U.S. Fish & Wildlife Service

Moores Run, Baltimore City, Maryland

Data Collection and Assessment Protocols for a Geomorphic Condition and Channel Stability Survey

CBFO-S04-03

May 2004

MOORES RUN, BALTIMORE CITY, MARYLAND DATA COLLECTION AND ASSESSMENT PROTOCOLS FOR A GEOMORPHIC CONDITION AND CHANNEL STABILITY SURVEY

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I. INTRODUCTION

The City of Baltimore (City) and the U.S. Fish and Wildlife Service, Chesapeake Bay Field Office (Service) entered into a cooperative agreement (Agreement 51410-1902-5047) to enhance cooperation and coordination between the City and the Service to allow for the conservation, enhancement, and restoration of stream and riparian habitats in the Baltimore City watershed.

The first project to develop from this agreement was Moores Run in Baltimore, MD (Figure 1). Moores Run is part of a stream monitoring network under the City's National Pollutant Discharge Elimination System (NPDES) permit. The City has monitored the assessment area since 2001. Several sets of survey data exist for Moores Run; but due to inconsistencies in data gathering, the City has been unable to reliably compare the data among the surveys.

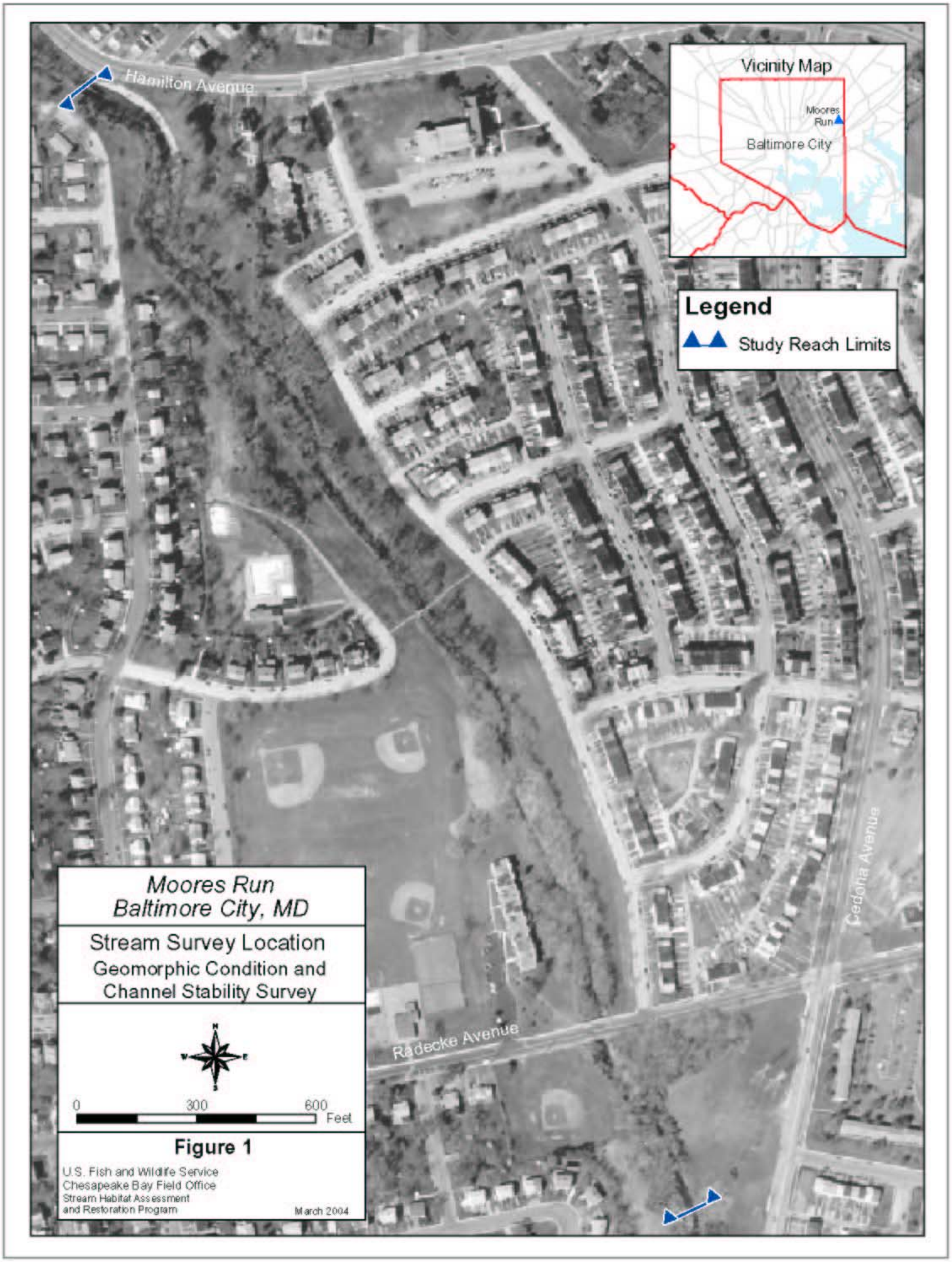
The project objectives were to collect baseline geomorphic and channel stability data, and to develop standard survey and assessment operating procedures for future surveys. The Service completed collection of the baseline data in October 2003 and released the *Moores Run, Baltimore City Maryland: Geomorphic Condition and Channel Stability Survey* (baseline report) (Eng et al. 2004) (CBFO-S04-01) in March 2004.

This report presents the protocols required to resurvey and assess the geomorphic and stability conditions at Moores Run. The purpose of these protocols is to ensure consistent survey techniques and assessment methods to produce comparable data. This report is a general work plan, and is not a stepwise instruction manual.

Surveys at Moores Run are important because the City can document stream changes, and validate stability and sediment predictions presented in the baseline and subsequent reports, including:

- Documenting geomorphic and channel stability changes
- Validating bank erosion and sediment supply predictions
- Validating lateral stability, vertical stability, and channel enlargement predictions

The protocols in this report are intended for surveyors trained and experienced with survey and assessment techniques presented in the manual *Stream channel reference sites: An illustrated guide to field technique* (Harrelson et al. 1994), and the course field manual *River Assessment and Monitoring* (Wildland Hydrology 2003). Surveyors should be familiar with the assessment procedures presented by Rosgen at the 2001 Federal Interagency Sediment Conference (2001(a) and 2001(b)). Surveyors should read the baseline report (CBFO-S04-01) and any subsequent reports, prior to any field surveys. Surveyors should also review the data provided in the reports and any additional data provided by the City.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II. SERVICE FIELD DATA PROTOCOLS

The Service partitioned the assessment area into nine study reaches (Figure 2) based on Rosgen stream type (Rosgen 1996) and existing geomorphic conditions, such as channel dimensions and stability. For each study reach, surveyors will conduct the following survey and assessment tasks:

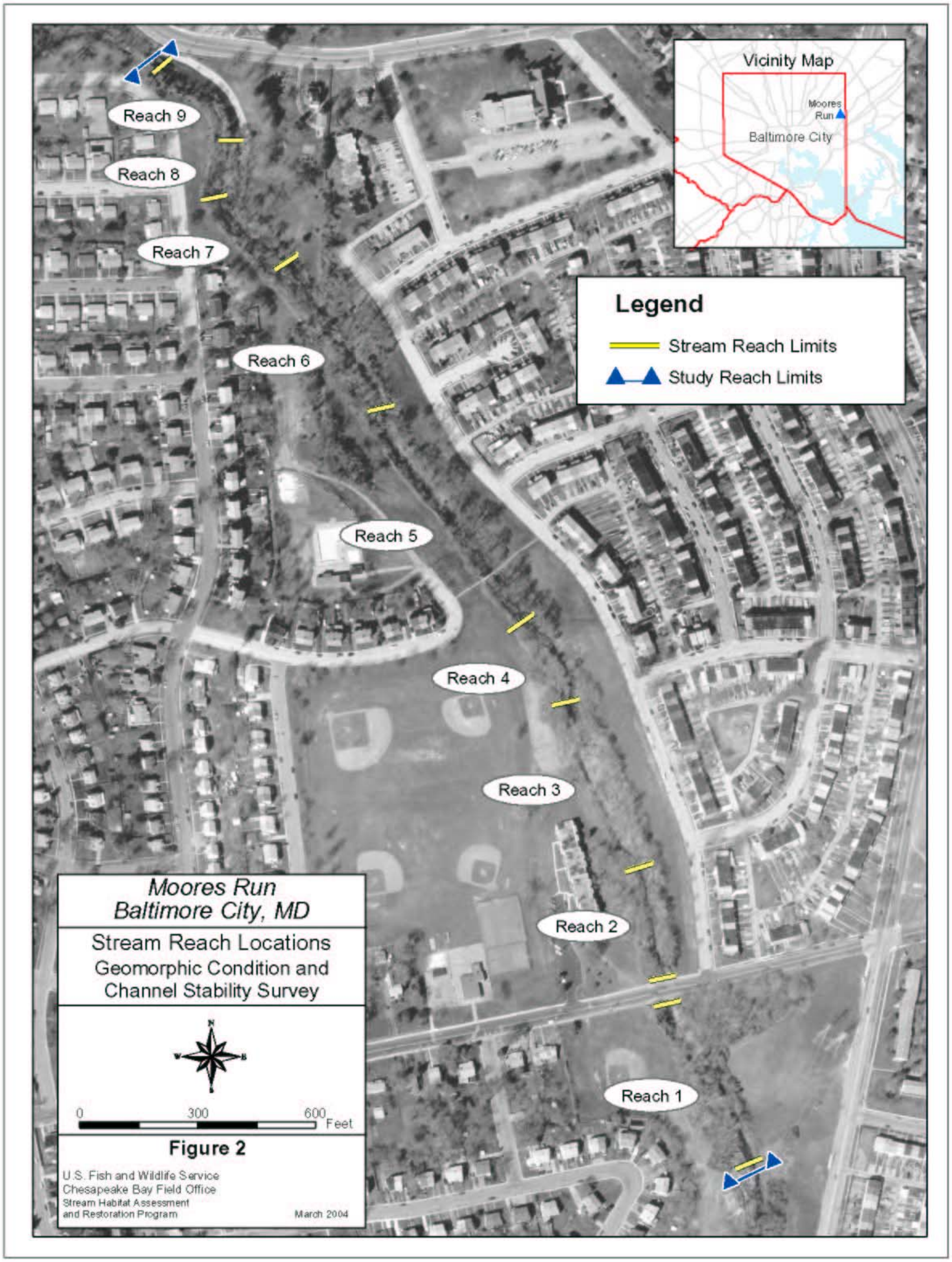
A. Bankfull Determination
B. Geomorphic mapping
C. Cross section survey
D. Bank profile survey
E. Bank erosion hazard index (BEHI) and near bank shear stress (NBS) assessments
F. Bank erosion validation and prediction
G. Longitudinal profile survey
H. Substrate characterization
I. Rosgen Level III stability and sediment assessment

The Service presents the individual tasks as they are presented in the baseline report (CBFO-S04-01). This order is not necessarily how surveyors will collect or analyze the survey data. For instance, surveyors will likely conduct the modified Pfankuch Stream Reach Inventory and Channel Stability (Pfankuch) assessment during the geomorphic mapping. However, the Service presents the Pfankuch assessment in the Rosgen Level III stability and sediment (Rosgen Level III) assessment section of this report. Although the Pfankuch assessment is an independent stability assessment, surveyors will only use the Pfankuch assessment in the Rosgen Level III assessment.

The Service presents each task in a separate section of this report. First, the Service provides a general description of the task (*i.e.*, purpose and use); then the Service provides survey procedures to maintain consistent data collection. Next, the Service provides assessment procedures to maintain consistent data analysis and presentation. Finally, the Service suggests analysis to assist in the comparison and interpretation of the data. Surveyors should compare their data only with data from the baseline survey or subsequent surveys. Surveyors should also consult with the City to determine any additional analysis and/or interpretation requirements.

A. Bankfull Discharge Determination

Bankfull discharge is the discharge (*or range of discharges*) which is responsible for the formation and maintenance of the stream channel dimensions, planform patterns and longitudinal profile. The stream typically develops bankfull indicator(s), such as a significant slope break or floodplain feature, along the stream banks at the bankfull stage. An accurate determination of the bankfull indicator(s) is one of the most critical aspects of assessing a stream because surveyors will base the entire survey and assessment on its determination. To ensure an accurate determination of the bankfull discharge, the Service verified the bankfull discharge determination with gage station data and published regional discharge curves.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Identifying bankfull in the Maryland Piedmont and in an urban situations can be difficult. Surveyors with experience in identifying bankfull in both situations will help the City gather consistent and comparable data.

For additional information on bankfull identification and validation and gage surveys, surveyors should refer to the baseline report (CBFO-S04-01), the book A View of the River (Leopold 1994), and the report *Maryland stream survey: Bankfull discharge and channel characteristics in the Piedmont hydrologic region* (McCandless and Everett 2002).

B. Geomorphic Mapping

A geomorphic map is a detailed, scaled, hand drawing of current stream and riparian conditions (Appendix A, p. A1), and is the first step in a detailed stream assessment. The geomorphic map contains a variety of important information, including:

- Study reach limits
- Existing cross section locations
- General channel dimensions (*i.e.*, bank and bankfull heights and widths)
- Bank stability conditions (*i.e*., BEHI and NBS)
- Bed features
- In-stream habitat condition (*i.e*., stream depths and substrate composition)
- Adjacent land uses and land cover
- Anthropogenic structures (*e.g*., bank revetments, outfalls, utility crossings, and bridge crossings)

The Service will discuss cross section and stability (*i.e*., BEHI and NBS) surveys and their assessments in the **Monumented Cross Sections**, and **Bank Erosion Hazard Index and Near Bank Shear Stress** sections of this report.

1. Geomorphic Map Survey

Surveyors will redraw geomorphic maps to allow for a comparison with previous maps. The following map procedures will ease map comparison and maintain consistency in data presentation:

a. Acquire the most recent aerial photograph of the assessment area
b. Print aerial photographs in the same scale (1 inch = 50 feet) and format as original geomorphic maps
c. Compile aerial photographs in a binder with mylar overlays for each sheet
d. Redraw geomorphic maps on mylar overlays
e. Use Service geomorphic map abbreviation and symbols (Appendix A, pp. A2 and A3)

The baseline report (CBFO-S04-01) provides the original geomorphic maps for reference and comparison.

2. Geomorphic Map Comparison

Surveyors will compare new geomorphic maps with previous geomorphic maps to determine changes in geomorphic conditions. Geomorphic map comparisons include, but are not be limited to, the following changes in:

- Rosgen stream types
- Study reach limits
- BEHI conditions
- NBS conditions
- Channel conditions (*e.g.*, debris jams, braid development, and substrate composition)
- Bed features
- Meander patterns
- Depositional patterns
- Bank revetment
- Adjacent land use

Additional investigation, such as the addition of a monumented cross section to evaluate a new Rosgen stream type or new reach BEHI and NBS condition, may be necessary if there are changes in the existing geomorphic conditions. The Service will discuss when additional investigation is required in the **Monumented Cross Sections**, and **Bank Erosion Validation and Prediction** sections of this report.

C. Monumented Cross Sections

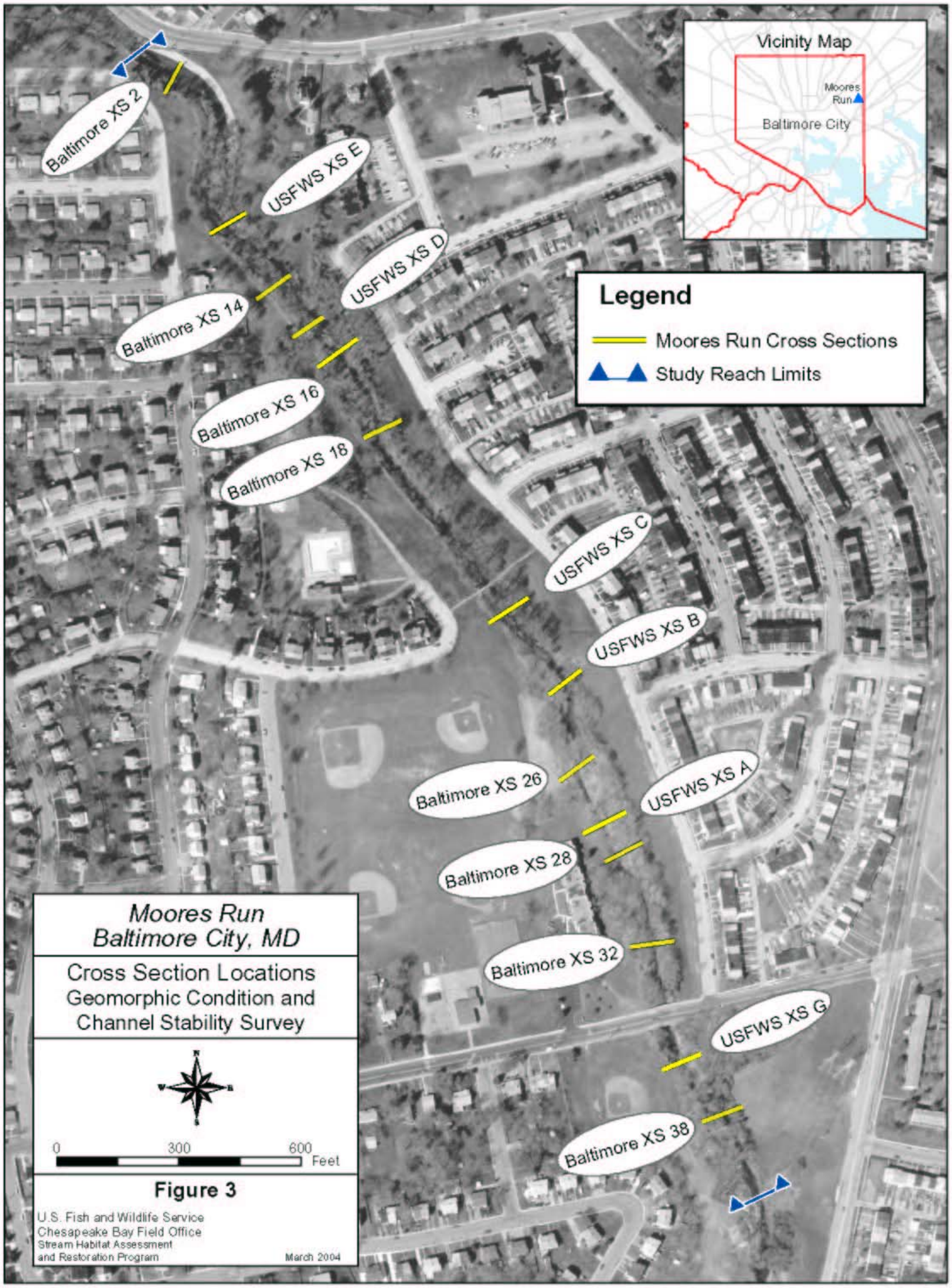
Monumented cross section surveys document existing channel dimensions, such as bankfull width, bankfull mean depth, and bankfull cross sectional area. Surveyors will use the cross section data for a variety of assessments, including:

- Determining the Rosgen stream type of study reaches
- Validating the lateral, vertical, and enlargement stability predictions from the previous Rosgen Level III stability and sediment assessment
- Monitoring bank erosion to validate actual bank erosion rates
- Assessing criteria for Rosgen Level III stability and sediment supply predictions

1. Cross Section Surveys

Surveyors will resurvey all monumented cross sections identified in the baseline report (CBFO-S04-01) (Figure 3) and subsequent reports. The following survey procedures will maintain consistency in data collection:

a. Obtain cross section monument global positioning system (GPS) coordinates and elevations for existing monumented cross sections
b. Survey cross section beginning at the downstream left monument (zero distance/station)
c. Calculate instrument height in Baltimore City datum



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d. Survey the thalweg, edge of water, and significant slope breaks in the active channel and on the bank (*e.g.*, inflection point, low flow bench, bankfull indicator, and top of bank)
e. Survey channel features (*e.g.*, depositional bars, tree line, and floodplain)
f. Survey floodprone elevation for riffle cross sections
g. Use the Service cross section abbreviations (Appendix A, p. A4)
h. Maintain monument and cross section identification, such as repainting, relabeling, and reflagging trees
i. Photograph the stream upstream and downstream of the cross section, include the cross section in the photograph
j. Photograph the left and right banks at the cross section with a surveyor and survey rod for reference
k. Update monument location maps if there are changes

The Service provides a summary table of the GPS coordinates and elevations for the baseline cross section monuments on pages A5 to A7 in Appendix A. The baseline report (CBFO-S04-01) provides monument location maps for the baseline cross sections.

2. <u>Cross Section Monument Installation</u>

Surveyors may encounter different geomorphic conditions than those assessed during the baseline survey, such as new Rosgen stream types or different combinations of BEHI and NBS ratings at study banks. If so, it will be necessary to install additional monumented cross sections to assess and/or monitor these new conditions. The following installation procedures will maintain consistency in cross section setup and data collection:

a. Use capped rebar or steel pipe for the cross section monuments
b. Install a bank profile toe pin monument (if site conditions allow for installation)
c. Calculate instrument height in Baltimore City datum
d. Incorporate cross section monuments into longitudinal profile survey
e. Paint and flag rebar and surrounding trees to identify the cross section
f. Draw a monument location map with compass bearing and distances from the painted trees to the monument
g. Provide GPS coordinates for the cross section monuments

The Service provides an example of a cross section monument map on page A8 in Appendix A.

3. <u>Cross Section Assessment</u>

Surveyors will enter the cross section field data into the appropriate cross section Microsoft Excel workbook, which plots the cross section and calculates the bankfull cross sectional dimensions, such as bankfull area, width, mean depth, and maximum depth. The following assessment procedures will maintain consistency in data analysis and presentation:

a. Obtain cross section Microsoft Excel workbooks from the City
b. Select appropriate cross section workbook

c. Copy the blank template worksheet as a new worksheet and rename worksheet with the new survey date
d. Enter new cross section field data into new cross section template worksheet
e. Plot cross section data
f. Add new plot to the overlay worksheet

Surveyors will compare the cross section overlays to evaluate and characterize changes in cross section conditions. The surveyors will perform the following analysis to characterize the changes:

g. Calculate annual percent cross section area change
h. Calculate average lateral change at the BEHI study bank
i. Conduct a trend analysis to evaluate past cross section changes and predict future cross section adjustments

Surveyors will also use the average lateral change to validate bank erosion predictions. The Service will discuss bank erosion validation in the **Bank Erosion Validation and Prediction** section of this report. The baseline report (CBFO-S04-01) provides the Service cross section data and plots for reference and comparison.

D. Bank Profile

A bank profile is a plot of the bank, generated by measuring points on the bank from a fixed reference point *(i.e.*, toe pin). Annual bank profile surveys will show lateral bank adjustments from which erosion rates can be determined. Bank profiles are used to determine lateral bank adjustments, because bank profiles are typically surveyed in more detail than cross section surveys. If site conditions prevented the installation of a toe pin, surveyors should conduct a more detailed survey of the study bank during the cross section survey.

1. <u>Bank Profile Survey</u>

Surveyors will resurvey the bank profiles identified in baseline report (CBFO-S04-01) and subsequent reports. During the baseline survey, the Service installed toe pins at the cross sections, wherever possible. Due to the coarse channel substrates, the Service was only able to install toe pins at two monumented cross sections. The following survey procedures will maintain consistency in data collection:

a. Set survey rod on the toe pin with edge of rod closest to the study bank flush with the monument cap
b. Use a rod level to ensure the rod used to measure height is perpendicular to the monument cap
c. Use a line level to ensure the rod used to measure distance is level
d. Survey all slope breaks up to a height which can be measured reliably from the toe pin
e. Measure distance and height from the toe pin for the slope breaks

2. Bank Profile Assessment

Surveyors will enter and plot the bank profile field data into a BEHI and bank profile Microsoft Excel workbook. The following assessment procedures will maintain consistency in data analysis and presentation:

a. Obtain BEHI and bank profile Microsoft Excel workbooks from the City
b. Select appropriate BEHI and bank profile workbook
c. Copy the blank template worksheet as a new worksheet and rename worksheet with the new survey date
d. Enter new bank profile field data into the new BEHI and bank profile worksheet
e. Plot the bank profile
f. Add new plot to the overlay worksheet

Surveyors will compare the bank profile overlays to evaluate and characterize lateral bank adjustments. The surveyors will perform the following analysis to characterize the changes:

g. Calculate average lateral change at the BEHI study bank
h. Conduct a trend analysis to evaluate past bank profile changes and predict future bank profile adjustments

Surveyors will also use the average lateral change to validate bank erosion predictions. The Service will further discuss sediment validation in the **Bank Erosion Validation and Prediction** section of this report. The baseline report (CBFO-S04-01) provides the Service bank profile data and plots for reference and comparison.

E. Bank Erodibility Hazard Index and Near Bank Shear Stress

The BEHI assessment predicts the erosion potential for a study bank, based on bank and bankfull height, rooting depth and density, bank angle, surface protection, bank materials, and bank stratification. The NBS assessment predicts the bank stress associated with the bankfull discharge for the BEHI study bank. Surveyors will conduct two types of BEHI and NBS assessments

- Reach BEHI and NBS to predict sediment contributions from bank erosion
- Cross section BEHI and NBS to validate bank erosion rates

The reach BEHI and NBS assessments are used to predict erosion rates and quantities for the entire assessment area. Surveyors will evaluate BEHI and NBS conditions for all banks prone to erosion. The cross section BEHI and NBS assessments are used to validate the erosion predictions for a particular BEHI and NBS combination. Validation of the bank erosion predictions is achieved by measuring annual lateral channel change at the monumented cross sections.

Surveyors will assess BEHI using a modified reach and cross section BEHI forms (Appendix A, pp. A9 to A12). These forms are derived from forms presented in the course field manual *River Assessment and Monitoring* (Wildland Hydrology 2003). The Service added an additional bank material category and adjustment, based on personal communications with David Rosgen (October 2003).

1. Reach BEHI Assessment

For efficiency, surveyors should conduct the reach BEHI assessment at the same time as the geomorphic mapping. The following reach BEHI assessment procedures will maintain consistency in data collection and presentation:

a. Assess all stream banks prone to erosion, excluding banks with significant deposition or stable concrete revetment (*i.e*., no indications of erosion along the revetment)
b. Partition the study banks based on changes in BEHI and/or NBS conditions (*e.g*., a study bank with one BEHI rating but two NBS conditions should be assessed as two separate study banks for ease of analysis)
c. Use the modified *reach* BEHI field form
d. Evaluate BEHI conditions for the entire length of study bank
e. Draw a typical bank profile in the space provided in the field form, with illustrations of rooting depth, bank protection, bank composition, and bank stratification.
f. Photograph the study bank with a surveyor and survey rod in the foreground as reference
g. Identify reach BEHI location and length on the geomorphic map
h. Use the same reach BEHI bank map labels, if BEHI and NBS conditions are the same (*e.g*., Bank 9 should be identified as Bank 9 for future surveys)
i. Use the same reach BEHI bank map labels and add a sequential letter if additional bank labels are required (*e.g*., Bank 9, Bank 9A, and Bank 9B)

2. Cross Section BEHI Assessment

Surveyors should conduct the cross section BEHI assessment following the completion of each cross section survey. The following cross section BEHI assessment procedures will maintain consistency in data collection:

a. Identify the study bank, at some cross sections, both banks were assessed for their erosion potential
b. Use the modified *cross section* BEHI field form
c. Assess the study bank directly inline with the cross section
d. Avoid evaluating upstream and downstream influences, such as boulder diversions or protection, when assessing the study bank
e. Photograph the study bank with surveyor and survey rod in the foreground as reference

Surveyors will compare the new BEHI results with the previous BEHI results to evaluate changes in BEHI conditions. The surveyors will perform the following analysis to characterize the changes:

f. Calculate new reach BEHI percentages (*e.g*., the low rating represents 30 percent of the banks)
g. Compare new and previous reach BEHI ratings and percentages
h. Compare new cross section BEHI rating with previous ratings
i. Conduct a trend analysis to evaluate past BEHI changes and predict future BEHI adjustments (*e.g*., a bank predicted to have a very low BEHI and NBS, and validated as stable, should have minimal lateral channel adjustments in the future, if site conditions remain consistent)

The baseline report (CBFO-S04-01) provides summary tables of the reach and cross section BEHI data and the cross section BEHI data sheets for reference and comparison.

3. <u>Near Bank Shear Stress Assessment</u>

Surveyors will determine reach and cross section NBS using one of the methods described in the course field manual *River Assessment and Monitoring* (Wildland Hydrology 2003). Surveyors will select the most appropriate method for their assessment objectives and conditions. The Service estimated NBS using the near bank maximum depth to bankfull mean depth ratio, at cross sections, and the channel pattern and cross section shape diagram (Wildland Hydrology 2003) for the baseline survey, where there were no cross sections.

Surveyors should determine NBS using quantitative methods, such as near bank maximum depth to bankfull mean depth ratio, before using qualitative methods, such as channel pattern and cross section shape diagram, whenever possible. Surveyors should use quantitative methods to determine NBS at monumented cross sections.

Surveyors will compare the new NBS results with previous NBS results to evaluate changes in NBS conditions. Surveyors will perform the following analysis to characterize the changes:

a. Calculate new NBS percentages (*e.g*., the low rating represents 30 percent of the banks)
b. Compare new NBS ratings and percentages with previous ratings and percentages
c. Compare new cross section NBS rating with previous ratings
d. Conduct a trend analysis to evaluate past NBS changes and predict future NBS adjustments (*e.g.,* a bank predicted to have a very low BEHI and NBS, and validated as stable, should have minimal lateral channel adjustments in the future, if site conditions remain consistent)

The baseline report (CBFO-S04-01) provides summary tables of the reach and cross section NBS data for reference and comparison.

F. Bank Erosion Validation and Predictions

Surveyors will measure annual lateral bank adjustments, at monumented cross sections, to validate predicted erosion rates and quantities. In the baseline study, the Service predicted bank erosion rates and quantities from reach BEHI and NBS ratings, and a bank erodibility curve developed by Wildland Hydrology for the Western United States (*i.e.,* Yellowstone National

Park; Rosgen 2001(a)). The final predictions of bank erosion quantities are a result of multiplying the erosion rate times the bank length times the bank height. The bank erosion validation is important because there are no bank erodibility curves for Maryland. Erosion rates based on lateral bank adjustments will allow the City to make more accurate erosion predictions, and to develop their own bank erosion curve.

1. Bank Erosion Validation and Revised Prediction

Surveyors will validate the bank erosion rates and revise the bank erosion predictions, if necessary. Surveyors will perform the following procedures for the validation:

a. Measure lateral change (*i.e*., annual erosion rate) for the monumented cross section, at the BEHI study banks
b. Relate cross section BEHI and NBS ratings, for the previous year, to the measured cross section erosion rates
c. Apply these cross section erosion rates to the same reach BEHI and NBS conditions
d. Recalculate bank erosion predictions based on revised erosion rates, for each reach BEHI study bank and each study reach
e. Use Yellowstone National Park bank erodibility curve for any unvalidated reach BEHI and NBS ratings

Wildland Hydrology presented the Yellowstone National Park bank erodibility curve at the 2001 Federal Interagency Sediment Conference (Rosgen 2001(a)). For an example of a bank erosion summary table, surveyors should refer to the summary table in the baseline report (CBFO-S04-01).

2. Reach and Cross Section BEHI and NBS Comparison

Changes in geomorphic and riparian conditions may result in different reach or cross section BEHI and NBS ratings than previous assessments. For example, loss of the riparian buffer, at a previously stable study bank, may result in a high (*i.e*., unstable) BEHI rating for the most recent BEHI assessment. Surveyors will compare new reach and cross section BEHI and NBS conditions to determine which reach BEHI and NBS combinations are not represented by existing monumented cross section.

Surveyors will install new monumented cross sections for reach BEHI and NBS combinations not represented by existing cross sections. For example, a new monumented cross section would be required if surveyors assess a reach BEHI and NBS combination of extreme and extreme, and there were no existing cross sections with an extreme BEHI and NBS rating.

For cross section monument installation procedures, surveyors should refer to the **Cross Section Monument Installation** section in this report. Surveyors will perform the following procedures for the BEHI and NBS comparison:

a. Compare new reach BEHI and NBS ratings with the new cross section BEHI and NBS ratings

b. Identify reach BEHI and NBS ratings which are not represented by a monumented cross section
c. Install new cross sections to represented new combinations of BEHI and NBS ratings

Surveyors may discontinue survey of cross sections with BEHI and NBS ratings not represented in the reach BEHI and NBS ratings, with the exceptions of cross sections used for stream classification, erosion monitoring, or another specific purpose. Another situation where surveyors may discontinue survey of a cross section is if two cross sections have the same BEHI and NBS rating.

G. Longitudinal Profile

The longitudinal profile survey documents the existing vertical stream position. Surveyors will use the longitudinal profile data for a variety of assessments, including:

- Determining slope for Rosgen stream type
- Assessing criteria for Rosgen Level III stability and sediment supply predictions (*e.g.*, slope for entrainment calculations and sediment capacity models)
- Monitoring changes in study reach slope
- Validating the vertical stability prediction made from the Rosgen Level III stability and sediment assessment

1. <u>Longitudinal Profile Survey</u>

Surveyors will resurvey the longitudinal profile for the entire assessment area of Moores Run. The following survey procedures will maintain consistency in data collection:

a. Begin survey from downstream limit of assessment area
b. Calculate instrument height in Baltimore City datum, using the USFWS RP-2 monument
c. Survey the same benchmarks identified in the baseline longitudinal profile survey
d. Locate study reach limits, cross sections, outfalls, and/or any other significant stream feature or structure
e. Survey the elevations corresponding to the lowest top-of-bank, bankfull, active channel, water surface, and thalweg
f. Survey at the tops and bottoms of facet features (*e.g.*, tops and bottoms of riffles, runs, glides, and pools) and at the maximum depth locations of pools

The Service provides a summary table of the GPS coordinates and elevations for the baseline longitudinal benchmark monuments on pages A5 to A7 in Appendix A. The baseline report (CBFO-S04-01) provides a monument location map for the Service established longitudinal profile benchmark (*i.e.*, Service Reference Point 2).

2. Longitudinal Profile Assessment

Surveyors will enter the longitudinal profile field data into the longitudinal profile Microsoft Excel workbook and plot the survey and benchmarks. The following assessment procedures will maintain consistency in data assessment and presentation:

a. Obtain longitudinal profile Microsoft Excel workbook from the City
b. Copy longitudinal profile data worksheet
c. Rename worksheet with new survey date
d. Enter field data in the appropriate worksheet columns
e. Plot longitudinal profile
f. Add new thalweg data to overlay plot

Surveyors will compare the longitudinal profile overlays to evaluate and characterize any changes in stream profile. The surveyors will perform the following analysis to characterize the changes:

g. Calculate annual percent vertical change (*i.e.*, overall and for each reach)
h. Calculate change in study reach slopes
i. Conduct a trend analysis to evaluate past longitudinal changes and predict future longitudinal adjustments

The baseline report (CBFO-S04-01) provides the Service longitudinal profile data and plots for reference and comparison.

H. Substrate Characterization

Bar samples and pebble counts are typical methods used to characterize the channel substrate. Surveyors will conduct bar samples and two types of pebble counts for the geomorphic condition and channel stability survey:

- Rosgen representative bar samples for entrainment calculations
- Rosgen representative pebble count for stream classification purposes
- Rosgen riffle pebble count for velocity and discharge calculations

During the baseline survey, the Service did not conduct bar sampling because there were only two bars: one consisting of boulder/large cobble, and another consisting of sand. The Service also did not conduct a reach average pebble count, because of the potential human health risks associated with poor water quality. The Service characterized the representative substrate condition for each of the study reaches based on field observations. The Service conducted two riffle pebble counts to determine relative roughness for velocity calculations. However, the Service conducted a gage calibration to determine the bankfull velocity and discharge.

This section provides procedures to collect a Rosgen representative bar sampling, if geomorphic conditions change and require the work. The section also provides procedures to collect the

Rosgen representative pebble count and riffle pebble count if the surveyors decide that the water quality conditions are safe to conduct the work.

1. Rosgen Representative Bar Sample

Surveyors will collect a bar sample for each stream type and stream condition, if the appropriate bar(s) exist. An example of a different stream condition that require bar samples is a stable and an unstable C stream type. Surveyors will use the bar sampling procedures presented in the course field manual *River Assessment and Monitoring* (Wildland Hydrology 2003).

2. Rosgen Representative Pebble Count

Surveyors will conduct a Rosgen representative pebble count for each stream type and stream condition. Surveyors will use the representative pebble count procedure presented in the course field manual *River Assessment and Monitoring* (Wildland Hydrology 2003).

3. Rosgen Riffle Pebble Count

Surveyors will conduct a riffle pebble count at cross sections used in hydraulic analysis. Surveyors will use the riffle pebble count procedure presented in the course field manual *River Assessment and Monitoring* (Wildland Hydrology 2003).

4. Substrate Assessment

Surveyors will enter the bar sample and pebble count field data into a bar sample or pebble count Microsoft Excel workbook, which plots the particle size distribution, and calculates the particle size for specific distributions, that is the D_{16}, D_{35}, D_{50}, D_{84}, and D_{95}. The following assessment procedures will maintain consistency in data assessment and presentation:

a. Obtain bar sample and pebble count Microsoft Excel workbook from the City
b. Enter bar sample or pebble count field data into the appropriate workbook

Surveyors will compare the results of the bar sample and pebble counts to evaluate and characterize any changes in bed composition. The surveyors will perform the following analysis to characterize the changes:

c. Compare particle size distributions (*i.e.*, D_{16}, D_{35}, D_{50}, D_{84}, and D_{95})
d. Conduct a trend analysis to evaluate past bed composition changes

The baseline report (CBFO-S04-01) provides the Service riffle pebble count data and plots for reference and comparison.

I. Rosgen Level III Stability and Sediment Assessment

The Rosgen Level III stability and sediment (Rosgen Level III) assessment (Rosgen 2001(b)) predicts lateral and vertical stability, channel enlargement potential, and sediment supply. The stability prediction is based on stability criteria derived from the representative cross section, bank erodibility, depositional pattern, planform characteristics, successional Rosgen stream type stage, and Pfankuch assessment (Pfankuck 1975). The sediment supply prediction is based on lateral and vertical stability rating, enlargement potential rating, and the Pfankuch channel stability rating.

1. Lateral Stability, Vertical Stability, and Enlargement Potential Assessment

Surveyors will conduct the stability and enlargement potential predictions for all the study reaches. The following assessment procedures will maintain consistency in data analysis:

a. Evaluate the stability criteria for each study reach
b. Use reference conditions for width/depth ratio and confinement criteria, if available

Surveyors will determine the stability and enlargement ratings based on the existing stream conditions in the study reach. The stability and enlargement potential assessment will help the surveyor interpret the processes contributing to the stability and enlargement ratings. For example, the Service determined that the right channel in Reach 03 was vertically degrading because of a low width/depth ratio. The Service verified this determination with a degrading rating for the study/reference width/depth ratio from the vertical stability assessment. When using the stability and enlargement assessment for interpretation, quantitative data, such as width/depth ratio, entrenchment, near bank shear stress, bank erodibility, and confinement have precedence over qualitative data, such as depositional pattern and meander pattern.

Surveyors will compare the new and previous stability predictions. The surveyors will perform the following analysis to characterize any changes:

c. Calculate new stability percentages (*e.g.*, the low rating represents 30 percent of the assessment area)
d. Compare new and previous stability and enlargement potential ratings and percentages
e. Conduct a trend analysis to evaluate past stability changes and predict future stability adjustments

The baseline report (CBFO-S04-01) provides a summary table of Rosgen Level III data for reference and comparison.

2. Modified Pfankuch Stream Reach Inventory and Channel Stability Assessment

The Pfankuch assessment is a general, overall stability evaluation, based on observations and information related to stream character and condition, in-stream habitat condition, and riparian character and condition.

Wildland Hydrology revised the Pfankuch assessment and field form by adapting the stability ratings for the Rosgen stream types (Rosgen 2001(b)). In addition, the Service modified the Pfankuch field form (Appendix A, p. A13) by adding an incising channel category for the channel capacity/enlargement criteria. This change is based on instructions presented by David Rosgen in the River Assessment and Monitoring course (2003).

a. Pfankuch Surveys

Surveyors will conduct the Pfankuch assessment for each study reach. The following procedures will maintain consistency in data collection:

1) Use the modified Pfankuch assessment field form
2) Evaluate conditions for each study reach
3) Use cross section data to evaluate the channel capacity/enlargement criteria in the office

b. Pfankuch Assessment

The following assessment procedures will ease data comparison and maintain consistency in data analysis:

1) Use reference (*i.e.*, potential) Rosgen stream type to determine channel stability rating
2) Use reference conditions for channel capacity/enlargement criteria

Surveyors will compare the new and previous Pfankuch assessment results. The surveyors will perform the following analysis to characterize any changes:

3) Calculate new Pfankuch rating percentages (*e.g.*, the low rating represents 30 percent of the assessment area)
4) Compare new and previous Pfankuch ratings and percentages
5) Conduct a trend analysis to evaluate past stability changes

The baseline report (CBFO-S04-01) provides the original Pfankuch assessment data for reference and comparison

3. Sediment Supply Assessment

Surveyors will predict the sediment supply for the study reaches. When using the Conversion of Stability Rating Categories to Sediment Supply Score chart, surveyors should use the higher sediment supply rating for scores that fall on rating partitions (*e.g.*, composite total stability score of 6 has a moderate sediment supply rating) to maintain consistency in data analysis.

Surveyors will compare the new sediment predictions with the previous predictions. The surveyors will perform the following analysis to characterize any changes:

a. Calculate new sediment supply percentages (*e.g.*, the low rating represents 30 percent of the assessment area)
b. Compare new and previous sediment supply ratings and percentages
c. Conduct a trend analysis to evaluate past sediment supply changes

The baseline report (CBFO-S04-01) provides the original sediment supply predictions for reference and comparison.

J. Quality Assurance and Control

Surveyors will provide quality assurance and quality control for all stages of the survey and assessment of the project. Surveyors will maximize standards and accuracy of data collection and management through the following procedures:

a. Surveyors assisting with field surveys will read the baseline (CBFO-S04-01) and any subsequent reports
b. Surveyors assisting with field surveys will review the data provided in the baseline (CBFO-S04-01) and any subsequent reports
c. Surveyors assisting with field surveys are trained and experienced in the field method procedures outlined in this report
d. Surveyors will ensure that the data accurately represents the stream conditions observed in the field.
e. Surveyors will review the entered data for accuracy

III. CONCLUSION

The purpose of these protocols is to ensure consistent survey techniques and assessment methods to provide comparable data. The City requires comparable data to document geomorphic and channel stability changes over time, and validation of stability and sediment predictions.

In addition to the current project objectives, the City can use the results of the geomorphic condition and channel stability surveys to identify problem areas and develop stream restoration priorities. The survey results can help the City identify areas of active or potential channel instability, and develop a cause and effect relationship between problems and the processes causing the problems. For example, straightening of a stream (*a cause or action*) could result in vertical degradation upstream of the straightening and lateral degradation downstream (*the effects*). By understanding the causes of the stability problems, the City can develop a better restoration priority and a more effective restoration design.

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6. Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology. Pagosa Springs, CO.

7. Rosgen, D. L. 2001(a). A Practical Method of Computing Streambank Erosion Rates, Proceedings of the 2001 Federal Interagency Sediment Conference, March 25-29, Reno, Nevada.

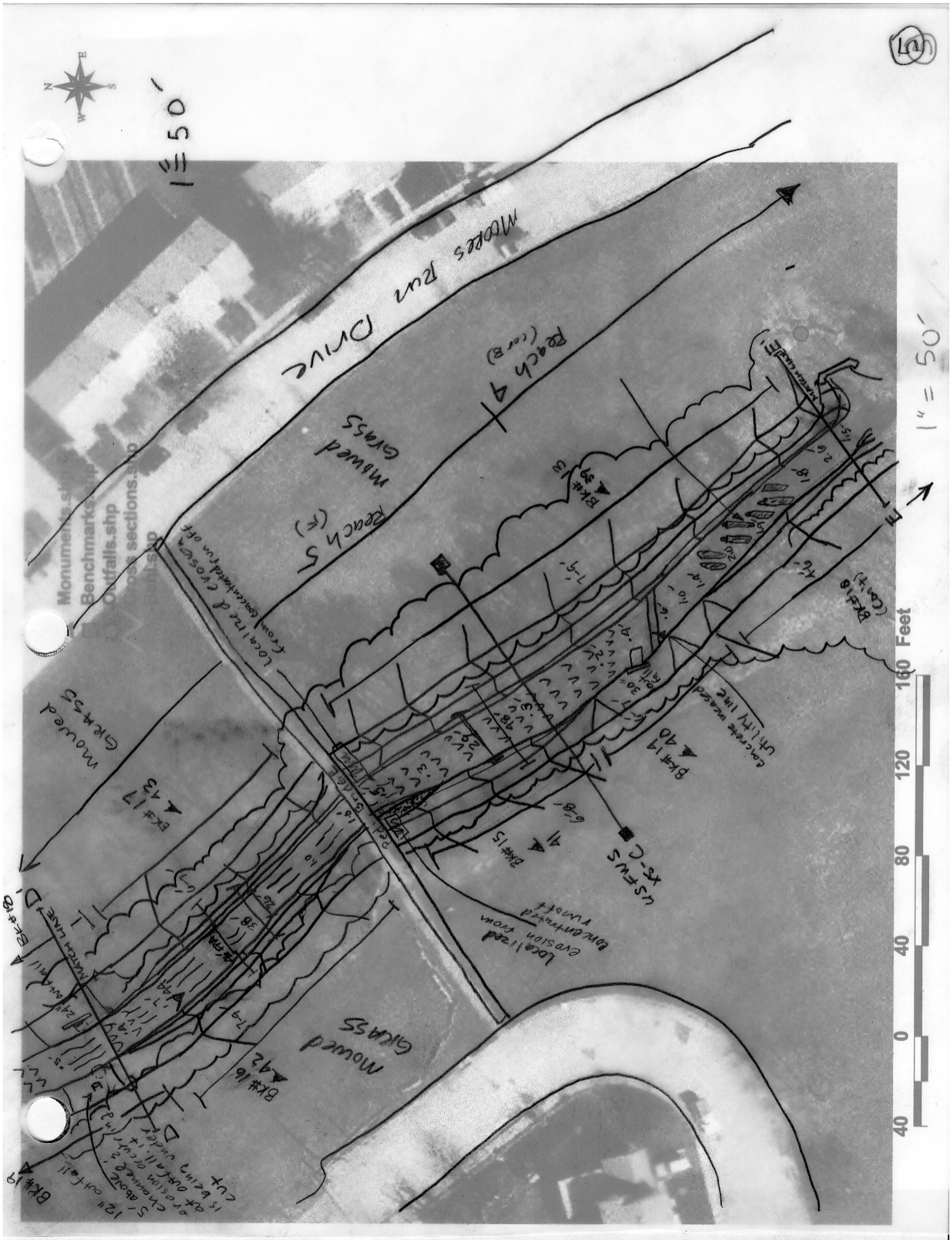
8. Rosgen, D. L. 2001(b). A Stream Channel Stability Assessment Methodology, Proceedings of the 2001 Federal Interagency Sediment Conference, March 25-29, Reno, Nevada.

9. Wildland Hydrology. 2003. River Assessment and Monitoring Course Field Manual. Pagosa Springs, CO.

APPENDIX A

MOORES RUN
DATA COLLECTION AND
ASSESSMENT PROTOCOL

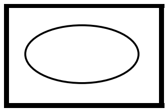
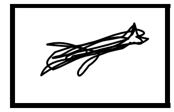
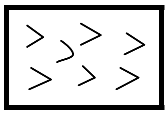
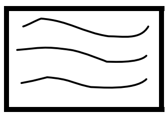
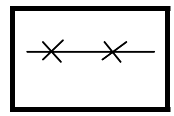
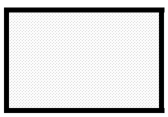
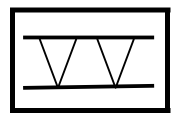
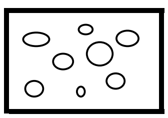
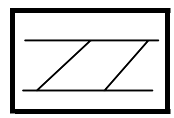
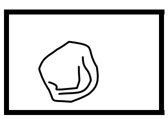
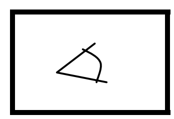
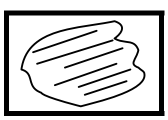
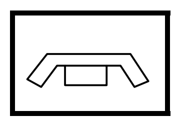
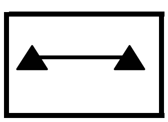
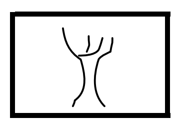
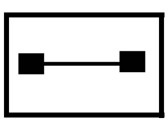
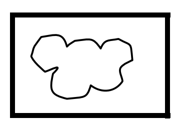
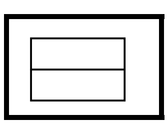
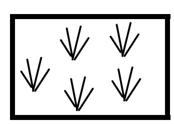
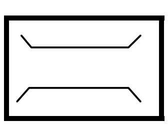
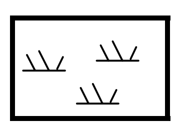
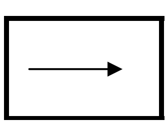
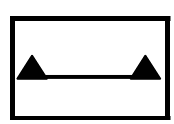
GEOMORPHIC MAP



GEOMORPHIC MAP ABBREVIATIONS

Abbreviations	**Definition**
USFWS	U.S. Fish and Wildlife Service
BC	Baltimore City
BKF	Bankfull
BEHI	Bank erosion hazard index
NBS	Near bank shear stress
BK	BEHI Bank (*e.g.*, BK #1)
Trib	Tributary
Ped	Pedestrian (*e.g.*, ped. bridge)
Ave	Avenue
Ct	Court
XS	Cross section

GEOMORPHIC MAP SYMBOLS

	Pool		Fallen Tree
	Riffle		Utility Crossing
	Run		Fence
	Sand		Raw Steep Bank
	Gravel		Stable Sloped Bank (angle of line represents angle of bank)
	Boulder		Camera Shot
	Bedrock		Outfall
	Baltimore City Cross Section		Individual Tree
	U.S. Fish and Wildlife Service Cross Section		Group of Trees
	Building		Herbaceous
	Bridge Crossing		Wetland
	Flow Direction		Project Reach Limits

CROSS SECTION ABBREVIATIONS

Abbreviations	Definition
USFWS	U.S. Fish and Wildlife Service
LTMON	Left top monument
LBMON	Left bottom monument
RTMON	Right top monument
RBMON	Right bottom monument
BPIN	Bottom toe pin
TPIN	Top toe pin
LTOB	Left top of bank
RTOB	Right top of bank
LBF	Left bankfull
RBF	Right bankfull
LEW	Left edge of water
REW	Right edge of water
SL BRK	Slope break
SL BRK (SL)	Slight slope break
IP	Inflection point
TW	Thalweg
LTOE SLP	Left toe slope
RTOE SLP	Right toe slope
BAR	Bar feature
FL	Fence line
TBERM	Top of berm
FT FLAT	Front flat
RLC CHAN	Relic channel
ROOT	Tree root
FT TERR	Front terrace
GS	Ground shot
CS	Channel shot
OC	Overflow channel
UNDERCUT	Undercut bank
GRVL	Gravel
ROCK	Rock
BLDR	Boulder
BR	Bedrock
T SCOUR	Top of scour
WALL	Wall
XS	Cross section

MOORES RUN MONUMENT INFORMATION

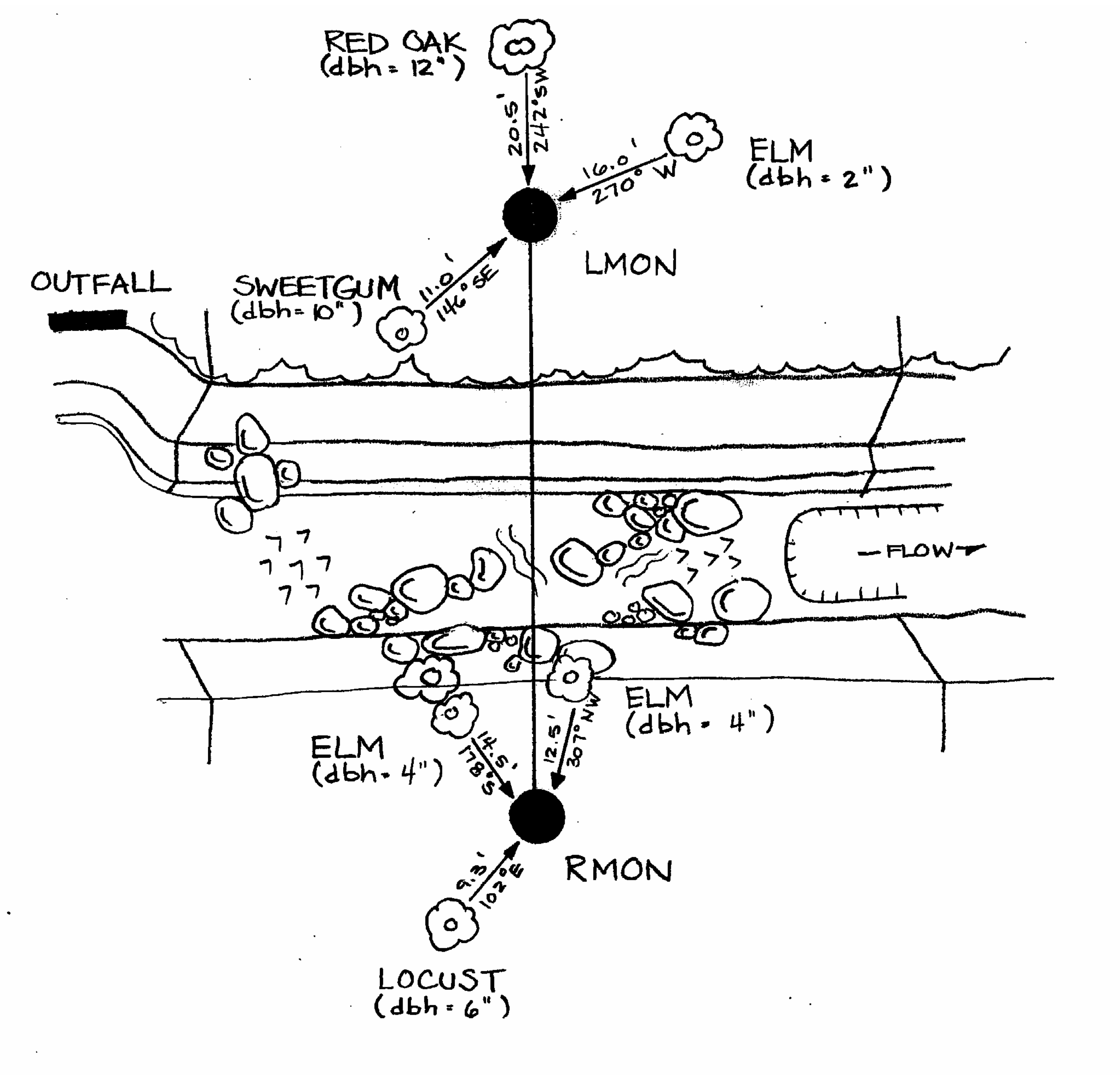
MONUMENT	GLOBAL POSITIONING SYSTEM (GPS) COORDINATE (NAD 83)	ELEVATION (ft) (Baltimore City Datum)
Cross Sections		
Service XS A		
Left	N: 39° 19' 53.5" (+/- 27 ft)	54.19 ft
	W: 76° 32' 06.8" (+/- 27 ft)	
Right	N: 39° 19' 53.0" (+/- 21 ft)	51.89 ft
	W: 76° 32' 08.0" (+/- 21 ft)	
Service XS B		
Left	N: 39° 19' 56.7" (+/- 24 ft)	59.98 ft
	W: 76° 32' 08.4" (+/- 24 ft)	
Right	N: 39° 19' 56.6" (+/- 21 ft)	58.45 ft
	W: 76° 32' 09.5" (+/- 21 ft)	
Service XS C		
Left	N: 39° 19' 59.0" (+/- 24 ft)	64.62 ft
	W: 76° 32' 10.4" (+/- 24 ft)	
Right	N: 39° 19' 58.6" (+/- 18 ft)	63.42 ft
	W: 76° 32' 10.8" (+/- 18 ft)	
Service XS D		
Left	N: 39° 20' 06.1" (+/- 18 ft)	78.88 ft
	W: 76° 32' 16.2" (+/- 18 ft)	
Right	N: 39° 20' 05.5" (+/- 12 ft)	74.84 ft
	W: 76° 32' 17.0" (+/- 12 ft)	
Service XS G		
Left	N: 39° 19' 47.8" (+/- 24 ft)	49.40 ft
	W: 76° 32' 04.4" (+/- 24 ft)	
Right	N: 39° 19' 47.7" (+/- 18 ft)	57.15 ft
	W: 76° 32' 06.0" (+/- 18 ft)	
Baltimore City XS 2		
Left	N: 39° 20' 11.9" (+/- 25 ft)	99.19 ft
	W: 76° 32' 20.7" (+/- 25 ft)	
Right	N: 39° 20' 11.3" (+/- 15 ft)	103.36 ft
	W: 76° 32' 21.2" (+/- 15 ft)	
Baltimore City XS 14		
Left	N: 39° 20' 06.9" (+/- 23 ft)	78.65 ft
	W: 76° 32' 17.2" (+/- 23 ft)	
Right	N: 39° 20' 06.5" (+/- 18 ft)	82.85 ft

MONUMENT	GLOBAL POSITIONING SYSTEM (GPS) COORDINATE (NAD 83)	ELEVATION (ft) (Baltimore City Datum)
	W: 76° 32' 17.8" (+/- 18 ft)	
Cross Sections (continued)		
Baltimore City XS 16		
Left	N: 39° 20' 04.8" (+/- 21 ft)	77.17 ft
	W: 76° 32' 15.6" (+/- 21 ft)	
Right	N: 39° 20' 04.8" (+/- 18 ft)	73.60 ft
	W: 76° 32' 16.2" (+/- 18 ft)	
Baltimore City XS 18		
Left	N: 39° 20' 03.1" (+/- 21 ft)	67.49 ft
	W: 76° 32' 14.2" (+/- 21 ft)	
Right	N: 39° 20' 02.7" (+/- 17 ft)	71.60 ft
	W: 76° 32' 14.9" (+/- 17 ft)	
Baltimore City XS 26		
Left	N: 39° 19' 54.9" (+/-19 ft)	55.93 ft
	W: 76° 32' 07.7" (+/- 19 ft)	
Right	N: 39° 19' 54.8" (+/- 19 ft)	56.17 ft
	W: 76° 32' 09.0" (+/- 19 ft)	
Baltimore City XS 28		
Left	N: 39° 19' 53.1" (+/-19 ft)	53.10 ft
	W: 76° 32' 06.6" (+/- 19 ft)	
Right	N: 39° 19' 52.3" (+/- 19 ft)	52.24 ft
	W: 76° 32' 07.6" (+/- 19 ft)	
Baltimore City XS 32		
Left	N: 39° 19' 50.4" (+/-22 ft)	49.71 ft
	W: 76° 32' 05.5" (+/- 22 ft)	
Right	N: 39° 19' 50.3" (+/- 23 ft)	50.45 ft
	W: 76° 32' 06.7" (+/- 23 ft)	
Baltimore City XS 38		
Left	N: 39° 19' 46.6" (+/-19 ft)	48.50 ft
	W: 76° 32' 03.6" (+/- 19 ft)	
Right	N: 39° 19' 46.1" (+/- 19 ft)	51.81 ft
	W: 76° 32' 04.6" (+/- 19 ft)	

MONUMENT	GLOBAL POSITIONING SYSTEM (GPS) COORDINATE (NAD 83)	ELEVATION (ft) (Baltimore City Datum)
Longitudinal Profile		
USFWS Reference Point 2	N: 39° 19' 44.0" (+/- 18 ft) W: 76° 32' 02.5" (+/- 18 ft)	48.53 ft
USGS Reference Mark 1 (Gage 01585230)	N: 39° 19' 48.6" (+/- 28 ft) W: 76° 32' 06.4" (+/- 28 ft)	60.08 ft
Baltimore City Benchmark (Screw in Radecke Bridge)	N: 39° 19' 49.1" (+/- 21 ft) W: 76° 32' 06.4" (+/- 21 ft)	56.60 ft
Baltimore City Benchmark 8988 (Screw at intersection of Newholme and Hamilton Avenue)	N: 39° 20' 13.0" (+/- 22 ft) W: 76° 32' 20.0" (+/- 22 ft)	95.66 ft.
Chiseled square on culvert (RB) at station 1589’	N: 39° 19' 58.3" (+/- 19 ft) W: 76° 32' 10.2" (+/- 19 ft)	54.25 ft.
Chiseled square on culvert (LB) at station 1893’	N: 39° 20' 00.7" (+/- 16 ft) W: 76° 32' 12.1" (+/- 16 ft)	61.63 ft.
Chiseled square on culvert (LB) at station 2257’	N: 39° 20' 03.8" (+/- 22 ft) W: 76° 32' 14.7" (+/- 22 ft)	67.15 ft.
Chiseled square on boulder (ID as #10) at station 2303’	N: 39° 20' 03.7" (+/- 16 ft) W: 76° 32' 14.9" (+/- 16 ft)	64.60 ft.
Chiseled square on boulder (Near LB – ID as #11) at station 2465’	N: 39° 20' 05.2" (+/- 21 ft) W: 76° 32' 15.9" (+/- 21 ft)	67.19 ft.

Moores Run
Reach 06
Baltimore Cross Section 16
(Stream Feature: Run)

Cross Section Monument Map



Cross Section Monuments = 2" Capped Steel Pipes

ROSGEN - REACH BEHI AND NBS FIELD FORM

<table>
<tr><td colspan="4">Stream:</td><td>Bank Label:</td><td rowspan="4">Comments:</td></tr>
<tr><td colspan="4">Reach:</td><td>BEHI Rating:</td></tr>
<tr><td colspan="4">Observer (s):</td><td>NBS Estimate Rating:</td></tr>
<tr><td colspan="4">Survey Date:</td><td></td></tr>
<tr><td colspan="3">Erodibility Variable</td><td>Index</td><td colspan="2" rowspan="20">Bank Sketch and Near Bank Shear Stress cross section sketch</td></tr>
<tr><td>Bank Height (ft) A</td><td>Bankfull Height (ft) B</td><td>A/B</td><td rowspan="2"></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="4">Root Depth/Bank Height</td></tr>
<tr><td>Root Depth (ft) C</td><td>C/A</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="4">Weighted Root Density</td></tr>
<tr><td>Root Density (%) D</td><td>D*(C/A)</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="4">Bank Angle</td></tr>
<tr><td>Bank Angle (degrees)</td><td colspan="2" rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td></td></tr>
<tr><td colspan="4">Surface Protection</td></tr>
<tr><td>Surface Protection (%)</td><td colspan="2" rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td></td></tr>
<tr><td colspan="3">Materials: Upper-sandy loam. Lower-gravel with sand matrix</td><td></td></tr>
<tr><td colspan="3">Stratification: Boundary between sandy loam and gravel</td><td></td></tr>
<tr><td colspan="3">TOTAL SCORE:</td><td></td></tr>
</table>

Bank Erosion Hazard Index

			Bank Erosion Potential					
			Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
Erodibility Variable	*Bank Height/ Bankfull Height*	Value	1.0 - 1.1	1.11 - 1.19	1.2 - 1.5	1.6 - 2.0	2.1 - 2.8	>2.8
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Root Depth/ Bank Height	Value	1.0 - 0.9	0.89 - 0.5	0.49 - 0.3	0.29 - 0.15	0.14 - 0.05	<0.05
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Weighted Root Density	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 5.0	<5.0
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Bank Angle	Value	0 - 20	21 - 60	61 - 80	81 - 90	91 - 119	>119
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Surface Protection	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 10	<10
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10

Bank Materials

Bedrock (Bedrock banks have very low bank erosion potential)

Boulders (Banks composed of boulders have low bank erosion potential)

Cobble (Subtract 10 points. If sand/gravel matrix > 50% of bank material, then do not adjust)

Sand/Silt Loam (Add 5 points)

Gravel (Add 5-10 points depending on percentage of bank material that is composed of sand)

Sand (Add 10 points if sand is exposed to erosional processes)

Silt/Clay (+ 0: no adjustment)

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

Total Score

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Page 2 of 2

ROSGEN - XS BEHI AND BANK PROFILE FIELD FORM

Stream:	**Bank Label:**	**Comments:**
Reach:	**Observer(s):**	
Survey Date:		

Erodibility Variable			**Index**
Bank Height (ft) A	Bankfull Height (ft) B	A/B	
Root Depth/Bank Height			
Root Depth (ft) C	C/A		
Weighted Root Density			
Root Density (%) D	D*(C/A)		
Bank Angle			
Bank Angle (degrees)			
Surface Protection			
Surface Protection (%)			
Materials: Upper-sandy loam. Lower-gravel with sand matrix			
Stratification: Boundary between sandy loam and gravel			
TOTAL SCORE:			

Bank Profile								
Horiz (ft)	Vert. (ft)	Note	Horiz (ft)	Vert (ft)	Note	Horiz (ft)	Vert (ft)	Note

Bank Profile

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Bank Erosion Hazard Index

			Bank Erosion Potential					
			Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
Erodibility Variable	*Bank Height/ Bankfull Height*	Value	1.0 - 1.1	1.11 - 1.19	1.2 - 1.5	1.6 - 2.0	2.1 - 2.8	>2.8
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Root Depth/ Bank Height	Value	1.0 - 0.9	0.89 - 0.5	0.49 - 0.3	0.29 - 0.15	0.14 - 0.05	<0.05
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Weighted Root Density	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 5.0	<5.0
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Bank Angle	Value	0 - 20	21 - 60	61 - 80	81 - 90	91 - 119	>119
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Surface Protection	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 10	<10
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10

Bank Materials

Bedrock (Bedrock banks have very low bank erosion potential)

Boulders (Banks composed of boulders have low bank erosion potential)

Cobble (Subtract 10 points. If sand/gravel matrix > 50% of bank material, then do not adjust)

Sand/Silt Loam (Add 5 points)

Gravel (Add 5-10 points depending on percentage of bank material that is composed of sand)

Sand (Add 10 points if sand is exposed to erosional processes)

Silt/Clay (+ 0: no adjustment)

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

Total Score

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

MODIFIED PFANKUCH STREAM REACH INVENTORY AND CHANNEL STABILITY EVALUATION

Stream:		**Observer(s):**		**Ex. Stream Type:**		**Ref. Stream Type:**	
Reach:		**Comments:**		**Grand Total:**	0.00		
Location:				**Stability Rating:**			
Date:				**Notes:**			

Location	Key	Category	Excellent			Good			Fair			Poor		
			Description	**Rating**	**Score**	**Description**	**Rating**	**Score**	**Description**	**Rating**	**Score**	**Description**	**Rating**	**Score**
Upper Banks	**1**	**Landform Slope**	Bank slope gradient < 30%.	2		Bank slope gradient 30-40%.	4		Bank slope gradient 40-60%.	6		Bank slope gradient > 60%.	8	
	2	**Mass Wasting**	No evidence of past or furture mass wasting.	3		Infrequent. Mostly healed over. Low future potential.	6		Frequent or large, causing sediment nearly year long.	9		Frequent or large, causing sediment nearly year long OR imminent danger of same.	12	
	3	**Debris Jam Potential**	Essentially absent from immediate channel area.	2		Present, but mostly small twigs and limbs.	4		Moderate to heavy amounts, mostly larger sizes.	6		Moderate to heavy amounts, predominantly larger sizes.	8	
	4	**Vegetative Bank Protection**	> 90% plant density. Vigor and variety suggest a deep, dense soil binding root mass.	3		70-90% density. Fewer species or less vigor suggest less dense or deep root mass.	6		50-70% density. Lower vigor and fewer species from shallow, discontinuous root mass.	9		< 50% density plus fewer species and less vigor indicating poor, discontinuous, and shallow root mass.	12	
Lower Banks	**5**	**Channel Capacity/ Enlargement**	Ample for present plus some increases. Peak flows contained. Ratio of w/d ratio to reference w/d ratio between 1.0-1.1. BHR = 1.0-1.1.	1		Adequate. Bank overflows are rare. Ratio of w/d ratio to reference w/d ratio between 1.1-1.2. BHR = 1.1-1.3.	2		Barely contains present peaks. Occasional overbank floods. Ratio of w/d ratio to reference w/d ratio between 1.2-1.6. BHR = 1.3-1.5.	3		Inadequate. Overbank flows common. Ratio of w/d ratio to reference w/d ratio > 1.6. BHR > 1.5.	4	
			For incising channels, ratio of w/d ratio to reference w/d ratio between 0.8-1.0.	1		**For incising channels**, ratio of w/d ratio to reference w/d ratio between 0.6-0.8.	2		**For incising channels**, ratio of w/d ratio to reference w/d ratio between 0.4-0.6.	3		**For incising channels**, ratio of w/d ratio to reference w/d ratio between 0.2-0.4.	4	
	6	**Bank Rock Content**	> 65% with large angular boulders. > 12" common.	2		40-65%. Mostly boulders and small cobbles 6-12".	4		20-40% with most in the 3-6" diameter class.	6		< 20% rock fragments of gravel sizes, 1-3" or less.	8	
	7	**Obstructions to Flow**	Rocks and logs firmly imbedded. Flow pattern without cutting or deposition. Stable bed.	2		Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4		Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6		Frequent obstruction and deflectors cause bank erosion year long. Sediment traps full, channel migration occurring.	9	
	8	**Cutting**	Little or none. Infrequent raw banks < 6".	4		Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6		Significant. Cuts 12-24" high. Root mat overhangs and sloughing evident.	12		Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16	
	9	**Deposition**	Little or no enlargement of channel or point bars.	4		Some new bar increase, mostly from coarse gravel.	8		Moderate deposition of new gravel and coarse sand on old and some new bars.	12		Extensive deposit of predominantly fine particles. Accelerated bar development.	16	
Channel Bottom	**10**	**Rock Angularity**	Sharp edges and corners. Plane surfaces rough.	1		Rounded corners and edges, surfaces smooth, flat.	2		Corners and edges well rounded in 2 dimensions.	3		Well rounded in all dimensions, surfaces smooth.	4	
	11	**Brightness**	Surfaces dull, dark or stained. Generally not bright.	1		Mostly dull, but may have < 35% bright surfaces.	2		Mixture dull and bright, *ie*. 35-65% mixture range.	3		Predominantly bright, > 65% exposed or scoured surfaces.	4	
	12	**Cosolidation of Particles**	Assorted sizes tightly packed or overlapping.	2		Moderately packed with some overlapping.	4		Mostly loose assortment with no apparent overlap.	6		No packing evident. Loose assortment easily moved.	8	
	13	**Bottom Size Distribution**	No size change evident. Stable material 80-100%.	4		Distribution shift light. Stable material 50-80%.	8		Moderate change in sizes. Stable materials 20-50%.	12		Marked distribution change. Stable materials 0-20%. Sand deposition.	16	
	14	**Scouring and Deposition**	< 5% of bottom affected by scour or deposition.	6		5-30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12		30-50% affected. Deposits and scour at obstructions, constriction and bends. Some filling of pools.	18		> 50% of the bottom in a state of flux or change nearly year long.	24	
	15	**Aquatic Vegetation**	Abundant growth moss-like, dark green perennial. In swift water, too.	1		Common. Algae forms in low velocity and pool areas. Moss here, too.	2		Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3		Perennial types scarce or absent. Yellow-green, short term bloom may be present.	4	
				Excellent Total	**0**		**Good Total**	**0**		**Fair Total**	**0**		**Poor Total**	**0**

Stream Type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107
Fair (Moderately Unstable)	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+
Stream Type	**D6**	**DA3**	**DA4**	**DA5**	**DA6**	**E3**	**E4**	**E5**	**E6**	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**
Good (Stable)	67-98	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107
Fair (Moderately Unstable)	99-125	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-126	108-120
Poor (Unstable)	126+	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	111+	111+	79+	79+	121+	121+	126+	121+