HABITAT QUALITY AND BIOLOGICAL INTEGRITY ASSESSMENT OF FRESHWATER STREAMS IN THE SAINT MARY'S RIVER WATERSHED

CHESAPEAKE BAY AND
WATERSHED PROGRAMS
MONITORING AND
NON-TIDAL ASSESSMENT
CBWP-MANTA- EA-01-2

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Final Data Report:

Habitat Quality and Biological Integrity Assessment of Freshwater Streams in the Saint Mary's River Watershed

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Introduction

This work was completed by the Maryland Department of Natural Resources under contract Number DACW 31-99-P-0048 from the U.S. Army Corps of Engineers.

The Saint Mary's River watershed is located in Saint Mary's County, Maryland, and encompasses approximately 45,200 acres. The watershed is located within the Coastal Plain physiographic province. The geologic strata in the area consist of unconsolidated sediments from the Quaternary and Tertiary periods (0-63 million years ago)(Maryland Department of Natural Resources 1968). Soils in the watershed are made up of varying proportions of sand, silt, gravel, clay, peat, greensand, and diatomaceous earth. The dominant land use in the watershed is forest (59%), followed by agriculture (23%), urban (17%), wetlands (0.8%) and barren land (0.2%). Saint Mary's County is currently experiencing an increase in urban land development largely due to the expansion of the Naval Air Warfare Center Aircraft Division.

Typically, as land in a watershed is converted to urban uses, soil compaction and impervious surface area increases causing stormwater to be delivered to streams at accelerated rates while infiltration declines. This results in increased erosion of stream channels and other associated ecological problems. According to the Maryland Office of Planning, about 6.4% of the Saint Mary's River watershed was impervious surfaces in 1994. Scientific studies have shown that once impervious surface area exceeds a certain threshold (usually about 10% to 15% of a watershed's area) serious ecological degradation occurs (Limburg and Schmidt, 1990; Imhof *et al.*, 1991; Weaver and Garman, 1994; Wichert, 1994,1995; Moscrip and Montgomery, 1997; Wang *et al.*, 1997, 2000;).

The overall goal of the Saint Mary's River Project is to provide information that will help Saint Mary's County plan land development in a manner that will minimize impacts to the county's aquatic resources. This goal will be achieved by identifying areas of high biological integrity where preservation efforts can be focused, along with biologically impaired areas where habitat restoration efforts can mitigate the impacts of previously developed and careful planning can minimize the impacts of new development. The Saint Mary's River Watershed Plan focuses on three objectives: mitigating the impact of stormwater flow from impervious surfaces to reduce the erosive power of stormflow events, increasing the quality of the stormwater which discharges into streams, and restoring damaged or lost instream and riparian wildlife habitat. This project will also serve as an educational tool in the county by promoting environmental awareness within the residential, business, and academic communities. The project is a multi-agency effort involving the US Army Corps of Engineers (ACOE), Saint Mary's College, Saint Mary's County, and the Maryland Department of Natural Resources.

The goals of the Saint Mary's River Project are (1) to sample the streams in the watershed to obtain baseline information on ecological conditions and fish distributions, and (2) to use the data to target areas for land preservation, planned development and habitat restoration efforts. This report describes results from ecological monitoring activities conducted by the Maryland Department of Natural Resources' (DNR), Maryland Biological Stream Survey (MBSS) in 1995 and 2000.

Methods

Using data from a total of 36 sites, stream conditions in the Saint Mary's River watershed were characterized to assist in developing recommendations for planning land development (Figure 1). The ACOE chose the locations of seven of these sites that were sampled by MBSS during 2000. Data from these seven sites were used to examine the influence of urban land development on stream ecological resources in the Saint Mary's River watershed. Results of this examination are described in this report and can be used to demonstrate the importance of careful land use planning. Locations of each of the seven sites are listed in Table 1 and data collected are included in appendix A. Along with these seven sites, assessment of stream conditions at 29 additional sites provided broader spatial coverage for a more accurate characterization of stream conditions throughout the Saint Mary's River watershed. Nine of these sites were randomly selected and sampled by the MBSS (two during 1995 and seven during 2000). Benthic macroinvertebrates were collected in 2000 at the remaining 20 sites as part of the Stream Waders volunteer monitoring program (coordinated by DNR). MBSS (Kazyak 2000) and Stream Waders (MDNR 2001) monitoring and assessment methods are described below.

Biological

Fish assemblage data were collected using double-pass electrofishing with direct current backpack units. Each 75 m long site was blocked at each end using block nets and all available habitats were thoroughly sampled. For each pass, all captured fish were identified to species, counted, and released. Fishes were collected during summer (June - September) to avoid the effects of spring and fall spawning movements on fish assemblages and to maximize electrofishing catch efficiencies. Fish data were analyzed in terms of species richness, composition, relative abundance, and general pollution tolerance. A Fish Index of Biotic Integrity (FIBI) was also calculated (Roth et al, 1998; Roth et al 1999). A list of fish species predicted to occur at each site was generated and compared to the actual list of species collected. Benthic macroinvertebrates were collected by Stream Waders volunteers using D-frame sampling nets during spring (March-April). A 100 organism sub-sample was processed and identified to family taxonomic level by DNR staff. These data were used to calculate a family-level benthic macroinvertebrate index of biotic integrity for each site. In addition to fish and benthic marcroinvertebrate information, the presence of herpetofauna, aquatic vegetation, and freshwater mussels was also recorded. Any taxon identified by the DNR's, Natural Heritage Division as rare, threatened, or endangered based on the official State Threatened and Endangered Species List as part of the State of Maryland Threatened and Endangered Species regulations (COMAR 08.03.08) was recorded.

Water Quality

Water quality information was collected *in situ* just prior to summer fish sampling. Parameters measured included dissolved oxygen (DO), pH, conductivity, turbidity and temperature. All measurements were taken with a Hydrolab™ multiprobe water quality meter, except for turbidity which was measured with a LaMotte™ turbidity meter. Both instruments were calibrated before sampling according to MBSS QA/QC guidelines (Kazyak 2000).

Physical Habitat

Physical habitat assessments were conducted to evaluate habitat effects on biota. MBSS habitat assessment procedures were derived from two methods: EPA's Rapid Bioassessment Protocols (Plafkin et al. 1989), as modified by Barbour and Stribling (1991), and Ohio EPA's Qualitative Habitat Evaluation Index (Ohio EPA 1987). Several parameters (instream habitat, epifaunal substrate, velocity/depth diversity, pool/glide/eddy quality, riffle quality, embeddedness, and shading) were scored based on visual observations. Quantitative measurements at each site included the number of woody debris and root wads, maximum depth, wetted width, depth, and discharge.

Land Use
Arc View software was used to generate site-specific land use and impervious surface information for each site using U.S. EPA Multi-Resolution Land Characteristic Consortium (MRLC) data. These land use data are based on Landsat TM data acquired in 1986-1993 and, as a result, *do not reflect land use changes that have occurred more recently than 1993.*

Quality Control/ Quality Assurance
Qaulity control and quality assurance procedures for this project followed the MBSS methods as outlined in Appendix B. These procedures have been accepted by the U.S. Environmental Protection Agency and meet all requirements as outlined in "The Guidelines and Specifications for Preparing Project Plans", EPA QAMS 005/80.

Table 1. Locations of each of the seven sites selected by ACOE and sampled by MBSS during 2000.

Site	Stream	Location	Coordinates
JA 1	Un-named Tributary to Jarboesville Run	Pegg Road (off Rt. 237) and Liberty. Site is on 2nd trib. to NW. about 500ft upstream from confluence.	38:15:52 N 76:28:43 W (ADC Saint Marys County Map Book, Map 18, E10)
JC1	Johns Creek	Flat Iron Rd. South from Rt. 5. Right on Shady Dr. Park where road crosses stream. Site is upstream about 200ft.	38:14:10 N 76:29:58 W (ADC Saint Marys County Map Book, Map 24, B2)
HR2	Un-named Tributary to Hilton Run	Willows Rd. to Hilton Dr. Site is about 500ft West then about 2000ft South above confluence.	38:14:43 N 76:28:09 W (ADC Saint Marys County Map Book, Map 18, G13)
PB1	Pembrook Run	Hermanville Rd. North from Rt. 5. 500ft North of Dixon Ct. and West about 200ft.	38:13:52 N 76:27:04 W (ADC Saint Marys County Map Book, Map 24, J3)
USM	Un-named Tributary to Saint Mary's River	235 South. Right on Chancellors Run Rd. First right, to end West to stream and site.	38:17:23 N 76:30:14 W (ADC Saint Marys County Map Book, Map 18, A5)
JA2	Jarboesville Run	Pegg Road (off Rt. 237) and Liberty. Northwest. First stream NW of road. Site is 1000ft upstream from confluence	38:15:52 N 76:28:29 W (ADC Saint Marys County Map Book, Map 18, F10)
HR1	Hilton Run	Willows Rd. to end of Hilton Dr. About 1500ft West, to second stream. Site is downstream 500ft and above confluence	38:14:41 N 76:28:09 W (ADC Saint Marys County Map Book, Map 18, G13)

Results/Discussion

ACOE sites

Adverse effects from anthropogenic stressors appeared to be minimal at four of the seven ACOE sites sampled in this study (JA1, JC1, HR2, and PB1) (Table 2). Protection of the catchments for these sites from development is necessary to preserve good quality, rare, or unique resources. JA1 warrants particular consideration for protection status due to the presence of iron color shiner (*Notropis chalybaeus*), a fish species which is designated "Highly State Rare" by the Maryland Department of Natural Resources, Natural Heritage Division. In addition to protection status, JC1, HR2, and PB1 would benefit from bank stabilization as 20, 20, and 40 square meters of stream bank were eroded at each site respectively. Three of the seven ACOE sites (HR1, JA2, and USM) were influenced by a number of stressors with USM being the most severely degraded site.

Table 2. Select water quality, physical habitat, land use, and biological parameters measured at seven sites sampled for this study (see Table 1). Values indicating the presence of anthropogenic stress are highlighted in red. Values highlighted in green indicate good quality, rare, or unique stream resources. Appendix C. shows thresholds for classifying values as good quality or degraded.

Parameter	HR1	HR2	JA1	JA2	JC1	PB1	USM
Fish IBI Score	Fair (3.0)	Good (4.0)	Good (4.3)	Fair (3.8)	Good (4.8)	Good (4.3)	Poor (2.8)
Expected Fish Species (%)	43	63	75	57	81	50	40
Tolerant Fish (%)	78	41	62	49	22	38	99
Rare Taxa (#)	0	0	1	0	0	0	0
D.O (mg/L)	6.0	8.4	6.0	8.0	8.7	8.7	5.8
pH (units)	6.63	6.50	6.95	6.86	7.62	6.87	5.67
Instream Habitat Score	13	14	18	10	16	17	8
Epifaunal Substrate Score	14	12	16	6	15	17	7
Velocity/Depth Diversity	12	7	10	7	15	15	4
Pool Quality Score	11	15	15	11	15	16	10
Eroded Bank Area (m^2)	80	20	0	150	20	40	140
Erosion Severity Score	2	1	0	2.5	1.5	1.5	3
Urban Land Use (%)	41.5	23.4	6.4	45.7	4.5	10.8	29.7
Impervious Land Cover	17.6	8.7	1.9	16.5	1.4	3.0	10.1

At the seven ACOE sits, more bank erosion (Figure 2), lower discharge (Figure 3), lower instream habitat scores (Figure 4) and lower Fish IBI scores (Figure 5) were observed at sites with greater than 10% impervious land cover in site catchments compared to sites with less impervious land cover in their catchments. Highly variable and temporally fluctuating hydrographs are often associated with streams in urbanized watersheds (Rosgen 1996) and are likely responsible for the extensive stream bank erosion and decreased base flows at sites with greater than 10% impervious land cover. The resulting loss of instream habitat is probably attributable to the displacement of large woody debris during high flow events, silt deposition, and lowered base flows as impervious land cover increases and infiltration decreases. Any or all of these physical alterations are possible reasons for low biological integrity observed at more urbanized sites.

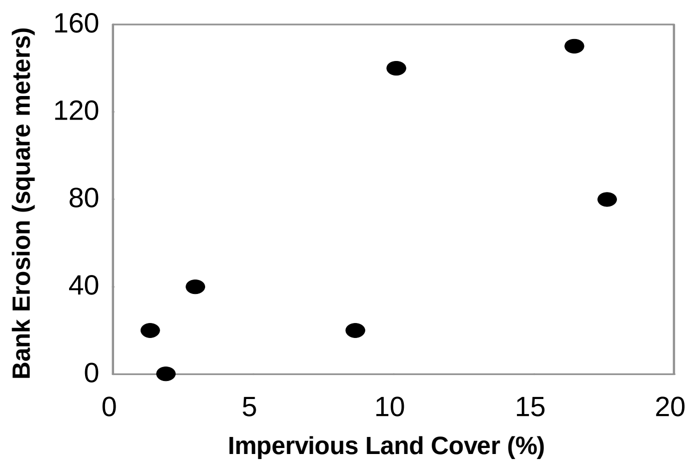

Figure 2. Bank erosion versus impervious land cover at seven Saint Mary's River watershed sampling sites.

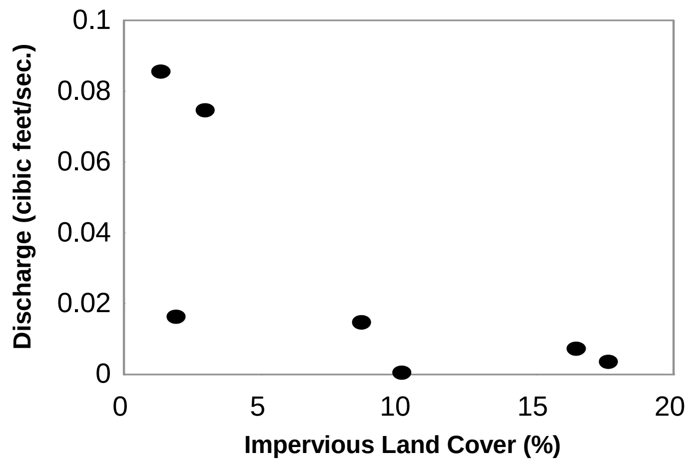

Figure 3. Discharge versus impervious land cover at seven Saint Mary's River watershed sampling sites.

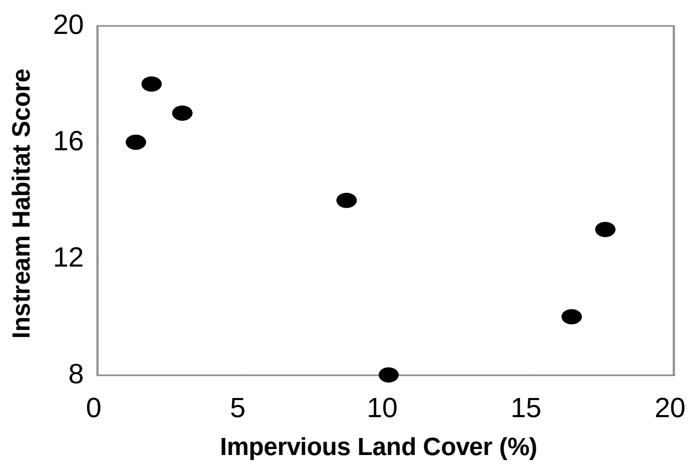

Figure 4. Instream Habitat Scores versus impervious land cover at seven Saint Mary's River watershed sampling sites.

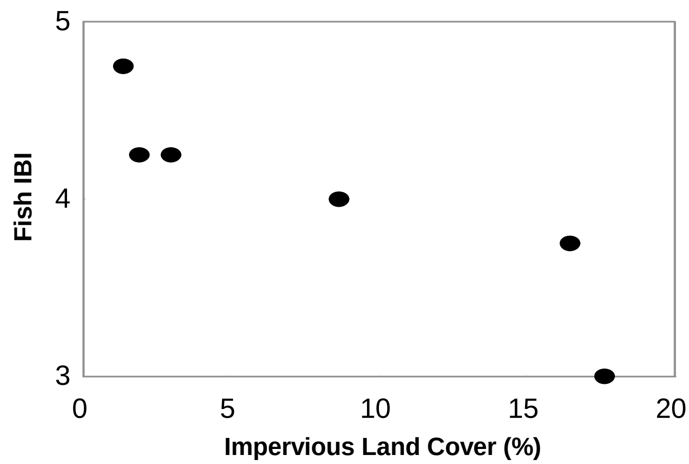

Figure 5. Fish IBI Scores versus impervious land cover at seven Saint Mary's River watershed sampling sites.

Watershed Characterization

Data collected from sampling sites (over 30% of all stream reaches) were available to evaluate streams in need of protection and restoration in the Saint Mary’s River watershed. This broad sampling density provides the opportunity for conducting an overall watershed assessment. Despite this major monitoring effort, however, over 100 other stream reaches were not sampled. The presence of good quality, rare, or unique stream resources in any of these unsampled reaches can not be ruled out. Additional monitoring in the watershed is needed for a more comprehensive watershed assessment.

All MBSS, ACOE. and Stream Waders sites were color coded for ecological condition and plotted on a map of the Saint Mary’s River watershed (Figure 7). Areas in need of protection were identified based on the catchments of sites with high biological integrity scores and rare taxa. Streams were identified and prioritized for restoration potential based biological condition (Table 3) at sampled sites. We used a four tiered approach to prioritize streams for restoration. Streams in catchments of sites with rare taxa were given top priority for targeting restoration activities. Streams in catchments of minimally degraded sites (Good IBI scores) received second priority. The third tier priority for restoration included catchments of sites with moderate degradation (Fair IBI scores). Finally, unless the impairment presents a human health hazard, we recommend that work on the fourth tier (severely degraded sites with Poor and Very Poor IBI scores) be deferred until habitat in reaches in higher priority catchments are protected and improved. Using this approach, thorough surveys of stream bank erosion and overall habitat quality are needed to find stream reaches in catchments of priority sites where habitat

improvements or storm-water control may be necessary.
There are a number of financial and ecological justifications for using this tiered approach for planning stream restoration projects. Financial justification is based on the lower cost and effort needed to restore a larger number of minimally-degraded streams compared to a few severely degraded streams. Ecological justification comes from a greater potential for restoration success in minimally-degraded streams compared to severely degraded streams because degraded streams often suffer from the influence of a greater number of stressors. As there are no streams in Maryland that are completely free from anthropogenic influences, the currently high biological quality of minimally degraded streams will be most effectively maintained or even improved by controlling erosive, urban run-off and enhancing instream habitat in their catchments.

The catchments of the un-named tributary to Jarboesville Run (site JA1) and the Upper Saint Mary's River (site 202) were given top priority for protection status based on the presence of rare fish species. Catchments of several other streams were also recommended for protection status based on Good IBI scores (Figure 7). Based on the results of this survey, degraded sites were found within the catchments upstream of sites 202 and PB1. Habitat restoration projects should be implemented at these degraded sites and any other impaired areas within the catchments of sites 202 and PB1, as well as other priority protection sites if their high biological quality is to be maintained. A number of streams had severely degraded physical habitat and biological quality. Although they may benefit from habitat improvement and control of urban run-off, focusing development in the catchments of these already degraded streams would render the least impairment to the overall biological quality of the Saint Mary's River watershed. However, development should be carefully planned to prevent further degradation of stream habitats in these catchments.

Summary

The influence of urban development on the Saint Mary's River watershed appears to be relatively severe. The best protection for streams in the watershed would come from curtailed development. A more realistic but also more uncertain strategy would be to direct growth away from the most undisturbed portions of the watershed. Protecting areas of high biological integrity and habitat quality by concentrating development in impaired areas would help to preserve some of the watershed's biological integrity and biodiversity. Focusing habitat improvement activities on minimally degraded streams first would provide additional protection to areas with high biological integrity and biological diversity. Surveys of habitat quality and stream bank erosion from urban run-off in the upstream catchments of minimally degraded streams would provide additional information necessary to plan habitat improvements and bank stabilization projects that would ensure the most benefit to the biological integrity and diversity of the Saint Mary's River watershed. In most cases, we recommend that a long-term, lower cost approach to stream restoration such as riparian buffer plantings be evaluated first before extensive channel modifications are considered.

Table 3. Prioritization of streams for protection and possible habitat restoration.

Priority	Stream name or site ID	Reason for Priority
1	Un-named Tributary to Jarboesville Run	Rare fish species and Good IBI score at base of watershed.
2	Saint Mary's River north of Norris Road and it's tributaries	Rare fish species and Good IBI score.
3	Jarboesville Run	Good IBI score at base of watershed; Fair IBI and a large amount of erosion upstream of confluence with Un-named Tributary.
3	Un-named Tributary to Hilton Run (Site HR2)	Good IBI score on reach.
3	Pembrook Run north of it's confluence with Eastern Branch and it's tributaries	Good IBI score at downstream end of watershed; poor IBI and a large amount of erosion in the uppermost part of the watershed.
3	Fisherman Creek, upstream of confluence with Amuski Run	Good IBI score.
3	Pembrook Run north of it's confluence with Eastern Branch and it's tributaries	Good IBI score at downstream end of watershed; poor IBI and a large amount of erosion in the uppermost part of the watershed.
3	Warehouse Run	Good IBI score.
3	Johns Creek	Good IBI score.
4	Saint Mary's River from the confluence with Jarboesville Run upstream including Deep Center Run and it's tributaries	Two Good IBI scores from Stream Waders and a Fair IBI score from MBSS.
5	Hilton Run (excluding above)	One Fair MBSS IBI score and and one fair Stream Waders IBI score, moderate bank erosion.
6	Eastern Branch at site 716-1	Fair Stream Waders IBI score, need more information on physical habitat quality before initiating habitat improvements.
6	Adams Creek at site 709-3	Fair Stream Waders IBI score, need more information on physical habitat quality before initiating habitat improvements.
7	Site 111	Poor MBSS and Stream waders IBI score.
7	Site 108	Poor MBSS IBI score, acidic stream, good physical habitat scores.
7	Sites 713-4, 709-2, 710-1, and 710-2	Poor Stream Waders IBI scores, need more information on physical habitat and water chemistry before initiating habitat improvements.

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Appendix A. Chemistry, physical habitat, land use, and biological data collected for the Army Corps of Engineers by the Maryland Department of Natural Resources at seven stream sites during ecological monitoring in summer 2000.

A-1. Water Chemistry.
Water chemistry for the seven Saint Mary's River Watershed sites sampled during summer 2000.

Parameter	HR1	HR2	JA1	JA2	JC1	PB1	USM
D.O (mg/L)	6.0	8.4	6.0	8.0	8.7	8.7	5.8
pH (units)	6.63	6.50	6.95	6.86	7.62	6.87	5.67
Temp. (C)	16.3	17.0	14.5	14.6	14.8	16.3	16.3
Conductance (µmho/cm)	0.083	0.084	0.057	0.122	0.086	0.060	0.085
Turbidity (NTU**)**	14.9	25.1	28.1	18.4	10.3	12.6	23.0

A-2. Physical Habitat.
Physical habitat scores for the seven Saint Mary's River Watershed sites sampled during summer 2000. In stream Habitat, Epifaunal Substrate, Velocity Depth Diversity, Pool Quality, and Riffle Quality scores are rated on a scale of 0-20, with 20 being the best quality habitat and 0 the poorest quality. Embeddedness and Shading are percentages. Erosion Severity was rated on a scale of 1-3, with 3 scored as severe, 2 moderate, 1 minor, and 0 meaning no erosion.

Parameter	HR1	HR2	JA1	JA2	JC1	PB1	USM
Instream Habitat	13	14	18	10	16	17	8
Epifaunal Substrate	14	12	16	6	15	17	7
Velocity/Depth Diversity	12	7	10	7	15	15	4
Pool Quality	11	15	15	11	15	16	10
Riffle Quality	11	0	9	13	15	14	7
Embeddedness (%)	30	100	20	70	40	30	90
Shading (%)	95	98	90	95	80	95	95
Eroded Bank Area (m^2)	80	20	0	150	20	40	140
Erosion Severity	2	1	0	2.5	1.5	1.5	3

A-3. Land Use

Land Use for the seven Saint Marys River watershed sites sampled during Summer 2000. All values are percentages of each sites total catchments. The four major land use categories used by the MBSS are Urban, Agriculture, Forest and Other. Categories ending with asterisks are included in one of the four MBSS categories (i.e. Impervious is included in the Urban land use category and Wetlands are included in the Other category).

Land Use Type	HR1	HR2	JA1	JA2	JC1	PB1	USM
Urban	41.52	23.43	6.40	45.68	4.52	10.76	29.71
Agriculture	15.91	18.25	22.30	16.04	31.95	15.12	17.46
Forest	32.19	48.67	66.20	31.51	61.03	67.60	51.91
Other	10.38	9.65	5.10	6.76	2.50	6.53	0.92
Impervious*	17.63	8.65	1.90	16.46	1.35	2.96	10.11
Wetlands*	6.27	9.58	4.90	6.76	2.12	6.45	0.00

A-4. Fish

Fish species collected at the seven Saint Marys River sites sampled during 2000**.**

Species	HR1	HR2	JA1	JA2	JC1	PB1	USM
American eel	2	3	7	0	23	23	1
Blacknose dace	0	0	0	0	4	0	0
Bluegill	0	2	9	0	3	6	2
Bluespotted sunfish	0	0	23	1	0	0	0
Brown bullhead	0	0	0	0	0	8	0
Chain pickerel	1	0	5	0	2	1	0
Creek chubsucker	0	24	15	10	2	1	0
Eastern mudminnow	45	20	145	59	13	0	34
Fathead minnow	0	0	0	0	0	0	123
Golden shiner	0	4	9	1	0	2	5
Ironcolor shiner	0	0	27	0	0	0	0
Least brook lamprey	2	1	33	20	66	4	0
Margined madtom	0	1	0	0	3	3	0
Pirate perch	0	8	20	0	5	2	0
Pumpkinseed	0	9	7	0	4	0	1
Redbreast sunfish	0	9	6	25	35	33	0
Sea lamprey	0	0	0	0	4	0	0
Swallowtail shiner	0	0	0	0	0	2	0
Tadpole madtom	0	3	0	0	4	3	0
Tessellated darter	10	4	2	6	50	19	0
Total # of Fish	60	88	308	122	218	107	166
total # of Species	5	12	13	7	15	13	6
Percent Tolerants:	78.33	40.70	61.69	49.18	22.02	38.32	99.40

A-5. Fish Index of Biotic Integrity (FIBI) Scores.

Maryland Department of Natural Resources has developed an Index of Biotic Integrity for non-tidal stream fish assemblages (FIBI) as a tool for evaluating the ecological conditions in streams (Roth et al. 1998). The FIBI evaluated various ecological attributes of fish assemblages and compared them to assemblages in minimally impacted reference sites. IBI scores were rated on a scale of 1 to 5, with 1 being the poorest possible score, and 5 being the best. Sites were then assigned scores of Good, Fair, Poor or Very Poor (see Appendix Table C-1).

Parameter	**HR1**	**HR2**	**JA1**	**JA2**	**JC1**	**PB1**	**USM**
FIBI Score	3.00	4.00	4.25	3.75	4.75	4.25	2.75

A-6. Herpetofauna

Herpetofauna observed in the Saint Marys River Watershed during Summer 2000 (A = Absent, P = Present).

Common Name	**Scientific Name**	**HR1**	**HR2**	**JA1**	**JA2**	**JC1**	**PB1**	**USM**
Bullfrog	*Rana catesbeiana*	A	P	A	P	P	A	P
Fowler's Toad	*Bufo woodhousii fowleri*	A	A	A	A	P	A	A
Green Frog	*Rana clamitans*	P	P	P	P	P	P	P
Northern Cricket Frog	*Acris crepitans crepitans*	A	A	A	A	A	A	P
Pickerel Frog	*Rana Palustris*	P	P	A	P	A	A	P
Southern Leopard frog	*Rana utricularia*	P	P	P	A	P	A	A
Eastern Mud Salamander	*Pseudotriton montanus*	A	A	P	A	A	A	A
Northern Two-Lined Salamander	Eurycea bislineata	A	A	P	A	A	A	A
Northern Water Snake	Nerodia s. sipedon	P	A	A	A	A	A	A
Green Snake	Opheodrys sp.	A	A	P	A	A	A	A

Appendix B: Quality Assurance/Quality Control (QA/QC)

The purpose of this appendix is to outline QA/QC activities which are part of the MBSS. The appendix includes descriptions of documentation procedures, responsibility and accountability of project personnel, training requirements, data quality objectives, facilities and equipment, information management, and data quality assessment. To achieve the objectives of the MBSS, it is imperative that all project personnel follow the procedures and guidance provided in this chapter.

B.1 INTRODUCTION

Quality assurance and quality control (QA/QC) are integral parts of data collection and management activities of the MBSS. The QA program for the MBSS was designed to: 1) ensure that data are of known and sufficient quality to meet the project objectives, and 2) provide estimates of various sources of variance associated with the individual variables being measured.

To be effective, the QA program must continually monitor the accuracy, precision, completeness, comparability, and representativeness of the data during all phases of the program. Components of the MBSS QA program include:

- establishment of Data Quality Objectives (DQOs);
- thorough investigator training;
- identification of project protocols and guidelines;
- comprehensive field and laboratory data documentation and management;
- verification of data reproducibility; and
- instrument calibration.

B.2 DATA QUALITY OBJECTIVES

The establishment of Data Quality Objectives (DQOs) for the MBSS is necessary to specify how good MBSS data must be to support decision making, including the level of uncertainty that the state is willing to accept. DQOs specify:

- the problem to be resolved;
- the decision to be made;
- the inputs to the decision;
- the boundaries of the study;
- the decision rule; and
- the limits on uncertainty.

It is important to note that DQOs are target values for data quality and are not necessarily criteria for the acceptance or rejection of data.

Because many aspects of the MBSS have not been rigorously tested in Maryland waters, adequate information to fully develop DQOs for the MBSS does not currently exist. Therefore, the DQOs listed below represent a preliminary analysis of the needs and gross expectations for MBSS data. Results of the first round of the MBSS will be used to refine DQOs for future rounds of the MBSS.

B.2.1 Preliminary DQOs for the MBSS

B.2.1.1 The Problem to be Resolved

With continuing impacts of point source pollution and ever increasing pressure from non-point source pollution, there is an increasing need to manage the aquatic resources of the state effectively and in a holistic manner. To accomplish this task, information about the current status of lotic (flowing) waters in the state is necessary. Information about the relative impacts of anthropogenic stressors on aquatic resources is also necessary in order to prioritize enforcement, restoration, monitoring, and management efforts. Of special importance to the MBSS is the ability to segregate the effects of acidic deposition from other stressors.

B.2.1.2 The Decision to be Made

Data from the MBSS will be used to support management decisions. Examples of such evaluations/decisions include:

- a determination of the extent and magnitude of acid deposition impacts on stream biota in Maryland;
- an evaluation of the degree to which the flowing, non-tidal waters of Maryland have balanced, indigenous populations of biota as specified in the Clean Water Act;
- a determination as to whether existing fishery management practices are adequate to protect important fish stocks;
- a determination as to whether specific waters of the state require further investigation of stressor sources and impacts;
- prioritization of watersheds for protection, restoration and/or enhancement;
- a determination as to which anthropogenic stressors need to receive intensified management and enforcement activities; and
- development of one or more validated biological indices for evaluation and monitoring of impacts from anthropogenic stresses.

B.2.1.3 Inputs to the Decision

Inputs to the above management decisions require specific biological, water quality, and habitat data collected in comparable fashion. Specific inputs include indices and population estimates which accurately depict the water quality, habitat quality, biological integrity, and fishability of Maryland streams and rivers.

B.2.1.4 Population of Interest

The current population of interest includes all non-tidal, 3rd order and smaller stream reaches of the State of Maryland, with the exception of non-wadable impoundments on 3rd order and smaller streams, and impoundments which substantially alter the riverine nature of the reach. In future years, the population of interest may be expanded to include 4th order and larger streams.

B.2.1.5 Comparability and Completeness

Comparability of data between field crews will be maximized by providing standardized training in MBSS techniques prior to sampling. Training requirements are specified by the Project Officer and included in the Scope of Work for each organization involved in field sampling. Training is mandatory for all participants of both the Spring and Summer Index Periods.

To utilize data from a given sampling segment during analyses, all data included on the MBSS data sheets which pertains to the analysis being conducted must be validated, plus all appropriate site location data.

B.2.1.6 Decision Rule

The following initial decision rules were established to provide a basis for management actions related to non-tidal, flowing waters in Maryland:

1) Determination of the status of streams and rivers with regard to balanced, indigenous populations will be based on species richness and abundance, presence-absence of historically present species, presence of introduced species which are perceived as nuisances or have known adverse impacts on native species. Community data at a site will be compared with community data obtained from within the watershed and physiographic region. A stream or river reach will be considered impaired if one or more historically present top predators are absent from a stream, if undesirable introduced species have displaced native species, if species richness is less than 70% of species richness at comparable locations, if abundance of native populations at a site is substantially less than the abundance observed at other comparable locations within the watershed or physiographic region, or if water quality at a site is too poor to support native fish.

2) Characterization of fishability at a site will be based on habitat quality (ranked as supporting, partially supporting, or non-supporting), abundance of recreationally important species of catchable size, and abundance of juveniles of recreationally important species. Abundance of a species in a stream will be based on a comparison to the highest densities observed in a watershed or physiographic region. Sites having population abundances within 50% of reference locations will be classified as fishable, while sites having densities between 1 and 50% of reference densities will be classified as marginal. Sites with no recreationally important fish species will be classified as non-fishable.

3) A decision to consider further investigations to identify particular anthropogenic impact sources will be made if biotic indices change more than 25% between stream reaches or between two segments of the same stream reach.

4) Ranking of potential for restoration or enhancement of streams and rivers will be based on: ultimate habitat potential to support native and/or sportfish populations, any limiting factors to habitat or water quality, and degree of public access.

5) The importance of various anthropogenic stressors will be evaluated based on relationships observed between biological data and habitat, water quality, landuse analysis, or other appropriate indicators. An individual stressor should be considered to be a primary cause of impairment if it explains 25% or more of the variation in one or more biological indices within a watershed, ecoregion, or drainage.

6) Abundance and/or species composition estimates at a given sample segment will be considered acceptable if overall capture efficiency exceeds 50%.

3.2.1.7 Limits to Uncertainty

Two important components of uncertainty are precision and bias. Precision and bias relate to the amount of random and systematic error, respectively, and are determined through the use of replication, performance evaluation samples of known composition, and confirmatory analyses by experts. As results from the initial round of the MBSS will provide a means of defining uncertainty, uncertainty limits are not included in this version of the sampling manual.

B.3 DOCUMENTATION

To ensure scientific credibility, study repeatability and cost effectiveness, all project activities of the MBSS need to be adequately documented. These activities include itinerary development, landowner contacts, adherence to sampling protocols, equipment calibration, field sampling, review of data sheets, field notes, information management, data quality assessment, data analyses, and interpretation of data. To minimize the possibility that needed documentation or data is not recorded, standardized forms and on-site verification of form completions by supervisory personnel should be employed as part of the MBSS. Each of the activities listed above is described in other sections of this manual, including documentation procedures and requirements.

B.4 RESPONSIBILITY AND ACCOUNTABILITY

The purpose of this section is to define the organizational structure and responsibilities of personnel involved in the MBSS. As multiple organizations are involved in the MBSS, adherence to the chain of authority and information outlined below is paramount to successful completion of the MBSS.

A number of personnel report directly to the Project Officer-- the Training Officer, the Quality Control Officer (QC Officer), the Field Crew Supervisor for each organization involved in field sampling, and the Data Management and Analysis Officer (DM Officer). Crew Leaders report to their respective Field Crew Supervisor for day to day activities and emergencies. The responsibilities of each of these personnel are described in the following sections.

B.4.1 Project Officer

The MBSS Project Officer has overall responsibility for successful completion of the MBSS. Specific duties of the Project Officer include selection of subordinates, direction and approval of training activities, contractor oversight, liaison with the public and resource agencies, document review, and peer review solicitation.

B.4.2 Training Officer

The Training Officer is responsible for training of all field sampling personnel. At the direction of the

Project Officer, the Training Officer coordinates with the QC Officer and the Field Program Leader to implement remedial or additional training deemed necessary during MBSS field sampling intervals.

B.4.3 Quality Control Officer

The QC Officer is responsible for implementation of all aspects of the MBSS QA/QC program, including inspection of field crews, data validation, taxonomic verification, site confirmation, calibration and maintenance of equipment, adherence to established protocols, and prompt identification of necessary remedial or corrective actions. The QC Officer is also responsible for oversight of laboratory QA/QC managers to ensure that all MBSS laboratory activities meet MBSS QA/QC requirements.

B.4.4 Field Crew Supervisor

The Field Crew Supervisor is responsible for day to day communication with Crew Leaders, coordination and approval of sampling schedules and itineraries, and other activities designated by the Project Officer.

B.4.5 Crew Leader

The Crew Leader is responsible for crew safety, sample scheduling, equipment maintenance and calibration, and performance of all sample collection activities in accordance with procedures and QA/QC requirements specified in the survey manual.

B.4.6 Field Sampling Crew

Members of the sampling crew are responsible for carrying out the instructions of the Crew Leader and informing the Crew Leader of any unsafe conditions, equipment, or other problems observed which could jeopardize the health and safety of the crew or the quality of sample collections.

B.5 TRAINING REQUIREMENTS

An important aspect of the MBSS QA program is the training program for field personnel which will be conducted prior to sampling. Training ensures consistent implementation of required procedures and attainment by each person of a minimum level of technical competency. All participants in MBSS field sampling must receive training as specified by the Project Officer. To verify the competency of MBSS crews, the QC Officer will conduct a one day visit with each crew prior to the Summer Index Period.

For personnel involved in sampling during the Spring Index Period, training will include water quality and benthic macroinvertebrate sampling using MBSS procedures. In addition, at least one member of each Spring sampling crew should be experienced in stream electrofishing techniques and approved as a benthic taxonomist by the Project Officer. For personnel involved in sampling during the Summer Index Period, training will include fish and herpetofauna sampling, habitat assessment, and taxonomy tests for fish, herpetofauna, and SAV.

B.6 FACILITIES AND EQUIPMENT

Preventive maintenance and calibration should be performed on all sampling equipment used as part of the MBSS. Maintenance and calibration procedures should be implemented as per manufacturers instructions. Unless otherwise specified, calibration should be performed daily prior to equipment use and anytime equipment problems are suspected. Preventative maintenance should be performed at intervals not to exceed the frequency recommended by the manufacturer. All equipment malfunctions should be fully corrected prior to reuse. For weighing scales, weekly checks should be conducted during field sampling using NIST standards or other accepted standards to demonstrate that instrument error is within limits specified by the manufacturer.

For each piece of equipment used as part of the MBSS, a bound logbook for calibration and maintenance should be maintained. Entries in the log should be made for all calibration and maintenance activities. Documentation will include detailed descriptions of all calibrations, adjustments, and replacement of parts, and each entry must be signed and dated.

To insure that MBSS equipment is operated within QA/QC requirements, the QC Officer should conduct periodic site equipment audits and promptly advise the Project Officer of any recommended corrective actions.

B.7 IMPLEMENTATION OF STANDARD OPERATING PROCEDURES

All of the standard operating procedures outlined in the MBSS sampling manual should be strictly followed. To insure that all procedures are properly implemented, the QC Officer should conduct periodic crew audits in the field. The audits should include: correctness in locating the sampling segment, field technique evaluations, verification of taxonomic identifications, completeness of data sheets and field notebooks, calibration and maintenance log review, and health and safety critique of crew activities.

B.8 INFORMATION MANAGEMENT

A schematic of general information management procedures is shown in Figure 3-1.

B.8.1 Field Information Management

To facilitate data recording during inclement weather, data sheets should be printed on waterproof paper. Backup copies of all field data sheets should be made at the completion of each sampling week. Rolls of film for developing should be uniquely marked and separate, uniquely labeled bags used to send film for developing. When developed, film slides should be uniquely marked as well and stored at room temperature under dark conditions.

To ensure that all field data for the MBSS are collected and recorded in a usable manner, all data should be PRINTED in the units specified on the MBSS data sheets. No writeovers are permitted on data sheets-- the incorrect entry should be lined out and the correct entry written in an obvious spot next to the line out. Data sheets for a given site should be consecutively labeled so that the total number of data sheets generated for each site is known. Recorded data should be reviewed at the point of entry and the Crew Leader should review and initial all data sheets prior to departure from the site. Legible copies of all data sheets should be provided to the Data Management and Analysis (DM) Officer on a bi-weekly basis during sampling.

Each sample collected as part of the MBSS will be assigned a sample number. The sample number will contain several unique identifiers to minimize the possibility of misidentification. In addition, chain-of-custody forms should be maintained for all water sample collections.

B.8.2 Data Entry

To verify that all data collected at a sampling segment is complete and acceptable, data entry of all data sheets will occur within 15 days after data sheets are received by the DM Officer. In the event that data is found to be unacceptable or incomplete, sampling can be repeated within the same index period. The DM Officer will maintain a bound logbook of all data entry information, and a back-up copy of all computerized data will be made and archived.

Data entry will be accomplished using entry screens designed to emulate data sheet format. Whenever possible, QA/QC checks will be embedded into data entry screens to ensure validity of data. All data will be double-entered using two different data entry operators and compared for consistency. Questionable data will be flagged and a determination of validity made by the DM Officer, the QC Officer, and the responsible Crew Leader. For all editing activities, full documentation of all changes is mandatory.

Automated review procedures such as range checks, frequency distribution of coded variables, and other internal consistency checks will be designed by the DM Officer and employed for data entry verification.

B.9 DATA QUALITY ASSESSMENT

Assessment of data quality against the established data quality objectives will be conducted to determine the overall performance of the QA program, identify potential limitations to use and interpretation of the data, and to provide information for other data users regarding usability of the data for other purposes.

The quality of MBSS data will be evaluated in several ways. Precision and bias associated with important elements of the sampling and measurement process for each variable measured will be evaluated using results from replicate sampling and performance evaluation studies. Information about precision, bias, and completeness will be used to determine the comparability of data acquired during each sampling year.

After data entry, verified data will be subjected to validation procedures to identify data values which are potentially erroneous. Various univariate and multivariate statistical procedures will be used on the verified data to identify outlying observations for which additional review is necessary.

At the end of each sampling year, specimens of all taxa collected must be verified by an appropriate recognized authority in fish, benthic macroinvertebrate, or amphibian taxonomy. Documentation of this verification should be included with the specimens as well as in tabular summary form. For benthic macroinvertebrates, the QC Officer will arrange for a random subset of at least 5% of the preserved benthic samples to be independently reprocessed in the laboratory. The QC Officer will prepare an annual written and tabular summary of all taxonomic-related QC activities.

As an additional measure of data quality assessment, scientific peer review of activities and products of the MBSS will be conducted at the direction of the Project Officer to help verify the technical soundness and utility of the data and its interpretation.

Appendix C. Thresholds for classifying physical habitat, chemical, and biological values as indicative of degradation or good quality, rare, or unique stream resources.

C-1. Fish Index of Biotic Integrity. Narrative descriptions of stream biological integrity associated with each of the IBI categories

Good	IBI score 4.0 - 5.0	Comparable to reference streams considered to be minimally impacted. Fall within the upper 50% of reference site conditions.
Fair	IBI score 3.0 - 3.9	Comparable to reference conditions, but some aspects of biological integrity may not resemble the qualities of these minimally impacted streams. Fall within the lower portion of the range of reference sites (10th to 50th percentile).
Poor	IBI score 2.0 - 2.9	Significant deviation from reference conditions, with many aspects of biological integrity not resembling the qualities of these minimally impacted streams, indicating some degradation.
Very Poor	IBI score 1.0 - 1.9	Strong deviation from reference conditions, with most aspects of biological integrity not resembling the qualities of these minimally impacted streams, indicating severe degradation.

Table C-2. Expected fish species. Narrative descriptions of stream biological integrity associated with each expected fish species quartile.

Good	75-100%	Comparable to reference streams considered to be minimally impacted.
Fair	50-74%	Comparable to reference conditions, but some aspects of biological integrity may not resemble the qualities of these minimally impacted streams.
Poor	25-49%	Significant deviation from reference conditions, with many aspects of biological integrity not resembling the qualities of these minimally impacted streams, indicating some degradation.
Very Poor	0-24%	Strong deviation from reference conditions, with most aspects of biological integrity not resembling the qualities of these minimally impacted streams, indicating severe degradation.

Table C-3. Percent Tolerant Fish. Scores for the FIBI metric "Percent Tolerant Fish"

Good	Metric Score =5	$\leq$ 50%	Comparable to reference streams considered to be minimally impacted. Fall within the upper 50% of reference site conditions.
Fair	Metric Score =3	$50<x\leq93$	Comparable to reference conditions, but some aspects of biological integrity may not resemble the qualities of these minimally impacted streams.
Poor	Metric Score =1	>93	Deviation from reference conditions, with most aspects of biological integrity not resembling the qualities of these minimally impacted streams, indicating degradation.

C-4. Rare Taxa. The presence of any taxa identified by the Maryland Department of Natural Resources, Natural Heritage Division as rare, threatened, or endangered indicates that the site should be considered for special protection status. The official State Threatened and Endangered Species List is part of the State Threatened and Endangered Species regulations (COMAR 08.03.08).

C-5. Dissolved Oxygen (DO). The state water quality criterion for DO is greater than 5.0 mg/L (COMAR 1997).

C-6. pH. The state water quality criterion for pH is 6.5 (COMAR 1997).

C-7. **Habitat Assessment**. Marginal and Poor habitat assessment scores (<10) were identified as possible stressors based on the MBSS Stream Habitat Assessment Guidance.

MBSS Stream Habitat Assessment Guidance				
Habitat Parameter	**Optimal 16-20**	**Sub-Optimal 11-15**	**Marginal 6-10**	**Poor 0-5**
1. Instream Habitat	Greater than 50% of a variety of cobble, boulder, submerged logs, undercut banks, snags, rootwads, aquatic plants, or other stable habitat	30-50% of stable habitat. Adequate habitat	10-30% mix of stable habitat. Habitat avail-ability less than desirable	Less than 10% stable habitat. Lack of habitat is obvious
2. Epifaunal Substrate	Preferred substrate abundant, stable, and at full colonization potential (riffles well developed and dominated by cobble; and/or woody debris prevalent, not new, and not transient)	Abund. of cobble with gravel &/or boulders common; or woody de-bris, aquatic veg., under-cut banks, or other pro-ductive surfaces common but not prevalent /suited for full colonization	Large boulders and/or bedrock prevalent; cobble, woody debris, or other preferred surfaces uncommon	Stable substrate lacking; or particles are over 75% surrounded by fine sediment or flocculent material
3. Velocity/Depth Diversity	Slow (<0.3 m/s), deep (>0.5 m); slow, shallow (<0.5 m); fast (>0.3 m/s), deep; fast, shallow habitats all present	Only 3 of the 4 habitat categories present	Only 2 of the 4 habitat categories present	Dominated by 1 velocity/depth category (usually pools)
4. Pool/Glide/Eddy Quality	Complex cover/&/or depth > 1.5 m; both deep (> .5 m)/shallows (< .2 m) present	Deep (>0.5 m) areas present; but only moderate cover	Shallows (<0.2 m) prevalent in pool/glide/eddy habitat; little cover	Max depth <0.2 m in pool/glide/eddy habitat; or absent completely

5. Riffle/Run Quality	Riffle/run depth generally >10 cm, with maximum depth greater than 50 cm (maximum score); substrate stable (e.g. cobble, boulder) & variety of current velocities	Riffle/run depth generally 5-10 cm, variety of current velocities	Riffle/run depth generally 1-5 cm; primarily a single current velocity	Riffle/run depth < 1 cm; or riffle/run substrates concreted
6. Embeddedness	Percentage that gravel, cobble, and boulder particles are surrounded by line sediment or flocculent material.			
7. Shading	Percentage of segment that is shaded (duration is considered in scoring). 0% = fully exposed to sunlight all day in summer; 100% = fully and densely shaded all day in summer			
8. Trash Rating	Little or no human refuse visible from stream channel or riparian zone	Refuse present in minor amounts	Refuse present in moderate amounts	Refuse abundant and unsightly

C-8. Erosion. Greater than 50 square meters of eroded area in a 75 m long stream site was considered extensive erosion. Erosion severity was rated as 0 = no erosion, 1 = minimal erosion, 2= moderate erosion, 3= severe erosion. Both stream banks were rated for severity individually. The average for both banks is reported. An average erosion severity $\geq$ 2.5 was considered severe.

C-9. Land Use. Arc View software was used to generate site-specific land use and impervious surface information for each site using U.S. EPA Multi-Resolution Land Characteristic Consortium (MRLC) data. These land use data are based on Landsat ™ data acquired in 1986-1993 and, as a result, *do not reflect land use changes that have occurred more recently than 1993.* Urban land use greater than 25% of the site catchment was considered indicative of extensive anthropogenic influence to the site. Impervious land cover greater than 10% of the site catchment has been associated with serious ecological degradation.