Martin O'Malley
Governor

John R. Griffin
Secretary

Deep Creek Lake Water Quality Monitoring Program, FY2011 Report

---

Prepared for Maryland Park Service

MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

Resource Assessment Service
MD Department of Natural Resources
Tawes State Office Bldg., D-2
Annapolis, MD 21401
www.dnr.maryland.gov

November 2011

Mission Statement

The Department of Natural Resources leads Maryland in securing a sustainable future for our environment, society, and economy by preserving, protecting, restoring, and enhancing the State's natural resources

The facilities and services of the Maryland Department of Natural Resources are available to all without regard to race, color, religion, sex, sexual orientation, age, national origin or physical or mental disability.

This document is available in alternative format upon request from a qualified individual with disability.

Additional Telephone Contact Information:

- Toll free in Maryland: 1-877-620-8DNR ext. 8627
- Out of state call: 410-260-8627
- TTY users call via the MD Relay

Reference:

Garrison, J. Shermer. 2011 Deep Creek Lake water quality monitoring program, FY2011 report. Prepared for Maryland Department of Natural Resources' Park Service. Resource Assessment Service, MD. Dept. Natural Resources, Annapolis.. xxp. + appendices..

This report is formatted as an electronic Adobe® Acrobat® document for viewing on the Internet or a computer. Limited copies of this report are printed on recycled paper. If you print a copy of this report, please use recycled paper to help conserve our resources

Executive Summary

Beginning in April 2009, DNR's Resource Assessment Service initiated a water quality study of Deep Creek Lake at the request of the Lake Manager and the Deep Creek Lake Workgroup. A seasonal, spatially diverse monitoring plan was developed that would characterize the lake's water quality condition, spatial and seasonal variations and define a baseline for future trend analyses.

This plan identified 7 monitoring sites in the mainstem lake between the dam and Turkey Neck and sites in 9 significant embayments. At each site, field water quality measures are recorded (temperature, dissolved oxygen, pH, conductivity) and water samples collected for laboratory analysis of nitrogen and phosphorus, suspended particulates and chlorophyll (a measure of algae). Starting in April 2009, data and water samples have been collected from each site monthly in the summer (May – September) and, weather permitting, in the fall (November), winter (January) and spring (March).

To assess stream loads of nutrients and sediment flowing into the lake, DNR also collects water quality samples for analysis of nutrients and sediments each month and during storm flows at two USGS stream gages on Cherry Creek and Poland Run. Additional water samples have been collected from other areas and analyzed after reported fish kills or algal blooms or to assess other complaints.

- Water quality conditions in the upper layers of the mainstem lake during summer fully support boating, fishing and water contact (swimming) activities in terms of State criteria including temperature, dissolved oxygen, pH and turbidity. High surface water temperatures during the 2010 and 2011 summer season resulted in a slightly shallower, but stronger thermocline and lower oxygen levels were observed near the thermocline in upper water layer.
- In shallower embayment sites in the lake, water quality conditions in this portion of the lake fully support recreational uses and aquatic life.
- Data from this monitoring effort shows that the trophic State or biological productivity of Deep Creek Lake is *Mesotrophic*. These waters have moderate levels of nutrients (nitrogen, phosphorus), chlorophyll (a measure of the mass of algae in the lake) and water clarity all which results in a moderate, but diverse level of biological productivity, including aquatic plants. The moderate trophic level supports a wide range of ecreational uses and habitat for aquatic life. The trophic status of Deep Creek Lake is among the best among public, recreational lakes in Maryland.
- Water quality data collected in this study data show good lake conditions for recreational uses, however, there remains a serious water quality concern caused by mercury contamination in the watershed from sources in other States. The principal source of this toxic contaminant is from coal-fired power plants in the US Midwest which emit mercury into the air. Through precipitation or dryfall, air deposition of mercury compounds on the lake and its watershed works its way to streams and the lake and, through the food chain, it accumulates in fish at levels that could harm human health problems if enough fish were consumed.. This is an issue that occurs in many other State lakes and is not isolated to Deep Creek Lake. The Maryland Department of the Environment advises that people

should limit their monthly consumption of certain fish taken from Deep Creek Lake, including Chain pickerel, Small and Largemouth bass and Yellow perch.

- While there are few historic water quality data sets to compare current measures, a cursory examination of trends appears to show an increase in conductivity (a measure of dissolved ions, like salts, which dissolves into water. An increase in conductivity indicates an increase some pollutant(s) that may include salts for deicing, nitrogen or phosphorus fertilizers or nitrates from septic tanks.
- Since fall 2010, the addition of automated samplers has allowed DNR to collect stream water samples during storms which will help us quantify nutrient and sediment loading to the lake.
- The design of this monitoring program will characterizes water quality conditions in Deep Creek Lake, but the monthly sampling interval cannot address short-term events or localized issues, like fish kills, algal blooms, and shoreland runoff to the lake

Table of contents

List of tables

List of figures

Introduction

Beginning in April 2009, DNR's Resource Assessment Service initiated a water quality study of Deep Creek Lake at the request of the Lake Manager and the Deep Creek Lake Workgroup. A seasonal, spatially diverse monitoring plan was developed that would characterize the lake's water quality condition, spatial and seasonal variations and define a baseline for future trend analyses. This program has now continued for a third year and this report addresses findings through summer of 2011.

Program goals

Continue implementation of a water quality monitoring program from fixed sites that are representative of open waters, selected embayments and tributaries of Deep Creek Lake to:

- define current water quality condition of the lake (physical and chemical characteristics and levels of nutrients and primary productivity),
- define baseline conditions to evaluate changes in water quality as trends,
- expand on selected existing tributary monitoring efforts to collect data to quantify annual loadings of nutrients and sediments from tributary streams.

Data usage / availability

All collected water quality data have been processed and stored on local DNR datasets in Microsoft Excel-formatted files. A hardcopy of the field and laboratory data collected are available in this report (Appendix A). An electronic copy of these files are available upon request.

Development of a publicly-accessible database through the Deep Creek Lake website is not currently scheduled due to resource constraints. However, efforts to provide public access to these data will continue. Water quality data in DNR databases will eventually be submited submitted through the State's node to the US Environmental Protection Agency's Water Quality Exchange (WQX) for long-term record-keeping and public access. Streamflow data from gages on Cherry Creek and Poland Run may be obtained from the US Geological Survey website: http://waterdata.usgs.gov/MD/nwis/.

Interim results of water quality monitoring efforts were presented to those attending the Deep Creek Lake Workgroup meetings and the Property Owner's Association annual meeting in August 2010. A technical poster presentation on long-term water quality trends in Deep Creek Lake watershed posted at the MD Water Monitoring Council annual meeting in Linthicum, MD in November 2010. Copies of these Microsoft PowerPoint slides and poster presentation are provided in Appendix C.

Prior to publishing this report, copies of DRAFT lake water quality datasets have been shared with staff of the MD Department of the Environment (MDE), which was evaluating whether to address Deep Creek Lake's seasonally low bottom oxygen conditions as a water quality impairment due to excess phosphorus and for assessment of reported fish kill event in June-July 2010 and an algal bloom event in August 2010.

Monitoring plan

Network design - lake

The FY2010 lake water quality monitoring plan (initiated in April 2009) was guided by a need to define water quality conditions of the lake in terms of physical and chemical characteristics and primary productivity. Before establishing sampling stations for this program, the long-term water quality monitoring record for Deep Creek Lake was reviewed. Many of the lake mainstem and tributary cove sampling stations are the same as or are near other water quality sampling sites that have been sporadically monitored since 1970. A widely spatial sampling pattern of sites in Deep Creek Lake mainstem and select tributary embayments was defined and are listed and shown in Table 1 and Figure 1. For FY2011, this program was continued as initially designed

> A network of seven monitoring sites for *in situ* water monitoring sites were spread throughout the mainstem lake between the dam/spillway area to the most upstream limit of the lake near Turkey Neck. *In situ* water column measures (temperature, pH, conductivity, oxygen) are recorded at each station. Water quality samples for laboratory analysis of select dissolved and particulate substances (nutrients, suspended sediments and biological pigments like chlorophyll) would be collected at only four of the most widely-spaced mainstem sites near the surface and near the bottom (Table 1; Figure 1).

Spatial water quality gradients in the mainstem lake are gradual, so a sampling network for physical, chemical and productivity measures are well spaced throughout the main lake. Measured profiles of temperature, pH, conductivity and dissolved oxygen through the water column define the thermal structure, seasonal cycling and are traditionally used to assess overall lake condition.

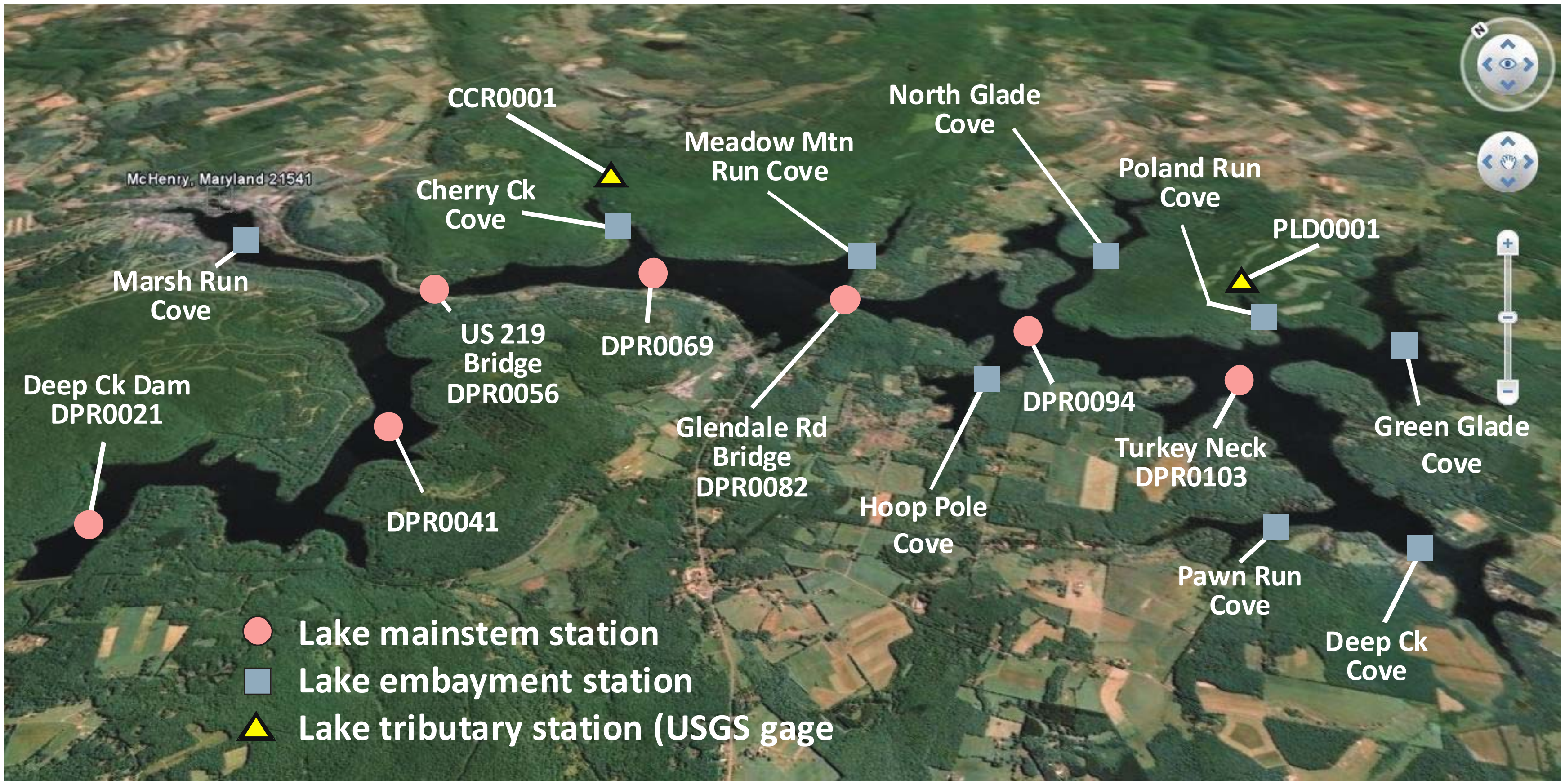
> Eight major tributary embayments were selected for monitoring, including Marsh Run, Cherry Creek, Meadow Mountain Run, North Glade Creek, Hoop Pole, Green Glade, Pawn Run and Deep Creek Coves. In addition to these sites, Poland Run Cove, one of the smallest embayments and tributary watersheds to Deep Creek Lake was included as land use in the watershed is rapidly changing from forest to developed (residential/golf course) and the US Geological Survey (USGS) is monitoring stream flow in lower Poland Run. (Table 1; Figure 1)

Compared to mainstem lake sites, higher levels of nutrients and suspended sediment are expected in lake embayment sites, for several reasons. Here, the ratio of source water volume (direct and collective watershed runoff and groundwater) to the volume of the embayment is much larger than in the mainstem lake so it will reflect more the source water quality rather than that of the lake. Water samples in embayment monitoring sites will have less residence time than mainstem water samples, so there is less time for settling of particulates and wind-forced mixing in shallower embayments will bring surface waters in contact with the sediments more frequently than waters in the deeper mainstem lake. It is expected that different land cover in these watersheds would affect embayment water quality in distinctive ways , however, seasonal and spatial variability has been high with low sample size (n=18, Apr 2009-June 2011) to statistically discern any watershed-related water quality differences. Continued monitoring (increasing the numbers of observations) will increase statistical power for comparisons.

Deep Creek Lake Water Quality Monitoring Program stations

DNR Station	Waterbody	River Mile	Latitude (dd mm N) NAD83	Longitude (dd mm W) NAD83	Description
Mainstem lake monitoring sites					
DPR0021	Deep Ck Lake	2.1	39 30.8652	79 23.1183	N of Slide Hollow, 0.4 m above spillway at deepest point,
DPR0041	Deep Ck Lake	4.1	39 30.6482	79 21.6219	N. Bee Tree Hollow, deepest spot (***in situ profile only***)
DPR0056	Deep Ck Lake	5.6	39 31.6882	79 20.6991	N side of MD Route 219 Bridge, deepest spot
DPR0069	Deep Ck Lake	6.9	39 31.1750	79 19.3950	Cherry Ck Cove mouth – mid-channel (***in situ profile only***)
DPR0082	Deep Ck Lake	8.2	39 30.4264	79 18.6791	N side of Glendale Rd. bridge
DPR0094	Deep Ck Lake	9.4	39 29.4880	79 18.0310	Between N Glade/Hoop Run Coves – (***in situ profile only***)
DPR0103	Deep Ck Lake	10.3	39 28.6372	79 17.4983	NW Turkey Neck, deepest location
Lake embayment monitoring sites					
MRC0011	Marsh Run Cove	1.1	39 32.5163	79 21.2310	Between ski area and McHenry
CCC0008	Cherry Ck Cove	0.8	39 31.8160	79 19.1610	Mid-distance between head and mouth of Cherry Ck. Cove
MMR0005	Meadow Mtn. Run Cove	0.5	39 30.6632	79 18.3678	0.5 mi NE of Glendale Rd. bridge - recoded from MMR0005
NGC0010	North Glade Cove	1.0	39 29.8800	79 17.1300	SW of Harvey Peninsula
UDC0004	Hoop Pole Cove	0.4	39 29.4583	79 18.47748	N of end of Boy Scout Rd
PLV0004	Poland Run Cove	0.2	39 28.8720	79 16.7880	Mid-distance between mouth and head of Poland Run Cove
GGC0015	Green Glade Cove	1.5	39 28.3614	79 16.4219	0.5 mi E of Turkey Neck, 0.2 mi NW of Hazelhurst at deepest cross section point
PWC0004	Pawn Run Cove	0.4	39 27.9410	79 18.6780	Mid-distance between head and mouth of Pawn Run Cove
DPR0119	Deep Creek Cove	0.6	39 27.3300	79 18.2470	Center of Deep Creek Cove - 0.5 mi S of Pawn Run Cove mouth. Original site (DPR0116) moved upstream starting May 2009
Lake tributary monitoring sites - enhanced nontidal stream monitoring					
CCR0001*	Cherry Creek	0.2	39 32.2335	79 18.9510	Cherry Creek at State Park Rd Bridge - USGS 03075905
PLD0001*	Poland Run	0.1	39 29.1850	79 16.5967	Poland Run nr Swanton, MD USGS 03075800

** Enhanced stream station (Base and storm flow sampling)*



FY2011 Deep Creek Lake water quality monitoring program sampling locations (Image source: ***GoogleMap***)

Each of the tributary embayment sampling sites are shallow compared to mainstem lake sampling sites and the presence of a seasonal thermocline is seldom observed unless the sampling site is located in a deep portion of the cove. Vertical profiles of temperature, dissolved oxygen, specific conductivity, and pH show lower variance, indicating that these embayment waters are well-mixed.

Network design - mainstem lake

The Maryland Department of Natural Resources (DNR) has historically collected and analyzed water quality samples each month since 1980 from a single, long term tributary to Deep Creek Lake. This site is located on lower Cherry Creek (CCR0001) at the crossing on State Park Road (Figure 1). This monitoring effort is funded as part of a federal Clean Water Act S.106 (water pollution) grant to Maryland as part of the US Environmental Protection Agency's (EPA) national water monitoring network and is continuing. Data from this single site provides long-term data and a basis for analysis of water quality trends.

In 2007, the DNR Park Service contracted with the US Geological Survey (USGS) to install and operate two real-time automated stream gages on lower Cherry Creek (USGS gage 03075905) and on lower Poland Run (USGS gage 03075800) (Figure 1). These sites were identified as being the largest watershed to Deep Creek Lake (Cherry Creek) and as a small watershed in which the dominant forest cover is being transformed into residential/commercial (golf course) land cover (Poland Run). The USGS gage on Cherry Creek is located immediately upstream of the State Park Road crossing where DNR has maintained its long-term water monitoring site.

Stream gages indirectly measure water flow by accurately measuring water level in the stream. By occasionally relating measured stream flow to water level during different seasons and flow stages, a statistical relationship between water level and stream flow can be defined. Stream flow data are reviewed and are posted every 15 minutes on the USGS' National Water Information System (Cherry Creek site - *http://waterdata.usgs.gov/usa/nwis/uv?03075905*); Poland Run site - *http://waterdata.usgs.gov/usa/nwis/uv?03075800*).

By sampling nutrients and sediment concentration as water quality conditions under different stream flows at different seasons, the load of material (mass, as in tons of nutrients, sediments, etc.) carried by these streams into the lake can be determined. The Chesapeake Bay Program partnership is using this process at stream gage sites throughout that watershed to:

- define relative pollutant loadings in tributary streams under different geological settings and land cover,
- define trends over a long period of time and,
- assess changes that upstream management activities (e.g., stormwater controls, best management practices, point source discharges) are having on the total amount of pollutants that are being discharged to the Bay.

At a smaller scale, this process is also being used by DNR to assess changes in nutrient and sediment loadings due to watershed restoration activities that are funded by the State's Chesapeake and Atlantic Coastal Bays Trust Funds. Because water samples must be collected over a range of streamflow conditions over different seasons, several years of data collection activities are required.

DNR's Resource Assessment Service has been collecting monthly stream samples at Cherry Creek and Poland Run stream gage sites since April 2009 (weather sometimes limiting physical access to the site or freezing conditions that affect sampling operations). Stormflow samples are planned at each site twice each quarter, though few were collected unless a storm event occurred on a predetermined sampling date. Sampling methods follow those prescribed in the Chesapeake Bay Non-Tidal Network program QA Project Plan (depth integrated samples collected at one to five intervals equally spaced across the stream). In August 2010, the installation of ISCO automated samplers in sheds along with stream gage equipment at both the Cherry Creek and Poland Run sites has allowed more consistent storm event sampling.with some samples collected during different flow portions of a storm event (rising flow levels, peak flow, falling flow levels). It will take several years of data collection to have sufficient data to assess loadings of sediment and nutrients with confidence

Other watershed monitoring networks

One component of the DNR-Park Service monitoring contract with DNR-Resource Assessment Service that is not included in this report addresses initial surveys of aquatic vegetation in Deep Creek Lake. In response to some complaints about "aquatic weeds" in upper tributary areas, a two-year assessment survey was conducted in 2010 and 2011. The results of this effort are summarized in a technical report (DNR, 2011).

The Garrett County Health Department routinely collects water quality samples from more than 20 sites around Deep Creek Lake on a regular basis between Memorial Day and Labor Day each year. This local program collects samples primarily for analysis of bacteriological levels to assess and for total nitrogen and total phosphorus. Additional information about this program is available in Appendix C

The MD Department of the Environment has conducted several surveys of Deep Creek Lake over the past five years in efforts to assess water quality complaints (algal blooms, fish kill events) and to determine the presence and extent of water quality impairments and define maximum pollutant loadings that the watershed can assimilate without exceeding criteria. Additional details about MDE's 2010-2011 sampling efforts to assess water quality in shallow embayments in the upstream half of the lake is summarized in Appendix C.

Other recent surveys include State and volunteer monitoring of stream health in the Deep Creek Lake watershed by surveying the macroinvertebrate and fish communities. These are also included in Appendix C.

Monitoring frequency

In most lakes with a water quality monitoring program, water samples are collected during the popular summer recreation season (May through September), when seasonal stratification will occur. For this assessment of Deep Creek Lake, additional water quality surveys have been scheduled during in the spring (March) and fall (November) when the water column is mixed. DNR's water quality field monitoring staff (Monitoring and Non-Tidal Assessment Division - MANTA) coordinate sampling activities with Deep Creek Lake State Park staff who help provide access to sampling sites with a Park Service vessel and providing a boat captain.

In December 2009, additional *in-situ* measures were recorded from sites off the US 219 and Glendale Road bridges, which are near lake stations DPR0056 and DPR0082. During late January 2010, ice cover on the lake was sufficiently thick enough to safely support monitoring staff and gear and, with the assistance of Western Regional DNR Fisheries Service staff, MANTA field staff were able to record *in-situ* measures and collect water samples from the surface and bottom of the lake through holes cut through the ice from sites in the lake near these bridge monitoring sites. One duplicate field sample was collected each month for quality assurance purposes.

In Cherry Creek and Poland Run, water quality and sediment samples were collected each month from April 2009 through June 2011 downstream of USGS gages. Sampling equipment sheds were built and attached to the USGS gage instrument sites and Isco automated samplers were installed in June 2010. Once these became operational, first quarterly storm-flow samples were collected beginning in August 2010.

A summary of monitoring activities by site and season is presented in Table 2.

FY2011 Deep Creek Lake water quality sampling summary

- Number of water quality samples submitted for laboratory analysis. All lake/cove sites include vertical profiles (water temperature, pH, dissolved oxygen, specific conductance)
-

		Summer		Fall			Winter			Spring			summer	
Site	**Station Code**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Total**
Main lake					not planned		**lake ice cover**	not planned	not planned	delayed by ice	replace March			
- Near dam	DPR0021	2	2	2	-	2	-	-	-	-	2	2	2	14
-	DPR0041	[b]	[b]	[b]	-	[b]	-	-	-	-	[b]	[b]	[b]	0
- Deep Ck bridge	DPR0056	2	2	2	-	2	0 [c]	1	-	-	2	2	2	15
-	DPR0069	[b]	[b]	[b]	-	[b]	-	-	-	-	[b]	[b]	[b]	0
- Glendale Rd. bridge	DPR0082	2	2	2	-	2	0 [c]	1	-	-	2	2	2	15
-	DPR0094	[b]	[b]	[b]	-	[b]	-	-	-	-	[b]	[b]	[b]	0
- Turkey Neck	DPR0103	2	2	2	-	2	-	-	-	-	2	2	2	14
Lake embayments					not planned		not planned	not planned	not planned	delayed by ice	replace March			
Marsh Run	MRC0011	1	1	1	-	1	-	-	-	-	1	1	1	7
Cherry Creek	CCC0008	1	1	1	-	1	-	-	-	-	1	1	1	7
Meadow Mtn Run	MMR0005	1	1	1	-	1	-	-	-	-	1	1	1	7
North Glade Cove	NGC0010	2 [a]	2 [a]	2 [a]	-	2 [a]	-	-	-	-	2 [a]	2 [a]	2 [a]	14
Hoop Pole Cove	UDC0004	1	1	1	-	1	-	-	-	-	1	1	1	7
Poland Run	PLV0004	1	1	1	-	1	-	-	-	-	1	1	1	7
Green Glade Creek	GGC0015	1	1	1	-	1	-	-	-	-	1	1	1	7
Pawn Run	PWC0004	1	1	1	-	1	-	-	-	-	1	1	1	7
Deep Creek	DPR0119	1	1	1	-	1	-	-	-	-	1	1	1	7
Tributary streams														
Cherry Ck	CCR0001	1	1	1	1	1	1	1	1	1	1	1	1	12
Poland Run	PLD0001	1	1	1	1	1	1	1	1	1	1	1	1	12

FY2011 Deep Creek Lake water quality sampling summary *(continued)*

		Summer		Fall			Winter			Spring			summer	
Site	**Station Code**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Total**
Tributary streams-storms							**ice cover**							
Cherry Ck	CCR0001	0	0	3	1	4	0	1	2	1	1	4	0	17
Poland Run	PLD0001	0	0	1	0	2	0	1	2	1	4	2	0	13
Other sites														
Unnamed sub-embayment	Beckman1	1 [c]	-	-	-	-	-	-	-	-	-	-	1 [c]	2
Unnamed sub-embayment	Beckman2	1 [c]	-	-	-	-	-	-	-	-	-	-	1 [c]	2
Tributary to UGX	UGX0000	-	-	1 [d]	-	-	-	-	-	-	-	-	-	1
Near Beckman's peninsula	UGXTRIB	-	-	1 [d]	-	-	-	-	-	-	-	-		1
Near Will O' Wisp	WILLOWSP	-	-	-	-	-	-	-	-	-	-	-	1 [c]	1
Arrowhead cove	ARROWHEAD	-	-	-	-	-	-	-	-	-	-	-	1 [c]	1
Near Glendale Bridge	GLENDLBRG	-	-	-	-	-	-	-	-	-	-	-	1 [c]	1
	Total/month	**22**	**20**	**26**	**3**	**26**	**2**	**6**	**6**	**4**	**25**	**26**	**25**	**191**

a (includes *replicate sample for quality control*); **b** (*vertical profile only*); ***c*** (fish kill); ***d*** (algal bloom)

This page intentionally blank

Methodology (protocols/procedures)

Field methods defined in the Deep Creek Lake Monitoring Program Scope of Work and in the Standard Operating Procedures for field sampling by DNR's Resource Assessment Service 's Annapolis Field Office were followed. Laboratory methods for samples collected for analysis follow those defined by the MD Department of Health and Mental Hygiene's Laboratories Administration and the US Geological Survey Sediment Laboratory in Lexington, KY.

At each lake station, local weather and environmental conditions were recorded. A calibrated instrument sonde (YSI6600) was used to measure a water quality profile of some water quality measures (Table 3). Water samples for more quantitative laboratory analysis (Table 4) were collected using a submersible pump for samples near the surface and, for some deep mainstem lake stations, near the bottom. Samples for laboratory analysis were processed, labeled and shipped to the Department of Health and Mental Hygiene laboratory in Baltimore for analysis in accordance with DNR field water quality monitoring protocols.

Deep Creek Lake Water Quality Monitoring Program - *in situ* field measurement parameters/analysis specifications

Parameter	Method/Reference	Sample Preservation	Holding Time	Minimum Detection Limit
*Temperature	*N.B.S.-calibrated EPA 1979 #170*	N/A	< 5 min.	0.1□C
*Dissolved oxygen	*Membrane Probe EPA 1979 #360*	N/A	< 5 min.	0.2 □g/L
*pH	*Glass Probe EPA 1979 #50*	N/A	< 5 min.	0.5 units
*Specific conductance	*Conductivity Bridge APHA #205*	N/A	< 5 min.	5 □mhos/cm
*Secchi disc depth	*8-inch Black/White*	N/A	< 5 min.	0.1 m

In addition to monthly lake samples, monthly water quality samples at both the Cherry Creek and Poland Run gage sites. Samples were collected as vertically integrated samples in accordance with "Non-tidal Network Program Standard Operating Procedures" – May 2006, at equal width intervals if the stream is wide, and composited for analysis. At least two samples are collected at each station each quarter during storm-flow events.

Water quality samples are collected and shipped to the DHMH laboratory for analysis. Sediment samples are labeled, stored and shipped to the US Geological Survey Sediment Laboratory in Lexington, KY for determining sediment concentration and, in storm-flow event samples the sand/fine fractions, as well. Sampling, sample handling and sample analysis conform to the non-tidal sampling QAPP and USGS laboratory SOPs (Table 6).

In addition to parameters that are directly measured, additional water quality parameters will be derived from the results of certain analyses:

- Total nitrogen = Particulate nitrogen + Total dissolved nitrogen
- Dissolved organic nitrogen = Total dissolved nitrogen - (Ammonium + Nitrate+Nitrite)
- Total phosphorus = Particulate phosphorus + Total dissolved phosphorus
- Dissolved organic phosphorus = Total dissolved phosphorus - Toral dissolved phosphorus

Deep Creek Lake Water Quality Monitoring Program - water quality parameters - DHMH laboratory specifications

Parameter	Method/Reference	Sample Preservation	Holding Time	Minimum Detection Limit
Dissolved organic carbon	*EPA 415.1*	Iced/Frozen	48 hrs./ 28 days	0.11 mg/L
Particulate carbon	*Exeter method 440*	Filtered, Frozen	28 days	0.001759 mg C
Ammonium	*EPA 1993 #350.1 (Lachat Flow Injection Analyzer)*	Iced/Frozen	48 hrs./ 28 days	0.037 mg/L
Particulate nitrogen	*Exeter method 440*	Filtered, Frozen	28 days	0.002363 mg N
Total dissolved nitrogen	*Alkaline persulfate digestion followed by EPA 1993 #353.2*	Iced/Frozen	48 hrs./ 28 days	0.033 mg/L
Nitrate + nitrite	*EPA 1993 #353.2 (Lachat Flow Injection Analyzer)*	Iced/Frozen	48 hrs./ 28 days	0.0024 mg/L
Nitrite	*EPA 1993 #353.2 (Lachat Flow Injection Analyzer)*	Iced/Frozen	48 hrs./ 28 days	0.0013 mg/L
Orthophosphate	*EPA 1993 #365.1 (Lachat Flow Injection Analyzer)*	Iced/Frozen	48 hrs./ 28 days	0.0023 µg/L
Particulate phosphorus	*Sample muffling, addition of HCl, followed by EPA 1993 #365.1*	Filtered, Frozen	28 days	0.003 mg/L
Total dissolved phosphorus	*Alkaline persulfate digestion followed by EPA 1993 #365.1*	Iced/Frozen	48 hrs./ 28 days	0.006 mg/L
Suspended solids	*EPA 1983 #160.2*	Iced	7 days	1.4 mg/L
Turbidity	*EPA 1993 #180.1*	Iced	48 hrs.	0.018 NTU
Chlorophyll α Phaeophytin α	*Spectrophotometric SM 20^{th} Ed. #10200 H*	Filtered, Frozen	4 weeks	0.1 mg/L - lowest QC sample
Total alkalinity	*Titration SM 20^{th} Ed. #2320 B*	Iced	14 hrs.	1 mg/L $CaCO_3$ (MDL is NA)

Deep Creek Lake Water Quality Monitoring program - stream sediment analysis - USGS-KY Sediment laboratory

Parameter	Method/Reference	Sample Preservation	Holding Time	Minimum Detection Limit
Suspended sediment	*Filtration or evaporation (very high concentrations) - Guy, 1969; Sholar and Shreve, 1998.*		.	.0001 g

Quality objectives/criteria

For all monitoring projects conducted by the Department, there is a DNR Quality Management Plan for Environmental Data that defines the framework for a system that ensures that quality data are collected. Field SOPs and DHMH Laboratories Administration and the USGS Sediment Laboratory establish data quality and measurement performance criteria (instrument and analysis limits) as well as quality control limits and MD Department of Health and Mental Hygiene's Laboratories Administration

Results

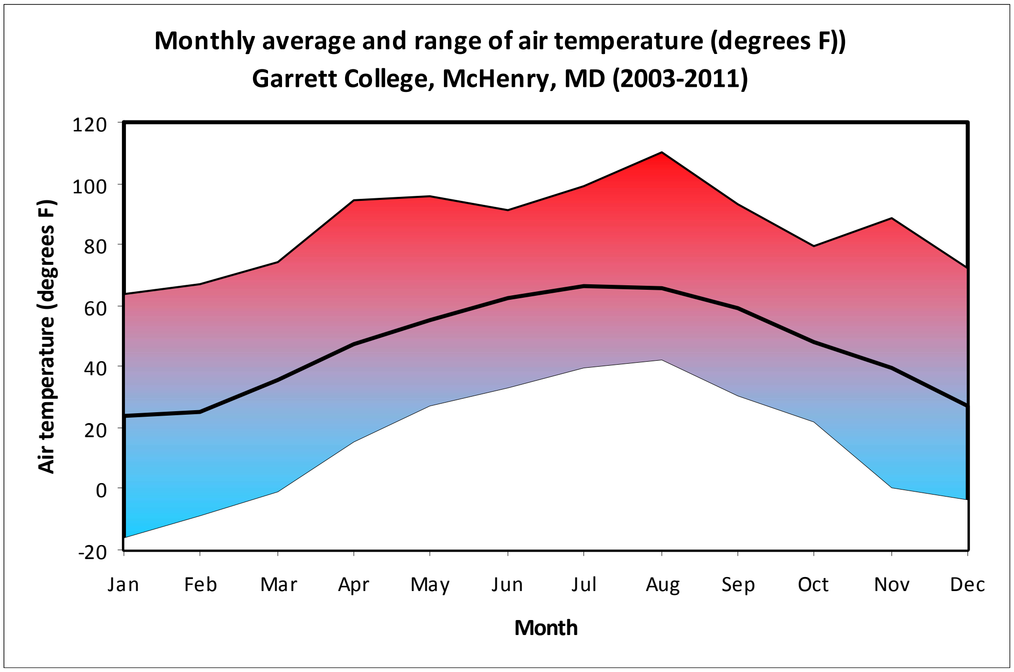
Local climate/weather summary

As a large impoundment, local and short-term climate conditions can have a significant impact on water quality in Deep Creek Lake. Past computer modeling efforts on the lake have used weather data from the National Weather Service site in Morgantown, WV. This site is located about 34 miles WNW of Deep Creek Lake at an elevation of 1,248 feet and within the Appalachian Plateau. About 31 miles and ENE from the lake is the Greater Cumberland Regional Airport, located in Wiley Ford, WV across the Potomac River from Cumberland, MD. This site is slightly closer to Deep Creek Lake than Morgantown, but it lies in the Ridge and Valley Province at an elevation of 775 feet. With Deep Creek Lake location on the Appalachian Plateau and at an elevation of about 2,300 feet, weather conditions at Deep Creek Lake should be more similar to conditions in Morgantown than to Cumberland.

At an elevation nearly twice as high as Morgantown, however, weather conditions at Deep Creek Lake can vary considerably from local Morgantown conditions. In 2003, a weather station was located in Garrett College in McHenry (KMDMCHEN1) at an elevation of 2600 feet. Historic data from this site is available (*http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KMDMCHEN1*) and were used for climate review for the 2009-2011 water monitoring seasons.

Temperature

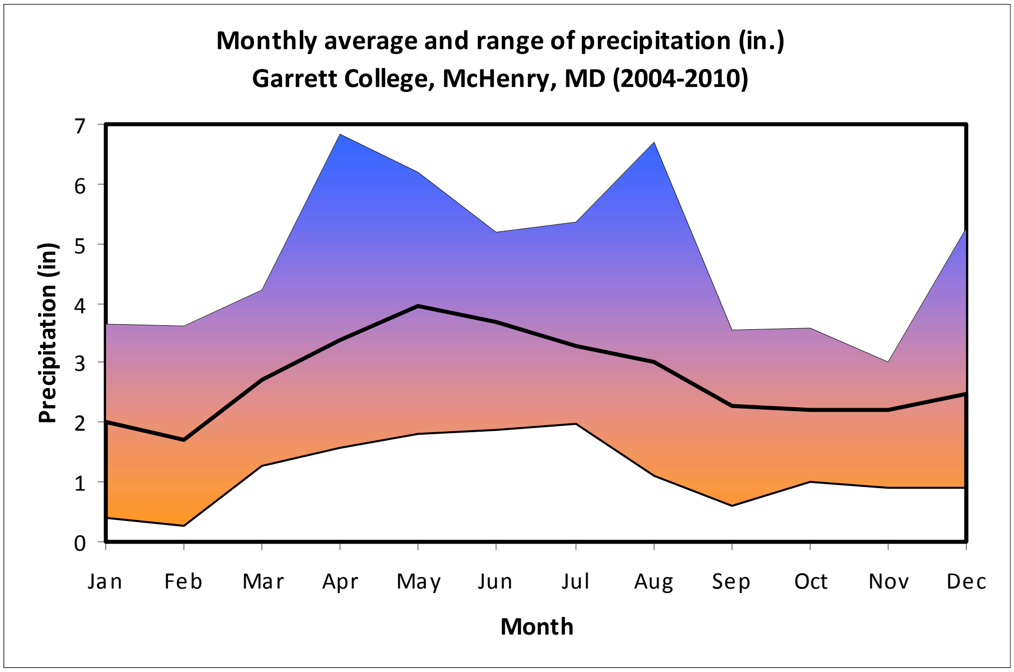
Daily average temperature data were summed by month for air temperature data recorded at the Garrett College weather station between 2003 and 2011. The monthly average and range of air temperatures are shown in the figure below.



Overall the average monthly temperatures are lowest in January and the highest in July, however, there are some excursions with some seasonally warm peaks observed in April, August and November.

Precipitation

Daily precipitation data were summed by month for precipitation data recorded at the Garrett College weather station between 2004 and 2011. The monthly average (black line) and range (shaded block) of precipitation are shown in the figure below.

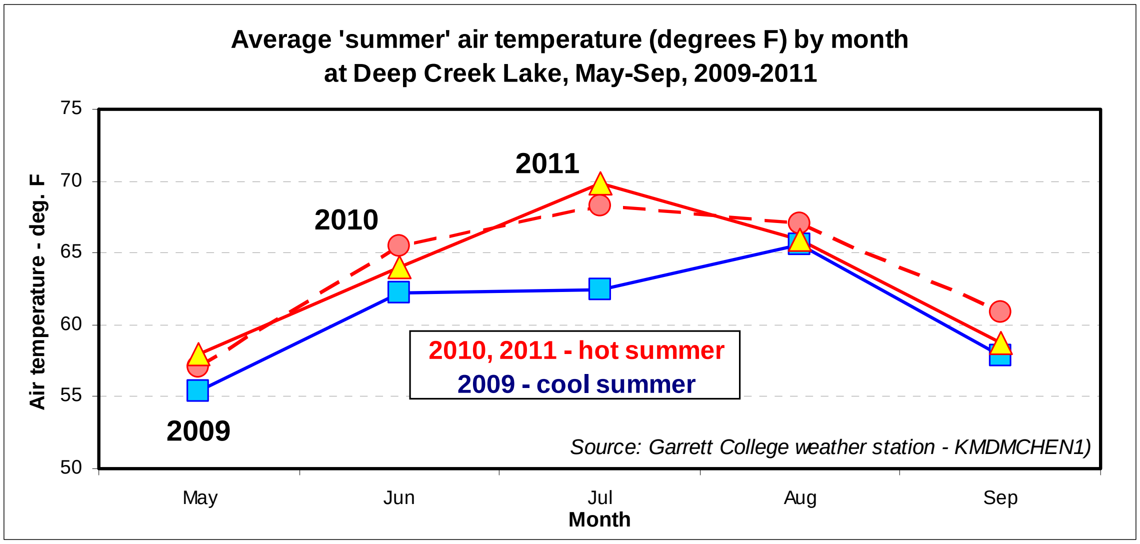


Overall, the highest precipitation occurs in the spring and the lowest precipitation levels occur in the fall. There are some seasonal excursions with high precipitation periods observed in April, August and December and low precipitation periods in February and September.

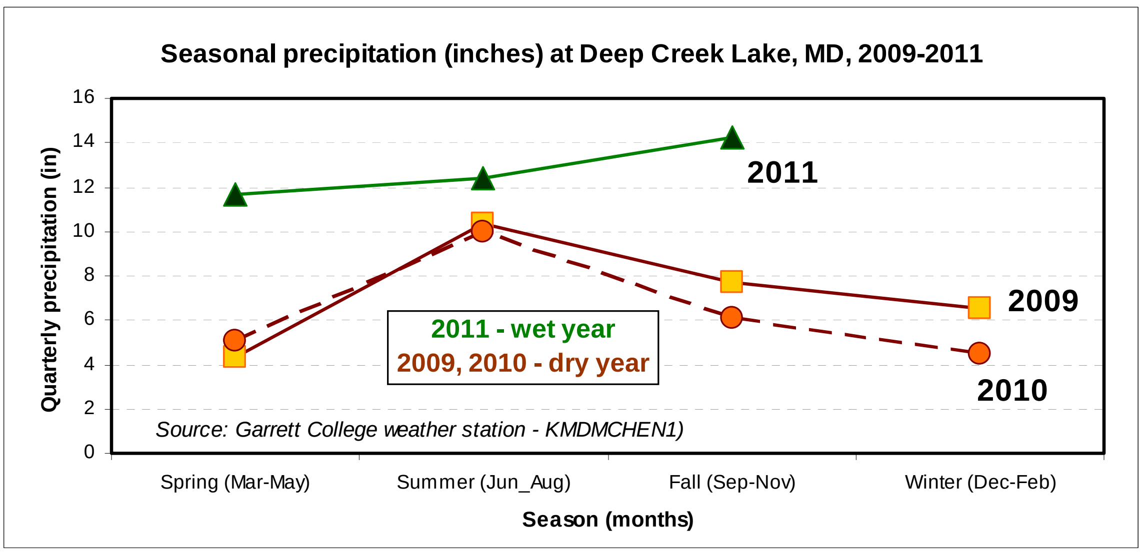
Summary climate conditions

Because of variable nature of temperature and precipitation, these data were examined in terms of monthly and quarterly periods. Significant differences were observed between years that likely affected water quality conditions in Deep Creek Lake.

For example, as shown in the figure below, a review of monthly air temperature data during the summer (May - September) season during the last three years of DNR water monitoring in the lake show that, in contrast to 2009 as a cool summer, both 2010 and 2011 were hot summers. Air temperatures in July in both 2010 and 2011 were, on average, nearly 8 degrees warmer than air temperatures in 2009. Lake processes affected by warmer temperatures (e.g., water temperature, microorganisms/plant/animal metabolism, water evaporation rates) may differ from conditions observed in 2009.



At the same time, the figure below summarizes annual precipitation rates by quarter with similar conditions observed in both 2009 and 2010 that are significantly drier than conditions observed in 2011. Again, lake processes affected by drier conditions (e.g. lower lake levels/fewer releases, lower turbidity and nutrient levels from runoff) may differ from wet conditions seen in 2009.



Combining these results provides the following climate matrix for the lake that may explain some of the observed results:

- 2009 - **cool** summer, dry year
- 2010 - **hot** summer, dry year
- 2011 - **hot** summer, **wet** year

Lake conditions

Water quality

Lake water quality describes the condition of a lake in relation to human needs or values. For example, a lake may be suitable for fishing, swimming, boating or any combination. As different users may perceive lake water quality differently (e.g., a lake that is "good" for fishing may not be considered "good" for swimming), water quality is often reported as a relative, rather than an absolute measure, so there can be different views about water quality of the same lake.

The federal Clean Water Act requires States to define uses of their waters and identify minimum and/or maximum levels of physical, chemical and biological measures that will support these uses. In Maryland, defined uses for waters in Deep Creek Lake watershed (including the lake and tributary streams) are documented in the Code of Maryland Regulations (COMAR 26.08.02.02 and 26.08.02.02-1) (map of designated uses in Garrett County available online at: *http://www.mde.state.md.us/programs/Water/TMDL/Water%20Quality%20Standards/Documents/www.mde.state.md.us/assets/document/Garrett_Cnty_DUs.pdf*).

In regulation, the Maryland Department of the Environment classifies Deep Creek Lake (and all waters in the watershed) as Use III-P for supporting uses including:

- swimming, boating, fishing and all other recreational activities involving water contact,
- protection of aquatic life and wildlife,
- agricultural supply and industrial water supply,
- propagation and growth of natural trout waters, and
- public water supply.

Specific criteria listed in COMAR to protect these uses are defined by limits on water temperature, dissolved oxygen, pH, bacteria and a long listing of toxic substances, including metals, inorganic and organic contaminants, are defined in COMAR 26.08.02.03-1 and 26.08.02.03-2).

The goal of this monitoring survey was not to assess whether Deep Creek Lake was impaired or that these waters meet water quality criteria for its designated use. These data, however, exist and were reviewed with respect to published criteria limits. A simple review of data collected in the surface waters (0.5 to 1m depth) of mainstem and tributary cove sites showed that since April 2009:

- no observations of surface dissolved oxygen concentrations were less than the minimum criterion of 5 mg/L, and
- at only 1 observation (out of 358 profiles) did the surface layer have a measured pH value below the minimum of 6.5 standard units. No observations exceeded the maximum pH criterion of 8.5.

Additionally, the Garrett County Health Department Environmental Director reported that there were no elevated levels of *Escherichia coli* bacteria in Deep Creek Lake in the summer of 2010 or 2011.

For several water quality measures, some data appear to exceed specific water quality criteria and further explanation is necessary. For example, out of 193 summer season (May – September) lake surface water temperature observations (2009-2011), 115 (nearly 60 percent exceeded the temperature criterion of 20 degrees C (68 degrees F). This is a result of natural solar heating of the lake and its tributaries rather than any effluent source, like a power plant. As the cause is natural, these high temperatures are not considered to be an impairment.

Also, during the summer season, the mainstem lake becomes thermally stratified with a warm surface layer (epilimnion) extending to a depth of 7 to 9 meters in depth and a cooler, deep water mass (hypolimnion) below that. At these depths, algae cannot produce oxygen because it is too deep for sunlight to penetrate and the thermocline forms a density barrier that slows the transfer of oxygen from the upper to the lower water mass. Respiration by bacteria, algae and animals in the hypolimnion slowly reduce oxygen levels below defined criteria and, in some cases, oxygen may be absent (anoxia). In these instances, only anaerobic bacteria can survive. These conditions will persist until the fall season (late September-October) when cooler surface water temperatures cool and approximate deep water temperatures and the water column becomes completely mixed. Because most of the waters in embayments do not exceed 7 to 9 meter depth, the seasonal thermocline in the mainstem lake will not be observed in the embayment areas. Again, the cause of the seasonally lower oxygen levels are due to natural stratification and respiration, so the these are not considered as impairments. In 2010, MDE studied this issue and determined that the low oxgen levels in the lake were not due to eutrophication by excessive phosphorus (MDE, 2010).

MDE currently identifies two impairments in Deep Creek Lake and watershed:

- Deep Creek Lake was identified on the State of Maryland's draft 2002 list of Water Quality Limited Segments [303(d) list] as impaired by mercury contamination, based on data for mercury concentrations in fish tissue. In 2002, the Maryland Department of the Environment (MDE) identified Deep Creek Lake as documented elevated methylmercury levels in the edible flesh of several fish species in the Deep Creek Lake (reference). The report on this impairment identifies the major source of methylercury as air deposition on the watershed due to air emissions from coal-fired power plants in the US Midwest. These compounds are carried into the lake, taken up and concentrated through the food chain until it reaches top predator species. Because fishers and their families catch and consume these fish and may accumulate methylmercury levels that can harm their health, MDE has issued a warning suggesting that the public limit their monthly consumption of Chain Pickerel, Yellow perch and Small- and Largemouth bass taken from Deep Creek Lake (and many other lakes in the State). The Total Maximum Daily Load report on this impairment is available online at: *http://www.mde.state.md.us/programs/Water/TMDL/ApprovedFinalTMDLs/Documents/www.mde.state.md.us/assets/document/Deep%20Creek%20Lake_122702_final(2).pdf*

- In 2002, MDE identified poor biological conditions in streams in the Deep Creek Lake watershed as an impaired condition (reference). This assessment was based on data from DNR's periodic Statewide survey of fish and macroinvertebrate health in its rivers and streams. Of the 12 sites assessed in the watershed, 11 (82%) were defined as being in poor health based on macroinvertebrate community indices and compared to reference conditions. Only one site was identified as being in Fair condition, due to better fish community indices. MDE has not yet developed an assessment of the cause(s) or source(s) of these impairments.

The Deep Creek Lake watershed is located within the Western Maryland Sub-basin in Garrett County, Maryland and is a sub-basin of the Youghiogheny watershed. The watershed drains an area of 41,435 acres and is mostly forested with significant agricultural acreage and recreational home development generally along the lake's shoreline.

The Maryland Department of the Environment (MDE) identified the waters of Deep Creek Lake and the Deep Creek Lake watershed on the following State submission to the US Environmental Protection Agency of updates to the federal Clean Water Act S.303(d) List of impaired waters in Maryland:for the following impairments:

- nutrient enrichment (excessive phosphorus) in Deep Creek Lake watershed (1996) and Deep Creek Lake (1998)
- low pH in Cherry Creek (1996)
- biological community impairment in Deep Creek Lake watershed (2002)
- methylmercury in Deep Creek Lake (2002), and
- fecal coliform bacteria in Deep Creek Lake watershed (2006).

An analysis of recent data and computer simulation modeling either confirms an impairment and defines the Total Maximum Daily Load (TMDL) or defines that there is no impairment and the summary reports provide documentation as a Water Quality Analysis report. In 2003, an impairment in Cherry Creek due to low pH levels was documented and a TMDL was approved by EPA.

In 2004, an impairment in Deep Creek Lake due to elevated methylmercury levels in sportfish was identified and a TMDL was approved by EPA. MDE has a regular fish tissue monitoring effort which examines toxic contaminants that can accumulate in commercial and recreationally-caught fish and shellfish. MDE maintains a Fish Consumption Advisory website which identifies all waterbodies in the State where public health advisory is listed (http://www.mde.state.md.us/programs/marylander/citizensinfocenterhome/pages/citizensinfocenter/fishandshellfish/index.aspx).

Fish consumption advisory for mercury contaminated fish, Deep Creek Lake

Consumption recommendations based on spacing of meals to avoid elevated exposure levels

Recommended meals per month

	General population (8 oz meal)	Women (childbearing age or are nursing) 8 oz. meal	Children (3 oz. meal)
Chain pickerel	6	5	3
Small / largemouth bass	4	3	2
Yellow perch	8	7	4

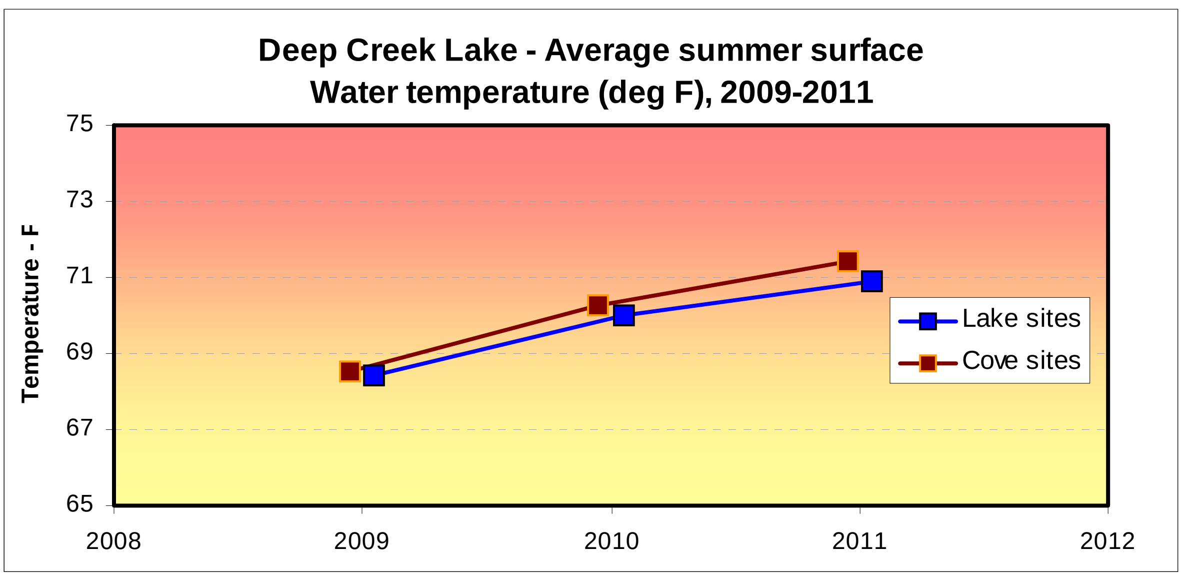
Source:
http://www.mde.state.md.us/programs/Marylander/CitizensInfoCenterHome/Documents/www.mde.state.md.us/assets/document/Maryland%20Fish%20Advisories%202011.pdf

In 2011, there was no impairment identified in Deep Creek Lake due to excessive phosphorus as a cause for eutrophication and this cause was removed from the impaired waters listing as EPA approved the Water Quality Analysis report.

For more information about Maryland's impaired waters, completed TMDL or WaterQuality Analysis reports, the reader is encouraged to explore the MDE Impaired waters website (*http://www.mde.state.md.us/programs/Water/TMDL/Integrated303dReports/Pages/Programs/WaterPrograms/TMDL/Maryland%20303%20dlist/index.aspx*)

http://www.mde.state.md.us/programs/Water/TMDL/Integrated303dReports/Documents/Integrated_Report_Section_PDFs/2010%20Integrated%20Report%20FINAL_Part_F5.pdf
1st through 4th order streams Fish and Benthic IBI cause unknown Low priority to address

Water temperature
Water temperature is an important . Temperature governs seasonal stratification of the lake, , the rate of biogeochemical and ecological processes, including reproduction, growth and habitat preferences among aquatic organisms. Water temperature also affects how people may recreate on the water (an exception here is made for the annual Deep Creek Dunk where the danger of wading into the lake during winter is apparently offset by the internal warmth of earning donations to support Special Olympics).

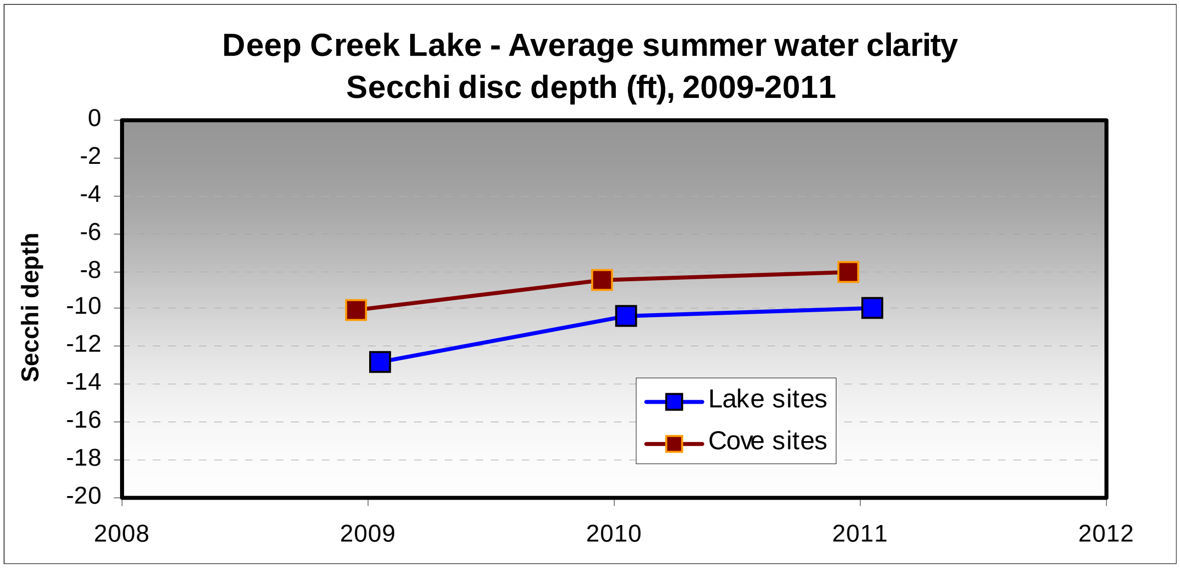


Water temperatures observed in Deep Creek Lake in FY 2011 ranged from 0.0 to 26.3 degrees C – the coldest occurring at the surface in January 2011 and the warmest at the surface in July 2011. A comparison of ***average*** annual summer season (May-September) surface water temperatures are shown in the figure below.

Between June and August at most lake sites, surface water temperatures exceeded the numeric temperature criteria for Use III-P waters (20 degrees C), which is the State's classification for

Deep Creek Lake, however, these high temperatures are naturally occurring due to direct solar insolation to the lake's surface and are not a result of any heated discharge, so there is no defined impairment by MDE.

Water clarity
Measured with an 8-inch Secchi disk, water clarity is recorded as the depth where the disk, with black and white quadrants, disappears/appears when lowered over the side of the boat. Water clarity expresses



Surface water temperatures at most lake sites between June and August exceeded the numeric temperature criteria for Use III-P waters, which is the classification Deep Creek Lake, however, these high temperatures are naturally occurring due to direct solar insolation to the lake's surface and are not a result of any heated discharge, so there is no defined impairment by MDE.

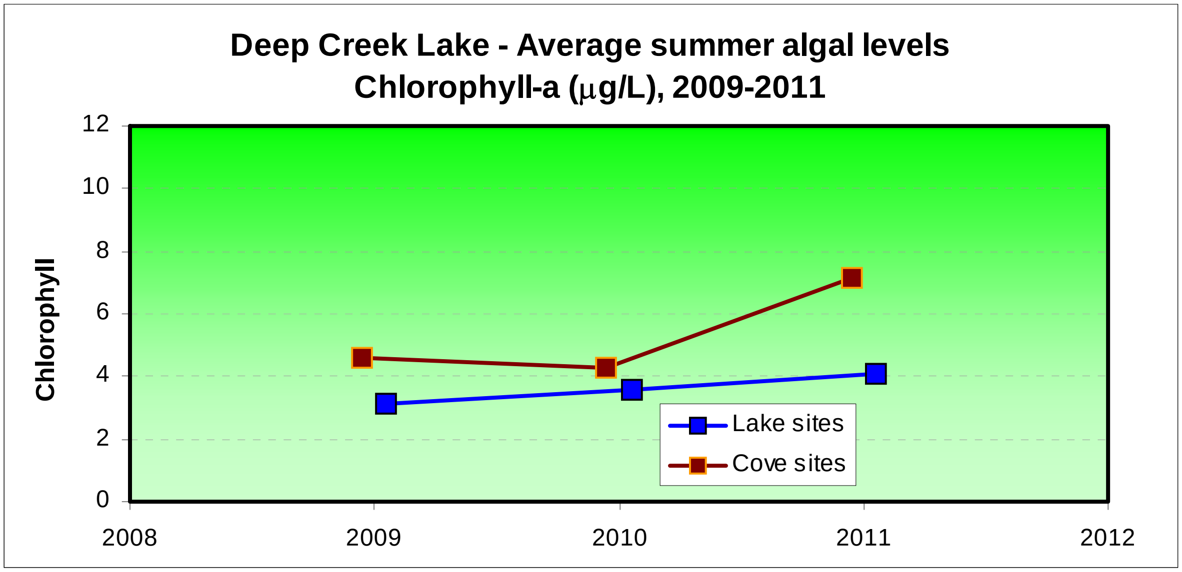
Summary:

- Average summer water clarity is higher (deeper Secchi depth) in mainstem lake than in tributary coves – averaging nearly 2 feet more visibility than the mainstem lake.
- Comparison of years show some change with lower water clarity during wet summers (2010, 2011) than in dry summers (2009).Lower water clarity during wet years
- When compared to Carlson's trophic scale, the average summer water clarity throughout the lake (mainstem and embayment coves) suggests that the lake is mesotrophic (6.6 to 26.2 feet). At times, low Secchi depths (less than 6.6 feet) observed in embayment sites suggest these waters are eutrophic (low water clarity due to an abundance of phytoplankton), but the embayments are shallow areas that are close to sources of runoff, shoreline erosion and turbulent mixing from the bottom. As explained later, trophic status is an assessment of biological productivity and proper interpretation of measured parameters requires that samples/data are reported as summer averages that are recorded in the deepest and most downstream portions of the lake. Where water clarity is affected by inorganic particulates

(silt/clay particles), assessment of lake trophic state using Secchi depth provides inaccurate results.

Chlorophyll a

The measure of chlorophyll-a, the principal photosynthesis molecule in many plants, provides an easy-to-assess approach to physically measuring algal biomass. In 2011, surface chlorophyll concentrations during summer ranged from 1.0 to 10.6 μg/L in mainstem sites and from 2.1 to 14.1 μg/L in embayment sites.

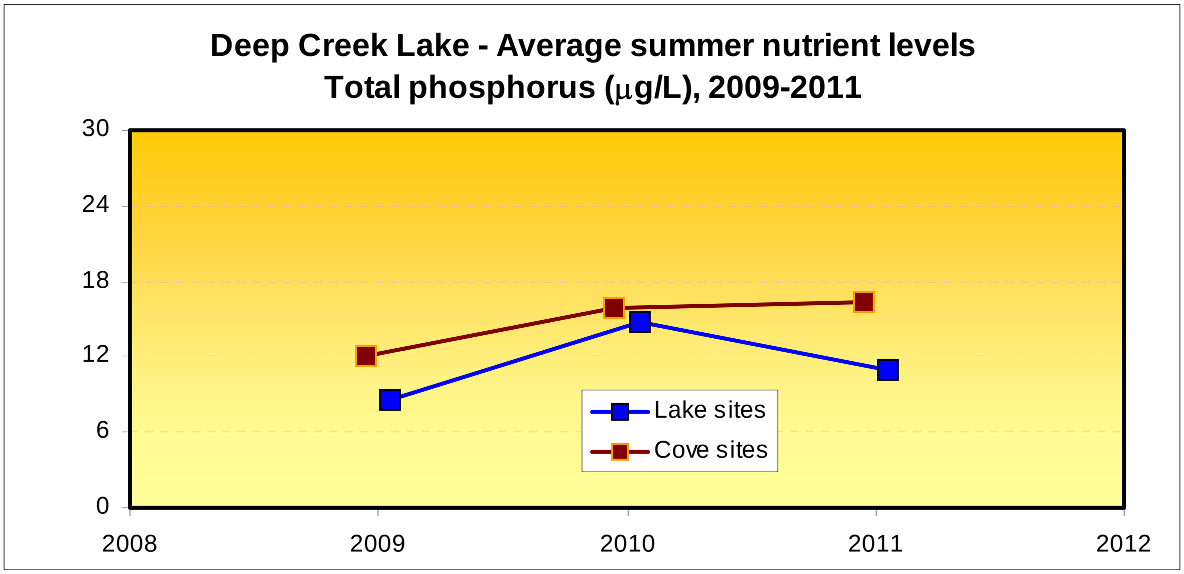


Summary:

- Higher chlorophyll/algae in coves
- Increased algae with nutrients (P) and warm temperatures,
- Average chlorophyll within mesotrophic range (1 to 7.3); highest levels in eutrophic range

Nutrients - phosphorus

In most instances, there is sufficient nitrogen in lakes and reservoirs to support a larger plant biomass, but additional growth is limited by the amount of available phosphorus in the system.

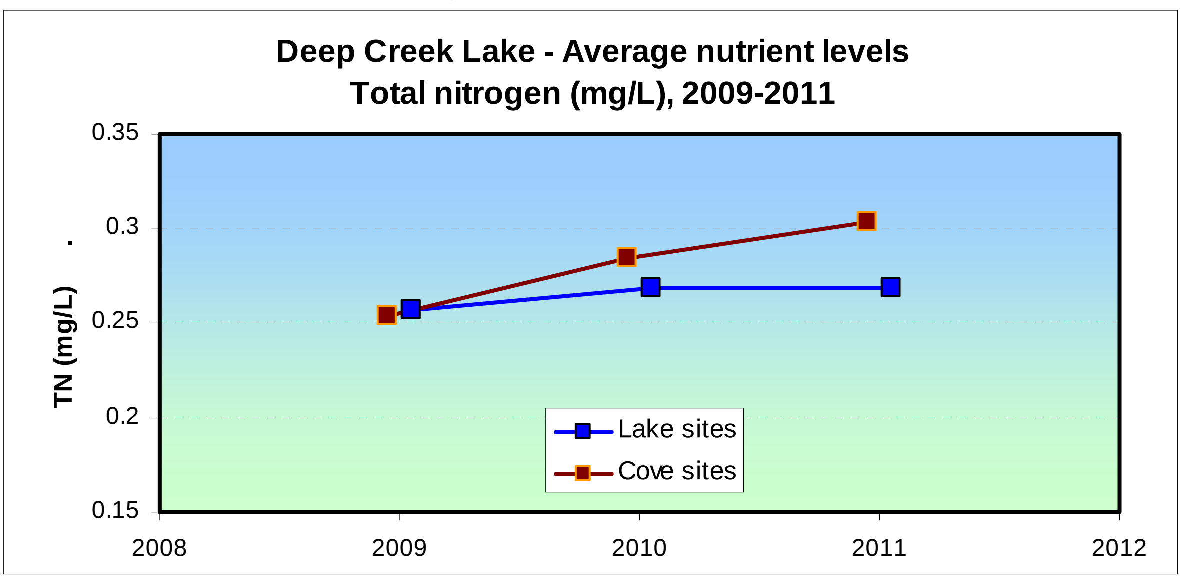


Summary:

- Higher total phosphorus (nutrient) levels are found in embayment areas coves than in the mainstem lake.

Nutrients - nitrogen

In most instances, there is an excess of nitrogen in lakes and reservoirs. This is not utilized by plants because of limited availability of the other principal nutrient, phosphorus.



Summary:

- Total nitrogen (nutrient) levels are slightly higher in coves than in mainstem lake.

Trophic status

"Trophic state" is defined as the total weight of living biological material (*biomass*) in a waterbody. It is the biological response to factors such as nutrient additions, but it also is modified by factors such as season, grazing, mixing depth, and so on. As a result, trophic state does not defining a static type of lake, but rather a continuum of "states" or condition.

Trophic state is often used to describe lake water quality, but it is an absolute measure describing the biological condition of a waterbody, not a relative measure that is subject to change because of the attitude or biases of the observer. An *oligotrophic* or a *eutrophic* lake has attributes of production that remain constant no matter what the use of the water or where the lake is located. For the trophic state terms to have meaning at all, they must be applicable in any situation in any location

Carlson's (1977) trophic state index (TSI) uses algal biomass to define these states using chlorophyll pigment levels, Secchi depth, and total phosphorus - each of which can be used to independently estimate algal biomass. Equations often used to calculate Carlson's Trophic State Index from Secchi disk depth (SD), Chlorophyll-a (CHL) and Total Phosphorus (TP) include:

- $TSI_{\text{(Secchi disk)}} = 60 - 14.41 * \ln(SD)$ *Secchi depth is reported in meters*
- $TSI_{\text{(Chlorophyll)}} = 9.81 * \ln(Chl) + 30.6$ *Chl is reported in $\mu g/L$*
- $TSI_{\text{(Total phosphorus)}} = 14.42 * \ln(TP) + 4.15$ *TP is reported in $\mu g/L$*

As a direct measure of biomass, is best defined by chlorophyll measurements with supplemental assessments possible using Secchi depth and TP. Trophic states, the general measurement ranges, general attributes and possible fisheries and recreation impacts are shown in the following table.

Summary of trophic state conditions (Carlson, 1996)

Trophic State Index	Chlorophyll (ug/L)	Secchi depth (m)	Total Phosphorus (ug/L)	Attributes	Fisheries / recreation
<30	<0.95	>8	<6	**Oligotrophy:** Clear water, oxygen throughout the year in the hypolimnion	Salmonid fisheries dominate
30 - 40	0.95 - 2.6	8 - 4	6 - 12	Hypolimnia of shallower lakes may become anoxic	Salmonid fisheries in deep lakes only
40 - 50	2.6 - 7.3	4 - 2	12 - 24	**Mesotrophy:** Water moderately clear; increasing probability of hypolimnetic anoxia during summer	Hypolimnetic anoxia results in loss of salmonids. Walleye may predominate
50 - 60	7.3 - 20	2 - 1	24 - 48	**Eutrophy:** Anoxic hypolimnion, macrophyte problems possible	Warm-water fisheries only. Bass may dominate
60 - 70	20 - 56	0.5 - 1.0	48 - 96	Blue-green algae dominate, algal scums and macrophyte problems	Nuisance macrophytes, algal scums, and low transparency may discourage swimming and boating
70 - 80	56 155	0.25 - .05	96 192	**Hypereutrophy:** (light limited productivity). Dense algae and macrophytes	
>80	> 155	< 0.25	192 - 384	Algal scums, few macrophytes	Rough fish dominate; summer fish kills possible

Using the summer season average of Secchi depth measures, and surface samples of chlorophyll and total phosphorus in mainstem lake and in embayment sites, the following results are obtained:

Comparison of trophic state indices (TSI) in Deep Creek Lake calculated with using different basis.

Location	TSI basis	2009	2010	2011
Mainstem lake	Chlorophyll	41.8	43.1	44.4
	Secchi depth	39.7	43.2	44.0
	Total phosphorus	41.0	37.8	37.3
Embayment	Chlorophyll	45.6	44.8	49.9
	Secchi depth	43.2	46.2	46.8
	Total phosphorus	40.0	44.0	44.4

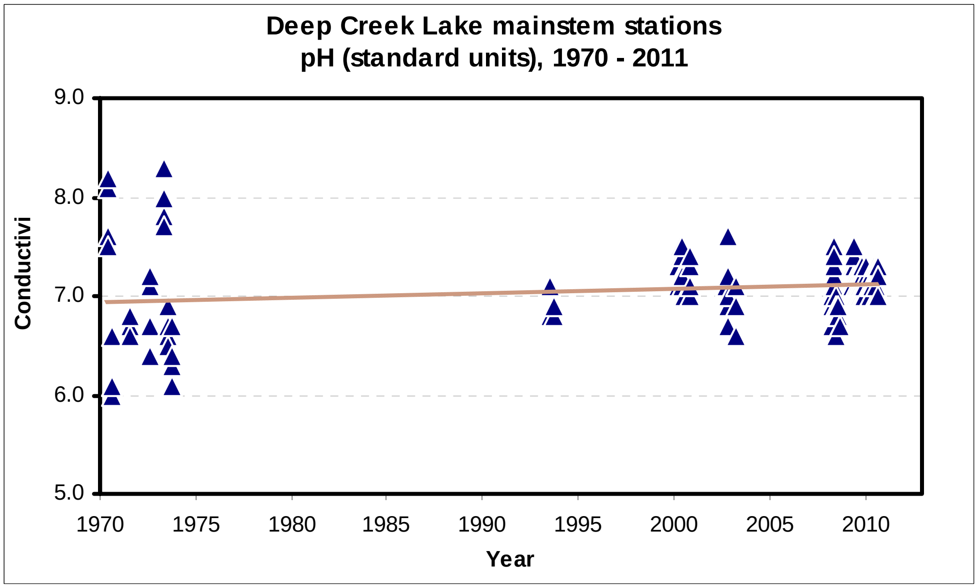
These Trophic State Indices, all in range of the upper 30's to near 50, clearly show that the trophic status of Deep Creek Lake is ***mesotrophic***. Some of the variability may be related to seasonal climate variations. Less turbidity (higher Secchi depth) during dry years (2009, 2010) means lower TSI. More algae will grow when there is more sunlight and hot (sunny) conditions (2010, 2011) so these years will have higher chlorophyll levels and higher TSI.

Trends

With only two complete years of data, there are insufficient data to define water quality trends with lake data collected by this program. There are, however, some water quality measures that have been collected in Deep Creek Lake at various times back to 1970. It's difficult to assess trends in some measures as their analysis methods have changed, but several measures use similar analytical methods. Using data from the same or nearby sites and only during the same summer period, there are some apparent long term water quality trends that should be examined more closely and more rigorously than visual change over time..

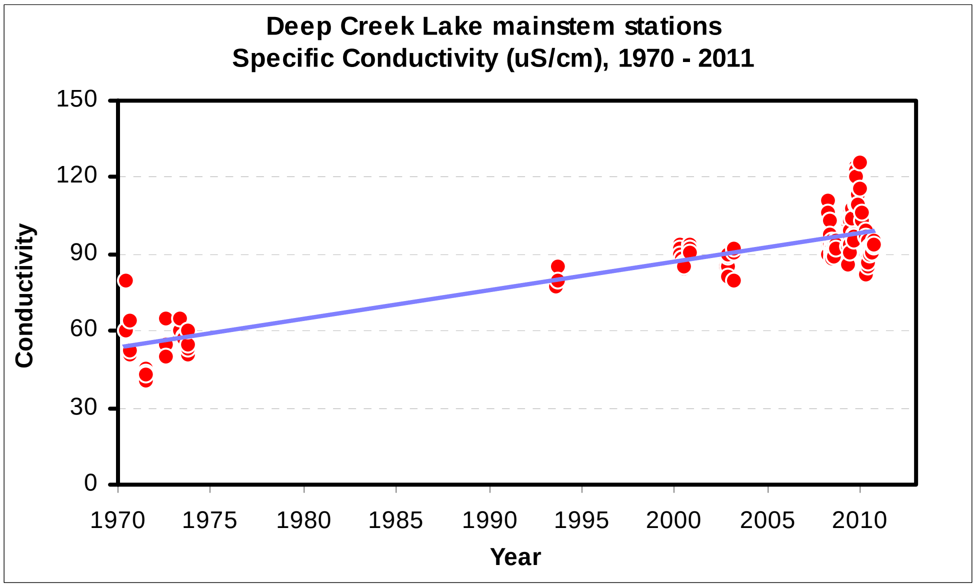
The figure below appears to show a possible, slight increase in pH (less acidity) over the last 40 years. Data collected in the early 1970's show substantial variability that may be due to measurement techniques. pH in samples collected later show much less seasonal/sampling variance. Increasing pH in Deep Creek Lake may be due to reductions of acidic air deposition, reductions or changes in the quality of abandoned coal mine drainage or increases in algal / plant productivity.

Long-term changes in pH in select Deep Creek Lake stations, 1970 - 2011



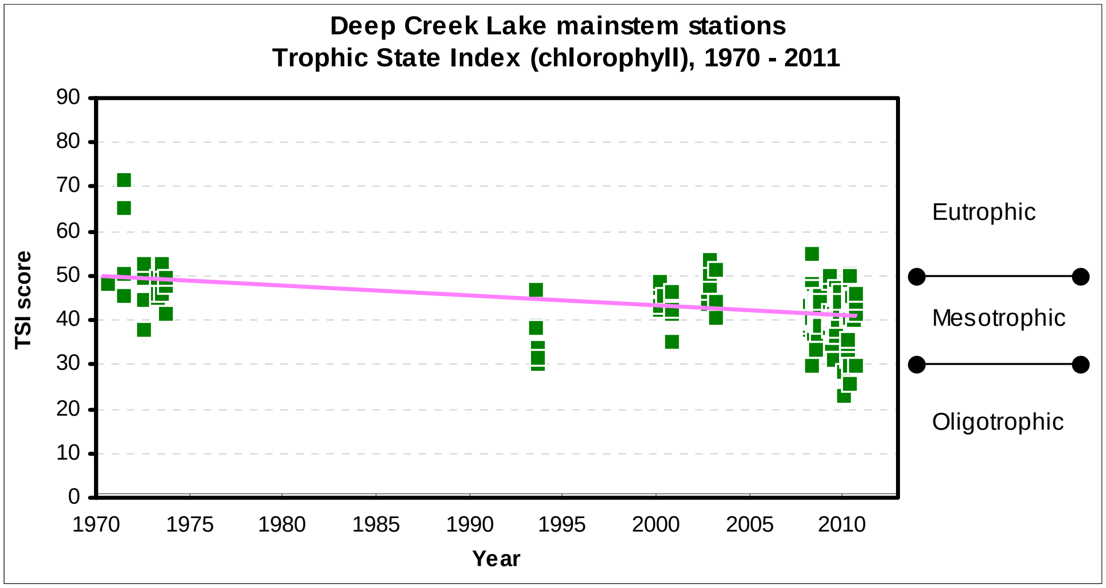
The figure below appears to show a substantial increase in specific conductivity between 1970 and 2011. Specific conductivity is a measure of dissolved ions in water, so materials that will dissolve in water (e.g., salts, as in deicing material, fertilizers and septic wastes) can be tracked

Long-term changes in specific conductivity in select Deep Creek Lake stations, 1970 - 2011



At present, conductivity levels in the lake are well below any level that would affect aquatic life , but if this trend continues or, if it is due to changes in land use in the lake watershed, then if conductivity continues to increase (to 200 uS/cm+), the aquatic community will start to change.

Finally, how has trophic condition changed in Deep Creek Lake over the past 40 years? Using the same datasets and using chlorophyll-a to define lake trophic state results in the following graph:



While it appears that there may be a slight decline in the calculated TSI over the past 40 years, there is enough variance in the data that there is likely no significance to the estimated trend line. That there have been no major shifts in trophic state is good news and perhaps a long-term measure of Trophic State should be considered as a standard indicator for managing Deep Creek Lake and its watershed.

Conclusions

With a few exceptions, water quality conditions in Deep Creek Lake meet water quality standards and support various recreational activities (swimming, fishing, boating), support aquatic life and commercial and industrial uses of lake waters. Exceptions to this statement must address the existing consumption advisory on key sportfish due to mercury contamination from sources outside of the watershed. In addition, the biological community in watershed streams are poor in comparison to other western Maryland streams for unknown reasons and low pH conditions persist in Cherry Creek due to past coal mining activities in this watershed.

Naturally-occurring, seasonally low oxygen conditions in the deep portion of the lake creates poor habitat conditions for fish, but it does not adversely affect recreational uses of the lake.

Biological productivity in the lake is moderate and the lake state is clearly mesotrophic. The lake supports a diverse population of phytoplankton and higher plants which helps support a diverse grazing/prey and predator chain.

Recommendations

- Continue the current lake water quality monitoring program in FY2013 to assess water quality conditions and define seasonal variance.
- Continuing to monitoring streamflow at two USGS gage sites at Cherry Creek and Poland Run and continue to collect water quality samples monthly and during stormflow events to help define the relationship between streamflow and nutrient and sediment concentrations so that loads of these pollutants can be determined. Long term monitoring at these sites will help define trends in water quality as land use changes occur in the Cherry Creek and Poland Run watersheds.
- Define and prioritize other management questions that may be addressed by specific monitoring studies or methods. As an example, one or more continuous water quality sensors to provide real-time data that can be used to help assess short-term variability that cannot be addressed by monthly samples, and provide some basic water quality information to Park Service staff and the public. With two or more continuous water quality monitors, quantitative estimates of productivity can be made as well as special studies addressing other real-time or short-term issues, like frequency/intensity of near-shore turbidity events. Continuous measurements of water levels under different wind conditions can help determine how wind may affect water levels around the lake.

This page intentionally blank

References

Carlson, R. 1977. A trophic state index for lakes. Limnol. Oceano. 22:361-369

___________. 1996. A trophic state index (from Carlson, R.E. and J. Simpson. 1996. *A Coordinator's Guide to Volunteer Lake Monitoring Methods*. N. Am. Lake Mgmt. Society. 96 pp. Online at: http://www.secchidipin.org/tsi.htm).

Code of Maryland Regulations. Title 26 (Environment) MD Department of the Environment; Subtitle 08 (Water pollution); Chapter 02 (Water quality); Regulation 03-2 (Numeric criteria for toxic substances in surface waters). Available online at: http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.03-2.htm

________. Title 26 (Environment) MD Department of the Environment; Subtitle 08 (Water pollution); Chapter 02 (Water quality); Regulation 03-3 (Water quality criteria specific to designated uses). Available online at: http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.03-3.htm

Garrison, J. Shermer. 2010a. Scope of Work - Deep Creek Lake 2010 Water Quality Monitoring Program. Prepared for MD Park Service. MD Department of Natural Resources, Resource Assessment Service, Annapolis.

________. 2010b. Deep Creek Lake water monitoring program, 2009 report. Prepared for MD Park Service. MD Department of Natural Resources, Resource Assessment Service, Annapolis.

MD Department of Natural Resources. 2011. Deep Creek Lake Submerged Aquatic Vegetation survey, Year 2. Report of survey activity and results. Prepared for DNR Park Service. Resource Assessment Service, Annapolis. 9p. + appendices

MD Department of the Environment. 2002. Total Maximum Daily Load of mercury for Deep Creek Lake, Garrett County, Maryland. Baltimore, MD. 20p + appendices. Online at: http://www.mde.state.md.us/programs/Water/TMDL/ApprovedFinalTMDLs/Documents/www.mde.state.md.us/assets/document/Deep%20Creek%20Lake_122702_final(2).pdf

________. 2010. Water quality analysis of eutrophication for Deep Creek Lake and the Deep Creek Watershed, Garrett County, Maryland. Baltimore, MD. 32 p + appendices. Online at: http://www.mde.state.md.us/programs/Water/TMDL/ApprovedFinalTMDLs/Documents/www.mde.state.md.us/assets/document/WQA_Deep_Creek_Nut_07292011_final.pdf and http://www.mde.state.md.us/programs/Water/TMDL/ApprovedFinalTMDLs/Documents/www.mde.state.md.us/assets/document/DCL_AppendixA.pdf

________. 2011. Maryland fish consumption advisories. Baltimore, MD. Online at: http://www.mde.state.md.us/programs/Marylander/CitizensInfoCenterHome/Documents/www.mde.state.md.us/assets/document/Maryland%20Fish%20Advisories%202011.pdf

Organization for Economic Cooperation and Development, 2001. Glossary of statistical terms. Available online at: http://stats.oecd.org/glossary/detail.asp?ID=2772.

WeatherUnderground. 2011. Monthly precipitation and air temperature data. Garrett College , McHenry, MD weather station (KMDMCHEN1). Data retrieved online from: http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KMDMCHEN1&day=1&year=2009&month=11&graphs

This page intentionally blank

ACRONYMS, TERMS AND ABBREVIATIONS

ac .... acre (1 ac. = 0.00156 square mile; = 0.4047 ha; = 43,560 sq. ft)
anoxia .... region of depleted dissolved oxygen (less than 0.2 mg/L), usually occurring in the seasonal hypolimnion
Chl-*a* .... Chlorophyll- ***a*** - organic molecule responsible for much of the photosynthetic activitiy in algae and vascular plants. Other, similar chlorophyll pigments are often present, but chlorophyll- ***a*** is often dominant.
dd .... day (numeric)
DHMH .... Maryland Department of Health and Mental Hygiene
DNR .... Maryland Department of Natural Resources
DO .... dissolved oxygen
EPA .... US Environmental Protection Agency
epilimnion ...... water mass above thermocline (metalimnion)
eutrophic .... high level of biological productivity/biomass often defined by high concentrations of nutrients (nitrogen and phosphorus) and algae and very low water clarity (turbid conditions)
ha .... hectare (1 ha = 2.471 ac; 0.0039 square mi; 107,639.4 sq. ft)
hypolimnion ... deep water mass found below the summer thermocline (metalimnion)
hypoxia .... region of low dissolved oxygen (less than 2.0 to 0.2 mg/L), often occurring in the seasonal hypolimnion or close to the bottom of the lake
kg/ha .... loading (kilograms per hectare) as in mass over an area
L .... liter (1 L = 1 kg; =0.264 gallons)
m .... meter (1 m = 3.281 feet; = 39.37 inches)
MDE .... Maryland Department of the Environment
mm .... month (numeric)
µg/L .... micrograms per liter (1 µg/L = 0.001 mg/L = 1 ppb = 1 mg/m^3)
µm .... micrometer (1 µm = 0.001 mm = 0.0000001 m = 0.00003937 in)
mg .... milligrams (1 mg =0 .001 g = 0.000001 kg)
mg/m^3 .... milligrams per cubic meter (1 mg/m^3 = 0.001 mg/L = 1 ppb = 1µg/L)
mL .... milliliters (1 mL = 0.001 L; = 1g)
mg/L .... concentration (mass per volume) 1 mg/L = 1,000 µg/L = 1,000 mg/m^3)
mesotrophic ... moderate level of biological productivity/biomass often defined by moderate to low concentrations of nutrients (nitrogen and phosphorus) and algae and relatively clear water
metalimnion ... thermocline region where the greatest rate of change in water temperature over depth occurs
n .... number of observations in a sample (sample size)
N .... nitrogen
oligotrophic .... low level of biological productivity/biomass often defined by low to very low concentrations of nutrients (nitrogen and phosphorus) and algae and very clear water
P .... phosphorus
pH .... an index of the measure of free hydrogen ions in the water (range is 1 to 14, where lower pH = more free hydrogen ions - acidic conditions)

ACRONYMS, TERMS AND ABBREVIATIONS - *continued*

residence time length of time water resides in a lake
RTRM .... Relative Thermal Resistance to Mixing
Secchi depth ... depth (m) at which a submerged Secchi disk (8-in. round disk with alternating black/white quadrants) disappears from view
thermocline .... depth in the water where the greatest rate of change in water temperature over depth occurs (metalimnion)
TN .... total nitrogen (= all particulate + dissolved forms of nitrogen)
TP .... total phosphorous (= all particulate + dissolved forms of phosphorus)
TSI .... Trophic State Index
TSS .... total suspended solids (mg/L)
USGS .... US Geological Survey (US Department of the Interior)
yyyy .... year (numeric)

Appendix A

Deep Creek Lake/Tributaries water quality data

Excel printout

Field data

Laboratory data

Appendix B

Deep Creek Lake water quality presentations
PowerPoint slides

Property Owners Association, August 19, 2010

MD Water Monitoring Council, November 18, 2010

Deep Creek Lake Workgroup, September 19, 2011

Appendix C

Other/recent/ongoing water quality surveys/presentations

MD Department of the Environment

Deep Creek Lake TMDL WQ Monitoring Effort - Fall 2011

In response to complaints about algal blooms in some areas of Deep Creek Lake that may require a nutrient loading limit, the Maryland Department of the Environment developed a water quality monitoring plan for Deep Creek Lake that focuses on nutrients in the nearshore/shallow southern cove areas for TMDL evaluation. In an effort to develop sample station locations that are representative of these areas and have some comparable water quality data, established Garrett County Health Department bacteria water quality stations, MDE/DNR main channel stations, as well as Maryland Geological Survey (MGS) sediment study stations were included in this monitoring effort. In 2011, 25 sampling stations were located in the upper half of the lake (Figure 1). Samples will be collected once in July, twice in August, and once in September. Samples will be collected at the surface. Since the focus is on evaluating the nearshore areas for possible nutrient TMDL evaluation, water quality sample analysis includes include the following suite of constituents:

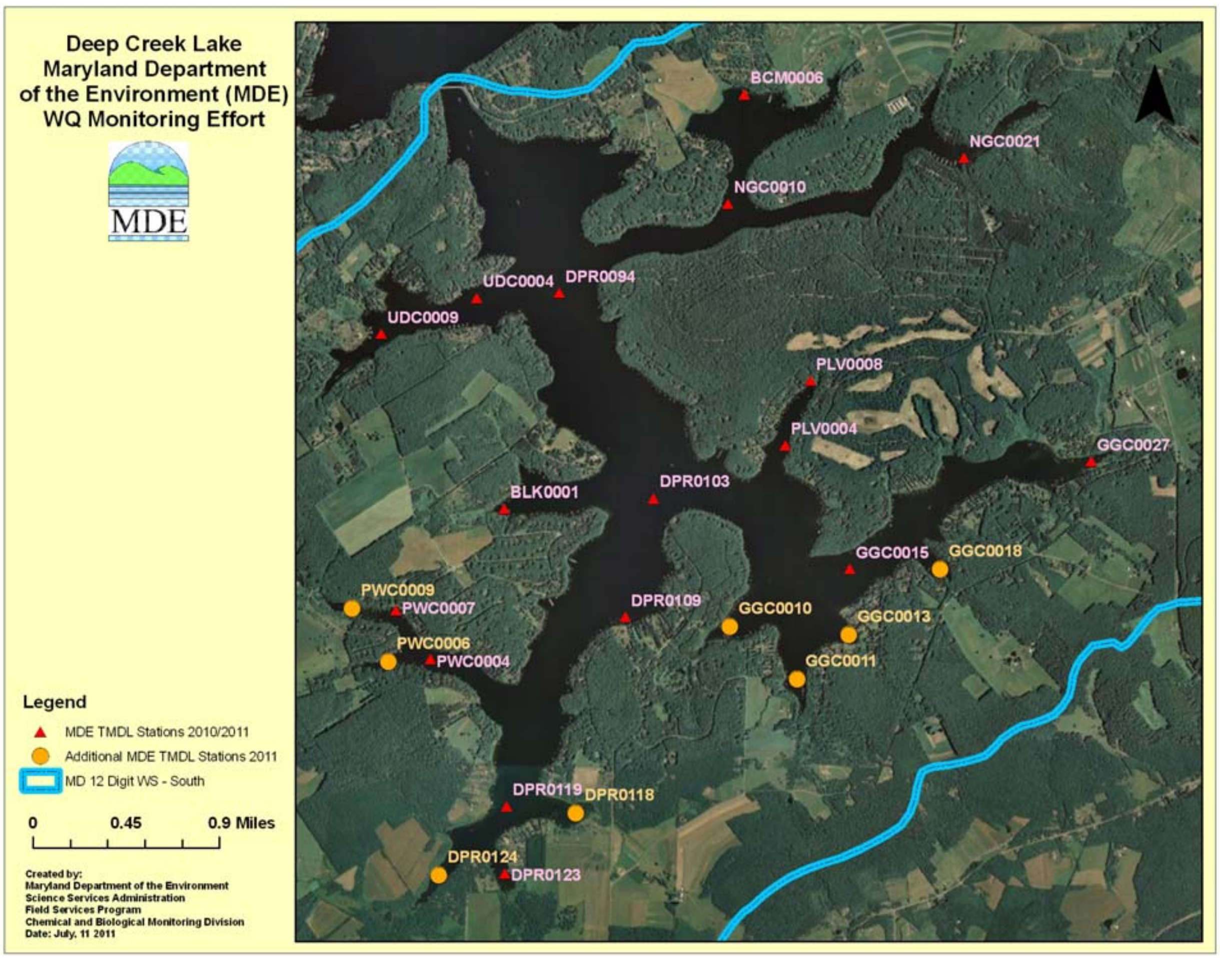
- dissolve inorganic nitrogen (ammonium, nitrite + nitrate)
- nitrite
- ortho-phosphate
- silicate
- total dissolved nitrogen and phosphorous
- total suspended solids
- particulate phosphorous, carbon, nitrogen
- chlorophyll-a
- dissolved organic carbon
- particulate inorganic phosphorous
- chloride, and
- sulfate

In addition, in-situ water quality parameters will be collected using a handheld Hydrolab for:

- water temperature (in the deep areas – thermal depth profile was conducted – which recently helped in a fish kill investigation)
- dissolved oxygen
- pH
- conductivity, and
- Secchi disk depth

This monitoring plan is limited in scope and was developed with the focus on TMDL nutrient water quality in the DCL shallow cove areas. In order to make sure that we are not duplicating our efforts, DNR and MGS have been contacted to make sure that we utilize our state resources in an efficient manner.

For additional information, please contact:
Maryland Department of the Environment
Tim Rule: 410-537-3688 or
Quentin Forrest: 443-482-2708



Appendix C - Other/recent/ongoing water quality surveys/presentations

Garrett County Health Department

Between Memorial Day and Labor Day, the Garrett County Health Department routinely collects bacteriological and samples for analysis of some water quality parameters at 23 sites around Deep Creek Lake (yellow dots on figure below).

Samples are collected biweekly and sent to the MD Department of Health and Mental Hygiene laboratory in Baltimore for analysis and returned for review. Seasonally, a swimming condition summary in Deep Creek Lake is posted and updated regularly on the MDE Healthy Beaches website (http://www.marylandhealthybeaches.com/).

In an e-mail to John Wilson on 9 November 2011, Steve Sherrard, the Garrett County Health Department's Environmental Health Director provided the following summary about water quality results from the summer of 2011:

> "Briefly, the quality of Deep Creek Lake from a bacteriological stand point concerning recreational water was very good this past summer. The highest e. coli count was 70.6, well below the 235 standard set for bathing beach water. Most counts were below 10."

-*e-mail from Steve Sherrard (Garrett County Health Department) to John Wilson (Land Acquisition and Planning, MD Department of Natural Resources), 9 November 2011.*

Note: 'e. coli' in the text above refers to *Escherichia coli*, a fecal coliform bacteria that is often tested as an indicator of untreated waste from human sewage. *E.coli* also are present in wastes from warm-blooded animals, such as pets (dogs and cats), livestock, wildlife, and waterfowl.

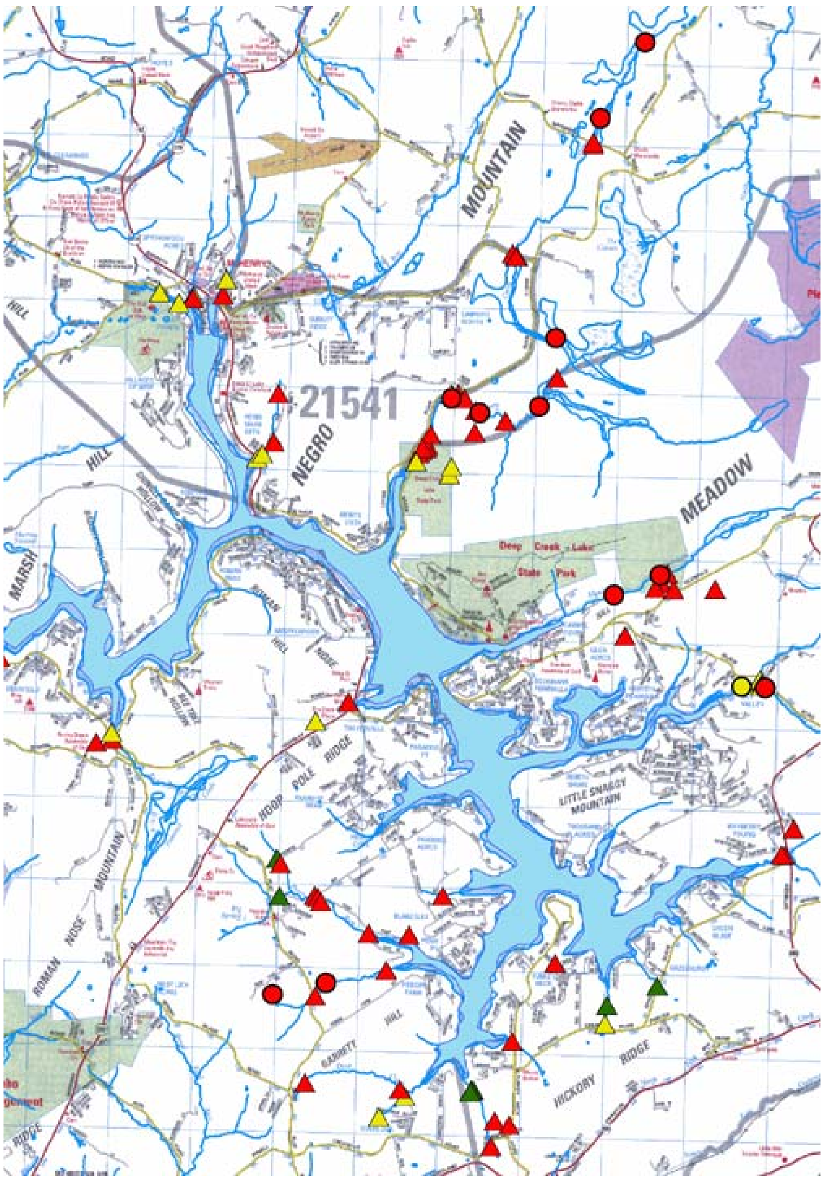
Appendix C - Other/recent/ongoing water quality surveys/presentations

Stream Waders / MD Biological Stream Survey

DNR biologists sampled fish and macroinvertebrates at 12 MD Biological Stream Survey sites in 1995 - 2009 (circles on figure below). Results suggest biological conditions were Poor at 11 sites (92%) while one site was classified as Fair (8%).

Stream Waders volunteers collected macroinvertebrate samples at 80 sites in 2004 - 2010 (triangles on figure below). Results suggest that biological conditions were Poor at most sites (60%), Fair at 30% of the sites and Good at 10% of the sites.

DNR Park Service staff are planning conducting additional stream surveys in 2011 - 2012 to assess conditions in streams just upstream of the lake.



Appendix C - Other/recent/ongoing water quality surveys/presentations

University of MD (EcoCheck) and Friends of Deep Creek Lake

In 2011, EcoCheck (http://www.eco-check.org), a partnership group between the University of Maryland Center of Environmental Science and the National Oceainc and Atmospheric Administration (NOAA), prepared a baseline condition assessment for the Friends of Deep Creek Lake (http://www.friendsofdcl.org). This 4-page document is available online at (http://ian.umces.edu/pdfs/ecocheck_newsletter_305.pdf) and is attached below.