Appendix A: Water-Quality Monitoring to Support Watershed Restoration

Contents

Figure

Table

Introduction

Baltimore City is primarily responsible for managing and monitoring water-quality conditions in the City water-supply reservoirs, and in selected tributaries in the reservoir watersheds. Because the reservoir watersheds lie largely outside the jurisdiction of the City, however, managing and assessing reservoir-watershed conditions that could affect reservoir water quality is shared by City, County, and State governments.

Management of the reservoir watersheds has been guided by characterizations and source-water assessments that reflect the environmental state of the reservoir watersheds and their tributaries. These characterizations and assessments have been helped or were followed by short-term and synoptic studies conducted on tributary streams in each reservoir watershed to identify nonpoint pollutant problems and their source areas, to develop and implement stream restoration strategies, and to improve tributary water and habitat quality and reduce pollutant loads. These activities are described using representative examples below. In each case, the descriptions are illustrative of these activities and are not a comprehensive summary of all activities that have been conducted in the reservoir watersheds by agencies of the State of Maryland or Baltimore and Carroll Counties.

Source-Water Assessments

Amendments to the 1996 Safe Drinking Water Act (SWDA) required states to conduct source-water assessments to evaluate the safety of all public drinking-water systems. These assessments are to include a comprehensive characterization of each reservoir watershed as well as the reservoir to better enable strategies to be developed to maintain or improve the quality of water, biota, and habitat in streams and reservoirs. The source-water assessment studies for both the Liberty and Loch Raven Reservoir watersheds were completed in 2003 and 2004, respectively (Winfield and Sakai, 2003; Maryland Department of the Environment, 2004). As part of these assessments, water-quality data from the core monitoring program were analyzed and summarized to describe point and nonpoint sources of pollutants. Information from these assessments has been used throughout this retrospective review.

Relevant to the retrospective review of the monitoring program, source-water assessments provided time-of-travel studies. These studies indicate that low flows can travel from the headwaters of tributaries to the reservoirs within approximately half a day to 2 days. High flows, however, such as those associated with storms, likely reach a reservoir fairly quickly, in less than a quarter to a half day.

The rapid traveltimes of storms have implications for long-term monitoring. Unless a storm runoff event is large enough to displace a major portion of the stored reservoir water, and in-lake monitoring occurs shortly afterwards, the direct impact of the storm on the reservoir is not measured. As noted by the Interstate Commission on the Potomac River Basin (2006), in-lake monitoring by the Reservoir Watershed Management Agreement (RWMA) partners is simply too infrequent (monthly to bi-monthly). By design, storm-related reservoir sampling also generally does not occur if reservoir conditions are unsafe for sampling, such as during storms. Thus, the probability of capturing the impact of a major storm-runoff event on the reservoirs is low. When a storm occurs and at least some of its effects on reservoir water quality are measured, the resultant data complicate analyses of long-term trends as well as modeling of water quality in the reservoir because few events are in fact adequately captured.

A consequence of the current reservoir monitoring is that the influence of storms on reservoir water quality, such as sedimentation and turbidity, nutrient enrichment (phosphorus), and changes in dissolved-oxygen concentrations, in both the epilimnetic and hypolimnetic layers also are poorly understood, and therefore, difficult to accurately model (Interstate Commission on the Potomac River Basin, 2006). The ability to obtain water-quality data for storm events in both the watershed tributaries and reservoirs is desirable to accurately assess conditions of state, changes in state, trends, and loads, and improve modeling to determine whether progress is being made towards addressing RWMA partner water-quality concerns and technical goals.

Other aspects of the source-water assessments that involve monitoring to address RWMA partner concerns, and achieve RWMA goals, are short-term studies conducted by RWMA partners that focus on the watershed tributaries. These studies are designed to describe the conditions of streams, to identify impaired streams, to identify actions needed to reduce impairments, and to prioritize impaired streams for restoration. They also are important to the large-scale long-term monitoring program. The source-water assessments include identification of areas impaired by agricultural or urban development. For those areas that are upstream of the long-term monitoring stations, their restroation could lead to detected improvements in tributary water-quality conditions. In addition, source-water assessments can help identify impaired areas, such as eroded streambeds and banks, or degraded forest areas, for restoration, that generally would not be identified and restored by use of traditional best-management practices (BMPs) that focus on agricultural or urban land use and land owners, which could also lead to improvements in monitored reservoir watershed tributary conditions.

Watershed Characterization Studies

As part of the source-water assessment studies, watershed-characterization studies have been conducted on the reservoir watersheds (Maryland Department of Natural Resources, 2002a; Maryland Department of the Environment, 2003; Baltimore County Department of Environmental Protection and Resource Management, 2008). These studies were conducted to partially fulfill Federal requirements under the National Storm Discharge Elimination Site (NPDES) Municipal Stormwater Discharge Permit, and State programs, such as the 1998 Maryland Clean Water Action Plan (Maryland Department of Natural Resources, 1998). Under the latter, the Liberty and Loch Raven-Prettyboy Reservoirs and their watersheds were designated as watersheds within the state that have the highest priority for protection and restoration, and warrant a comprehensive watershed-restoration action plan.

As part of each watershed characterization, information was compiled on land use and land cover and known or potential point and nonpoint sources of pollutants. Most nonpoint sources of pollutants actually are defined in relation to land use and land cover, on the basis of early studies that compared different types of land use and land cover to water-quality data obtained from the long-term tributary dry-weather monitoring program (Baltimore City Department of Public Works, 1996, 2000, 2001). In addition, short-term monitoring and synoptic studies were used to help characterize water quality in relation to land use within selected reservoir watershed subbasins. The selected subbasins include subbasins identified by the long-term monitoring network as source areas for elevated nutrient and sediment loads, as well as subbasins not covered by the long-term monitoring network—for example, within close proximity to the reservoirs. Examples of monitoring data collected, and information provided from the analysis of these data, are provided as part of this retrospective to show (a) that impairment conditions in tributary streams directly relate to RWMA goals and water-quality concerns, and (b) that the location of impaired streams and plans to restore impaired streams have a bearing on the design of the long-term monitoring network.

Short-Term Stream Monitoring Studies

Short-term monitoring (typically 1–2 years) of stream-water quality is conducted by RWMA partners to address water-quality conditions in the small subbasins within each reservoir watershed. Using the Loch Raven Reservoir watershed as an example, short-term (1-year) monitoring was conducted at over two dozen stream sites in the lower part of this watershed in 1998 (fig. A1). The monitoring stations were used in part to assess source-water conditions, and most were established around the periphery of the reservoir in subbasins not covered by the long-term monitoring network in the reservoir watersheds (see **Main Report**, fig. 3). Selected monitoring stations were located in Piney Run primarily to address concerns with effluent discharge by the wastewater treatment plant (WWTP) at Hampstead, Maryland.

The purposes of this monitoring network were to provide data to: (a) address potential risks to drinking-water quality and aquatic health from pollutants—nutrients, metals, and bacteria or other pathogens—in stream base- and stormflows; (b) calibrate a model to estimate loads by land use, to further aid the identification of excessive pollutant-source areas; and (c) for Piney Run, to determine if the Hampstead WWTP effluent impacted downstream water quality and quantity. From the monitoring data, the State and Baltimore County (Maryland Department of the Environment, 2003) determined that:

a) Subbasins where development reflected urban and residential land use produce elevated base and stormflows relative to rural subbasins with agricultural or forested land use.

b) Subbasins with developed land use had elevated nitrogen and phosphorus concentrations in base and stormflows compared to subbasins with appreciable forest cover. Nitrate concentrations were elevated at 13 of 15 sites under low-flow conditions, indicating widespread contamination of groundwater.

c) Selected agricultural and urban sites had high concentrations of fecal coliform bacteria during low flow, which was attributed to livestock operations at the agricultural sites, but elevated concentrations also were found at selected urban sites for unknown reasons. *Cryptosporidium* was not detected. *Giardia* cysts were detected by presumptive and definitive tests, but at concentrations well below levels related to an infectious dose of 150 cysts.

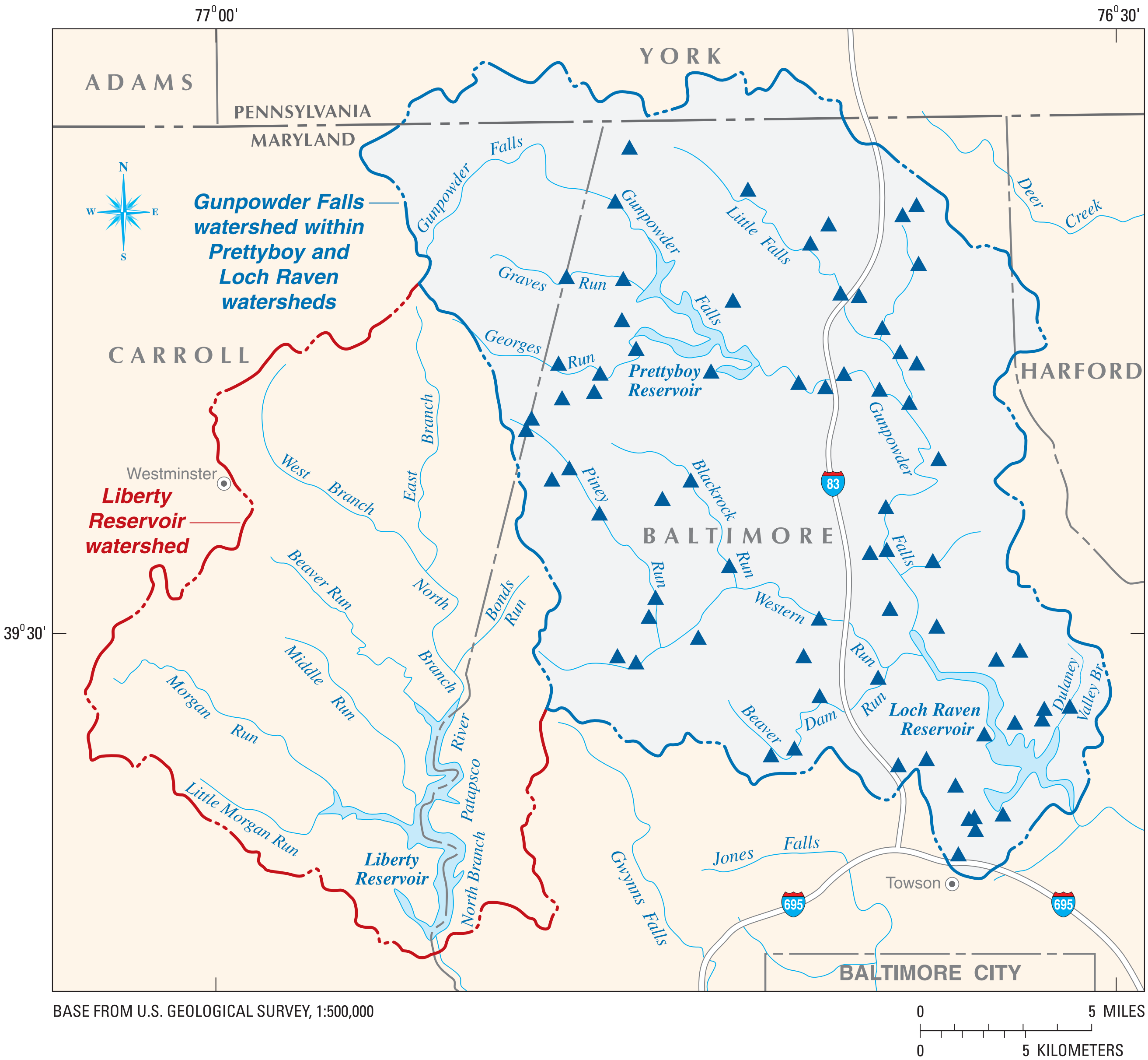
d) Arsenic, barium, chromium, and nickel did not exceed water-quality standards during base or stormflows, but two metals (copper and lead) were considered a potential threat to aquatic life at two locations, likely as a result of livestock operations, with the highest concentrations occurring during stormflows.

e) Stream pH was within the acceptable range (6.5–8.5 standard units), except in areas underlain by limestone karsts, where base-flow pH was likely to exceed 8.5.

f) Concentrations of dissolved oxygen typically were above the 5.0 mg/L (milligrams per liter) RWMA standard. Biological oxygen demand, chemical oxygen demand, and total organic carbon concentrations indicated little potential for oxygen depletion in these streams.

g) Although storm data were limited, atrazine concentrations did not appear to pose a health risk in either base or stormflows.

h) Hampstead WWTP effluent constituted approximately 82 percent of base flow in the headwaters of Piney Run and effluent quality determined stream-water quality downstream. During recorded stormflows (peak discharges of 20–40 ft^3/s, or cubic feet per second), the WWTP flow was only 4 ft^3/s, and had considerably less influence on stream-water quality.



EXPLANATION

GUNPOWDER FALLS WATERSHED WITHIN PRETTYBOY AND LOCH RAVEN WATERSHEDS

LOCATION OF BALTIMORE COUNTY MONITORING SITES (includes Piney Run sites, water-level sensors, chemical monitoring sites, source-water sites, and biological monitoring sites)

Figure A1. Gunpowder Falls watershed monitoring sites within Loch Raven and Prettyboy Reservoir watersheds (modified from Baltimore County Department of Environmental Protection and Sustainability, formerly Baltimore County Department of Environmental Protection and Resource Management, 1998).

Stream Surveys

Three types of stream surveys have been used to characterize water-quality conditions in subbasins in the Baltimore Reservoir watersheds, and include synoptic surveys for nutrients (nitrogen and phosphorus), stream corridor and stability surveys, and stream habitat and biological surveys.

Synoptic Surveys for Nutrients

Spring low-flow nutrient synoptic surveys, in lieu of short-term monitoring, are another method used to determine relations between land use and land cover (human activities) and nutrient loads, and help identify pollutant source areas on a subbasin scale. By design, these surveys were conducted in the spring—in April 2002 for the Carroll County parts of the Liberty Reservoir watershed (Maryland Department of Natural Resources, 2002b) and in April 2006 for the Prettyboy Reservoir watershed (Maryland Department of the Environment, 2006a). Although total phosphorus concentrations are not highest in reservoir tributaries in the spring, nitrate concentrations and dry-weather flows are on average highest in April. Thus, nitrogen and phosphorus dry-weather loads were expected to be at or near their annual highs in April.

Within each watershed, synoptic data were used to describe and compare low-flow nutrient concentrations and loads among subbasins (table A1). For the Liberty Reservoir watershed, and according to synoptic-survey criteria, among the 41 synoptic sites, all sites exhibited elevated nitrogen—59 percent (25/41) had high to excessive nitrogen concentrations, and 15 percent (6/41) of the sites also had high to excessive (instantaneous) areal-weighted nitrogen loads or yields (Maryland Department of Natural Resources, 2002b). For orthophosphate-phosphorus, only 8 percent of the survey sites had concentrations that were considered high to excessive, but none of the sites had phosphorus loads that exceeded baseline conditions (0.0005 kilograms per hectare per day or less). The Middle Run and Western Run subbasins had the greatest number of internal subbasins with high to excessive low-flow nutrient concentrations. In addition, most sites in the four sub-watersheds covered by this survey (which also included Snowden Run and Roaring Run tributaries) that had high to excessive nutrient concentrations were in developed headwater subbasins.

For the Prettyboy Reservoir watershed, all but 1 of the 68 nutrient synoptic sites exhibited excessive nitrate-nitrite concentrations at low flows compared to the survey baseline standard, and most (88 percent or 60/68) sites had concentrations that were considered high to excessive

Table A1. Nutrient synoptic summaries for Liberty and Prettyboy Reservoir watersheds (from Maryland Department of Natural Resources, 2002b and Maryland Department of the Environment, 2006a).

[%, percent, equals the ratio of the number of sites with either baseline to moderate, or high to excessive, nitrate-nitrite or orthophosphate concentrations (or loads) to total number of synoptic sites, multiplied by 100; N, nitrogen; P, phosphorus; <, less than; >, greater than; mg/L, milligrams per liter; kg/ha/d, kilograms per hectare per day]

Reservoir/ watershed	Date of synoptic	Synoptic site distribution	Number of synoptic sites	Proportion of total number of synoptic sites (%)							
				With nitrate-nitrite N concentrations within the specified range		With nitrate-nitrite N areally weighted loads within the specified range		With orthophosphate P concentrations within the specified range		With orthophosphate P areally weighted loads within the specified range	
				Baseline to moderate (<1 to 3 mg/L)[1]	High to excessive (3.1 to >5 mg/L)[2]	Baseline to moderate (<0.01 to 0.02 kg /ha/d)[1]	High to excessive (0.021 to >0.03 kg / ha/d)[2]	Baseline to moderate (<0.005 to 0.010 mg/L)[1]	High to excessive (0.011 to >0.015 mg/L)[2]	Baseline to moderate (<0.0005 to 0.001 kg/ha/d)[1]	High to excessive (0.0015 to >0.003 kg/ha/d)[2]
Liberty	April 2002	Among four subbasins	41	41	59	85	15	70	8	100	0
Prettyboy	April 2006	Throughout watershed	68	12	88	4	96	93	7	100	0

[1] First value defines baseline concentrations, which are less than the specified numerical value; moderate values lie between the defined upper threshold for baseline values up to the second value specified. Ranges were defined by Frink (1991) for the Chesapeake Bay watershed.

[2] High concentrations are those that occur at the first value and up to the second value; excessive concentrations are those that exceed the second value. Ranges were defined by Frink (1991) for the Chesapeake Bay watershed.

(table A1). Furthermore, approximately 96 percent of the sites had basin-area-weighted-flow (instantaneous) nitrogen loads that were excessive. Only about 8 percent of the subbasins had high to excessive orthophosphate-phosphorus concentrations, and none of the sites had high to excessive phosphorus loads. Subbasins with high to excessive nitrate-nitrite concentrations often were clustered together, and chiefly occurred in two subbasins—Georges Creek and Prettyboy Branch sub-watersheds (Maryland Department of the Environment, 2006a). High to excessive nutrient concentrations were associated with agricultural and developed subbasins, mainly row-crop and livestock agriculture and low-density residential communities on septic systems.

Collectively, the synoptic surveys were shown to be useful in the identification of subbasins within each reservoir watershed that were potential source areas for high to excessive nutrient (primarily nitrogen) concentrations and, in some cases, nutrient loads, at low flows. Results from the two synoptic surveys, however, cannot be compared to prioritize subbasins among reservoir watersheds as the synoptic in each reservoir watershed occurred in different years with different hydrologic conditions. The Liberty Reservoir watershed synoptic was conducted in 2002 during a very dry spring. Surveyed low-flow nutrient concentrations were lower than the typical annual averages for streams in this and other watershed areas (Maryland Department of Natural Resources, 2002b). The Prettyboy Reservoir watershed synoptic occurred in 2006 during a very wet spring. Surveyed low-flow nutrient concentrations were higher than typical averages for streams in this and other watershed areas (Maryland Department of the Environment, 2006a). For reasons similar to those described above, results cannot be combined for the synoptic and short-term monitoring. The short-term monitoring in the Loch Raven Reservoir watershed was conducted in 1988, a relatively dry year.

Stream Corridor and Stability Surveys

In addition to nutrient surveys, stream corridor and stability surveys have been developed and used to assess the impact of land use and land cover (human activities) on the physical condition of streams in the reservoir watersheds, and aid in the development of RWMA watershed restoration action strategies and priorities (Maryland Department of Natural Resources, 2002c; Maryland Department of the Environment, 2004, 2006b). Collectively, these surveys have provided a wealth of data and information in relation to both of these objectives, including the following:

a) Information on the occurrence, extent, and possible causes of observed instabilities in third- and lower-order streams, including bed incision or aggregation and bank erosion (widening or mass wasting) or deposition, and the potential for continued erosion and, if performed, effective restoration;

b) Information on the integrity of the riparian zone adjacent to the stream, including the type, width, density, and appearance of vegetation; and

c) Information on stream-corridor biotic and water-quality indicators, including physical habitat, and the occurrence and conditions that result from stormwater BMPs, storm-drain outfalls, roadways, construction, exposed sewer lines, non-permitted discharges, and trash or dumping.

Corridor and stability surveys used in the Baltimore reservoir watersheds differed in that the former primarily obtained information through visual observation, were more qualitative than quantitative in nature, and thus enabled coverage of a greater number of streams in a subbasin than the latter. Stream-corridor studies generally were conducted before stream-stability surveys over large areas of the reservoir watersheds. The information obtained from corridor studies allowed the RWMA partners to make general comparisons of stream conditions among major, and within a major, minor, subbasins within the reservoir watersheds. In this regard, they helped identify small subbasins within a major subbasin whose stream corridors appeared to be impaired.

On the basis of information obtained from the stream-corridor surveys, stream-stability surveys were developed mainly to further examine streams in the subbasins. The subbasins surveyed for stability generally had a high frequency of potentially moderately to highly impaired water-quality conditions. The objectives of stream-stability surveys were to provide detailed information on: (a) the current morphological states of the small (generally first- and second-order) stream corridors within a targeted subbasin, (b) the likelihood these streams would maintain their current morphology or undergo a change in morphology, and (c) if their morphological condition was unstable, whether or not stream restoration was warranted, and what it likely would require.

Stability surveys appear to be an effective monitoring tool for the RWMA partners to help determine what restorative actions on which streams would be most effective in a surveyed subbasin. Because of the quantitative data requirements of stream-stability surveys, however, they generally have been conducted in only a few major subbasins in each reservoir watershed, and within each major subbasin, generally on some but not all small subbasins within a major subbasin.

Collectively, the stream-corridor and stability surveys (Maryland Department of Natural Resources, 2002c; Maryland Department of the Environment, 2004, 2006b) have shown that highly unstable (eroding) and chiefly first- and second-order stream corridors occur in a variety of different but mostly headwater settings in surveyed subbasins in all three reservoir watersheds. These settings range from reaches without any riparian (forested) buffer lying adjacent to developed lands to the presence of more than adequate riparian buffers that are subject to inadequately controlled stormwater runoff. Where stream erosion is observed, channels are most often undergoing incision, or if already incised, are widening through bank cutting; many of the stream corridors undergoing degradation (incision, widening, or both) are in upland headwater basins, and these eroding streams likely are a major source of sediment to downstream tributaries and inevitably the watershed reservoirs. The RWMA partners have identified and prioritized stream reaches for restoration activities throughout the surveyed subbasins in each reservoir watershed.

Stream Habitat and Biological Surveys

Two types of monitoring surveys have been used to assess the habitat conditions related to the biotic health of reservoir watershed tributary streams. Initial stream-habitat assessments were frequently conducted as part of the stream-corridor and stability studies. The results from these surveys have provided site-specific information that is useful in the characterization of the suitability of streams to support designated uses related to recreational fishing, and to sustain native and stocked trout populations.

Stream habitat surveys identified fish-migration barriers. Barriers most often consisted of debris blockages or limited flow and depth conditions, but included human-constructed structures that could interfere with fish migration.

Although information was not available for the lower Loch Raven Reservoir watershed, during stream corridor surveys for the Liberty Reservoir watershed, survey crews identified 32 such barriers (Maryland Department of Natural Resources, 2002c). The majority of these barriers (22/32) blocked the entire width of the stream. Artificial barriers (23) dominated, and included dams (9), pipe crossings (5), road crossings (5), concrete debris (3), and a streamgage. Natural barriers (9) included beaver dams (3), natural falls (3), and an in-stream pond, a channelized stream, and a large rock. On a sub-watershed basis, West Branch, Middle Run, and Snowdens Run had 18, 9, and 5 barriers, respectively.

For the Prettyboy Reservoir watershed, stream-corridor survey crews identified 17 fish migration barriers (Maryland Department of Natural Resources, 2006b). Most of the barriers were artificial (12/17), and included road crossings (10) and dams (2). Natural barriers consisted of natural falls (2) and debris dams (2).

Stream-stability surveys also provided a more detailed assessment of stream characteristics related to biological habitat for generally small (first- and second-order) streams. On the basis of surveys conducted in the lower Loch Raven and Prettyboy Reservoir watersheds, and in addition to intermittent fish barriers, the most commonly encountered habitat impairments that would limit fish migration and populations were low-flow (shallow depth) conditions and a lack of in-stream epifaunal vegetation and attached or fixed woody debris. Both of these conditions led to poor to very poor Physical Habitat Index values based on the Maryland Biological Stream Survey (MBSS) protocols (Kayzak, 2001) for about one-third of the stream reaches surveyed in the lower Loch Raven Reservoir sub-watersheds, and about one-tenth of the reaches surveyed in the Prettyboy Reservoir sub-watersheds. On the other hand, fish barriers were more likely to restrict fish migration at sites surveyed in the Prettyboy Reservoir watershed than at sites surveyed in lower Loch Raven Reservoir watershed.

Additional information on the physical habitat conditions related to the biotic health of streams has been obtained through the MBSS. The MBSS surveys were conducted in the Baltimore reservoir watersheds in 1994, 1997, and 2000. Although the results of the MBSS surveys for the Loch Raven or Prettyboy Reservoir watersheds were not readily available at the time of this review, results for the Carroll County part of the Liberty Reservoir watershed were summarized as part of the watershed characterization (Maryland Department of Natural Resources, 2002a). In addition, the MBSS 2000 survey in the Liberty Reservoir watershed was augmented by MBSS Stream Waders, which nearly doubled the number of surveyed sites.

On the basis of the MBSS results, physical habitat conditions in the Liberty Reservoir watershed for most stream sites were rated fair to good. Only 5 of nearly 100 assessed sites were rated as poor and only 1 site as very poor. Based on habitat conditions, Liberty Reservoir watershed streams scored an average of 6.47 on a scale of 1 (worst) to 10 (best). For this size watershed, a score of 6.0 or less implies restoration is needed and a score of 8 or greater implies protection is recommended.

Two other measures of tributary biotic conditions in the Baltimore reservoir watersheds have been provided by routine benthic and fish surveys conducted as part of the MBSS. On the basis of surveys conducted in 1994, 1997, and 2000 in the Liberty Reservoir watershed, with the latter being augmented by additional data collection through the MBSS Stream Waders program, the Maryland Department of Natural Resources and Carroll County summarized survey findings as listed below (Maryland Department of Natural Resources and Carroll County, 2002a).

In relation to benthos integrity, the MBSS Program assessed 58 monitoring sites throughout the Liberty Reservoir watershed between 1995 and 2000. An additional 52 sites were sampled by citizen volunteers in 2000. Relative to reference streams, about 53 percent of the sites were considered good (or minimally degraded) with respect to reference stream conditions. A total of 16 sites (28 percent) were rated poor, with degraded conditions in relation to reference sites.

In relation to macro-invertebrate communities, Liberty Reservoir watershed streams scored an average of 6.89 on a scale of 1 (best) to 10 (worst). For nontidal watershed areas of this size, a score of less than 6 implies restoration is needed and a score of 8 implies protection is recommended.

In relation to fish communities, most streams in the Liberty Reservoir watershed were rated fair to good on the basis of MBSS data obtained between 1995 and 2000. The rating fair to good implies a generally diverse range of fish species are present at a site. Only a few sites were rated as poor.

In relation to fish communities, the Liberty Reservoir watershed streams generally are in good condition. The average site score of 8.87 on a scale of 1 (worst) to 10 (best) for streams in the Liberty Reservoir watershed implied that individual sites with scores of 8 or greater should be protected.

Although MBSS summaries were not available for the Loch Raven and Prettyboy Reservoir watersheds, these surveys form an important part of the Baltimore reservoir long-term monitoring strategy. The surveys provide the opportunity to periodically assess the biotic health of the reservoir watershed streams in a systematic and well-documented manner. Although surveys have been conducted since 2000 in all three reservoir watersheds, results have not been summarized. Ultimately, however, the MBSS data will provide for trend analysis related to the biotic health of reservoir streams.

Whereas the long-term monitoring program has helped identify subbasins that appeared to be sources of excessive nutrients and sediment, the collective components of the source-water assessments—watershed characterizations, short-term monitoring and synoptic surveys, stream-corridor and stability studies, and stream-habitat and biota surveys—enable the RWMA partners to describe the state of the watershed tributaries within these subbasins, identify impaired tributaries, develop restoration activities to address those impairments, and prioritize impaired streams for restoration. From these collective studies, however, it also is apparent that most impaired streams are located in headwater areas. Given their general location, the intensity of survey efforts to correctly identify the nature of stream impairments, and the resources required for reducing or eliminating impairments, it likely will take considerable time to restore impaired streams. Therefore, it is important to realize that it is likely to take considerable time before the full effects of restoration activities become apparent at the downstream tributary monitoring stations operated as part of the long-term monitoring program for major subbasins within each of the reservoir watersheds.

References Cited

Baltimore City Department of Public Works, 1996, Volume I: Selected graphics, report conclusions, and discussion: Baltimore, Maryland, Reservoir Watershed Management Progress Report, 128 p.

Baltimore City Department of Public Works, 2000, Appendix C: Reservoir water quality assessment for Loch Raven, Prettyboy and Liberty reservoirs, Interim Report, *in* Action report 2000 for the reservoir watersheds: Baltimore, Maryland, Watershed Protection Committee, 37 p.

Baltimore City Department of Public Works, 2001, Reservoir water quality assessment for Loch Raven, Prettyboy, and Liberty reservoirs: Baltimore, Maryland, 39 p.

Baltimore County Department of Environmental Protection and Resource Management, 1998, Gunpowder watershed characterization: Research design and monitoring procedures: Towson, Maryland, Baltimore County, 13 p.

Baltimore County Department of Environmental Protection and Resource Management, 2008, Prettyboy Reservoir watershed characterization report: Towson, Maryland, 101 p.

Frink, C.F., 1991, Estimating nutrient exports to estuaries: Journal of Environmental Quality, v. 20, no. 4, p. 717–724.

Interstate Commission on the Potomac River Basin, 2006, Modeling framework for simulating hydrodynamics and water quality in the Prettyboy and Loch Raven Reservoirs, Gunpowder River basin, Maryland: Rockville, Maryland, 230 p., plus appendixes.

Kayzak, P.F., 2001, Maryland Biological Stream Survey sampling manual: Annapolis, Maryland, Maryland Department of Natural Resources, 83 p.

Maryland Department of the Environment, 2003, Water quality and management plan for the Loch Raven watershed study area in Baltimore County, Maryland: Annapolis, Maryland, 180 p.

Maryland Department of the Environment, 2004, Source water assessment for Loch Raven watershed: Baltimore, Maryland, 99 p., plus appendixes.

Maryland Department of the Environment, 2006a, Nutrient synoptic survey in the Prettyboy watershed, Baltimore and Carroll Counties, Maryland, 2005, as part of a Watershed Restoration Action Strategy: Baltimore, Maryland, 20 p.

Maryland Department of the Environment, 2006b, Stream corridor assessment survey for the Prettyboy reservoir watershed: Baltimore, Maryland, 59 p.

Maryland Department of Natural Resources, 1998, Maryland clean water action plan, final (1998) report on unified watershed assessment, watershed prioritization and plans for restoration action strategies: Annapolis, Maryland, Clean Water Action Plan Technical Workgroup, 39 p., plus appendixes.

Maryland Department of Natural Resources, 2002a, Liberty reservoir watershed characterization-Carroll County portion, Maryland Department of Natural Resources: Annapolis, Maryland, and Carroll County, Maryland, 96 p.

Maryland Department of Natural Resources, 2002b, Nutrient and biological synoptic surveys in portions of the Carroll County drainage to Liberty reservoir: Annapolis, Maryland, 38 p.

Maryland Department of Natural Resources, 2002c, Liberty reservoir stream corridor assessment: Annapolis, Maryland, 103 p.

Winfield, G.L., and Sakai, J., 2003, Task 6: Final Liberty watershed assessment: Baltimore, Maryland, Department of Public Works, Bureau of Water and Wastewater, Project No. 812 On-Call Engineering Services, 110 p., plus appendix.

Appendix B: Descriptions of Data Collected at Watershed Tributary and Reservoir Monitoring Stations

Appendixes

Appendix B1. Baltimore City monitoring network station locations, 2007.

[N, north; W, west; NPDES, National Pollutant Discharge Elimination System; USGS, U.S. Geological Survey; WP, weather permitting, usually April through November or December]

Watershed	Station type	Reservoir location	Station identifier	Latitude, N (degrees, minutes, seconds)	Longitude, W (degrees, minutes, seconds)	Station location	Associated USGS gage	Comment
Liberty	Reservoir	Lower	NPA0042	39 23 20.00668	76 52 51.61888	Liberty Gatehouse, maximum depth 105 feet		
		Lower	NPA0059	39 23 48.47139	76 53 10.61397	Liberty at Route 26 Bridge, mid-channel		WP, requires boat
		Middle	NPA0067	39 25 04.09886	76 52 56.28529	Liberty at Oakland Road Point, near intake		WP, requires boat
		Upper	NPA0105	39 26 56.59918	76 52 40.35257	Liberty at Nicodemus/Deer Park Bridge, mid-channel		
	Tributary		BEA0015	39 29 22.55919	76 54 10.28399	Beaver Run at Hughes Road	01586210	
			LMR0015	39 25 36.29438	76 57 37.85655	Little Morgan Run at Bartholow Road		
			MDE0026	39 27 45.72575	76 54 27.22165	Middle Run at Louisville Road		
			MOR0040	39 27 07.22750	76 57 18.84300	Morgan Run at London Bridge Road	01586610	
			NPA0165	39 30 03.78299	76 53 00.61143	North Branch Patapsco at Route 91 (below outfall)	01586000	
			UZP0002	39 29 47.68237	76 52 12.78678	Bonds Run at Hollingsworth Road		
	NPDES		STP7704	39 30 14.34065	76 53 08.64558	Effluent Congoleum manufacturing plant		Grab, if discharge
			STP8000	39 35 14.32810	76 51 06.05665	Effluent Roy F. Weston manufacturing plant		Grab, if discharge
Loch Raven	Reservoir	Lower	GUN0142	39 25 50.86953	76 32 39.57712	Loch Raven Gatehouse		
		Middle	GUN0156	39 26 50.67932	76 33 20.68793	Loch Raven at Loch Raven Drive Bridge		Bridge access
		Middle	GUN0171	39 27 04.77082	76 34 08.44553	Loch Raven between picnic and golf course areas		WP, requires boat
		Upper	GUN0174	39 27 46.16274	76 34 49.59077	Loch Raven at Dulaney Valley Road Bridge		Bridge access
		Upper	GUN0190	39 29 00.28084	76 34 53.65176	Loch Raven at power lines		WP, requires boat
	Tributary		BEV0005	39 29 08.36173	76 38 44.59508	Beaver Dam Run at Beaver Run Lane	01583600	
			DVB0000	39 27 58.10206	76 32 43.51881	Dulaney Valley Branch at Loch Raven Drive		
			GUN0258	39 32 59.29999	76 38 09.95642	Gunpowder Falls at Glencoe Road	01582500	
			GUN0387	39 37 08.38463	76 41 26.10235	Gunpowder Falls at Falls Road	01581920	
			GUN0398	39 37 08.62153	76 42 23.89133	Gunpowder Falls 500 feet below Prettyboy Dam		
	(Pond)		JNR0003	39 28 02.09216	76 33 29.69286	Jenkins Run at Dulaney Valley Road		Grab, if flow
			LIT0002	39 36 07.34671	76 37 19.03368	Little Falls at Blue Mount Road	01582000	
			WGP0050	39 30 38.38894	76 40 36.83822	Western Run at Western Run Road	01583500	
	NPDES		STP8005	39 35 50.14921	76 50 03.52134	Effluent Hampstead Wastewater Treatment Plant		Grab, if discharge
Prettyboy	Reservoir	Lower	GUN0399	39 37 11.37820	76 42 26.02913	Prettyboy Dam Gatehouse		
		Lower	GUN0401	39 37 14.12232	76 42 36.07822	Prettyboy 1,000 feet upstream of Prettyboy Dam		WP, boat
		Middle	GUN0437	39 38 52.33959	76 45 19.25522	Prettyboy at Beckleysville Road Bridge		Bridge access
	Tributary		GOB0017	39 37 33.47745	76 46 22.06942	Georges Run at Georges Creek Road	01581870	
			GRG0013	39 39 16.99906	76 46 46.13531	Grave Run at Gunpowder Road	01581830	
			GUN0476	39 41 20.98079	76 46 49.77908	Gunpowder Falls at Gunpowder Road	01581810	
	NPDES		STP8006	39 39 27.88889	76 52 46.84074	Effluent Manchester Wastewater Treatment Plant		Grab, if discharge

Appendix B2. Baltimore City monitoring for Liberty Reservoir: treatment facility, reservoir, and tributaries—sample location, water-quality parameters, and frequency.

[NPDES, National Pollutant Discharge Elimination System; TF, treatment facility, R, raw, or T, treated, water sample or measurement, taken in facility; raw-water sample or measurement taken at all other locations; D, daily; W, weekly; M, monthly; 2xW, twice weekly; 2xM, twice monthly; (S), spring-summer-fall (approximately April through November); (W), winter (approximately December through March); E, storm event; *, permitted discharge, grab sample, if flow; ---, not sampled; °C, degrees Celsius, mg/L, milligrams per liter, µg/L micrograms per liter; L, liter; mL, milliliter; #, number; MP, most probable; µmhos/cm, micromhos per centimeter; $CaCO_3$, calcium carbonate]

Water-quality parameter	Liberty Reservoir													
	Ashburton		Reservoir site identifier				Watershed tributary site identifier						NPDES site identifier	
	TF, Raw	TF, Treated[1]	NPA0042	NPA0059	NPA0067	NPA0105	BEA 0015	LMR 0015	MDE 0026	MOR 0040	NPA 0165	UZP 0002	STP7704*	STP8000*
Temperature, air, °C	---	---	2xM(S), M(W)	2xM(S)	2xM(S)	2xM(S), M(W)	M	M	M	M	M	M	M	M
Temperature, water, °C	D	D	2xM(S), M(W)	2xM(S)	2xM(S)	2xM(S), M(W)	M	M	M	M	M	M	M	M
Color (True), color units	2xW	2xW	2xM(S), M(W)	---	---	---	---	---	---	---	---	---	---	---
Secchi disc, meters	---	---	2xM(S), M(W)	2xM(S)	2xM(S)	2xM(S), M(W)	---	---	---	---	---	---	---	---
Turbidity, nephelometric units	D	D	2xM(S), M(W)	M(S)	M(S)	M	M	M	M	M	M	M	M	M
Total solids, mg/L	M	M	---	---	---	---	M	M	M	M	M	M	M	M
Total suspended solids, mg/L	---	---	---	---	---	---	M, E	M	M	M, E	M, E	M	M	M
Volatile suspended solids, mg/L	---	---	---	---	---	---	E only	---	---	E only	E only	---	---	---
Chlorophyll-*a*, µg/L	---	---	2xM(S), M(W)	2xM(S)	2xM(S)	2xM(S), M(W)	---	---	---	---	---	---	---	---
Total algal count, #/mL	W	W	2xM(S), M(W)	M(S)	M(S)	M	---	---	---	---	---	---	---	---
Algal identification	W	W	2xM(S), M(W)	M(S)	M(S)	M	---	---	---	---	---	---	---	---
Total and fecal coliforms, MP#/100 mL	D	D	---	---	---	---	---	---	---	---	---	---	---	---
Cryptospiridium and Giardia, #/L	M	---	---	---	---	---	---	---	---	---	---	---	---	---
Specific conductance, µmhos/cm	---	M	2xM(S), M(W)	2xM(S)	2xM(S)	2xM(S), M(W)	M	M	M	M	M	M	M	M
Dissolved solids, mg/L	---	M	2xM(S), M(W)	M(S)	M(S)	M	M	M	M	M	M	M	M	M
Hardness, mg/L as $CaCO_3$	D	D	M	M(S)	M(S)	M	---	---	---	---	---	---	---	---
pH, Standard units	D	D	2xM(S), M(W)	2xM(S)	2xM(S)	2xM(S), M(W)	M	M	M	M	M	M	M	M
Alkalinity, mg/L as $CaCO_3$	D	D	2xM(S), M(W)	M(S)	M(S)	M	M	M	M	M	M	M	M	M
Dissolved oxygen, mg/L	2xW	2xW	2xM(S), M(W)	2xM(S)	2xM(S)	2xM(S), M(W)	M	M	M	M	M	M	M	M
Manganese, mg/L	D	D	2xM(S), M(W)	M(S)	M(S)	M	---	---	---	---	---	---	---	---
Iron, mg/L	3xW	3xW	M	M(S)	M(S)	M	---	---	---	---	---	---	---	---
Phosphorus, total, mg/L	M	M	2xM(S), M(W)	M(S)	M(S)	M	M, E	M	M	M, E	M, E	M	M	M
Nitrogen, nitrate, mg/L	M	M	M	M(S)	M(S)	M	M, E	M	M	M, E	M, E	M	M	M
Nitrogen, ammonium, mg/L	M	M	M	M(S)	M(S)	M	M	M	M	M	M	M	M	M
Nitrogen, total Kjeldahl, mg/L	---	---	---	---	---	---	E only	---	---	E only	E only	---	---	---
Carbon, total organic, mg/L	2xM	2xM	---	---	---	---	---	---	---	---	---	---	---	---
Trihalomethanes, µg/L	M	M	---	---	---	---	---	---	---	---	---	---	---	---
Haloacetic acids, µg/L	M	M	---	---	---	---	---	---	---	---	---	---	---	---
Sodium, mg/L	M	M	---	---	---	---	---	---	---	---	---	---	---	---
Chloride, mg/L	M	M	2xM(S), M(W)	M(S)	M(S)	M	M	M	M	M	M	M	M	M

[1] Additional constituents only for treated water: calcium, magnesium, potassium, aluminum, arsenic, sulfate, silica, fluoride, residual chlorine, and selected metals, radionuclides, and synthetic and volatile organic compounds.

Appendix B3. Baltimore City monitoring for Loch Raven Reservoir: treatment facility, reservoir, and tributaries—sample location, water-quality parmeters, and frequency.

[NPDES, National Pollutant Discharge Elimination System; TF, treatment facility, R, raw, or T, treated, water sample or measurement, taken in facility; raw-water sample or measurement taken at all other locations; D, daily; W, weekly; M, monthly; 2xW, twice weekly; 2xM, twice monthly; (S), spring-summer-fall (approximately April through November); (W), winter (approximately December through March); E, storm event; *, grab sample, if flow; **, permitted discharge, grab sample, if flow; ---, not sampled; °C, degrees Celsius, mg/L, milligrams per liter; µg/L, micrograms per liter; L, liter; mL, milliliter; #, number; MP, most probable; µmhos/cm, micromhos per centimeter; $CaCO_3$, calcium carbonate]

Water-quality parameters	Loch Raven Reservoir															
	Montebello		Reservoir site identifier					Watershed tributary site identifier						NPDES site identifier		
	TF, Raw	TF, Treated[1]	GUN 0142	GUN 0156	GUN 0171	GUN 0174	GUN 0190	BEV 0005	DVB 0000	GUN 0387	GUN 0256	WGP 0050	LIT 0002	GUN 0398*	JNR 0003*	STP 8005*, **
Temperature, air, °C	D	D	2xM(S), M(W)	M(W)	2xM(S)	M(W)	2xM(S)	M	M	2xM	M	M	M	M	M	M
Temperature, water, °C	D	D	2xM(S), M(W)	M(W)	2xM(S)	M(W)	2xM(S)	M	M	2xM	M	M	M	M	M	M
Color (True), color (apparent) units	D	D	2xM(S), M(W)	M(W)	M(S)	M(W)	M(S)	---	---	---	---	---	---	M	---	---
Secchi disc, meters	---	---	2xM(S), M(W)	M(W)	2xM(S)	M(W)	2xM(S)	---	---	---	---	---	---	---	---	---
Turbidity, nephelometric units	D	D	2xM(S), M(W)	M(W)	M(S)	M(W)	M(S)	M	M	M	M	M	M	M	M	M
Total solids, mg/L	M	M	---	---	---	---	---	M	M	M	M	M	M	---	M	M
Total suspended solids, mg/L	---	---	---	---	---	---	---	M, E	M	M	M, E	M	M	---	M	M
Volatile suspended solids, mg/L	---	---	---	---	---	---	---	E	---	---	E	E	---	---	---	---
Chlorophyll-*a*, µg/L	---	---	2xM(S), M(W)	M(W)	2xM(S)	M(W)	2xM(S)	---	---	---	---	---	---	---	---	---
Total algal count, #/mL	W	W	2xM(S), M(W)	---	---	---	---	---	---	---	---	---	---	---	---	---
Algal identification	W	W	2xM(S), M(W)	---	---	---	---	---	---	---	---	---	---	---	---	---
Total and fecal coliforms, MP#/100 mL	D	D	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cryptospiridium and Giardia, #/L	M	M	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Specific conductance, µmhos/cm	M	M	2xM(S), M(W)	M(W)	2xM(S)	M(W)	2xM(S)	M	M	2xM	M	M	M	M	M	M
Dissolved solids, mg/L	M	M	---	---	---	---	---	M	M	M	M	M	M	---	M	M
Hardness, mg/L as $CaCO_3$	D	D	---	---	---	---	---	---	---	---	---	---	---	---	---	---
pH, Standard units	D	D	2xM(S), M(W)	M(W)	2xM(S)	M(W)	2xM(S)	M	M	2xM	M	M	M	M	M	M
Alkalinity, mg/L as $CaCO_3$	D	D	2xM(S), M(W)	M(W)	M(S)	M(W)	M(S)	M	M	M	M	M	M	M	M	M
Dissolved oxygen, mg/L	D	D2	2xM(S), M(W)	M(W)	2xM(S)	M(W)	2xM(S)	M	M	2xM	M	M	M	---	M	M
Manganese, mg/L	D	D	2xM(S), M(W)	M(W)	M(S)	M(W)	M(S)	---	---	---	---	---	---	M	---	---
Iron, mg/L	3xW	3xW	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Phosphorus, total, mg/L	M	M	2xM(S), M(W)	M(W)	M(S)	M(W)	M(S)	M, E	M	M	M, E	M, E	M	M	M	M
Nitrogen, nitrate, mg/L	M	M	2xM(S), M(W)	M(W)	M(S)	M(W)	M(S)	M, E	M	M	M, E	M, E	M	M	M	M
Nitrogen, ammonium, mg/L	M	M	2xM(S), M(W)	M(W)	M(S)	M(W)	M(S)	M	M	M	M	M	M	M	M	M
Nitrogen, total Kjeldahl, mg/L	---	---	---	---	---	---	---	E	---	---	E	E	---	---	---	---
Carbon, total organic, mg/L	2xM	2xM	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Trihalomethanes, µg/L	M	M	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Haloacetic acids, µg/L	M	M	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Sodium, mg/L	M	M	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Chloride, mg/L	M	M	---	---	---	---	---	M	M	M	M	M	M	---	M	M

[1] Additional constituents for treated water: calcium, magnesium, potassium, aluminum, arsenic, sulfate, silica, fluoride, residual chlorine, and selected metals, radionuclides, and synthetic and volatile organic compounds.

Appendix B4. Baltimore City monitoring for Prettyboy Reservoir: reservoir and tributaries—sample location, water-quality parameters, and frequency.

[NPDES, National Pollutant Discharge Elimination System; M, monthly; (S), spring-summer-fall (approximately April through November); (W), winter (approximately December through March); **, permitted discharge, grab sample, if flow; ---, not sampled; °C, degrees Celsius, mg/L, milligrams per liter; µg/L, micrograms per liter; L, liter; mL, milliliter; #, number; MP, most probable; µmhos/cm, micromhos per centimeter; $CaCO_3$, calcium carbonate]

Water-quality parameters	Prettyboy Reservoir						
	Reservoir site identifier			Watershed tributary site identifier			NPDES site identifier
	GUN0399	GUN0401	GUN0437	GOB0017	GRG0013	GUN0476	STP8006**
Temperature, air, °C	M(W)	M(S)	M	M	M	M	M
Temperature, water, °C	M(W)	M(S)	M	M	M	M	M
Color (True), color units	M(W)	M(S)	M	---	---	---	---
Secchi disc, meters	M(W)	M(S)	M	---	---	---	---
Turbidity, nephelometric units	M(W)	M(S)	M	M	M	M	M
Total solids, mg/L	---	---	---	M	M	M	M
Total suspended solids, mg/L	---	---	---	M	M	M	M
Volatile suspended solids, mg/L	M(W)	M(S)	M	---	---	---	---
Chlorophyll-*a*, µg/L	M(W)	M(S)	---	---	---	---	---
Total algal count, #/mL	M(W)	M(S)	---	---	---	---	---
Algal identification	---	---	---	---	---	---	---
Total and fecal coliforms, MP#/100 mL	---	---	---	---	---	---	---
Cryptospiridium and Giardia, #/L	M(W)	M(S)	M	M	M	M	M
Specific conductance, µmhos/cm	---	---	---	M	M	M	M
Dissolved solids, mg/L	---	---	---	---	---	---	---
Hardness, mg/L as $CaCO_3$	M(W)	M(S)	M	M	M	M	M
pH, Standard units	M(W)	M(S)	M	M	M	M	M
Alkalinity, mg/L as $CaCO_3$	M(W)	M(S)	M	M	M	M	M
Dissolved oxygen, mg/L	M(W)	M(S)	M	---	---	---	---
Manganese, mg/L	---	---	---	---	---	---	---
Iron, mg/L	M(W)	M(S)	M	M	M	M	M
Phosphorus, total, mg/L	---	---	---	---	---	---	---
Nitrogen, nitrate, mg/L	M(W)	M(S)	M	M	M	M	M
Nitrogen, ammonium, mg/L	M(W)	M(S)	M	M	M	M	M
Nitrogen, total Kjeldahl, mg/L	---	---	---	---	---	---	---
Carbon, total organic, mg/L	---	---	---	---	---	---	---
Trihalomethanes, µg/L	---	---	---	---	---	---	---
Haloacetic acids, µg/L	---	---	---	---	---	---	---
Sodium, mg/L	---	---	---	---	---	---	---
Chloride, mg/L	---	---	---	M	M	M	M

Appendix C: Review of Baltimore Reservoir Ashburton and Montebello Treatment Facilities Laboratory Quality-Assurance Plans

Contents

Introduction

The following quality-assurance (QA) plans for the Ashburton and Montebello treatment facility laboratories were requested and reviewed as part of the retrospective review, and are included in this Appendix. Except for minor reformatting, the plans are presented as they were received. For selected headings, no additional text appears in plan after the heading.

Ashburton Laboratory Quality Assurance Plan, Revision 3, 2007

This plan was obtained in March 2007 from Savita Bagel, Laboratory Manager, Ashburton Laboratory, Baltimore, Maryland. It has been minimally reformatted for inclusion in this Appendix.

1. **Organization Chart, Line Authority - see list (attached list not requested)**

2.

3. **Analytical Procedures (see the Standard Operating Procedures (SOP) manual)**

4. **Sample Handling Procedures**

Sample Acceptance and Logging—There is a sample log for all samples coming into the laboratory. All samples must be collected, stored and preserved in accordance with EPA guidelines. More specific instructions are in the SOPs.

Sample Rejection—Samples are rejected for improper labeling, collection, storage or holding times.

Sample Disposable—Samples are disposed of after all analyses are completed or at the end of the holding time.

Sample Storage—Chlorine and pH analyses must be done immediately when the sample comes into the lab. For most other analyses the samples are stored in the refrigerators before analysis. For metals analyses the samples should be preserved with nitric acid to less than pH 2.

Sample Tracking—All samples should be recorded in the sample log book.

Chain of Custody—Is needed for samples being transported to or from Montebello, including samples for metals analysis.

5. **Sampling Procedures**

Containers—The container must be appropriate for the intended analysis and must be labeled with the location, date and time of collection. Sterile bottles with sodium thiosulfate are used for micro samples. Acid-washed bottles are needed for metal analyses.

Preservation—All, except samples for metal analysis, must be kept on ice or refrigerated until analyzed. If analyses for nitrate, ammonia and phosphates cannot be completed within 48 hours, the samples are preserved by acidifying to < pH 2 with concentrated sulfuric acid. Samples for metal analysis should be acidified to < pH 2 with concentrated nitric acid. They must be held for 16 hours after acidification and then can be held for up to 6 months. If the turbidity is > 1 NTU, the sample must be digested. (see SOPs.)

QC Samples—Should be done quarterly for fluoride, nitrites, and nitrates <u>and as many other parameters as possible.</u> The complete analysis should be done on the yearly Performance Evaluation samples each spring. As many analysts as possible should complete each analysis.

Documentation—All samples must be logged into the sample log book and/or have a paper form with the required information. Included must be the name of the sampler, date and location of the sample and a list of parameters for analysis.

Special Instructions—Care must be exercised to take samples that will be representative of the water being tested and to avoid contamination of the sample at the time of collection or in the period before analysis.

Plant Process Samples—Samples can be taken from the sink taps, anytime, except when the water flow thru the plant has been changed recently. A change in flow may affect the water quality temporarily. Samples should be analyzed immediately when possible.

Metals Analyses Samples—The tap should be opened and the water allowed to run to waste for 2 to 3 minutes or for a sufficient time to permit clearing of the service line. Chlorine and pH determinations must be done at this time. The flow from the tap should then be restricted to one that will permit filling the bottle without splashing. The bottles can be filled almost to the top leaving enough air space to permit mixing. For a first draw sample for lead analysis, the line should be thoroughly flushed and then allowed to sit unused for 6 to 8 hours. The sample should then be collected as soon as the tap is opened.

Utility Maintenance Samples—There are no restrictions on these samples except that we need to know the location and the time collected. These analyses are not done by approved methods and are only an approximation, but good enough to tell whether city water, sewage or ground water is involved.

Watershed Samples—Are collected by the watershed samplers.

Water Quality Management Samples—Storm water runoff samples for nutrient analyses are preserved before they come to the lab.

Distribution Samples—Must be collected by a State Certified Sampler and are almost always analyzed at Montebello.

Waste Lake Samples—All composite samples must be analyzed each week to meet the requirements of the NPDES permit for the plant.

6. Calibration Procedures

Standards Source—ERA, NSI, SPEX, Fisher, Perkin Elmer.

Comparability Checks—New standards are run against old standards with a QC sample.

Frequency—The pH meter is calibrated each morning and afternoon with three certified buffers. The calibration is checked with each use. The balance calibration is checked monthly. All turbidimeters in the plant are calibrated each month by the Instrumentation group. Calibration of other instruments is done each day of use. A set of at least 3 standards and a blank must be used. An appropriate standard or QC sample must be checked after a set number (usually 10) of samples. Standards and QC samples must be run again at the end of the run. More specific instructions are in each SOP.

7. Documentation

There are calibration books for pH and fluoride as well as for the digital berets and balances. For other analyses the analyst keeps the calibration documentation with the sample results.

8. Data Reduction, Validation and Reporting

Calculations

Units Units must be clearly marked as to mg/L or (text ends here)

Transcription/Transfer Each analyst records their results on the report form.

Report Format The report format varies with the type of sample.

Documentation

9. QC Checks—see SOPs for specific instructions.

Reagent Blanks—Are done for each set of analyses.

Replicate Analyses—At least 10 % of samples must be duplicated.

Check Sample Recoveries

Matrix Spike Recoveries—Are done for every sample analyzed by graphite furnace. For fluorides, the spikes are done each day. For nitrates, the spikes should be done on at least 10 % of the samples or whenever the matrix changes.

Instrument Control Standard Response

Internal Standard Response

Control Charts—Are done for fluoride, nitrates, nitrites and all metal analyses.

Documentation—If the QC is not acceptable, the samples must be run again. Any out of control sample or standard on the control charts must be documented with the corrective action: The sample could be rerun or recalibration was done or maintenance of the instrument was needed.

10. Specific Routine Procedures

Accuracy—All graphite furnace samples are spiked. 10% of other samples are spiked.

Precision—Duplicates are done to demonstrate precision.

Completeness

Timeliness—All samples must be analyzed within the approved holding time unless clearly marked on the report of results. Compliance samples must always be done within the approved holding time.

Legibility

Clarity

11. Schedules of internal and external system and data quality audits and inter laboratory comparisons.

The EPA performance evaluation samples for chemistry are done each year for all analyses that are done in the lab. At least once each quarter, QC samples are done for nitrates, nitrites and fluorides. QC samples are included for each of the metals analyses each time they are run.

12. Preventive Maintenance

Operating Manuals—There is a file drawer for operating manuals and instruction books for most equipment. A file folder of instructions and a record of repairs and replacement parts will be included there.

Service Schedule—Both balances are cleaned and calibrated each year by American Scale. Class S weights are used to check the balance calibration each month.

Spare Parts Inventory—Some spare parts are kept on hand including parts for the glass still and various bulbs for the spectrophotometer and the turbidimeter. Backup equipment is available for the ion meter, the pH meter, the turbidimeter and the spectrophotometer. There is cooperation with the Montebello Lab for emergencies.

Service Agreements—The annual service contract agreement for the Perkin Elmer Atomic absorption spectrometer includes two preventive maintenance visits each year.

Documentation—All service and repairs should be documented in the appropriate file folder in the equipment file. Records for the AA are in the desk nearest the AA.

13. Corrective Action

QC Failure—If the QC results are not acceptable, the analysis must be repeated.

PE Failure—Every aspect of the analysis must be examined to determine the problem. Correction must be as soon as possible and steps taken to ensure that the problem will not occur again.

Audit Deficiency—Must be corrected as soon as possible.

Complaint

14. Record Keeping Procedures

Keep original data for at least 5 years. Monthly reports are kept on disk (two copies) and at least one paper copy is in the lab as well. As needed, reports are kept on disk as well as on paper. Reports are distributed as needed to other people.

Montebello Laboratory Quality Assurance Plan for Chemical Analysis, Revision 3, 2007

This plan was obtained in March 2007 from Lisa Jones, Laboratory Manager, Montebello Laboratory, Baltimore, Maryland. It has been minimally reformatted for inclusion in this Appendix.

1. Organization Chart

INEZ HAWK, LABORATORY TECHNICAL ADMINISTRATOR

LISA JONES, LABORATORY TECHNICAL SUPERVISOR

DEBORAH PITTS, MICROBIOLOGIST SUPERVISOR

JOSEPH BRENNAN, CHEMIST II

OMACHILE TAUPYEN, CHEMIST I

MARIA REED, MICROBIOLOGIST II

KAREN CAMPBELL, LAB ASSISTANT II

JOHN HOHMAN, POLLUTION CONTROL ANALYST II

RICHARD NUSS, CHEMIST III

THO NGUYEN, CHEMIST III

All of the chemists have at least 20–30 hours of college level chemistry courses. Each new analyst is trained and checked by a senior analyst. The laboratory supervisor is responsible for implementing the QA plan. Each analyst is responsible for doing analyses with the required quality control.

The laboratory supervisor is responsible for making sure that all personnel are updated on changes in regulations and methodology. The analysts should be able to make the necessary changes with minimal assistance.

The Microbiologists have a Microbiological Quality Control and Procedures Manual. The Microbiologist Supervisor makes changes in methods and procedures. Now, while that position is vacant, the laboratory supervisor will make changes when necessary.

On weekends and holidays, one analyst does both the routine chemistry and microbiology. Therefore, all chemists and microbiologists must demonstrate the ability to perform the routine chemical and microbiological analyses that are done on weekends and holidays. This is done before they work a weekend.

2. Data Quality Objectives:

Compliance samples are done with approved methods and all appropriate quality control, being careful to observe required holding times. Plant process samples occasionally can be done more informally; e.g., manganese. Waste lake samples need to be done as quickly as possible with screening tests that do not necessarily require all the usual quality control.

3. Analytical Procedures-Dates of Revision (see the SOP manual)

Alkalinity-titration method-2/28/97

Ammonia-Electrode method-11/9/98

Calcium Carbonate Stability-2/11/97

Carbon dioxide-titrimetric method-12/20/95

Chloride-argentometric method-12/95

Chloride-see ion chromatography method-11/5/98

Chlorine-amperometric titration-2/27/97

Color-Visual comparison-11/6/98

Dissolved Oxygen-electrode-12/95

Fluoride-ion selective method-10/95

Hardness-EDTA titration-2/28/97

Iron-Phenanthroline method-12/95

Ion Chromatography for nitrate, chloride and sulfate-11/5/98

Jar test procedure-3/22/96

Manganese for plant process-11/6/98

Nitrate-electrode method-11/4/98

Nitrate-see ion chromatography method-11/5/98

Nitrite-colorimetric method-3/16/98

PH-electrometric-11/19/96

Phosphate-total-ascorbic acid method-11/16/95

Silica-molybdosilicate-12/95

Sulfates-see ion chromatography method-11/5/98

Threshold odor number (TON)-12/19/95

Total Organic Carbons 4/2000

Total suspended solids-Dried at 180^{o}C-4/2002

Total Solids-11/3/98

Turbidity-Nephelometric Method-3/20/97

Volatile solids-11/3/98

Organics:

Trihalomethanes	EPA 524.2
HAA's	EPA 552
VOC's	EPA 524.2
EDB, DBCP	EPA 504
Organohalide Pesticides	EPA 505
Chlorinated Pesticides	EPA 508, 515.1
TTHM Formation Potential	EPA 510.1

4. Sampling Procedures

Containers—The container must be appropriate for the intended analysis and must be labeled with the location, date, time of collection and collector. Sterile bottles with sodium thiosulfate are used for micro samples. Acid-washed (25% HNO_3) bottles are needed for metal analyses. Leak samples are collected in clean glass pint bottles. Watershed samples are collected in acid (50% HCI) rinsed plastic liter bottles.

Preservation—All samples, except samples for metal analysis, must be kept on ice or refrigerated until analyzed. If analyses for nitrate, ammonia and phosphates cannot be completed within 48 hours; acidifying to < pH with concentrated sulfuric acid preserves the samples.

Samples for metal analysis should be acidified to pH 2 with concentrated trace metal grade nitric acid. They must be held for 16 hours after acidification and then can be held for up to 6 months.

Special Instructions—Care must be exercised to take samples that will be representative of the water being tested and to avoid contamination of the sample at the time of collection or in the period before analysis. Paperwork must be filled out in ink.

Plant Process Samples—Samples can be taken from the sink taps, anytime, except when the water flow through the plant has been changed recently. A change in flow may affect the water quality temporarily. Samples should be analyzed immediately when possible. Chlorine and pH must be done immediately. Immediately is considered to be within 15 minutes.

Metals Analyses Samples—The tap should be opened and the water allowed to run to waste for 2 to 3 minutes or for a sufficient time to permit clearing of the service line. Chlorine and pH determinations must be done at this time. The flow from the tap should then be restricted to one that will permit, filling the bottle without splashing. The bobbles can be filled almost to the top leaving enough air space to permit mixing. For a first draw sample for lead analysis, the line should be thoroughly flushed and then allowed to sit unused for 6 to 8 hours. The sample should then be collected as soon as the tap is opened.

Watershed Samples—Are collected by the watershed samplers and will come with all needed paperwork.

Organic Bottles—Must be cleaned according to the appropriate EPA protocol for each method.

Distribution Samples—Must be collected by a Certified Sampler and are always analyzed at Montebello.

5. Sample Handling Procedures

Sample Acceptance and Logging

All samples must be recorded in the sample log book and/or have a paper form with the required information. Included must be the name of the sampler, date and location of the sample and a list of parameters for analysis. All samples must be collected, stored and preserved in accordance with EPA guidelines. More specific instructions are in the SOPs. Samples from the Ashburton Lab should have a chain of custody with the appropriate information.

Sample Rejection—Samples are rejected for improper labeling, collection, storage or holding times.

Sample Storage—Chlorine and pH analyses must be done immediately when the sample comes into the lab. This means they must be done within 15 minutes of collection. For most other analyses the samples are stored in the refrigerators before analysis. For metals analyses the samples are to be preserved with nitric acid to less than pH 2 and then can be held at room temperature.

Sample Disposal—Samples are disposed of after all analyses are completed or at the end of the holding time.

Sample Tracking—All samples are to be recorded in the sample logbook. Microbiological samples for coliform analysis must be logged into the micro book and stored in the Micro refrigerator on the shelf for coliform samples.

Chain of Custody—Is needed for samples being transported to or from Ashburton, including samples for metals analysis.

6. Calibration Procedures

Standards Source ERA, SPEX, Fisher

Comparability Checks New standards are run against old standards with a QC sample.

Frequency The pH meter is calibrated each morning with two certified buffers. The calibration is checked with each use. The balance calibration is checked monthly. All turbidmeters in the plant are calibrated quarterly by the Instrumentation group. Calibration of other instruments is done each day of use. A set of at least 3 standards and a blank must be used. An appropriate standard or QC sample must be check after a set number (usually 10) of samples. Standards and quality control samples must be run again at the end of the run. More specific instructions are in each SOP.

Documentation There are calibration books for pH and fluoride and balances. For other analyses the analyst keeps the calibration documentation with the samples results.

7. Analytical Procedures

Standard Operating Procedures are in SOP manual and should be reviewed by the analysts frequently. The complete method citation is included at the beginning of the SOP. The date of the last revision is at the bottom of the SOP.

8. Data Reduction, Validation and Reporting

Units Units must be clearly marked.

Transcription/Transfer Each analyst records his or her results on the report form.

Report Format The report format varies with the type of sample.

Documentation results can only be reported if all the QC has been satisfactory.

9. QC Checks see SOPs for specific instructions.

Reagent Blanks are done for each set of analyses.

Replicate Analyses at least 10% of samples must be duplicated.

Check Sample Recoveries The required percentage range varies with the type of analyses.

Matrix Spike Recoveries For fluorides, the spikes are done each day. For nitrates the spikes should be done on at least 10% of the samples or whenever the matrix changes.

Instrument Control Standard Response varies for each instrument.

Control Charts are done for fluoride, nitrates, and nitrites.

Documentation If the QC is not acceptable, the samples must be run again. Any out of control recovery on the control charts must be documented with the corrective action:

The sample was rerun or recalibration was done or maintenance of the instrument was needed.

Accuracy 10% of all samples are spiked for certified analyses.

Timeliness All samples must be analyzed within the approved holding time unless results are clearly marked on the report. Compliance samples must always be done within the approved holding time.

Method Detection Limits (MDL) must be done at least annually by each new analyst.

Quality Control procedures for microbiology are included in the Microbiology Manual.

10. Schedules of internal and external system and data quality audits and inter-laboratory comparisons.

The EPA Performance Evaluation samples for chemistry are done each year for all analyses that are done in the lab.

As many analysts as possible should complete each analysis. At least once each quarter, QC samples are done for nitrates, nitrites and fluorides. QC samples are included for each of the ORGANICS analyses each time they are run.

11. Preventive Maintenance

Operating Manuals There is a file drawer for operating manuals and instruction books for most equipment. A file folder of instructions and a record of repairs and replacement parts for each instrument are included there.

Service Schedule All balances are cleaned and calibrated each year by American Scale. Class 1 weights are used to check the analytical balance calibration each month.

Spare Parts Inventory Some spare parts are kept on hand including parts for the glass still and various bulbs for the spectrophotometer and the turbidimeter. Backup equipment is available for the ion meter, the pH meter, the turbidimeter and the spectrophotometer. There is cooperation with the Ashburton Lab for emergencies.

Service Agreements The Ion Chromatograph is covered by a service contract with preventive maintenance visits. The same applies to the autoclave, dishwasher, and the Total Organic Carbon Analyzer. Service contracts are generally in effect for the GC/MS.

All service and repairs should be documented in the appropriate maintenance log book near the equipment.

12. Corrective Action

QC Failure- If the QC results are not acceptable, the analysis must be repeated. If the holding time has expired, the sample cannot be rerun and the results must re-check the SOP to see if everything was done correctly. Check to be sure that all reagents are correct. Depending on the type of analysis, recalibration might be required. Dilution of the sample might be helpful. Check with the laboratory supervisor or chemist III for more suggestions.

PE Failure every aspect of the analysis must be examined to determine the problem. Corrective action must be taken as soon as possible to ensure that the problem will not occur again. Check the SOP. Reagents should be checked. The instrument used may need to be serviced. Preventive maintenance procedures should be reviewed. The results of the investigation should be written up and given to the laboratory supervisor to be sent in the response to the State.

Audit Deficiency must be corrected as soon as possible.

13. Record Keeping Procedures

Original data in workbooks is kept for at least five years. Copies of the weekly Watershed data are sent to the watershed section.

Plant monthly reports are kept on disk (two copies) and at least one paper copy is in the lab as well. Copies are sent to the State MDE, to the Water System Manager, Water Systems Assistant Manager, the Water Quality Laboratory Administrator and the Water Quality Lab Supervisors.

Microbiological results are reported by telephone. The paperwork is filed for future reference.

Appendix D: Plant Ecology Group (PEG) Model of Seasonal Succession of Plankton in Freshwater

The Plankton Ecology Group (PEG) model sequentially describes the general trend of a spring bloom of small diatoms, followed by the progression during summer from large colonial green algae to large diatoms, then large dinoflagellates and (or) finally blue-green algae (Sommer and others, 1986). In so doing, the PEG model incorporates the relative importance of physical factors, nutrients (nitrogen and phosphorus), and grazing in shaping phytoplankton community structure throughout the growing season in freshwater lakes, as follows (from Sommer and others, 1986, with modified formatting):

a) Towards the end of winter, nutrient availability and increased light permit unlimited growth of the phytoplankton. A small crop of fast-growing algae, for example golden-brown (*Cryptophyceae sp.*) and centric diatoms develops.

b) This crop of small algae is grazed upon by herbivorous zooplanktonic species, which become abundant due to hatching from resting eggs and to high fecundity by high levels of edible algae.

c) Planktonic herbivores with short generation duration times increase their populations first and are followed by slower growing species.

d) The herbivore populations increase exponentially up to the point at which their density is high enough to produce a community filtration rate, and so cropping rate, which exceeds the reproduction rate of the phytoplankton.

e) As a consequence of herbivore grazing, the phytoplankton biomass decreases rapidly to very low levels.

f) There then follows a 'clear-water' equilibrium phase which persists until inedible algae species develop in significant numbers. Nutrients are re-cycled by the grazing process and can accumulate during the 'clearwater' phase.

g) Herbivorous zooplanktonic species become food-limited and both their body weight per unit length and their fecundity declines. This results in a decrease in their population densities and biomasses.

h) Fish predation accelerates the decline of herbivorous planktonic populations to very low levels and this trend is accompanied by a shift towards a smaller average body size amongst the surviving crustaceans.

i) Under the conditions of reduced grazing pressure and sustained non-limiting concentrations of nutrients, the phytoplankton summer crops start to build up. The composition of the phytoplankton becomes complex due to both the increase in species richness and to the functional diversification into small 'undergrowth' species, which are available as food for filter-feeders, and into large 'canopy' species, which are only consumed by specialists such as raptors or parasites.

j) At first, the edible algae (such as golden-brown (*Cryptophyceae sp.*) and inedible colonial green algae become predominant. They deplete the soluble reactive phosphorus to nearly undetectable levels.

k) From this time onwards, the algal growth becomes nutrient-limited and this prevents an explosive growth of 'edible' algae. Grazing by predator-controlled herbivores balances the nutrient-limited growth rate of edible algal species.

l) Competition for phosphate leads to a replacement of green algae by large diatoms, which are only partly available to zooplankton as food.

m) Silica-depletion leads to a replacement of the large diatoms by large dinoflagellates and/or blue green algae (*Cyanophyta sp.*).

n) Nitrogen depletion ultimately favors a shift to nitrogen-fixing species of filamentous blue-green algae.

o) Larger species of crustacean herbivores are replaced by smaller species and by rotifers. These small species are less vulnerable to fish predation and are less affected by interference with their food collecting apparatus which can be caused by some forms of inedible algae. Accordingly, their population mortality is lower and their fecundity is higher than that of the larger species.

p) The smaller species of herbivores coexist under a persistent fish predation pressure and the increased possibility of food partitioning, which is associated with the greater species complexity of the phytoplankton.

q) The population densities and species composition of the zooplankton fluctuate throughout the summer, the latter being also influenced by temperature.

r) The period of autogenic succession is terminated by factors related to physical changes, which includes increased mixing depth resulting in nutrient replenishment and a deterioration of the effective underwater light climate.

s) After a minor reduction in algal biomass, an algal community develops which is adapted to being mixed. Large unicellular or filamentous algal forms appear. Among them diatoms become increasingly important with the progress of autumn.

t) This association of poorly-ingestible algae is accompanied by a variable biomass of small, edible algae.

u) This algal composition together with some reduction in fish predation pressure leads to an autumnal maximum of zooplankton which includes larger forms and species.

v) A reduction of light energy input results in a low or negative net primary production and an imbalance with the algal losses, which causes a decline of algal biomass to the winter minimum.

w) Herbivore biomass decreases as a result of reduced fecundity due both to lower food concentrations and to decreasing temperature.

x) Some species in the zooplankton produce resting stages at this time, whereas other species produced resting stages earlier.

y) At this period in the year, some cyclopoid species 'awake' from their diapauses and contribute to the over-wintering populations in the zooplankton.

Reference Cited

Sommer, U., Gliwicz, Z.M., Lampert, W., and Duncan, A., 1986, The PEG-model of seasonal succession of planktonic events in fresh waters: Archiv für Hydrobiologie, v. 106, no. 4, p. 433–471.

Prepared by USGS West Trenton Publishing Service Center.
Edited by Valerie M. Gaine.
Graphics and layout by Timothy W. Auer.

For additional information, contact:
Director, MD-DE-DC Water Science Center
U.S. Geological Survey
5522 Research Park Drive
Baltimore, MD 21228

or visit our Web site at:
http://md.water.usgs.gov

Koterba, M.T., and others—**The Water-Quality Monitoring Program for the Baltimore Reservoir System, 1981–2007**—Scientific Investigations Report 2011–5101

ISBN 978-1-4113-3170-9

Printed on recycled paper