APPENDIX A

BCS Method Description

The Basin Condition Score (BCS): a subwatershed assessment methodology used in the preparation of the Upper Patuxent River Watershed Restoration Action Strategy (WRAS)

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Introduction

The purpose of this document is to summarize a prioritization methodology to use in ranking subwatersheds in the Upper Patuxent River Watershed for restoration activities.

Methods

In this approach, indicators were developed to evaluate overall subwatershed conditions. These indicators are based upon data collected during the Stream Corridor Assessment (SCA) performed by DNR staff, biological and water quality data collected concurrently with and prior to the SCA work, and GIS data developed by DNR and the Counties. The methods used in the SCA are found in Yetman (2001). Water quality assessment methods are described in DNR (2002). Biological assessment methods are described in Pavlik and Stribling (2003), DNR (2002) and in PGDER (1995).

Some indicators are believed to better characterize critical ecological processes. Consequently, these indicators were weighted to emphasize the importance of some variables over others when evaluating subwatershed health. Each indicator was either unweighted or had a weighting factor of 2 or 3 applied. The decision about which indicator to weight was based upon scientific literature and the best professional judgment of the authors. Besides having a lesser impact on ecological processes in a subwatershed of interest, indicators were also left unweighted if it was judged that data of poor quality had to be used to score the indicator. The authors made data quality decisions in consultation with GIS professionals and through discussions with participants of the SCA assessment.

The points for each indicator were summed to develop the Basin Condition Score (BCS), leading to a condition classification as illustrated in Table 1. In addition, individual indicators were grouped and scored under various categories, allowing an evaluation of where problems exist within a particular subwatershed even if an overall score indicates only moderate or low impairment. Using the ranges, subwatershed conditions were classified as described below:

Table 1. Scoring ranges for BCS methodology.

Indicator Group	Subwatershed Quality Rating			
	Good	**Fair**	**Poor**	**Very Poor**
Water Quality Conditions	<5	5-11	12-17	>17
Living Resource Conditions	<18	18-38	39-65	>65
Habitat Conditions	<38	38-83	84-128	>128
Landscape Conditions	<33	33-72	73-111	>111
Hydrologic Conditions	<8	8-17	18-26	>26
OVERALL BCS	<101	101-220	221-345	>345

A. WATER QUALITY CONDITIONS. Water quality data provide insight into the ability of organisms to survive in aquatic systems and these data also provide an indication of the impacts of development or other anthropogenic activities in a subwatershed. Water quality data were collected during a synoptic survey of the study area (DNR 2002).

WQ1—Baseflow Nitrate/Nitrite Concentration Departure

Justification: Nutrient concentrations associated with relatively unimpaired subwatersheds have been documented for Coastal Plain watersheds. In addition, excess nutrient loading has been shown to be a main impairment in Chesapeake Bay water quality.

Scoring Definition: This indicator is scored using nitrate concentration determined in synoptic sampling. The level of departure from levels listed below, which is based upon guidance from USEPA (2000) and local unpublished data, is considered indicative of impairment. An average is taken of all available concentration values within a subwatershed of interest.

Definition	Score (Unweighted)	Quality Rating
<0.1 mg/L	1	Good
0.1 to 0.3 mg/L	4	Fair
>0.30 to 0.50 mg/L	7	Poor
>0.5 mg/L	10	Very Poor

WQ2—Baseflow Orthophosphorous Concentration Departure

Justification: Nutrient concentrations associated with relatively unimpaired watersheds have been documented for Coastal Plain watersheds. In addition, excess nutrient loading has been shown to be a main impairment in Chesapeake Bay water quality.

Scoring Definition: This indicator is scored using orthophosphate concentrations determined in synoptic sampling. The level of departure from levels listed below is considered indicative of impairment. These categories are based upon DNR (2002). An average is taken of all available concentration values within a subwatershed of interest and scored as described below:

Definition	Score (Unweighted)	Quality Rating
<0.005 mg/L	1	Good
0.005 to 0.010 mg/L	4	Fair
0.011 to 0.015 mg/L	7	Poor
>0.015 mg/L	10	Very Poor

B. LIVING RESOURCE CONDITIONS. Samples of the benthic macroinvertebrate community along with fish population data were collected in all subwatersheds. In addition, data from DNR on anadromous fish usage and on the presence or absence of threatened and endangered species was also obtained. With this information, a total of four indicators are described to evaluate overall biological conditions in the study subwatersheds. In order to evaluate overall living resource conditions, an indicator group score is calculated by summing the scores of all four indicators and scored using the ranges in Table 1.

LR1—Aquatic Insect Community Condition

Justification: Benthic macroinvertebrates are considered reliable indicators of aquatic system health (Stepenuck et al 2002). These groups integrate water quality impacts over longer time frames because of repeated exposures to whatever pollutants flow through the system, making them a more reliable indicator of water quality degradation than synoptic water quality samples.

Scoring Definition: Based upon sampling done as part of this study, the level of departure from Maryland reference values defined by work done by the Maryland Department of Natural Resources as part of its Maryland Biological Stream Survey (MBSS) resulted in the calculation of an index of biotic integrity (IBI). These IBI values are given qualitative scores that are used as described below.

Definition	Score (Weighting Factor 3)	Quality Rating
Score of Good	3	Good
Score of Fair	12	Fair
Score of Poor	21	Poor
Score of Very Poor	30	Very Poor

LR2—Anadromous Fish Utilization

Justification: Because anadromous fishes return to the same streams each season, these species are an indicator of moderate to high quality habitat conditions. Like invertebrates, these species integrate water quality impacts over longer time frames due to the presence of multiple life history phases utilizing these areas.

Scoring Definition: The presence or absence from subwatersheds as detailed in Mowrer and McGinty (2002) forms the basis of the score. A total five species are evaluated: yellow perch, white perch, American shad, blueback herring, and alewife. Because of the age of the data, this indicator is unweighted.

Definition	Score (Unweighted)	Quality Rating
4 or 5 species use the subwatershed	1	Good
2 or 3 species use the subwatershed	4	Fair
1 or 2 species use the subwatershed	7	Poor
No species use the subwatershed.	10	Very Poor

LR3—Presence/Absence of Sensitive Species Protection Areas

Justification: Loss of biodiversity is indicative of an impacted subwatershed. The presence of areas supporting rare or endangered species signify high quality habitat within that subwatershed.

Scoring Definition: Because of the nature of the GIS data associated with this indicator, exact locations, numbers, and extent of distribution are not know for the species in question. Consequently, the presence or absence of these species is used to score this indicator.

Definition	Score (Unweighted)	Quality Rating
1 or more SSPA present in subwatershed	1	Good
No SSPA present in subwatershed	10	Very Poor

LR4—Stream Fish Community Condition

Justification: These groups integrate water quality impacts over longer time frames because of repeated exposures to whatever pollutants flow through the system, making them a more reliable indicator of water quality degradation than collecting water quality samples. Stream fishes also occupy top carnivore niches in these systems. Depressed fish populations are effective in identifying poor stream conditions (Schleiger 2000).

Scoring Definition: For fish sampling locations, an Index of Biological Integrity (IBI) was calculated using metrics described in Roth et al (1997) with data from DNR (2000). These values are given qualitative scores that are used as described below.

When more than one site within a subwatershed was sampled, an average IBI was calculated. In cases where an unsampled subwatershed evaluated with all the other indicators is nested within a larger subwatershed where the fish sampling occurred, the IBI or average IBI in the large subwatershed was applied to all the nested subwatersheds.

If a nested subwatershed has been sampled as part of a larger subwatershed, only the IBI applicable to that subwatershed is used. No average is calculated for that subwatershed. Subwatersheds where sampling was attempted but no water was found receive a score of very poor. Finally, if a "no data" condition exists for this indicator in a subwatershed that is otherwise assessed, then this indicator is scored by giving it the quantitative score of habitat indicator group.

Definition	Score (Weighting Factor 3)	Quality Rating
IBI of Good	3	Good
IBI of Fair	12	Fair
IBI of Poor	21	Poor
IBI of Very Poor	30	Very Poor

C. HABITAT CONDITIONS. Habitat conditions were evaluated as part of the biological assessments performed in the study subwatersheds and as part of the Stream Corridor Assessment (SCA) performed by the Maryland Department of Natural Resources. Using the various habitat impairment indicators evaluated during SCA and as part of the biological assessment described above, the following six indicators were developed:

HC1—Channel Erosion

Justification: Channel erosion can be a serious habitat impairment. While streams naturally erode banks and rework floodplains over time, excess streambank erosion due to watershed development results in siltation of spawning areas, smothers bottom dwelling invertebrates, and can have adverse impacts on stream channel and floodplain form and function (Waters 1995).

Scoring Definition: Data on eroding banks were collected during the SCA. Each bank was rated during the field assessment. Using the severity rating given during that evaluation, only banks rated moderate in severity or greater were used in calculating this indicator. Channelization impacts were not included in this indicator. The total amount of both banks in this condition was divided by the total amount of stream bank in the subwatershed (double the total GIS-derived stream length) and scored as described below:

Definition	Score (Weighting Factor 3)	Quality Rating
Value <0.10	3	Good
Value between 0.10 and 0.20	12	Fair
Value between 0.21 and 0.30	21	Poor
Value >0.30	30	Very Poor

HC2—Pipe Outfalls

Justification: As described in Yetman (2001), pipe outfalls represent potential non-point source pollution directly piped into the stream system. The number of outfalls is also an indirect indicator of development density with more outfalls equal to increased development.

Scoring Definition: The total number of outfalls per square mile of subwatershed was calculated and scored as described below:

Definition	Score (Unweighted)	Quality Rating
<2 per sq. mi.	1	Good
2 to 5 per sq. mi.	4	Fair
6 to 10 per sq. mi.	7	Poor
>10 per sq. mi.	10	Very Poor

HC3—Buffer Conditions

Justification: Riparian buffers are necessary for stream stability and are a major component of stream habitat through the production of woody debris (Everett and Ruiz 1993, Benke et al 1985, Palmer et al 1996). Streams with more diverse and healthy biological communities tend to have more extensive streamside forested buffers.

Scoring Definition: Buffer impairment was evaluated during the SCA. Using the severity rating given during that evaluation, only buffer impairments rated moderate in severity or greater were used in calculating this indicator. Buffer conditions on both banks were evaluated, but impacts associated with channelization were not included in this indicator. Consequently, the total amount of buffer on both banks in the defined condition was divided by the total amount of potential stream buffer (double the GIS-derived stream length) and scored as described below:

Definition	Score (Weighting Factor 3)	Quality Rating
Value <0.10	3	Good
Value 0.10 to 0.20	12	Fair
Value 0.21 to 0.30	21	Poor
Value >0.30	30	Very Poor

HC4—Fish Barriers

Justification: Free access to habitat is necessary to preserve ecological integrity of stream systems. Barriers to migration, particularly man-made ones, disturb the natural movement of individuals and their usage of available stream habitat.

Scoring Definition: Barriers associated with both natural and manmade structures are evaluated as part of the SCA. Since height of the barrier is provided, barriers greater than 12 inches are considered high enough to impede river herring, so those barriers greater that 12 inches are counted. The total percentage of stream mileage lost above all the blockages was divided by the total amount of habitat available and scored as described below:

Definition	Score (Weighting Factor 3)	Quality Rating
Value <0.10	3	Good
Value 0.10 to 0.20	12	Fair
Value 0.21 to 0.30	21	Poor
Value >0.30	30	Very Poor

HC5—Overall Habitat Rating

Justification: Overall habitat ratings were developed for each subwatershed using data collected as part of the biological sampling work. Instream habitat and streamside condition are well correlated with biological health and ecological function.

Scoring Definition: A subwatershed habitat rating was developed for each subwatershed based upon the total scores observed at all sites throughout a subwatershed of interest. This subwatershed composite score is given a qualitative rating as described in Pavlik and Stribling (2003) and was then used to score this indicator as described below:

Definition	Score (Weighting Factor 3)	Quality Rating
Rating of Comparable	3	Good
Rating of Supporting	12	Fair
Rating of Partially Supporting	21	Poor
Rating of Non-Supporting	30	Very Poor

HC6—Channel Alterations

Justification: Channelization and other alterations of stream systems typically have adverse impacts on water quality (Maxted et al, 1995), stream geomorphology (Hupp 1992, Waters 1995), and biological communities (Waters 1995).

Scoring Definition: Channel alterations are evaluated as part of the SCA. Using the severity rating given during that evaluation, only channel alterations rated moderate in severity or greater were used in calculating this indicator. The total length of channel altered is divided by the total amount of stream length to obtain the following:

Definition	Score (Weighting Factor 2)	Quality Rating
Value <0.10	2	Good
Value 0.10 to 0.20	8	Fair
Value 0.21 to 0.30	14	Poor
Value >0.30	20	Very Poor

D. LANDSCAPE CONDITIONS. Various subwatershed-wide landscape conditions were evaluated using GIS data. The following seven indicators were developed and are described below:

LC1—Current % Imperviousness

Justification: There is evidence to suggest that total levels of impervious surface in a watershed are directly related to a watershed's overall condition (Schueler and Holland 2000).

Scoring Definition: As described in Schueler and Holland (2000), streams with less than 10% total impervious surface are considered relatively unimpaired, those between 10 and 25% are stressed, while those with greater than 25% are considered impaired. Imperviousness can be estimated using impervious coefficients derived from local land use conditions in the geographic area where the watershed of interest in located. For subwatersheds in Anne Arundel County, imperviousness is estimated using land use data from 1995 with impervious coefficients derived from AA County (2002b) applied to the total area of each land use polygon. The land use categories in the 1995 data set were more general than the ones used in AA County (2002b). Consequently, the 1995 land use data were overlaid on to year 2000 aerial photography in order to determine which category was appropriate for use. Subwatersheds in Prince George's County also used locally derived coefficients to determine imperviousness.

Definition	Score (Weighting Factor 3)	Quality Rating
≤10%	3	Good
11-18%	12	Fair
19-25%	21	Poor
>25%	30	Very Poor

LC2--Road Crossings

Justification: The number of road crossings on streams has been shown to relate to sediment delivery to developing watersheds (Haskins and Mayhood 1997). Increased numbers of road crossings are also associated with increased watershed development as roadways are constructed to support development needs.

Scoring Definition: The higher the number of crossings, the more potential for adverse impacts on stream channel conditions. Dividing the total number of road crossings by subwatershed area in square miles provides the indicator score, as described in Haskins and Mayhood (1997).

Definition	Score (Unweighted)	Quality Rating
<1.5	1	Good
1.5 to 2.0	4	Fair
>2.0 to 3.0	7	Poor
>3.0	10	Very Poor

LC3—Forest polygon edge/area

Justification: The presence of large forest blocks has been shown to have a positive impact on aquatic and terrestrial species (Rich et al 1994) while forest fragmentation has been demonstrated to have adverse impacts on species that depend upon intact forest areas (Gates and Evans 1996)

Scoring Definition: The more intact the forest area within a subwatershed, the greater the continuity of forest area within the subwatershed. This indicator is calculated by dividing the total perimeter (feet) of all forest polygons by the area (square feet) of all the forest polygons. Because of the uncertainty associated with the GIS characterization of the necessary data layers, this indicator is unweighted.

Definition	Score (Unweighted)	Quality Rating
< 0.006	1	Good
0.006 to 0.008	4	Fair
0.009 to 0.010	7	Poor
>0.010	10	Very Poor

LC4—Full Build Out Increase in Impervious Cover

Justification: Numerous studies have shown that increased impervious cover (IC) in a watershed leads to degradation of stream ecological conditions. Estimating future build out provides an indication of susceptibility to ecological degradation compared with current conditions.

Scoring Definition: Scored as LC1 using the relationship between current imperviousness and future impervious surface by comparing recent land use/land cover information with predicted build out as described in County zoning maps.

Definition	Score (Weighting Factor 2)	Quality Rating
<10% IC at full build out	2	Good
11-18% IC at full build out	8	Fair
19-25% IC at full build out	14	Poor
>25% IC at full build out	20	Very Poor

LC5—Percent of Subwatershed in Proposed Greenway

Justification: Anne Arundel County has identified land area in the County for inclusion in a series of corridors connecting natural areas collectively known as Greenways (Anne Arundel County 2002a). Subwatersheds located in the proposed greenway are likely to have higher levels of protection and preservation than those outside this area because greenway areas were identified as lands having significant ecological value compared to other lands in the County.

Scoring Definition: This indicator is scored using the percentage of total subwatershed area proposed for inclusion in the County Greenway.

Definition	Score (Weighting Factor 2)	Quality Rating
>30% of subwatershed in proposed Greenway	2	Good
20 to 30% of subwatershed in proposed Greenway	8	Fair
10 to 19% of subwatershed in proposed Greenway	14	Poor
<10% of subwatershed in proposed Greenway	20	Very Poor

LC6—Percent of Subwatershed Land Area with Permanent Protection

Justification: Protected land usually means that little future development will occur within an subwatershed of interest. Other condition factors being equal, subwatersheds with large amounts of protected land are of higher quality because of the likelihood of being habitat islands in future developed areas surrounding them.

Scoring Definition: Land considered permanently protected includes County, State or Federal parkland or wildlife conservation areas, lands with conservation easements, or any lands with other types of protection that prevents its conversion from open space to developed area. The total amount of this land will be computed as a percentage of total subwatershed area. There is some overlap with LC5.

Definition	Score (Weighting Factor 2)	Quality Rating
>80% land area in permanent protection	2	Good
50 to 80% of sub in perm. protection	8	Fair
30 to 49 % of sub in perm. protection	12	Poor
<30% of sub permanently protected.	20	Very Poor

LC7—Percent of Subwatershed Land Area in Agricultural Land Use

Justification: Conversion of forest areas to agricultural land use can have adverse, long-term impacts on stream systems (Harding et al 1998). Subwatersheds with large amounts of cropland are likely to be more impacted than those with lesser amounts of these land uses (Richards et al 1996).

Scoring Definition: Land cover classified as agriculture is used to score this indicator, with the categories breaks loosely inspired by Harding et al (1998). The total amount of land in this category is divided by the subwatershed area and scored as described below:

Definition	Score (Weighting Factor 2)	Quality Rating
<10% of subwatershed in Ag	2	Good
10 to 25% of subwatershed in Ag	8	Fair
26 to 35% of subwatershed in Ag	12	Poor
>35% of subwatershed in Ag	20	Very Poor

E. HYDROLOGIC CONDITIONS

HY1—Flooding Potential

Justification: Flooding is a significant concern to some stakeholders in assessed subwatersheds. This indicator scores the potential of damage to developed areas and intrusion into the 100-yr floodplain by older structures.

Scoring Definition: An examination is made of developed land and its presence or absence in the 100-yr floodplain.

Definition	Score (Weighting Factor 2)	Quality Rating
No developed land in 100-yr FP	2	Good
0 to 15% of 100-yr FP includes developed land	8	Fair
16 to 25% of 100-yr FP includes developed land	12	Poor
>25% of 100-yr FP includes developed land.	20	Very Poor

HY2—Stream Baseflow Condition

Justification: A major impact associated with development concerns the loss of baseflow in stream channels. Because of the lack of recharge, baseflow in urban and suburban streams is typically depressed compared to undeveloped watersheds, with streams frequently dry even during light or moderate drought conditions. The maintenance of baseflow during dry months is a critical habitat feature for aquatic organisms.

Scoring Definition: This indicator is scored using the channel flow status parameter scored during the habitat assessment performed as part of the biological sampling conducted in the study subwatersheds and as part of the representative sites evaluated during the SCA stream walks. For the SCA data, all indicators were scored using the qualitative categories that are part of the RBP habitat assessment (Optimal, Suboptimal, Marginal, Poor). These ratings were converted to values by selecting the median value within the category (18 for Optimal, 13 for Suboptimal, 8 for Marginal, and 3 for Poor). All scores within each subwatershed were then averaged and scored as described below:

Definition	Score (Unweighted)	Quality Rating
Rated optimal	1	Good
Rated suboptimal	4	Fair
Rated marginal	7	Poor
Rated poor	10	Very Poor

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