Problem Identification and Restoration Priority Rating:

A restoration priority rating of high, moderate and low was used to rate stream reaches relative to one another. The reach rating was based on specific criteria used to best indicate whether or not a stream was stable and if unstable, the relative severity of instability. Five reaches were rated as high priority, seven reaches were rated as moderate priority, and twelve reaches were rated as low priority. Reaches 5 and 6 were rated as high priority because both reaches are significantly incised and severely degrading as a result of a significant head cut. Reach 14 was also rated high priority as a result of the major head cut at the upstream end of the reach. The majority of the reach is stable however, with some minor aggradation.

The entire upper right tributary, Reaches 18 through 21, is an area of high concern even though only two reaches, Reaches 19 and 21, were rated as high priority. Currently Reaches 19 and 21, and the two unsurveyed reaches are severely degrading and comprise nearly 80 percent of the entire tributary. If these reaches are not restored, their degradation effects will ultimately impact the stable reaches.

The majority of reaches with a moderate priority rating received this rating due to localized instability problems. Localized instability problems primarily include eroding banks, aggradation from debris jams, and braided areas. These areas were considered moderate priority since the impacts only affect a small area, the rate of adjustment is not as rapid as the high priority reaches, and the potential for recovery for most the areas is fair to good.

Seven significant site-specific problem areas where identified within the watershed. Four of the problem areas are head cuts on Reaches C2, 5, 14, and the unsurveyed reach between Reach 21 and the confluence with the mainstem. The other three site-specific problem areas include: the hill slope failure adjacent to Reach 18; the erosion occurring adjacent to Reach 15 as a result of runoff from West Cuddihy Road; and the stormwater runoff from the Navy exchange complex.

Report Recommendations

Three categories of recommends are suggested: 1) best management practices; 2) typical stream restoration solutions; and 3) future use of assessment protocols.

Best Management Practices:

The primary best management practice for the West Cuddihy watershed is to minimize land use changes. The stream systems within the watershed are highly sensitive to change and disturbance. The watershed already has eleven percent impervious surface areas and research indicates that streams can begin to destabilize with an increase of just five to ten percent impervious surface areas (Booth and Rienalt, 1993; Galli, 1994; Schueker and Claytor, 1997). Therefore, activities such as vegetation clearing, building and road development, and earth moving should be limited.

Typical Stream Restoration Solutions:

Examples of restoration solutions are categorized into two groups: 1) site-specific restoration structures and 2) reach reconfiguration solutions. The site-specific restoration group is further categorized into three sub-groups: 1) grade control, 2) bank stabilization, and 3) fish habitat structures. Grade control structures are used to prevent streams from down-cutting and forming head cuts. Bank stabilization structures are used to prevent streambanks from rapidly adjusting. Channel reconfiguration is used for reaches that have pattern instability and require channel dimension, profile and geometry restoration.

The use of these solutions however cannot be implemented until a detailed stream restoration design is completed. The detailed stream restoration design is required to determine the type, location and size of restoration structures. Restoration structures are merely tools to implement the restoration design. Installation of restoration structures based on the level of data collected as part of this study is premature and would affect the success of any restoration attempts.

Future Use of Assessment Protocols:

Two protocols are assessed in this report: 1) a detailed watershed assessment and 2) a rapid watershed assessment. The FWS has developed these protocols with specific application purposes. The detailed watershed assessment protocol is used to develop a detailed PRNAS stream conditions database. The FWS and PRNAS environmental staff will use the database to identify and prioritize problem areas, conducted trend analyses, document baseline conditions, predict potential impacts of proposed PRNAS development projects, and conduct environmental assessments of and suggest recommendations on PRNAS activities. The database will also be used to calibrate FWS and PRNAS staff for the use of the rapid watershed assessment protocol. The rapid assessment protocol is used only to identify and prioritize problems areas within a watershed based on qualitative and semi-quantitative data. The data collected from the rapid assessment protocol can be used for preliminary environmental analyses.

Detailed Watershed Assessment - The detailed watershed assessment protocol requires data on channel dimensions, profile, pattern, bank erodability, and substrate. The FWS and PRNAS used this study to test the effectiveness of the detailed watershed assessment protocol for PRNAS watersheds. The FWS determined the protocol to be effective and efficient in identifying and prioritizing problem areas based on its application in the West Cuddihy watershed. However, three other components should be added to the protocol that would refine the identification and prioritization of problem areas.

The first component is a geomorphic map of each reach surveyed. A geomorphic map is used to show the current condition, in detail, of geomorphic features in the stream and adjacent flood plain. The map also assists in the evaluation of current stream condition and stream potential. The second component is recording the length and height of all eroding banks. Additionally a Bank Erodability Hazardous Index (Rosgen, 1996) rating should be done for each of the eroding banks. This detailed quantified bank erosion information will allow each bank to be ranked relative to one another. The last component is critical shear stress calculations. Critical shear stress calculations can be used to estimate whether a stream is aggrading, degrading, or stable. This component is more critical to conduct if there is not time to resurvey monumented cross sections over a period of time.

Rapid Watershed Assessment Protocol - The rapid watershed assessment protocol involves walking the entire stream system within a watershed to identify reach types and problem areas. It was developed based on the database of stream conditions collected from the West Cuddihy detailed watershed assessment. A standardize field data sheet is completed for each reach type identified. The field data sheet records four categories of information: 1) hill slope characteristics; 2) hydrologic characteristics; 3) riparian characteristics; and 4) stream channel characteristics. The restoration priority rating analysis is the same analysis used for the detailed watershed assessment with some minor changes. The near-bank stress criteria is not included since surveyed cross-sections are not part of the rapid watershed assessment. The bank erodability, channel entrenchment, and incision criteria are qualitatively rated.

The rapid watershed assessment protocol requires field testing before it is applied to the remaining PRNAS watersheds. Additionally, the West Cuddihy stream conditions database must be compared to other stream conditions existing within PRNAS to confirm that the database is representative of the entire PRNAS.

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1.0 INTRODUCTION

1.1 Purpose

The purposes of the West Cuddihy watershed assessment are to: 1) characterize physical conditions of stream habitat, 2) identify sources of stormwater runoff that contribute to the degradation of stream and riparian habitats, and 3) target and prioritize stream reaches and riparian areas for restoration. This assessment and report are a pilot study and are recommended as a standard protocol to assess other watersheds within the Patuxent River Naval Air Station (PRNAS). Additionally, a rapid watershed assessment protocol is included to identify and prioritize problem areas more rapidly. The U. S. Fish and Wildlife Service – Stream Restoration Branch (FWS) developed the rapid protocol based on the detailed stream conditions database produced from the detailed watershed assessment pilot study. Additional detailed watershed assessments of typical watershed types within the Patuxent Naval Air Station may be required to produce a complete stream conditions database that represents all stream conditions on the PRNAS. The need for additional detailed watershed assessments will be depended upon how well stream conditions of the West Cuddihy represent stream conditions on the remainder of the PRNAS.

1.2 Study Area

The study area is a small watershed located on the PRNAS in St. Mary's County, Maryland adjacent to the Patuxent River (Figure 1). The West Cuddihy watershed has a drainage area of 188 acres with approximately one mile of mainstem channel draining directly to the Patuxent River. The watershed is relatively long with steep slopes, deep V-shaped ravines and narrow, and low gradient floodplains. The upper half of the watershed above Buse Road is primarily residential and commercial with some forested areas. The lower half of the watershed is mostly forested with two major power line crossings, evidence of an old clear cut and a small area of residential development.

1.3 Report Outline

This report contains four main sections: 1) methodology, 2) watershed characterization, 3) problem identification and rating, and 4) report recommendations. The methodology section describes the field data collection and data analysis protocols. The watershed characterization section provides a brief historic overview of past land use activities within the watershed and a description of current stream conditions. The problem identification and ranking section uses data collected as part of the watershed characterization section to identify site-specific problems and rank them relative to one another in terms of problem severity and restoration priority. The report recommendations section provides broad watershed-level Best Management Practices, samples of typical site-specific stream restoration methods, discussion of the pilot study assessment protocol, and a rapid watershed assessment protocol for PRNAS.

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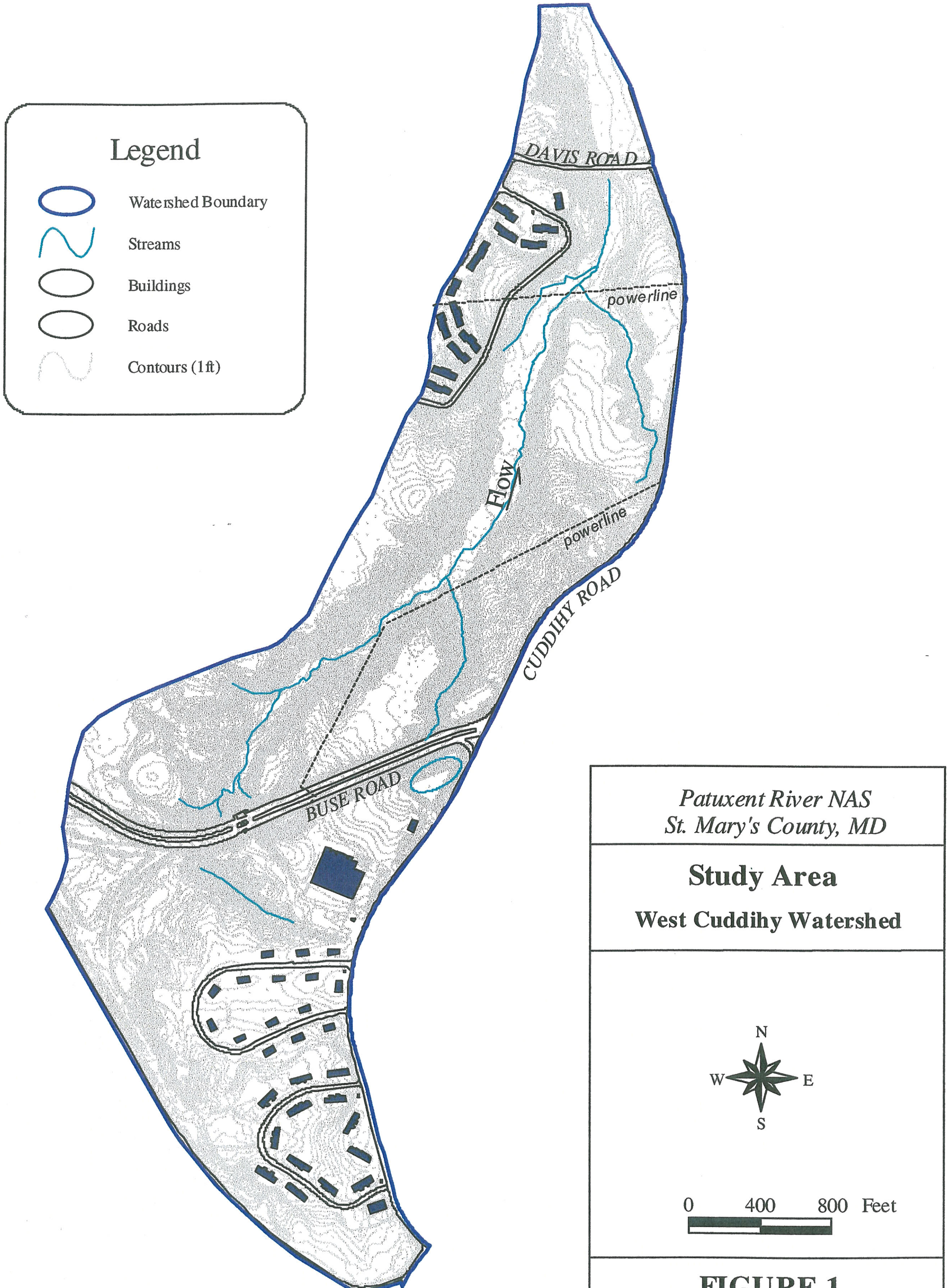


Patuxent River NAS
St. Mary's County, MD

Study Area

West Cuddihy Watershed

FIGURE 1

July 2000

Data Source: Patuxent River Naval Air Station

2.0 METHODOLOGY

2.1 Pilot Watershed Selection

The FWS and resource staff from the PRNAS conducted a preliminary assessment of all watersheds to identify the variety of stream types and conditions existing on the PRNAS. FWS and PRNAS staff walked each watershed to obtain qualitative descriptions of stream and riparian habitat conditions. The qualitative descriptions were based on visual observations and focused on Rosgen stream types, bed and bank stability, stream and riparian habitat diversity, current and future land use activities, and stormwater management practices. Upon completion of the assessment, the FWS and the PRNAS staff selected the West Cuddihy watershed for the pilot study based on the wide range of stream types and conditions existing within the basin. Preliminary observations, indicated the presence of both stable and unstable reaches (e.g., aggrading and degrading), ten different Rosgen stream types, two stormwater management areas, and a good mix of land use activities.

2.2 Field Data Collection

The FWS divided the stream systems within the watershed into 30 different morphological homogenous reaches to organize the collection of field data. All reaches had both quantitative and qualitative field data collected to characterize stream condition and to assess stream stability. Quantitative field data collected included channel width, depth, entrenchment, slope, sinuosity, substrate particle distribution (reach average and riffle), and bank condition. Monumented classification riffle and erosion cross-sections, longitudinal profile, bank erodibility hazardous index rating, and reach average and riffle pebble counts. The qualitative field data included observations of bed stability, sediment supply, and vegetation composition. The FWS initially collected field data in 1997, and in 2000, one monumented cross-section per reach was resurveyed by FWS to validate estimates of stream stability.

Field data collected for each reach were used to classify the stream according to the Rosgen Stream Classification system (Rosgen, 1996). The Rosgen Stream Classification system uses specific bankfull channel characteristics such as width, depth, cross sectional area, entrenchment, sinuosity, water surface slope, and substrate composition to categorize streams into set groups which share similar fluvial geomorphic relationships. The classification system assigns a letter and number value to classify stream types based on the bankfull channel characteristics. The letter value is based on width, depth, cross sectional area, entrenchment, sinuosity, and water surface slope and the number value is based on the substrate composition. The Rosgen Classification system is in Appendix F.

In each reach, monumented cross sections were surveyed at a visually representative classification site and at selected locations with eroding streambanks. The FWS modified the Rosgen Stream Classification system to address transition reaches and bi-modal pebble counts based on personal communications with Dave Rosgen. Transition reaches are reaches that are currently adjusting and do not fully meet all the classification criteria for a specific Rosgen stream type. The modifications list the two Rosgen stream types which represent the transition reach with an arrow between the two Rosgen stream types to show the direction of adjustment. For example, a Rosgen stream type of G4←A4 would indicate that the reach was a Rosgen stream type A4 that is now degrading to a Rosgen stream type G4. A Rosgen stream type of C4 → E4 would indicate that the reach is recovering from a Rosgen stream type C4 to a Rosgen stream type E4. The direction of the arrow indicates the status of a stream in its evolutionary trend. If the arrow is pointing to the left, then the stream is degrading. If the arrow is pointing the right, then the stream is recovering.

A bi-modal pebble count was modified by showing both dominant substrate particle sizes, based on frequency distribution, in the Rosgen stream type classification. For example, a Rosgen stream type C4/5 would indicate that the reach D50 (most dominate particle size in the substrate) is sand (5) but was originally gravel (4). This modification is primarily used in streams that are aggrading and would result in the original substrate being covered with finer particles.

The FWS initially decided to use the Pfankuch (1978) assessment protocol to evaluate stream stability and physical habitat conditions. The Pfankuch assessment is a rapid assessment procedure designed to evaluate stream stability in the western United States. Following use of the Pfankuch assessment for seven reaches within the West Cuddihy watershed, the FWS determined that the intrinsic differences in stream characteristics between the PRNAS coastal streams and the western United States streams precluded it's use. The FWS was still able to evaluate channel stability through interpretations of Rosgen stream type and bank erodibility indexes, since both provide assessment information about the same processes as the Pfankuch Protocol. The monumented cross-sections resurveyed in 2000 were used by the FWS to verify estimates of channel stability.

The FWS - Stream Restoration Branch was also to conduct an integrated physical and biological stream assessment of the watershed, but due to staff and budget reductions, the FWS was unable to conduct the biological assessment. The Contaminants Branch of the FWS, however did receive funding to conduct a current biotic and water quality assessment of four watersheds on PRNAS, one of which included the West Cuddihy. The results from the Stream Restoration Branch's physical stream assessment and the Contaminants Branch's biological assessment of the West Cuddihy watershed will be integrated into a separate summary report, providing PRNAS with an example of the type of information produced from an intensive assessment. Upon review of the summary report by PRNAS, the Stream Restoration Branch could conduct the rapid watershed assessment of the other three watersheds assessed by the Contaminants Branch to provide integrated physical and biological assessments for these three watersheds as well.

2.3 Data Analysis

The FWS analyzed the data to identify and rate stream stability problems. Field data from cross-sections, longitudinal profiles and pebble counts were plotted on Excel spreadsheets to generate a quantitative description of stream morphology. Such data included channel bankfull width, depth, cross-sectional area and estimated discharge, width to depth ratio, entrenchment, and incision; water surface slope; substrate particle distribution, near-bank stress, and bank erodability score. Bankfull is defined as the stream flow associated with the flow that moves the majority of the sediment most of the time and maintains the channel's dimension, profile, and pattern. Entrenchment is defined as the vertical containment of a stream and the degree to which it is incised in the valley floor. Incision is defined as the ratio of the bankfull height to the top of bank height. Particle substrate distribution is the quantitative description of channel bottom material sizes. The near-bank stress is defined as the stress place on the lower, outside bank of a meander bend caused by flows. The bank erodability score is based on a quantitative measurement of bank angle, height, soil composition, armament, and bankfull height to top of bank height.

Bankfull discharge was estimated by multiplying bankfull cross sectional area and velocity. Velocity was calculated by using Manning's equation. The roughness coefficient in Manning's equation was calculated by using the Manning's roughness coefficient 'n' versus Friction Factor (u/u*) plot developed by Rosgen (1994). The friction factor (u/u*) was calculated by using the Relative Roughness (d/D84) versus Friction Factor (u/u*) plot developed by Leopold, Wolman, and Miller (1964).

The FWS then conducted a stream sensitivity analysis based on the management interpretations of various stream types as presented in Rosgen (1996). The stream sensitivity analysis evaluated such parameters as sensitivity to disturbance, recovery potential, and sediment supply. The recovery potential relates to the stream's ability to recovery on its own once the disturbance is removed. The FWS compiled all of these data into one table to conduct a qualitative evaluation of restoration priority for each reach relative to one another.

The FWS also identified significant site-specific problem areas and potential stormwater retrofit and conversion opportunities. FWS identified the significant site-specific problem areas during the field data collection, based on the current and potential impacts resulting from the problem areas. Likewise, stormwater retrofit and conversion opportunities were identified by the FWS based on the condition of stream reaches directly downstream of stormwater runoff sources.

3.0 WATERSHED CHARACTERIZATTION

3.1 Historic Overview

The PRNAS is an active naval research, development, test and evaluation, engineering, and fleet support center for air platforms. Established in 1942, PRNAS was created to centralize air testing facilities established prior to World War II. During the 1950's the station developed jet aircraft and improved conventional weapons. The U.S. Naval Pilot Training School (TSP) was also established at the station during this time frame. In the 1960's, ordnance testing, as well as other programs, at the station were escalated as the

Vietnam conflict intensified. In 1975, PRNAS became the Navy's principle site for development testing. The station continued to grow throughout the 1980's and under the military's base realignment and closure program, a large number of personnel and programs have been relocated to the PRNAS in the 1990's.

Since the establishment of the PRNAS several land use activities have occurred in the West Cuddihy watershed which has and continues to influence stream geomorphology. When the PRNAS was established, West Chuddihy watershed was completely forested with the exception of one railroad bisecting the middle of the watershed in an east-west direction. The first land use change occurred in the 1970's when an on-base housing development was constructed at the headwaters of the watershed. During the 1980's there were two vegetation clearings. In 1983/84, approximately 10 acres of timber was harvested in the lower northeast portion of the watershed. In 1985, two power lines and associated vegetation clearing transected the watershed in an east-west direction. Also in the late 1980's another on-base housing development was constructed in the extreme lower northwest portion of the watershed. In 1993 the Navy Commissary Complex was constructed directly adjacent to the housing development constructed in the 1970's. And in 1994 a new gate entrance into the PRNAS was constructed over the old rail road bed.

All of these development activities comprise 41 percent of the watershed and have resulted in 11 percent impervious surfaces within the watershed. The effect of such a large impervious surface coverage significantly influences the watershed's stream geomorphology. Details of these effects are presented later in the report. However, increases of impervious surfaces result in increases of stormwater runoff and thus a new flow regime of larger, flashy flows within stream systems. The shape and pattern of a stream is developed and maintained by the amount of water flowing within its channel. With a larger, flashy flow, a stream must adjust its shape and pattern to accommodate the new flow regime. And with these rapid changes in land use activities, the streams will also rapidly adjust. Streams are typically unstable during rapid adjustment periods, which has occurred and is currently occurring to the stream systems within the West Cuddihy watershed.

3.2 Physical Setting

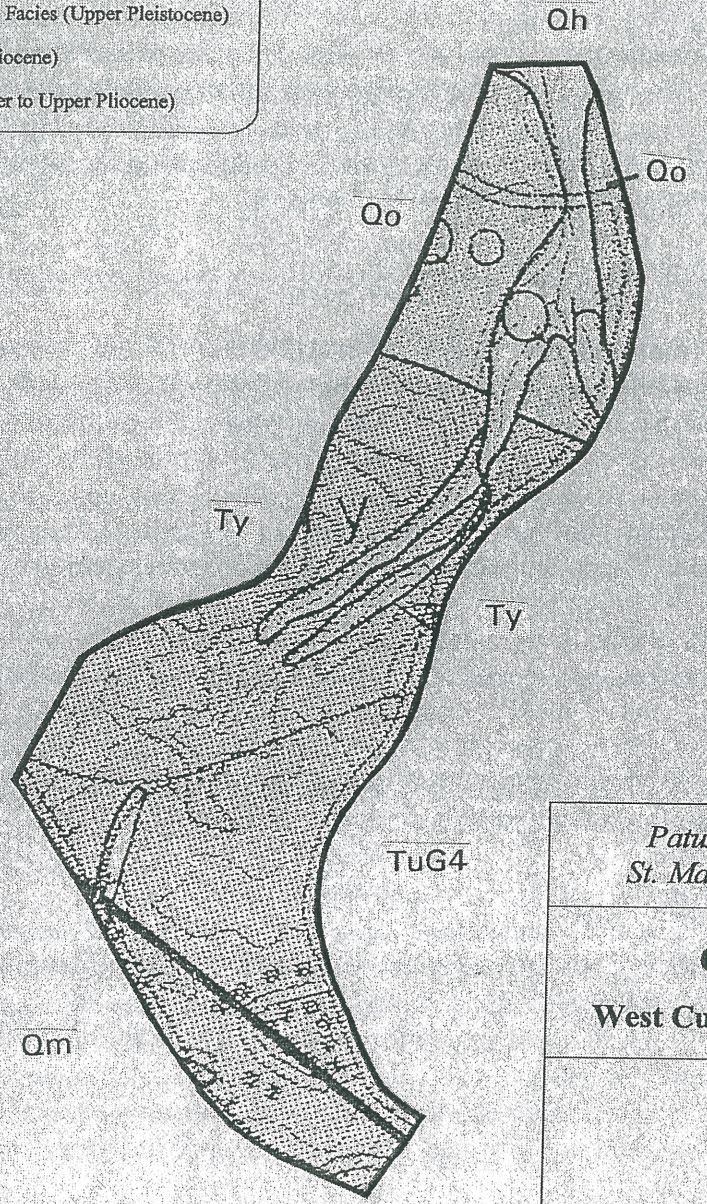
3.2.1 Geology

The most upper layer of the geology within the watershed consists of four primary formations: 1) Upland Gravel (upper pliocene), 2) Omar Formation, Estuarine Facies (upper pleistocene), 3) Holocene Deposits Undivided, and 4) Yorktown Formation (lower to upper pliocene) (Figure 2). The rise and fall of sea level over the centuries greatly influenced all three geological formations, and as a result, both fluvial and marine processes formed the current geology. The Upland Gravel extends from the upper part of the project watershed to its middle and the Omar Formation starts from this point and continues to the bottom of the watershed. The Holocene Deposits and Yorktown Formations are adjacent to the stream.

Legend

Geological Descriptions

Qh	Holocene Deposits, undivided
Qm	Maryland Point Formation (Upper Pleistocene)
Qo	Omar Formation, Estuarine Facies (Upper Pleistocene)
TuG4	Upland Gravel 4 (Upper Pliocene)
Ty	Yorktown Formation (Lower to Upper Pliocene)



Patuxent River NAS
St. Mary's County, MD

Geology
West Cuddihy Watershed

N
W E
S

Not To Scale

FIGURE 2

Data Source: St. Mary's County Soil Survey, 1978

May 2000

The upper layer of the Upland Gravel formation has two distinct layers: a medium gravel (10-20 feet thick) layer underlain by muddy coarse sand (15 to 20 feet thick). Underlying these two layers are three depositional layers: the estuary shore and transgressive layers of fine gravel, an estuary center layer of muddy sand, and a regressive, prograding fluvial layer of medium to coarse gravel. The Omar formation is predominantly sandy clay to clayey sand. The Holocene Deposits are unconsolidated deposits of poorly sorted sand and gravel to poorly sorted to well sorted sand, silt, and clay. The Yorktown Formations are a thin, dark green to black, sparsely fossiliferous, fine-grained, glauconitic sand, present between elevations of 40 to 60 feet.

3.2.2 Soils

The St. Mary's County, Maryland Soil Survey (U.S. Department of Agriculture - Soil Conservation Service, 1978) has mapped the project watershed within the Matapeake-Mattapex-Sassafras soil association. However, the soils and the steep V-shaped ravines within the project watershed are more characteristic of the Beltsville-Croom-Evesboro soil association. Soil surveys commonly have inclusions that allow for exceptions to its broad characterizations of soil associations and groups, as is the case in the project watershed. Figure 3 displays the soil types of the watershed.

The Beltsville soils within the project watershed are silty, very acidic, moderately well drained, moderately sloped and located in upland areas and hill slopes. There is a hard, dense fragipan in the lower part of the subsoil (approximately 22" –28" below ground) which prevents root growth and downward movement of water. The water table is typically perched within a depth of one-half to two and one-half feet. The soil is moderately erodable and water runs off readily.

The Croom soils are gravelly sand loam, well drained, steeply sloped and located in uplands. The soils were formed on old fluvial deposits of gravel containing sand and clay. There is a thin soil layer underlain by a hard, compacted or cemented subsoil consisting of a gravelly sand clay loam. The soil is droughty and has a shallow root zone. Erosion can be severe if vegetation is cleared or the soil is disturbed, ultimately leading to the formation of gullies. There are some Chillum soils within the project watershed which have very similar characteristics of Croom soils except they are generally located on ridge tops and were formed as silt or sand deposits over dense gravelly material.

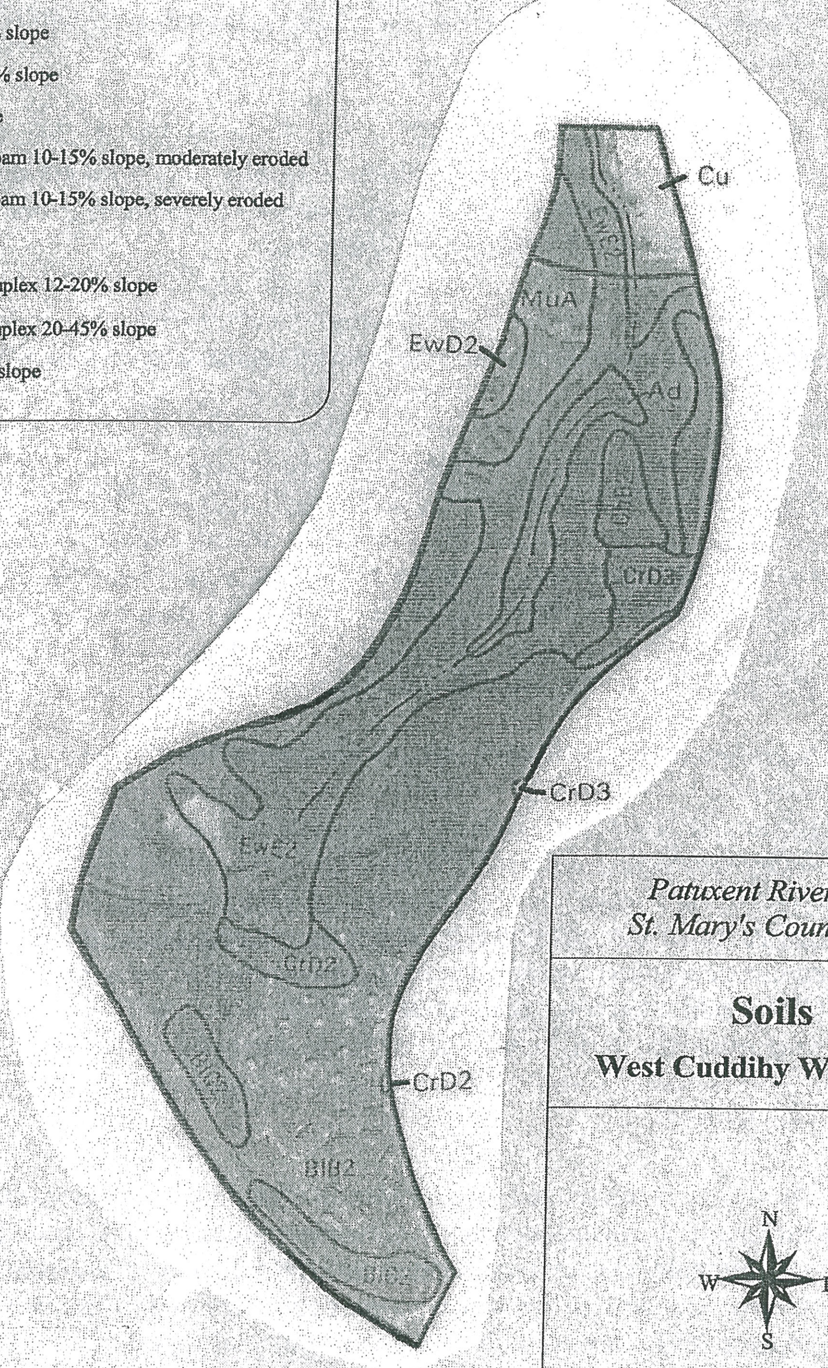
The Evesboro soils are sandy, excessively drained, steeply sloped, very deep (5') and have been cut by many deep V-shaped ravines in upland areas. They were formed in old marine deposits of sand that have been worked or partially reworked by wind and water. Their permeability is rapid and erosion is moderate to severe.

There is also an area of Alluvial soils that formed from materials recently washed from uplands and deposited in a narrow, low gradient floodplain area within the project watershed.

Legend

Soil Descriptions

Ad	Alluvial Land, Wet
BlB2	Beltsville Silt Loam 2-5% slope
BlC2	Beltsville Silt Loam 5-10% slope
ChB2	Chillum Loam 2-6% slope
CrD2	Croom Gravelly Sandy Loam 10-15% slope, moderately eroded
CrD3	Croom Gravelly Sandy Loam 10-15% slope, severely eroded
Cu	Cut & Fill Land
EwD2	Evesboro-Westphalia Complex 12-20% slope
EwE2	Evesboro-Westphalia Complex 20-45% slope
MuA	Mattapex Silt Loam 0-2% slope



Patuxent River NAS
St. Mary's County, MD

Soils

West Cuddihy Watershed

N W E S

Not To Scale

FIGURE 3

Data Source: St. Mary's County Soil Survey, 1978

May 2000

3.2.3 Land Use

Three general types of land use exist within the West Cuddihy watershed: forested, urbanized, and wetlands (Figure 4).

Accounting for 52% (115 of 223 acres) of the total landscape, forested areas constitute the largest portion of the watershed. Forested land types are identified as upland areas characterized by native pioneer, succession, or climax vegetation species and are found in contiguous tracts throughout the watershed.

Residential, commercial and industrial developments account for 41% (92 acres) of the watershed's landscape. These developed landscapes may be further categorized as urban or maintained land uses. Urban land uses, which include residential communities, commercial establishments, and roadway networks, comprise the greatest proportion of the developed landscape. These areas are typically characterized by expansive tracts of impervious surfaces and are located along headwater reaches (Figure 6). Two roadway crossings also culvert over portions of the stream and divide the watershed: Buse Road (located about mid-way down the basin) and Davis Road (located at the bottom of the basin). Maintained land uses in the watershed are generally associated with powerline right of ways and characterized by a dominant scrub/shrub vegetation layer. Several powerlines cross the watershed and transect the stream at several locations (Figure 1).

Streams and wetlands comprise the remaining 7% (16 acres) of the West Cuddihy watershed. The streams occurring in the watershed are classified as perennial or ephemeral. Perennial streams are the mainstem and tributary streams found in lower valley elevations, and generally maintain flows year round. Ephemeral streams are typically headwater streams found around the periphery of the watershed and provide a source of hydrology for perennial streams. Palustrine wetland systems found adjacent to streams constitute the remainder of the watershed landscape. Extensive forested wetlands (PFO) were identified along portions of the watershed. Open-water wetlands (POW) were prevalent at the bottom of the basin due to beaver activity.

3.2.4 Climate

The area is characterized by a temperate climate with traceable levels of precipitation year round. Climatology data obtained from the Naval Atlantic Meteorology and Oceanography Detachment located on PRNAS shows mean daily temperatures ranging from the low 40°F in the winter to the upper 70°F in the summer. Annual precipitation averages 40.57 inches, with notable rainfall year round. Snow and freezing rain is not uncommon in the winter, however the frequency of freeze-thaw cycles diminishes the effects of frozen precipitation on the water budget. Table 1 below presents the monthly averages and ranges of temperature and precipitation occurring on PRNAS for the duration of our study (from March 1997 through March 2000).

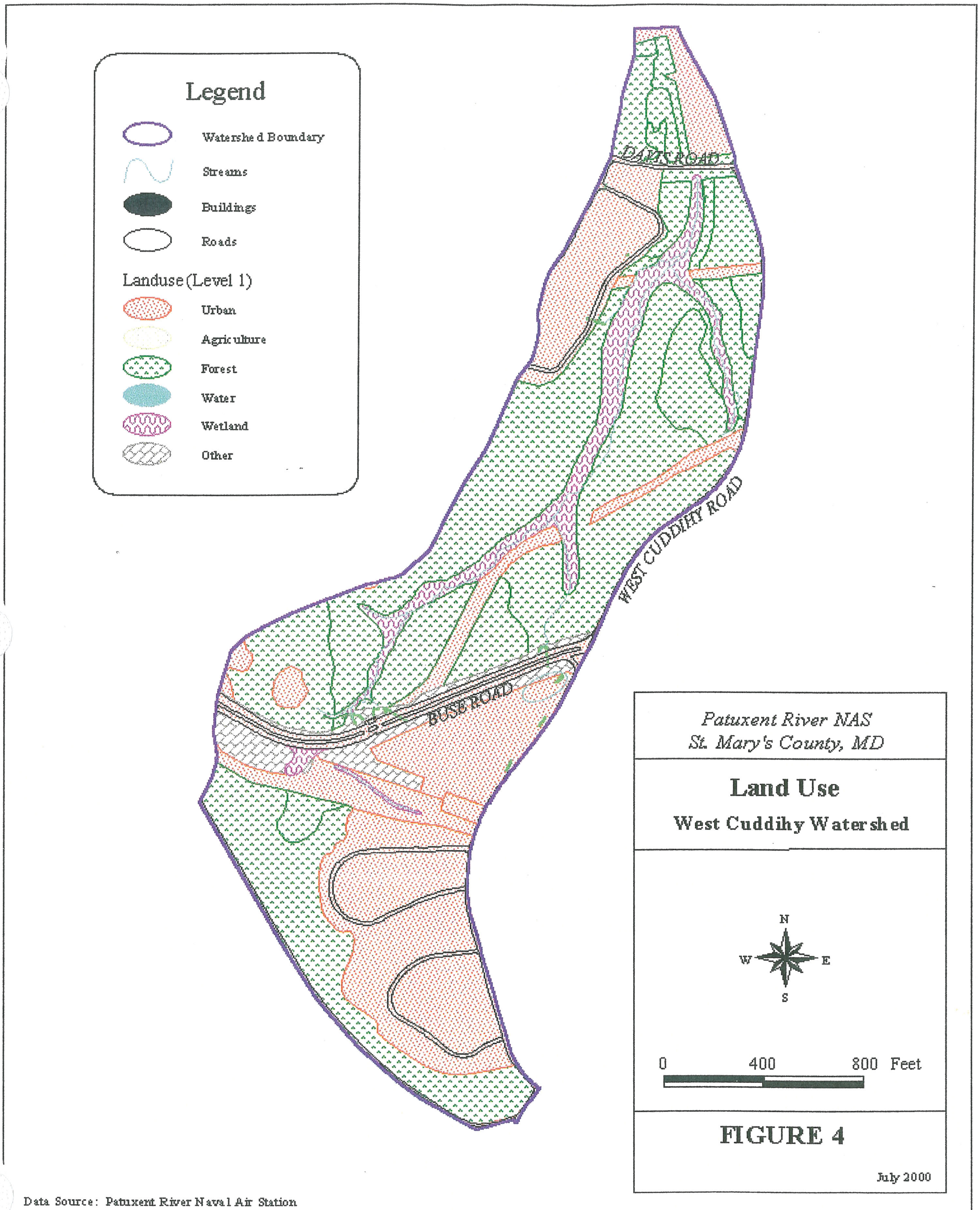


FIGURE 4

July 2000

Data Source: Patuxent River Naval Air Station

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	Monthly Average and Range for March 1997 through March 2000												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Temperature (°F) Average Min Max	39.0 10 72	40.6 5 71	47.0 22 88	54.3 30 84	64.2 38 91	71.9 44 97	77.8 58 101	76.8 55 100	70.8 45 97	58.1 31 89	49.2 24 75	41.3 16 80	57.6 31.5 87
Precipitation (inches) Average Min Max	4.84 2.80 6.58	3.86 0.97 7.70	4.78 3.88 5.75	2.79 1.82 3.35	1.96 0.42 3.77	3.34 1.12 5.80	3.11 1.16 5.97	2.65 1.22 4.32	4.87 1.48 11.58	2.18 1.08 2.85	3.34 0.85 7.38	2.85 2.38 3.57	3.38 1.6 5.72

3.2.5 Topography

The watershed topography is characterized as steeply sloped hillsides surrounding the circumference of the watershed that have been cut by several deep V-shaped ravines which drain into narrow, shallow sloped floodplains (Figure 1). Watershed elevations range from 135 feet above mean sea level (MSL) in the extreme southern portion of the watershed to sea level at the extreme northern portion of the watershed. The hillside slopes range from 28 percent to 56 percent. The upper watershed floodplain has a typical valley width of 50 feet and a valley slope of 5 percent. The lower watershed floodplain has a typical valley width of 100 feet and a valley slope of 2.6 percent.

3.3 Hydrology

A hydrologic analysis of the watershed was conducted by PRNAS in 1989 and 1999 as part of the Naval Air Station's regional stormwater management plan. The analyses identified stormwater runoff problem areas and provided solutions for the problem areas. The analyses evaluated among several parameters, peak discharge. The peak discharge estimates provide information necessary to characterize the existing hydrologic regime. The estimates also provide a basis for evaluating the affects on watershed hydrology from land use changes and implementation of best management practices.

A comparison of percent impervious surface, runoff amounts and peak discharge estimates for pre-development conditions, 1989 conditions and existing conditions shows the effects of the construction activities that occurred during the period of 1989 and 1999 (Table 2). The construction activities include the Navy exchange complex andBuse Road. While these increases can be directly contributed to recent development activities, the increase in total runoff and peak storm discharges are amplified by the soil types and steep slopes within the watershed.

Table 2 – Stormwater Runoff and Discharge Estimates

	Percent Impervious Surface* (%)	Total Runoff* (acre feet)		2-yr 24 hr Storm Peak Discharge (cfs)	10-yr 24 hr Storm Peak Discharge (cfs)
		2-yr	10-yr		
Pre-Development	Unknown	5.52	20.18	36**	168*
1989 Conditions	6	8.30	25.69	56*	229*
1999 Conditions	26	12.33	32.85	71**	264**

* - Data from the 1989 Stormwater Management Plan
** - Data from the 1999 Stormwater Management Plan

The soil types within the project watershed can be divided into two very distinct groups on the basis of run-off characteristics. The soil groups located on the ridge areas have moderately high surface runoff potential, steep slopes, minimal water storage area, perched water tables, and shallow, hard fragipan or compacted/cemented subsoils. These general characteristics along with the narrow V-shape topography result in a flashy flow regime that is sensitive to land use changes. A flashy flow regime causes stream water levels to rise and fall rapidly during a storm event. The perched water tables can cause mass wasting (a large collapse of hillside) from pipe erosion between the fragipan and upper soil layers, thus becoming a significant source of sediment and potentially affecting stream channel alignment and dimensions. The soils on the ridge areas are also a potentially significant sediment supply source, since they can be severely eroded if they are cleared of vegetation or disturbed.

The stream valley floor soils are very sensitive to change in watershed land use activities due to the flashy runoff, steep V-shape ravines, and the severe erosion potential of these loose sandy soils. Even though the soils are very deep and permeable, their severe erosion potential can result in active channel incision if there are rapid and sudden changes in land use activities within the watershed. Incision can go quite deep since the underlying subsoil/geology is made up of unconsolidated deposits of poorly sorted sands and gravel to poorly sorted to well sorted sand, silt, and clay which are also moderately to severely prone to erosion. Stream systems which are unstable within this soil group typically have a large sediment budget with some areas degrading while other areas are aggrading.

The increases in runoff and peak storm discharges have resulted in a new flow regime for the watershed compared to pre-development conditions. The streams are now required to convey nearly twice as much flow for a 2-year storm. The channel forming, or bankfull, flow associated with a stream is typically somewhere between a 1 and 2-year storm event. Thus, the stream channels will most likely adjust by down-cutting and widening to accommodate the new flow regime. The areas directly downstream of the recent land use changes will experience the most notable impacts of stream adjustments. These areas include the entire upper east tributary and the upper section of the mainstem downstream of Buse Road (Figure 1).

3.4 Vegetation

Large tracts of vegetation extend throughout Patuxent River Naval Air Station. The vegetative communities of West Cuddihy Basin are densely forested providing a closed canopy cover for considerable portions of the stream and adjacent riparian corridor. Characterized as a temperate deciduous community, mature red maple (*Acer rubrum*), tulip poplar (*Liriodendron tulipifera*), sweetgum (*Liquidambar styraciflua*) and oak (*Quercus spp.*) dominate the basin□s vegetation (Figure 5).

All 30 of the study reaches are dominated by continuous tracts of mature vegetation providing a dense canopy cover. The dominant species of red maple (*Acer rubrum*), tulip poplar (*Liriodendron tulipifera*), sweetgum (*Liquidambar styraciflua*) and oak (*Quercus spp.*) span the basin, extending well into the riparian area and onto the stream banks. Beneath this mature canopy, sparse to moderate patches of shade tolerant vegetation are present. Species commonly found in these understory areas include mountain laurel (*Kalmia latifolia*), sweet pepperbush (*Clethra alnifolia*), highbush blueberry (*Vaccinium corymbosum*) and flowering dogwood (*Cornus florida*).

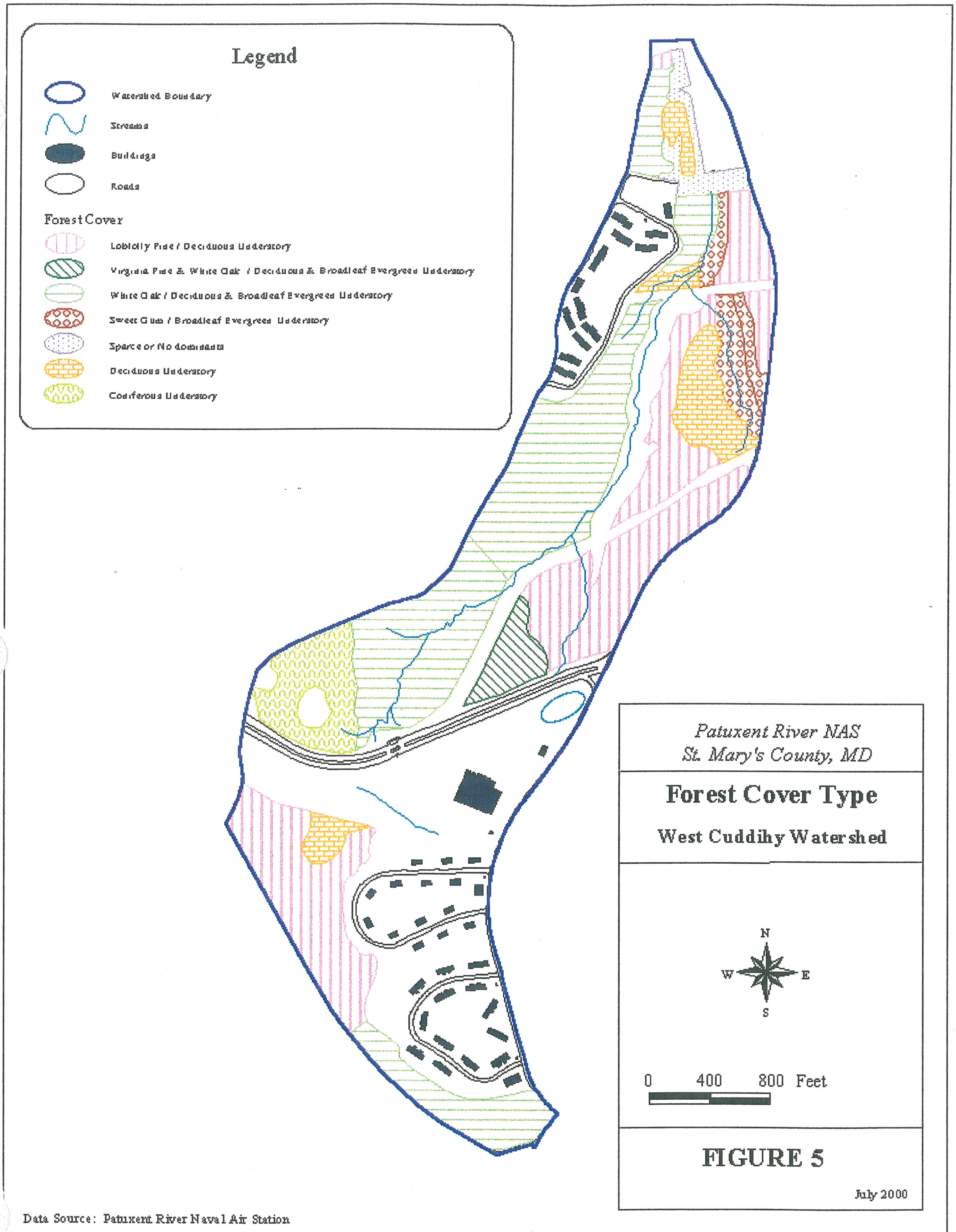
The maintenance of two powerline right-of-ways traverse West Cuddihy Basin has resulted in communities of scrub/shrub vegetation. These right-of-ways transect the upper and lower commissary and study Reaches 14, 17, and 21. Dominant vegetation species within these communities include sweet pepperbush (*Clethra alnifolia*), highbush blueberry (*Vaccinium corymbosum*), red maple (*Acer rubrum*), American holly (*Ilex opaca*), and multiflora rose (*Rosa rugosa*).

Significant ground cover communities have established in the flood plain of Rosgen D stream types. These reaches, characterized by braided stream channels and extensive riparian wetlands, are found in Reaches 9, 10, 11, 12 and 17. Dominant vegetation species found within this strata are lizard's tail (*Saururus latifolia*), royal fern (*Osmunda regalis*), sedges (*Scirpus spp.*), and rushes (*Juncus spp.*). A detailed list of plant species is located in Appendix C.

3.5 Stream Geomorphology

3.5.1 Overall Watershed Characterization

Twenty-four different stream reaches within the watershed were surveyed, and six other reaches were identified but not surveyed (Figure 6). Twelve reaches were surveyed on the mainstem; one on the lower west tributary; one on the upper west tributary; five on the lower east tributary; and four on the upper east tributary. The unsurveyed reaches were similar to other reaches within the watershed and therefore, their Rosgen stream classifications were extrapolated from the surveyed reaches. The general Rosgen stream types of Aa, A, B, Bc, C, E, Eb, D, and G exist within the watershed. Table 3 provides the results of the Rosgen stream classification.



Legend
Watershed Boundary
Streams
Buildings
Roads
Forest Cover
Loblolly Pine / Deciduous Understory
Virginia Pine & White Oak / Deciduous & Broadleaf Evergreen Understory
White Oak / Deciduous & Broadleaf Evergreen Understory
Sweet Gum / Broadleaf Evergreen Understory
Sparce or No dominants
Deciduous Understory
Coniferous Understory
Patuxent River NAS
St. Mary's County, MD
Forest Cover Type
West Cuddihy Watershed
N
W
E
S
0 400 800 Feet
FIGURE 5
July 2000
Data Source: Patuxent River Naval Air Station

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Table 3 – Rosgen Stream Types Existing within West Cuddihy

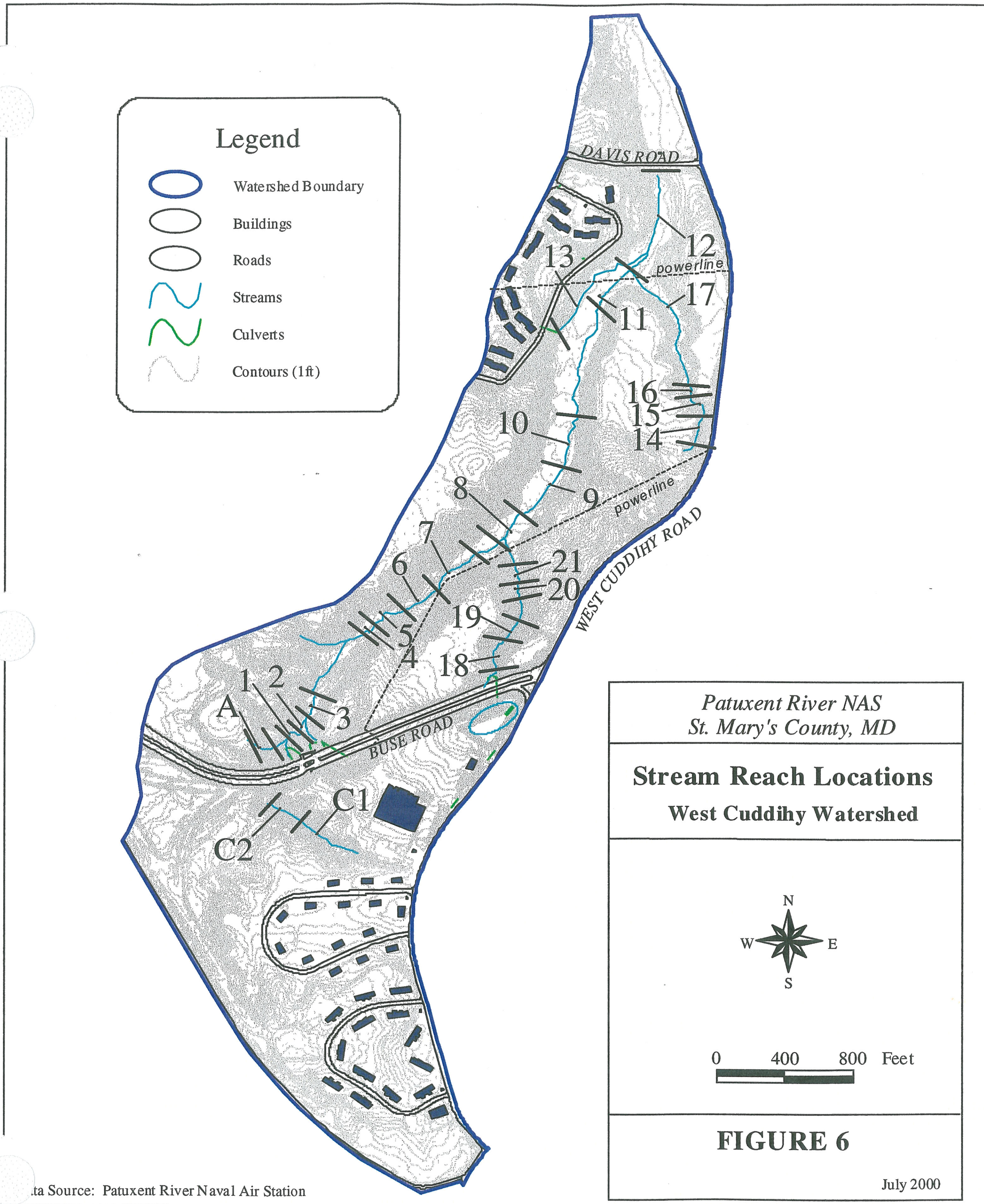
Stream Type	Linear Feet	Percent of Total
Aa+6	95	1.5
A4/5	418	6.4
B4/5	177	2.7
Bc5	395	6.0
C4	533	8.1
E4/5	2,751	41.9
Eb4/5	196	3.0
D5	712	10.8
G4/5	1121	17.1
G6	171	2.6
Total	**6,569**	

Rosgen A stream types represent approximately eight percent of the total stream length within the watershed. They are steep, entrenched and confined channels that are highly sensitive to disturbance and have a poor recovery potential. Entrenchment is the vertical containment of a stream and the degree to which it is incised in the valley floor. A stream that is highly entrenched has a small floodplain width (i.e., a steep mountain stream) and a stream that is slightly entrenched has a large floodplain width (i.e., a large meadow). These stream types are generally found in the tributary and headwaters areas of this watershed with slopes of four percent or greater. An example of a Rosgen A stream type is shown in Appendix A, Photograph 1.

Rosgen B stream types represent approximately nine percent of the total stream length within the watershed. They are moderately entrenched, low sinuosity channels with a slope of two to four percent that are moderately sensitive to change and have an excellent recovery potential. Sinuosity is defined as 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 are also generally found in the tributary and headwaters areas of this watershed. An example of a Rosgen B stream type is shown in Appendix A, Photograph 2.

Rosgen C stream types represent approximately eight percent of the total streams within the watershed. They 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. These stream types are generally found on the mainstem where there are low valley slopes and relatively large floodplain areas. An example of a Rosgen C stream type is shown in Appendix A, Photograph 3.

Rosgen E stream types represent approximately 44 percent of the total streams within the watershed. They are slightly entrenched, low gradient, and meandering channels with


Legend
Watershed Boundary
Buildings
Roads
Streams
Culverts
Contours (1ft)
DAVIS ROAD
powerline
powerline
WEST CUDDIHY ROAD
BUSE ROAD
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
A
C1
C2
Patuxent River NAS
St. Mary's County, MD
Stream Reach Locations
West Cuddihy Watershed
N
W
E
S
0
400
800
Feet
FIGURE 6
July 2000
ta Source: Patuxent River Naval Air Station

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low width/depth ratios and well developed floodplains that are highly sensitive to disturbance but have good recovery potential. Width/depth ratio is defined as 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 are also generally found on the mainstem where there are low valley slopes and relatively large floodplain areas. An example of a Rosgen E stream type is shown in Appendix A, Photograph 4.

Rosgen D stream types represent approximately 11 percent of the total streams within the watershed. They are braided (multi-channels), high width/depth ratio channels found in well developed floodplains that are highly sensitive to disturbance and have a poor recovery potential. They are also typically considered unstable, transitional streams that were once a Rosgen C or E stream type. These stream types are generally on the mainstem where there has been some type of disturbance. An example of a Rosgen D stream type is shown in Appendix A, Photograph 5.

Rosgen G stream types represent approximately 20 percent of the total streams within the watershed. They are entrenched, moderately steep, incised channels that are highly sensitive to disturbance and have a very poor recovery potential. Incision is defined as 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 an Rosgen A, B, C, or E stream type. These stream types are generally found throughout the watershed where there has been some type of disturbance. An example of a Rosgen G stream type is shown in Appendix A, Photograph 6.

The overall conditions of the streams within the watershed vary. Both natural processes and human activities have had and continue to influence the evolution and condition of streams. Beaver activity, debris jams, vegetation density, significant storm events, mass wasting, vegetation clearing, housing and commercial developments, permanent and temporary road crossings, and stormwater management facilities have all resulted in varying spatial and temporal stream impacts. These activities, combined with the flashy flow regime and sensitivity of the streams, have resulted in an overall stream system that is continually adjusting at variable rates. The stream types that are less sensitive to disturbance (approximately 50 to 70 percent) are generally stable and are adjusting at a naturally occurring rate. Those streams that are sensitive to disturbance and appear to have had some type of disturbance (approximately 30 to 40 percent) are unstable and adjusting at rates too rapid for biological resources to be sustained. Specific stream morphological conditions are presented in Section 3.5.2 Reach Characterization.

The FWS Contaminants Branch conducted a rapid bioassessment West Cuddihy watershed. They conducted a rapid bioassessment at 3 sites within the watershed: 1) WCA, located in the upper one-third of watershed, 2) WCB, located in the middle one-third of the watershed, and 3) WCC, located in the lower one-third of the watershed. The results of their assessment indicated that the overall bioassessment scores, based on percent comparability to a reference, were highest at WCA, which were assessed as non-impaired. The two remaining sites, WCB and WCC, were assessed as being slightly impacted. Species composition at these sites was lower than expected due to the loss of some taxa that are considered pollution tolerate. Their assessment also noted several areas with unstable, eroding streambanks and heavy sediment loads that can have major impacts on benthic communities through smothering of benthic organisms or limiting the amount of available habitat. An explanation of why their assessment indicated a relatively high species diversity and rating as only slightly impaired, even with a heavy sediment load, may be attributed to the presence of abundant woody debris which serves as a substrate for benthic colonization. The irregularity of woody surface areas and effects of physical flow of the water, are important attributes of woody debris that contribute to habitat variability.

3.5.2 Reach Characterization

This section summarizes the results of the morphologic stream assessment conducted by the FWS in the West Cuddihy watershed. Characterization descriptions of reaches with similar morphologic conditions are combined. Table 4 provides a summary of Morphologic parameters for each reach are summarized in Table 4. Below reaches are characterized according to stability and stream type. Detailed reach descriptions such as cross-sectional plots, pebble counts, longitudinal profiles, and 1997/2000 cross-section overlays are presented in Appendix B – Detailed Stream Reach Characterization Data.

3.5.2.a Reaches C1, C2, A, and 1

Reach	Rosgen Stream Type	Length (ft.)	Water Surface Slope (ft/ft)
C1	G6	77	0.025
C2	G6	94	0.012
A	A+6	95	0.145
1	A4/5	168	0.025

Reach	BKF Width(ft)	AVG BKF Depth(ft)	W/D Ratio	FPW (ft)	Entrenchment Ratio	C/S Area (ft^2)	D50 (mm)
C1	2.33	0.60	3.88	5.9	2.53	1.4	<0.062
C2	2.60	0.54	4.78	4.49	1.73	1.42	<0.062
A	2.69	0.55	4.93	4.75	1.76	1.47	<0.062
1	3.30	0.44	7.43	3.97	1.20	1.46	0.35

These reaches are relatively stable with some minor, localized bank and bed adjustments occurring. Reach C2 has a 4-foot head cut that has reached a clay layer and is no longer rapidly moving upstream. A photograph of a head cut is located in Appendix A, photograph 7. For Reach 1, comparison of 1997 and 2000 cross section surveys

TABLE 4
SUMMARY OF STREAM CHARACTERISTICS
West Cuddihy Basin, Patuxent Naval Air Station – 2001

LOCATION	ROSGEN CLASSIFICATION																PATTERN			EROSION CROSS SECTION									
	Reach	Reach Length (ft)	Stream Type	BKF Width (ft)	AVG BKF Depth (ft)	FPW (ft)	W/D Ratio	Entrench-ment Ratio	Cross-section Area (ft2)	Bank-full Disch-arge (cfs)	Water Surface Slope (ft/ft)	Valley slope (ft/ft)	Thal Length (ft)	Valley length (ft)	Sinuosity	D50 (mm)	Riffle D84 (mm)	Lm (ft)	Rc (ft)	BW (ft)	BKF Width (ft)	Cross-sectnal area (ft2)	BKF Depth (ft)	Avg shear stress (lbs/ft2)	nb shear stress (lbs/ft2)	facet slope (ft/ft)	nb strss/ avg strss	BEHI	Notes
Commissary	1	77	G6	2.33	0.60	5.90	3.88	2.53	1.40	N/A	0.025	0.024	78.0	77.0	1.01	<0.062	<0.062	N/A	3.8	N/A	3.30	1.38	0.41	0.64	2.56	0.072	4.00	16.90	
Commissary	2	94	Gc6	2.60	0.54	4.49	4.78	1.73	1.42	N/A	0.012	0.013	94.0	87.0	1.08	<0.062	12.00	N/A	N/A	N/A	3.88	1.91	0.48	0.36	0.04	0.001	0.11	40.70	
Mainstem	A	95	Aa+6	2.69	0.55	4.75	4.93	1.76	1.47	N/A	0.145	0.148	92.0	90.0	1.02	<0.062	N/A	30	5.6	5	2.60	1.59	0.61	5.52	2.64	0.05	0.48	37.50	
Mainstem	1	168	A5	3.30	0.44	3.97	7.43	1.20	1.46	6.1	0.025	0.029	156.1	132.0	1.18	0.35	38.59	21	7.4	9	3.82	1.59	0.41	0.65	0.01	0.0004	0.02	32.10	
Mainstem	2	86	E4/5	5.50	0.55	20.15	9.96	3.66	3.04	5.5	0.005	0.006	85.7	84.0	1.02	0.44	23.13	40	3.7	7	5.69	4.01	0.71	0.24	0.02	0.0005	0.07	26.90	
Mainstem	3	196	Eb4/5	2.99	0.71	8.87	4.20	2.97	2.13	7.1	0.03	0.030	196.3	172.5	1.14	0.38	0.48	39	4.8	13	3.45	3.53	1.02	1.72	0.49	0.0096	0.29	21.20	
Mainstem	4	98	E5	8.00	0.72	67.00	11.07	8.38	5.78	6.4	0.01	0.01	97.8	86.2	1.13	0.68	5.15	N/A	6.1	10	8.50	5.21	0.61	0.19	0.38	0.01	2.01	37.60	
Mainstem	5	244	G5 ← E5	5.84	0.45	9.05	13.08	1.55	2.61	9.6	0.039	0.029	244.0	240.0	1.02	0.21	0.50	N/A	N/A	50	3.12	2.67	0.84	2.03	0.73	0.02	0.36	24.70	
Mainstem	6	252	Gc5 ← E5	3.90	0.85	5.01	4.58	1.29	3.32	11.2	0.014	0.014	251.5	248.0	1.01	0.35	6.00	N/A	7.6	14	6.35	4.16	0.47	0.41	0.42	0.016	1.04	36.30	
Mainstem	7	395	Bc5 → C5	7.28	0.54	10.61	13.46	1.46	3.94	10.9	0.010	0.01	395.3	329.0	1.20	0.18	0.46	46	5.4	20	6.42	3.19	0.50	0.25	0.07	0.00	0.26	37.10	Entrenched from past head cut & is/has aggraded
Mainstem	8	307	C5 → E5	16.77	0.35	38.30	47.64	2.28	5.90	13.5	0.0067	0.0073	307.0	284.0	1.08	0.19	8.00	72	8.9	21	15.43	5.29	0.34	0.14	0.12	0.0032	0.87	33.20	
Mainstem	9	436	D/E	8.33	0.66	119.97	12.67	14.40	5.48	N/A	N/A	N/A	N/A	435.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	*Wetland
Mainstem	10	185	D/E5	5.20	1.32	131.00	3.93	25.19	6.88	22.7	0.005	0.006	184.5	162.0	1.14	0.14	4.34	12	4.2	12	7.37	6.98	0.95	0.30	0.11	0.002	0.37	29.00	
Mainstem	11	155	D/E4/5	6.63	0.80	91.10	8.30	13.73	5.30	N/A	0.002	0.002	155.0	137.0	1.13	N/A	N/A	70	5.6	15	6.95	10.52	1.51	0.19	1.83	0.033	9.73	20.40	new beaver dam since 1997
Mainstem	12	712	D5 ← E5	9.00	0.57	65.30	15.79	7.26	5.13	N/A	0.0049	0.0054	712.0	642.5	1.11	N/A	N/A	20	6.1	31	15.05	4.31	0.29	0.09	N/A	0.0065	N/A	18.50	new beaver dam since 1997
West Trib	13	353	C5	9.93	0.34	85.00	29.49	8.56	3.34	5.4	0.008	0.011	134.5	100.0	1.35	1.17	16.00	57	10.7	17	12.06	3.58	0.29	0.18	0.06	0.003	0.31	17.70	new beaver dam since 1997
Bott. East Trib	14	142	Cross section was surveyed at the head cuts. BKF could not be determined							N/A		N/A	N/A	131.0	N/A	0.18	0.23	N/A	6.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	*Bankfull not determined
Bott. East Trib	15	83	B5a	4.68	0.53	9.36	8.83	2.00	2.48	4.9	0.059	N/A	82.8	N/A	N/A	0.18	8.85	35	22.6	8	3.98	2.83	0.65	2.39	0.70	0.022	0.29	32.50	
Bott. East Trib	16	94	B6	6.54	0.29	7.41	22.67	1.13	1.88	4.9	0.022	0.025	94.0	82.0	1.15	0.06	13.46	32	6.6	17	6.03	2.23	0.37	0.50	0.17	0.024	0.35	38.20	
Bott. East Trib	17	954	C/E/D	23.00	0.17	51.63	134.09	2.24	3.94	N/A	0.024	0.025	954.0	853.0	1.12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	xs in braid, reach also has E & C channels. Changed BKF/Wetland
Top East Trib	18	112	G5 ← A5	2.83	0.40	3.79	7.10	1.34	1.13	5.2	0.046	0.052	111.9	98.0	1.14	0.11	33.32	35	3.6	15	5.63	1.68	0.24	0.76	0.08	0.009	0.11	30.60	
Top East Trib	19	105	G5 ← A5	3.12	0.47	4.00	6.60	1.28	1.48	5.6	0.031	0.034	104.7	95.5	1.10	0.07	40.34	24	10.0	6	4.55	1.14	0.25	0.46	0.51	0.030	1.12	38.90	Now a 'B' from severe aggradation
Top East Trib	20	87	Gc5	4.26	0.49	6.90	8.78	1.62	2.07	5.7	0.0127	0.0129	86.7	85.1	1.02	0.40	27.71	33	9.5	9	4.14	1.92	0.43	0.27	0.54	0.0227	1.99	38.50	
Top East Trib	21	98	G5 ← E5	4.18	0.46	4.46	9.11	1.07	1.92	5.9	0.051	0.057	92.2	82.0	1.12	0.26	N/A	20	5.9	11	6.69	3.79	0.55	1.75	3.37	0.058	1.93	50.00	

(Appendix B) shows that the channel has had minor lateral adjustment, probably as result of road runoff from Buse Road. The lateral erosion remains minor due to the dense riparian vegetation and low near bank stress. Additionally, Reach 1 has a low width/depth ratio and as a result, is efficient in transporting the moderate sediment load derived from hillside erosion, again as a result of runoff from Buse Road. These streams will remain stable if the flow regime remains unchanged. Instream habitat may support aquatic biota, in the perennial sections only, but will have impacts from Buse Road runoff and the moderate sediment supply associated with hillside erosion.

Some consideration should be given to correcting the head cut. Even though movement of the head cut has slowed considerable due to the clay layer, once the stream has cut through the clay layer, upstream migration of the head will continue resulting in severe degradation of upstream reaches.

3.5.2.b Reaches 2, 3, 4 and Unsurveyed Reach between 3 and 4

Reach	Rosgen Stream Type	Length (ft.)	Water Surface Slope (ft/ft)
2	E4/5	86	0.005
3	Eb4/5	196	0.030
4	E5	98	0.010
Unsurveyed Reach	E4/5	150	N/A

Reach	BKF Width(ft)	AVG BKF Depth(ft)	W/D Ratio	FPW (ft)	Entrenchment Ratio	C/S Area (ft^2)	D50 (mm)
2	5.50	0.55	9.96	20.15	3.66	3.04	0.44
3	2.99	0.71	4.20	8.87	2.97	2.13	0.38
4	8.00	0.72	11.07	67.0	8.38	5.78	0.68

All of these reaches are relatively stable with some minor, localized bank and bed adjustments occurring as a result of small debris jams. The localized instability caused by debris jams does not significantly impact the overall stability of the stream but does provide diverse habitat for wildlife. The stream reaches have higher width/depth ratios and shallower stream gradients than the upstream reaches and, as a result are less efficient in transporting the moderate to high sediment load and thus some minor aggradation has occurred. The stability of the streams is threatened by a major head cut located in Reach 5 immediately downstream of Reach 4. If this head cut is not addressed and it will continue to migrate upstream and destabilize upstream reaches. However, these streams will remain stable if the head cut is stabilized and the flow regime remains unchanged. Instream habitat may support aquatic biota, but be impacted by the moderate to high sediment load.

3.5.2.c Reaches 5 and 6

Reach	Rosgen Stream Type	Length (ft.)	Water Surface Slope (ft/ft)
5	G5←E5	244	0.039
6	G4/5 ←E4	252	0.014

Reach	BKF Width(ft)	AVG BKF Depth(ft)	W/D Ratio	FPW (ft)	Entrenchment Ratio	C/S Area (ft^2)	D50 (mm)
5	5.84	0.45	13.08	9.05	1.55	2.61	0.21
6	3.90	0.85	4.58	5.01	1.29	3.32	0.35

Both of these reaches have significant lateral and vertical adjustments occurring as a result of a major head cut, that has gone through Reach 6 and is at the upstream end of Reach 5, about to enter Reach 4. An example of bank erosion is located in Appendix A, photograph 8. The head cut originated in either Reach 7 or 8 from an unknown past disturbance. In Reach 5, comparison of the 1997 and 2000 cross section surveys indicates that the channel has down-cut approximately 1.2 feet and both banks have migrated outward approximately 1.0-foot each. The Reach 6, 1997/2000 cross section overlay indicates that the channel is relatively unchanged, with the exception of some bank erosion, which indicates that the head cut had already gone through Reach 6 before the 1997 cross section was surveyed. Both of the reaches are significantly incised and a large storm event is required for flows to reach the flood plain. As a result, erosive factors are extremely high and will cause the streams to continually adjust (widen and deepen) until the streams can build a new, lower elevation flood plain. Until this new flood plain is built, Reaches 5 and 6 habitat conditions will be poor and will supply a large amount of sediment to downstream reaches.

3.5.2.d Reaches 7 and 8 and Unsurveyed Reaches between 7 and 8

Reach	Rosgen Stream Type	Length (ft.)	Water Surface Slope (ft/ft)
7	Bc5→C5	395	0.010
Unsurveyed Reach	C5→E5	160	N/A
8	C5→E5	307	0.0067

Reach	BKF Width(ft)	AVG BKF Depth(ft)	W/D Ratio	FPW (ft)	Entrenchment Ratio	C/S Area (ft^2)	D50 (mm)
7	7.28	0.54	13.46	10.61	1.46	3.94	0.18
8	16.77	0.35	47.64	38.30	2.28	5.90	0.19

All three of these reaches have adjusted significantly from past disturbances and are still evolving into more stable configurations. At one time, all of these reaches were probably Rosgen E4 stream types, but due to a significant head cut, they became incised. Over the years the streams have adjusted laterally and aggraded in an attempt to build a new flood plain. An example of channel aggradation is located in Appendix A, photograph 9. The 1997/2000, cross section overlays for reaches 7 and 8 indicate some minor aggradation and channel adjustments. All of these reaches have to convey a high sediment load coming from Reaches 5 and 6. Additionally, Reach 8 has to convey a very high sediment load coming from the upper east tributary. In an attempt to convey the high sediment loads, Reach 7 is evolving towards a stable Rosgen C4 stream type and Reach 8 is evolving into a Rosgen E4 stream type. All of these reaches have a good recovery potential based on the management interpretations of the Rosgen stream types (Rosgen, 1996). And if the flow regime remains unchanged and the degradation upstream in Reaches 5 and 6 is corrected, these reaches should adjust into a more stable form able to efficiently convey the high upstream sediment loads and provide improved instream habitat for aquatic biota.

3.5.2.e Reaches 9, 10, 11, and Unsurveyed Reach between 10 and 11

Reach	Rosgen Stream Type	Length (ft.)	Water Surface Slope (ft/ft)
9	E/D	436	N/A
10	E/D5	185	0.005
Unsurveyed Reach	E/D5	570	N/A
11	E/D5	155	0.002

Reach	BKF Width(ft)	AVG BKF Depth(ft)	W/D Ratio	FPW (ft)	Entrenchment Ratio	C/S Area (ft^2)	D50 (mm)
9	8.33	0.66	12.67	120	14.40	5.48	N/A
10	5.20	1.32	3.93	131	25.19	6.88	0.14
11	6.63	0.80	8.30	91	13.73	5.30	N/A

All of these reaches are relatively stable with some minor, localized bank and bed adjustments occurring as a result of small debris jams. Some of the riffles within all of the reaches are embedded with fine sands, which is indicative of a moderate to high sediment load. However, the reaches have good width/depth ratios and access to well developed flood plains that allow the streams to convey a majority of the heavy sediment load. Debris jams and other localized disturbances have caused some areas within the reaches to become braided. Braided reaches are typically considered unstable, however the braided sections in these reaches are fairly stable as a result of the existing dense riparian vegetation. The Reach 10, 1997/2000, cross section overlay indicates some localized aggradation from fallen trees. The fallen trees have caused a back-water effect and settling of fine materials. A new beaver dam at the downstream end of Reach 11 has created a pond area that covers approximately 65 percent of the reach. Localized and temporal channel adjustments will continue to naturally occur (including construction of beaver dams) within these reaches, offering a diversity of habitat types and conditions for terrestrial and aquatic biota.

3.5.2.f Reach 12

Reach	BKF Width(ft)	AVG BKF Depth(ft)	W/D Ratio	FPW (ft)	Entrenchment Ratio	C/S Area (ft^2)	D50 (mm)
12	9.00	0.57	15.79	65.3	7.26	5.13	N/A

Reach 12 is 712 feet long and is a Rosgen D5 ← E5 stream type. This reach was probably a Rosgen E5 stream type but has evolved into Rosgen D5 stream type most likely from the back-water effect of Davis Road. Back-water is defined as an area where water is ponded due to some type of flow blockage or constriction downstream. The back-water effect has resulted in settling of fine materials and considerable channel aggradation, thus causing a braided channel. The riparian vegetation in this reach is sparse and, as a result, the channel is not stable like the Rosgen D stream types located in Reaches 9, 10, and 11. The instability of the reach is confirmed by the 1997/2000 cross section overlay. The overlay indicates that several old braids no longer exist and new braids have been created. This reach is highly sensitive to disturbances and will continue to adjusted its configuration until the back-water effect from Davis Road is resolved.

3.5.2.g Reach 13

Reach	BKF Width(ft)	AVG BKF Depth(ft)	W/D Ratio	FPW (ft)	Entrenchment Ratio	C/S Area (ft^2)	D50 (mm)
13	9.93	0.34	29.49	85.0	8.56	3.34	1.17

Reach 13 is 353 feet long and is a Rosgen C4 stream type. The stream is fairly stable, but the new beaver dam on Reach 11 affects the lower downstream end. A back-water effect has occurred and the lower/middle part of the reach has aggraded. The channel is still defined but the flow has gone subsurface and reappears approximately 75 feet upstream of its confluence with the mainstem. The effects of the beaver dam on the reach are minor and localized. The most significant impact is the loss of aquatic habitat where the flow has gone subsurface. However, the reach has a fair recovery potential and should adjust naturally on its own and the aquatic habitat should improve.

3.5.2.h Reaches 14, 15, and 16

Reach	Rosgen Stream Type	Length (ft.)	Water Surface Slope (ft/ft)
14	N/A	142	N/A
15	B5a/4a	83	0.059
16	B5/4	94	0.022

Reach	BKF Width(ft)	AVG BKF Depth(ft)	W/D Ratio	FPW (ft)	Entrenchment Ratio	C/S Area (ft^2)	D50 (mm)
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	4.68	0.53	8.83	9.36	2.00	2.48	0.18
16	6.54	0.29	22.67	7.41	1.13	1.88	0.06

Reaches 15 and 16 are relatively stable with some minor, localized bank and bed adjustments occurring as a result of a significant head cut on the upstream end of Reach 14. In 1997 two head cuts existed in Reach 14. Recently, however, one of the head cuts has been filled with what appears to be concrete construction debris. The other head cut continues to erode into the hill slope and remains a significant source of sediment supply. The stream characteristics of Reaches 15 and 16 (e.g., low width/depth ratio, low sinuosity, steep gradient, and moderate recovery potential) enable them to remain stable and efficiently transport a majority of the heavy sediment load coming from Reach 14. However, some of the riffle areas are embedded with fine sands and thus have marginal aquatic habitat areas. This is also why the stream reaches have bi-modal substrate distributions. Both reaches are gravel beds, but they are covered by fine sediments originating from the head cut on Reach 14. Both 1997/2000, cross section overlays for Reaches 15 and 16 indicate minimal channel adjustments and confirm their stability. There is however, significant erosion occurring adjacent to Reach 15 as a result of runoff from West Cuddihy Road. This erosion is a significant source of sediment supply and if not stabilized, will continue to erode and potentially threaten the structural integrity of West Cuddihy Road.

3.5.2.i Reach 17

Reach	BKF Width(ft)	AVG BKF Depth(ft)	W/D Ratio	FPW (ft)	Entrenchment Ratio	C/S Area (ft^2)	D50 (mm)
17	23.00	0.17	134.1	51.63	2.24	3.94	N/A

Reach 17 is 954 feet long and contains Rosgen C/E/D stream types. The stability of this reach varies, depending on the Rosgen stream type. The Rosgen E stream types are stable and the Rosgen C stream types are also stable, but possibly adjusting into a Rosgen E stream type. The Rosgen D stream types are easily adjusted and unstable. The specific causes of the braided reaches are uncertain, but it could be related to the high sediment load and shallow gradient or localized disturbances. Additionally, the recently constructed beaver dam on Reach 11 that extends into to Reach 17 further affects the downstream end of the reach. The 1997/2000, cross section overlay was surveyed in a Rosgen D stream type and indicates aggradation of some old braids and the creation of new braids, which is typical for a Rosgen D stream type. The recovery potential for the Rosgen D stream types is poor and natural adjustment into a stable form will require a long period of time.

3.5.2.j Reach 18

Reach	BKF Width(ft)	AVG BKF Depth(ft)	W/D Ratio	FPW (ft)	Entrenchment Ratio	C/S Area (ft^2)	D50 (mm)
18	2.83	0.40	7.10	3.79	1.34	1.13	0.11

Reach 18 is 112 feet long and is a Rosgen G4/5← A4. This reach is currently stable based on surveys, however the channel is highly entrenched which indicates that the channel has down-cut sometime in the past. The 1997/2000, cross section overlay also indicates that the channel has not adjusted greatly. The down-cutting has temporarily slowed or stopped as a result of a hard clay layer. The soil maps for this area show that clay layers are only 6 to 18 inches thick and are underlain with loose gravels and sands. Once the stream has down-cut through this clay layer, the rate of incision will increase significantly. The cause of down-cutting is uncertain, but could be related to increased runoff from the recently constructed Navy Exchange complex and stormwater management pond directly upstream of Reach 18. There is also a massive hill slope failure on the east valley side adjacent to Reach 18. The failure could be related to the down-cutting of the stream or because of the soil characteristics of the watershed. This hill slope failure is a significant source of sediment and if not stabilized, will continue to contribute sediment to the streams, causing further adjustments.

3.5.2.k Reach 19 and Unsurveyed Reach between Reaches 19 and 20

Reach	Rosgen Stream Type	Length (ft.)	Water Surface Slope (ft/ft)
19	G4/5 ← A4	105	0.031
Unsurveyed Reach	G ← A	130	N/A

Reach	BKF Width(ft)	AVG BKF Depth(ft)	W/D Ratio	FPW (ft)	Entrenchment Ratio	C/S Area (ft^2)	D50 (mm)
19	3.12	0.47	6.60	4.00	1.28	1.48	0.07

Both reaches are very unstable, with severely eroded banks and fallen trees throughout. The Reach 19, 1997/2000, cross section overlay indicates that the reach has aggraded three feet and the right bank has eroded as much as three feet. The aggradation is mostly likely related to the significant sediment supply from the hill slope failure along Reach 18. The eroded banks are a result of the channel trying to regain cross sectional area lost to the severe channel aggradation. Both of these reaches will continue to degrade further with a low potential for recovery.

3.5.2.l Reach 20

Reach	BKF Width(ft)	AVG BKF Depth(ft)	W/D Ratio	FPW (ft)	Entrenchment Ratio	C/S Area (ft^2)	D50 (mm)
20	4.26	0.49	8.78	6.90	1.62	2.07	0.40

Reach 20 is 87 feet long and is a Rosgen E5. This reach is currently stable with good instream habitat and able to pass the heavy sediment load due to its efficiently shaped channel (e.g., low width/depth ratio and low sinuosity). This reach could severely degrade though, if the head cuts directly downstream in Reach 21 are not stopped and move upstream through Reach 20.

3.5.2.m Reaches 21 and Unsurveyed Reach between 21 and Confluence with Mainstem

Reach	Rosgen Stream Type	Length (ft.)	Water Surface Slope (ft/ft)
21	G4/5 ← E4	98	0.051
Unsurveyed Reach	G ← E	200	N/A

Reach	BKF Width(ft)	AVG BKF Depth(ft)	W/D Ratio	FPW (ft)	Entrenchment Ratio	C/S Area (ft^2)	D50 (mm)
21	4.18	0.46	9.11	4.46	1.07	1.92	0.26

Both of these reaches are unstable with several head cuts and severely eroding banks throughout. These reaches are incised and are a significant source of sediment supply. There are three small head cuts in Reach 21 that are currently held in place with dense tree roots and the unsurveyed reach has one significant head cut (4 to 5-foot in height) at its upstream end. The head cut on the unsurveyed reach could be a result of the head cut that went through Reach 8, since it enters the mainstem at Reach 8. This head cut will continue to move upstream and if not stopped, could ultimately destabilize the entire tributary.

4.0 Problem Identification and Rating

A restoration priority rating of high, moderate and low was used to rate stream reaches relative to one another. The reach rating was based on specific criteria that would best indicate whether or not a stream was stable and if unstable, the relative severity of instability. Criteria such as near-bank stress, bank erodability, bed stability, entrenchment, and incision; were used to determine if a stream is or has the potential to adjust laterally and vertically. For example, a reach would be considered potentially unstable if its near-bank stress and bank erodability ratings were high, and it was actively incising.

Additionally the management interpretations of the Rosgen stream types as presented in Rosgen (1996) were used to determine the sensitivity of each reach to disturbance, recovery potential, and potential source of sediment. The use of these management interpretations in determining a reach's overall restoration priority, based on this study's rating system, is mostly applicable for unstable reaches only. This is true because, on stable reaches, the assessment criteria, used in the management interpretations, have less influence then on unstable reaches. For example, a stable reach may have a high rating as a potential source of sediment because of its stream classification type. But since it is stable and not eroding, it is not considered a potential source of sediment. Therefore, it would not be rated as a high priority for restoration.

A reach would receive a high restoration priority rating if it was unstable, had a high sensitivity to disturbance, a low recovery potential, and was a potential source of large sediment loads. Conversely, a reach would have a low priority rating if it was stable; regardless if it was highly sensitive to disturbance, had a low recovery potential, and was a high potential source of sediment. A reach would receive a moderate priority rating for two reasons, first, if it was the same as the example provided for a low priority rated reach, but had significant degradation occurring upstream or downstream of the reach, and second, if the overall reach was stable but had localized instability problem areas.

Lastly, site-specific problem areas were identified during the collection of field data. An example would be a severe head cut migrating upstream that would impact an otherwise stable, but sensitive reach.

4.1 Reach Problem Identification and Priority Rating

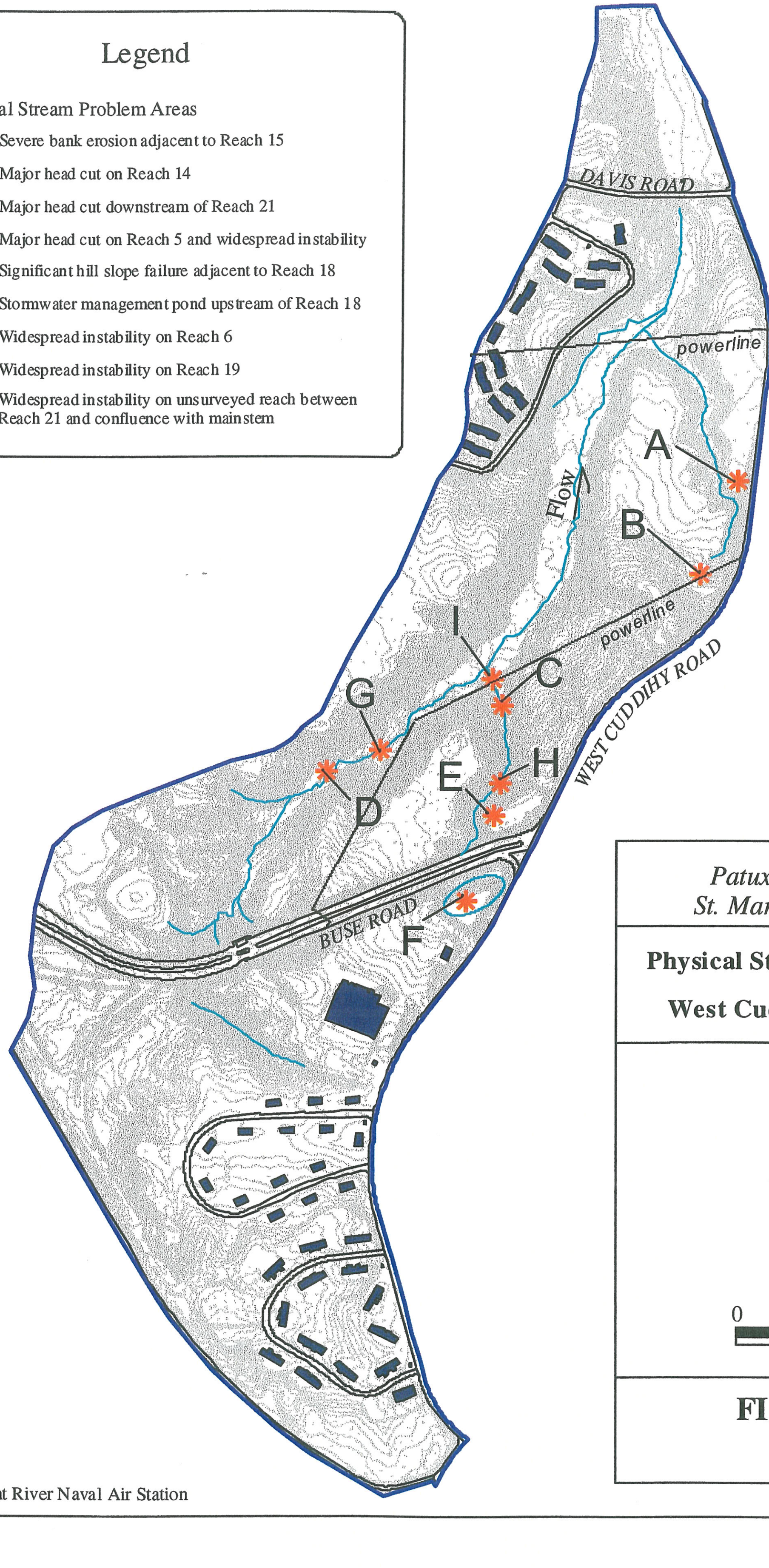
Table 5 provides a summary of the individual reach rating criteria and the overall restoration priority rating for each reach. Five reaches were rated as high priority, seven reaches were rated as moderate priority, and twelve reaches were rated as low priority. Reaches 5 and 6 were rated as high priority because both reaches are significantly incised and severely degrading as a result of a significant head cut. The near-bank stress and bank erodability for Reach 5 are rated as very low, but those ratings were for 1997 conditions. The reach has since down-cut 1.5 feet and based on visual observations, new ratings would most likely be high or very high. Reach 14 was also rated high priority as a result of the major head cut at the upstream end of the reach. The majority of the reach is stable however, with some minor aggradation.

The entire upper east tributary, Reaches 18 through 21, is an area of great concern even though only two reaches, 19 and 21, were rated as high priority. Currently the latter two,

Legend

Physical Stream Problem Areas

- A Severe bank erosion adjacent to Reach 15
- B Major head cut on Reach 14
- C Major head cut downstream of Reach 21
- D Major head cut on Reach 5 and widespread instability
- E Significant hill slope failure adjacent to Reach 18
- F Stormwater management pond upstream of Reach 18
- G Widespread instability on Reach 6
- H Widespread instability on Reach 19
- I Widespread instability on unsurveyed reach between Reach 21 and confluence with mainstem



Patuxent River NAS
St. Mary's County, MD

Physical Stream Problem Areas

West Cuddihy Watershed

N W E S

0 400 800 Feet

FIGURE 7

July 2000

Data Source: Patuxent River Naval Air Station

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TABLE 5
STREAM REACH RESTORATION PRIORITY RATING
West Cuddihy Basin, Patuxent Naval Air Station, 2001

Reach	Stream Type	nb shrstss/ avg shrstss	Bank Erodability	Bed Stability	Sediment Supply	Entrenchment	Incision Ratio		Disturbance Sensitivity*	Recovery Potential*	Potential Source of Sediment*	Relative Priority
							CX-Class	CX-Eros				
Commissary 1	G6	Extreme	Low	Stable	Low	2.53	1.47	3.02	Very High	Poor	High	Low
Commissary 2	Gc6	Very Low	Very High	Stable	High	1.73	1.00	6.68	Very High	Poor	High	Low
Mainstem A	Aa+6	Very Low	High	Stable	Low	1.76	1.44	1.95	High	Poor	High	Low
Mainstem 1	A5	Very Low	High	Stable	Moderate	1.20	1.86	1.80	Extreme	Very Poor	Very High	Low
Mainstem 2	E4/5	Very Low	Moderate	Stable	Low	3.66	1.00	1.42	Very High	Fair	Very High	Low
Mainstem 3	Eb4/5	Very Low	Moderate	Stable	High	2.97	1.00	1.00	Very High	Poor	Very High	Moderate
Mainstem 4	E5	Extreme	High	Stable	High	8.38	1.00	1.00	Very High	Fair	Very High	Moderate
Mainstem 5	G5 ← E5	Very Low	Moderate	Degrading	Moderate	1.55	3.08	1.79	Extreme	Very Poor	Very High	High
Mainstem 6	Gc5 ← E5	Low	High	Degrading	High	1.29	5.34	5.69	Extreme	Very Poor	Very High	High
Mainstem 7	Bc5 → C5	Very Low	High	Aggrading	High	1.46	3.12	2.46	Moderate	Excellent	Moderate	Moderate
Mainstem 8	C5 → E5	Low	High	Aggrading	Very High	2.28	1.32	1.52	Very High	Fair	Very High	Moderate
Mainstem 9	D/E	N/A	N/A	Stable	Moderate	14.40	1.50	N/A	Very High	Poor	Very High	Low
Mainstem 10	D/E5	Very Low	Moderate	Stable	Moderate	25.19	1.00	1.20	Very High	Good	Moderate	Low
Mainstem 11	D/E4/5	Extreme	Moderate	Stable	High	13.73	1.00	1.11	Very High	Good	Moderate	Low
Mainstem 12	D5 ← E5	N/A	Low	Aggrading	Very High	7.26	1.01	1.00	Very High	Poor	Very High	Moderate
West Trib 13	C5	Very Low	Low	Stable	Moderate	8.56	1.00	1.07	Very High	Fair	Very High	Low
Bott East Trib 14	N/A	N/A	N/A	Aggrading/ Degrading	Extreme	N/A	N/A	N/A	Major head cut			High
Bott East Trib 15	B5a	Very Low	High	Stable	Moderate	2.00	1.00	1.57	Moderate	Excellent	Moderate	Moderate
Bott East Trib 16	B6	Very Low	High	Stable	High	1.13	2.01	3.58	Moderate	Excellent	Moderate	Low
Bott East Trib 17	C/E/D	N/A	N/A	Stable	Moderate	2.24	1.00	N/A	Very High	Poor	Very High	Moderate
Top East Trib 18	G5 ← A5	Very Low	High	Stable	Low	1.34	1.66	2.78	Extreme	Very Poor	Very High	Low**
Top East Trib 19	G5 ← A5	Moderate	High	Aggrading	Very High	1.28	3.55	2.59	Extreme	Very Poor	Very High	High
Top East Trib 20	Gc5	Extreme	High	Stable	Very High	1.62	1.34	1.30	Very High	Good	Moderate	Low***
Top East Trib 21	G5 ← E5	Extreme	Extreme	Degrading	Very High	1.07	3.64	3.28	Extreme	Very Poor	Very High	High

* These ratings area based on Rosgen's Management Interpretations of Various Stream Types, 1994.

** Reach 18 could be a future problem if the stream cuts down through the clay layer. Restoration of this reach should be done after the high priority sites are restored.

*** This reach was rated low priority even though it has a very high near bank stress and high erodability because Rosgen E stream types typically have high stresses and erodability, but are stable because their channel shape is the most efficient for sediment transport.

and the two unsurveyed reaches which comprise nearly 80 percent of the entire tributary are severely degrading. If these reaches are not restored, their degradation effects will ultimately impact the stable reaches.

The majority of the reaches that have a moderate priority rating received this rating due to localized instability problems. Localized instability problems primarily include eroding banks, aggradation from debris jams, and braided areas. These areas were considered moderate priority since the impacts only affect a small area, the rate of adjustment is not as rapid as the high priority reaches, and the potential for recovery for most the areas is fair to good.

4.2 Site-Specific Problem Identification

Seven significant site-specific problem areas were identified within the watershed (Figure 7). Figure 8 shows both the physical stream problem areas identified by this report and the biological problem areas identified in the biological assessment report prepared by the FWS Contaminants Branch. Four of the problems areas are head cuts on Reaches C2, 5, 14, and the unsurveyed reach between Reach 21 and the confluence with the mainstem. The other three site-specific problem areas include: the hill slope failure adjacent to Reach 18; the erosion occurring adjacent to Reach 15 as a result of runoff from West Cuddihy Road; and the stormwater runoff from the Navy Exchange complex. The existing stormwater pond provides extended detention for 2 and 10-year storm events. Management of a 1-year storm event is necessary to reduce erosive flows to the downstream reaches (e.g., Reach 18). The conversion of the pond to manage a 1-yr storm event is also considered a Best Management Practice.

5.0 Report Recommendations

This section of the report presents the FWS recommendations based on the watershed assessment. Three categories of recommendations are suggested: 1) best management practices; 2) typical stream restoration solutions; and 3) future use of assessment protocols.

5.1 Best Management Practices

The primary best management practice for the West Cuddihy watershed is to minimize land use changes. The stream systems within the watershed are highly sensitive to change and disturbances. The watershed already has eleven percent impervious surface area and research indicates that streams can begin to destabilize with an increase of just five to ten percent impervious surface areas (Booth and Rienalt, 1993; Galli, 1994; Schueker and Claytor, 1997). Additionally, Maryland Department of Natural Resources reported in their Maryland Biological Stream Survey study a change in macroinvertebrate diversity and abundance in watersheds with as little as six percent impervious surface areas (Roth, et.al 1999). Therefore, activities such as vegetation clearing, building and road development, and earth moving should be limited.

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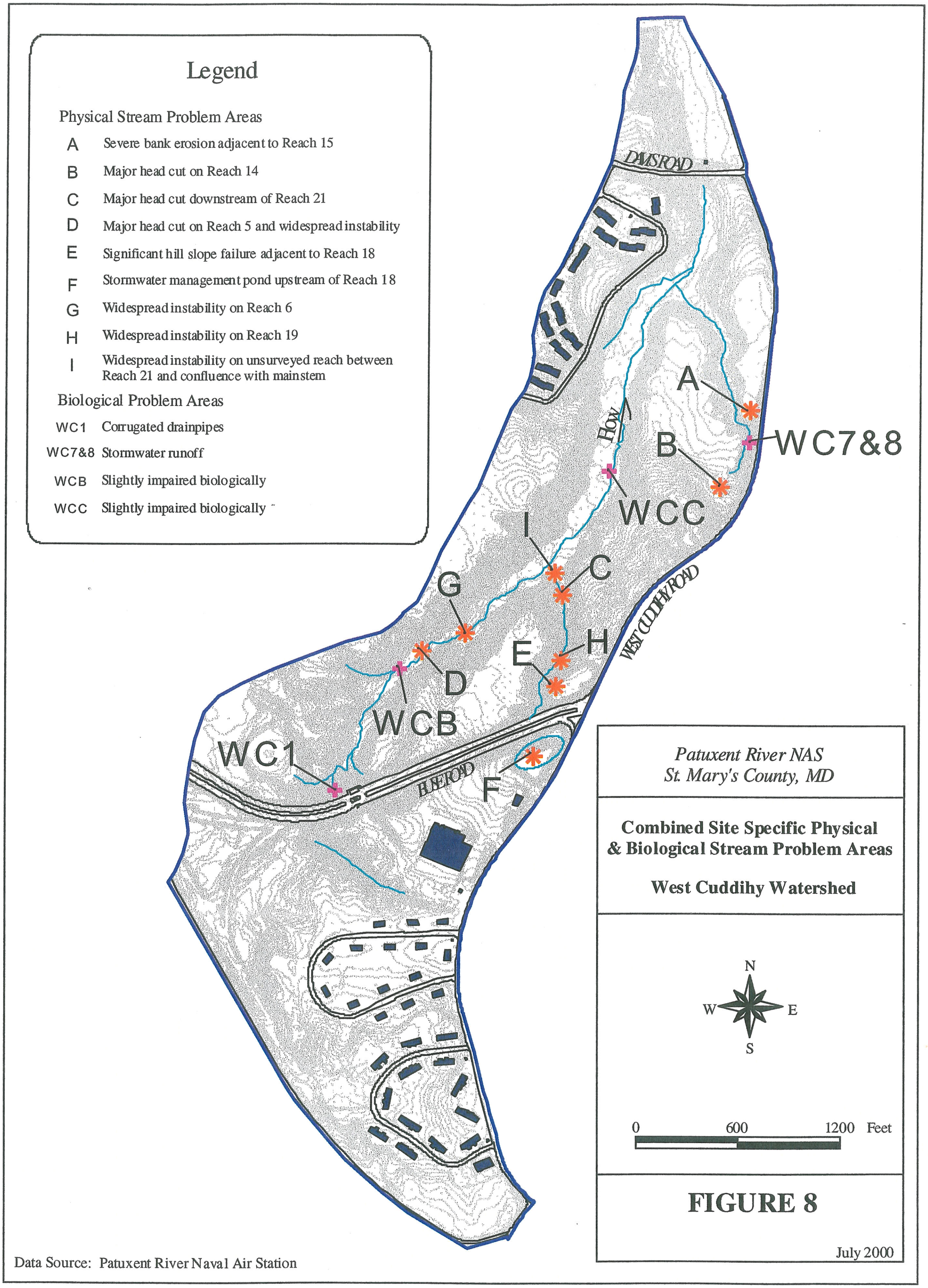

Legend
Physical Stream Problem Areas
A Severe bank erosion adjacent to Reach 15
B Major head cut on Reach 14
C Major head cut downstream of Reach 21
D Major head cut on Reach 5 and widespread instability
E Significant hill slope failure adjacent to Reach 18
F Stormwater management pond upstream of Reach 18
G Widespread instability on Reach 6
H Widespread instability on Reach 19
I Widespread instability on unsurveyed reach between Reach 21 and confluence with mainstem
Biological Problem Areas
WC1 Corrugated drainpipes
WC7&8 Stormwater runoff
WCB Slightly impaired biologically
WCC Slightly impaired biologically
A
B
C
D
E
F
G
H
I
WC1
WC7&8
WCB
WCC
Flow
WEST CUDDIHY ROAD
Patuxent River NAS
St. Mary's County, MD
Combined Site Specific Physical & Biological Stream Problem Areas
West Cuddihy Watershed
N
W
E
S
0
600
1200
Feet
FIGURE 8
July 2000
Data Source: Patuxent River Naval Air Station

5.2 Typical Stream Restoration Solutions and Structures

This section provides examples of stream restoration solutions and structures that could be used to restore the problem areas within the West Cuddihy watershed. The use of these solutions and structures, however cannot be implemented until a restoration design is completed. The detailed stream assessment and restoration design is required to determine the type, location and size of restoration structures. Restoration structures are merely tools to implement the restoration design. Installation of restoration structures based on the level of data collected as part of this study is premature and would affect the success of any restoration attempts.

Examples of restoration solutions and structures are categorized into two groups: 1) site-specific restoration structures and 2) reach reconfiguration solutions. The site-specific structures are further categorized into three sub-groups: 1) grade control; 2) bank stabilization; and 3) fish habitat. A list of potential site-specific restoration structures is provided below for each sub-group.

5.2.1 Site-Specific Restoration

5.2.1.1 Grade Control Structures

Grade control structures are used to prevent streams from down-cutting and forming head cuts. The following are examples of grade control structures:

- Step pool
- Cross vane
- Rock/log sill

5.2.1.2 Bank Stabilization

Bank stabilization structures are used to prevent streambanks from rapidly eroding. The following are examples of bank stabilization structures:

- Root wads
- Rock/log vane
- J-hook vane
- Rock toe stabilization with vegetation planting
- Vegetation facsines/bundles
- Vegetation mats
- Branch packing
- Joint rock/vegetation planting
- Live stakes

5.2.2 Channel reconfiguration

Channel reconfiguration is used for reaches that have pattern instability and require channel dimension, profile and geometry restoration. Often the site-specific restoration structures listed above are used in combination with channel reconfiguration restoration. Channel reconfiguration requires a higher level of effort to produce a restoration design. Additionally, the restoration design requires reference reach data and hydraulic computations as a basis for design criteria for the targeted stream restoration. The use of reference reach data and hydraulic computations also apply to the other two previous sub-groups as well. The following are examples of channel reconfiguration solutions, many of which are used in combination with each other:

- Decrease width to depth ratio
- Increase sinuosity
- Reduce entrenchment and incision
- Increase radius of curvature on channel bends
- Convert braided channels into a single channel
- Develop riffle/pool habitat sequence
- Relocate channel to a new location in the flood plain to regain access to flood plain

5.3 Future Use of Assessment Protocols

Two protocols are assessed in this section: 1) a detailed watershed assessment and 2) a rapid watershed assessment. The FWS has developed these protocols with specific application purposes. The detailed watershed assessment protocol is used to develop detailed stream conditions databases. The FWS and PRNAS environmental staff will use these databases to identify and prioritize problem areas, conducted trend analyses, document baseline conditions, predict potential impacts of proposed PRNAS development projects, and conduct environmental assessments of and suggest recommendations on PRNAS activities. These databases will also be used to calibrate FWS and PRNAS staff for the use of the rapid watershed assessment protocol. The rapid assessment protocol is used only to identify and prioritize problems areas within a watershed based on qualitative and semi-quantitative data. The data collected from the rapid assessment protocol can not be used for any environmental analyses.

5.3.1 Detailed Watershed Assessment Protocol

The detailed watershed assessment protocol requires data on channel dimensions, profile, pattern, bank erodability, and substrate. A detailed description of the protocol is provided in Section 2.0 Methodology. The FWS and PRNAS used this study to test the effectiveness of the detailed watershed assessment protocol for PRNAS watersheds. The FWS determined the protocol to be effective and efficient in identifying and prioritizing problem areas based on its application in the West Cuddihy watershed. The protocol provided sufficient data to allow the FWS to adequately identify and characterize stream types, estimate stream stability, and rate restoration priority of the reaches relative to one another. However, three other components should be added to the protocol that would refine the identification and prioritization of problem areas.

The first component is a geomorphic map of each reach surveyed. A geomorphic map is used to show the current condition, in detail, of geomorphic features in the stream and adjacent flood plain. The map also assists in the evaluation of current stream condition and stream potential. Geomorphic features that should be recorded include depositional bars, terraces, vegetation, slope breaks, riffles, pools, runs, step pools, eroding banks, culverts, road crossings, storm drains, disturbances (natural and man-made), and unique features. An example of a geomorphic map is provided in Appendix D.

The second component is recording the length and height of all eroding banks. Additionally a Bank Erodibility Hazard Index (BEHI) rating should be done for each of the eroding banks. This detailed quantified bank erosion information will allow each bank to be ranked relative to one another. An example bank ranking is provided in Appendix D.

The last component is critical shear stress calculations. Critical shear stress calculations can be used to estimate whether a stream is aggrading, degrading, or stable. Specifically, shear stresses show what size of substrate particle moves at bankfull flows. If the particle size moved is less than the D50 (50% of particles at least this size), then the stream is most likely aggrading. If the particle size moved is greater than the D84 (84% of particles at least this size), then the stream is most likely degrading. If the particle size moved is somewhere between the D50 and D84, then the stream is most likely stable. This component is more critical to conduct if there is not time to resurvey monumented cross sections over a period of time.

5.3.2 Rapid Watershed Assessment Protocol

An objective of this project is to develop a rapid watershed assessment protocol to rapidly identify and prioritize problem areas. The rapid watershed assessment protocol is developed from a database of stream conditions collected from a detailed watershed assessment. The detailed stream conditions database contains data on a wide range of stream types and conditions and is used by assessors as a calibration tool for using the rapid assessment protocol. A detailed stream conditions data base is needed for each general type of watershed at the PRNAS. The watersheds should be grouped into general watershed types based on similar characteristics such as land use, vegetation cover type, percent impervious surface, topography, soil, geology, and hydrology. The West Cuddihy watershed was chosen as the pilot study because it appeared to be the most representative watershed in the entire PRNAS. A brief field reconnaissance needs to be conducted of the remaining watersheds to determine if the West Cuddihy has representative stream conditions of the entire PRNAS. If it does, then the rapid watershed assessment can be to identify and prioritize problem areas in the remaining PRNAS watersheds.

The rapid watershed assessment protocol involves walking the entire stream system within a watershed to identify reach types and problem areas. A standardize field data sheet is completed for each reach type identified. The field data sheet records four categories of information: 1) hill slope characteristics; 2) hydrologic characteristics; 3) riparian characteristics; and 4) stream channel characteristics. An example field data sheet is provided in Appendix E. The hill slope characteristics describe land form, surface erosion, and vegetation community. The land form characterizes existing and potential slope failures based on percent slope, soil and geology, size, and land use activities. The surface erosion characterizes existing and potential surface erosion based on type and degree of erosion, erosion area size and particle size, type of overland flow, and land use activities. The vegetation community characterizes the type of existing vegetation based on stand diversity and density and sensitivity to disturbance.

The hydrologic characterization describes the flow regime based on land use and cover type, hydrologic soil groups, flood damage potential, road and storm water runoff, and culvert and bridge crossings. The riparian characterization describes the riparian vegetation based on stand diversity and density, length and width of riparian zone, bank protection capability, and recruitment potential of local woody debris.

The stream channel characterization describes the stream channel bed forms and bank stability. The bed form characterizes bed stability based on bank and bed materials, bed controls, depositional features, and entrenchment and incision. The bank stability is characterized based on bed stability, width to depth ratio, debris channel obstructions, and potential sediment supply source. Two examples of completed field sheets are provided in Appendix E.

The restoration priority rating analysis is the same analysis used for the detailed watershed assessment with some minor changes. The near-bank stress criteria is not included since there are not any surveyed cross-sections as part of the rapid watershed assessment. The bank erodability, channel entrenchment, and incision criteria are qualitatively rated. Lastly, this rapid watershed assessment can only be used once the stream conditions databases are developed from detailed assessments of typical watersheds at PRNAS.

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