DRAFT

Level I Water Quality Inventory – Marsh-Billings-Rockefeller NHP

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Executive Summary

In association with the Baseline Water Quality Data Inventory and Analysis Program of the NPS-Water Resources Division we conducted a Level I water quality inventory for Marsh-Billings-Rockefeller NHP (MABI). The goal was to sample water quality parameters for key water bodies within park boundaries, identify key water resource management issues and recommend appropriate long-term monitoring strategies. There are two water bodies in the Park, a 6-hectare lake and a brook (the Pogue Stream) fed by the lake through a culvert in an earthen dam.

There are continuing water quality concerns in the Park that may affect the water resources therein. There is a cow pasture adjacent to the Pogue Stream. The nearness of the pasture increases the likelihood of runoff degrading water quality of the brook. Runoff from the roads is contributing sediment to the streams during storm events. In contrast to the Pogue Stream, any changes in the water quality of the Pogue are a consequence of the natural conditions in the surrounding forests. Examples of such contributing factors are runoff, organic loading from leaf litter and resuspension of bottom sediments. These factors will change with alteration of the forest cover surrounding the basin.

The water quality of the Park's water bodies is good. The remote location of the water bodies and the geographical isolation makes it unlikely that there are any immediate threats to water quality by anthropogenic activities. The Pogue's water quality (presently good) would be significantly affected by any change in runoff engendered by alteration of watershed forest cover. The Pogue Stream also possesses good water quality. The remote location of the Pogue makes it unlikely that water quality degradation would come from its' source. However, it hasn't been ascertained whether the change in pasturing effected the desired change in coliform levels. Additionally, it would be important to better constrain *E. coli* levels as this parameter will be changed by Vermont's new state standard for presence of bacterial contamination (Vermont Water Quality Board, personal communication).

Because of these concerns, we would recommend multiple sampling for fecal coliform and *E. coli* at the brook. A minimum effort would consist of collecting five biweekly samples in the late summer and/or early fall at the Pogue Stream. This sampling could be repeated every two or three years to track trends in bacterial contamination. This sampling would serve as an

early warning system that would alert Park resource managers to a sudden degradation of water quality.

Introduction

Marsh-Billings NHP (MABI) is an historic park found just outside of the village of Woodstock Vermont. MABI is comprised of three zones. The 222.6-hectare "historic zone", is situated near the peak of Mount Tom, adjacent to a town park (see Figure 1). Located within the historic zone is an extensive cross-country ski trail system that utilizes historic carriage roads and some contemporary ski trails. The 35.6-hectare "Protection Zone" of the park consists of the Billings Farm & Museum, a privately owner and managed museum and operational dairy farm on the Ottaquechee River at the confluence of the Gulf Stream just north of the town center. Two scenic easements on privately owned land comprise the Third Zone, the “Scenic Zone”. The Protection and Scenic Zones are not included in this study due to their private ownership.

The major water resources in the park consist of a small pond and a brook system fed by the pond. The 6-hectare pond, named the Pogue, is near the summit of the park and is surrounded mixed hardwoods, mainly birch (*Betula* sp.) and beech (*Fagus* sp.). This pond was originally a quaking bog and was enlarged into a small lake in the 1880’s by the Billings family (Wilcke et al 2000). In 1890, a dam was constructed which converted the pond into a small lake with an outlet to a brook via a culvert in an earthen dam. There is an irrigation pipe that also draws water from the Pogue. It is used to water two old (but still operational) watering troughs along the main carriage road and for watering the lawn and flowerbeds of the mansion grounds at the base of the mountain. It is also used for lawn and garden irrigation purposes by the Billings Farm & Museum under deed.

One major brook (the Pogue Stream) runs out of the Pogue and eventually runs into Barnard Brook, draining much of the park. This brook passes through mature stands of oak, beech and Norway spruce with emergent herbaceous wetland habitat along the stream borders. Until 1995, the creek ran inside the cow pasture and was a source of fecal coliform contamination (Farris 1994). In 1998, Park resource managers moved the fence to exclude the cattle from foraging in the stream. One sampling location was selected near the cow pasture (MABI-2).

The entire park lies on Silurian-Devonian bedrock of the Waits River formation (Doll 1970; Chang et al 1965). Most of the park is described as glacial till, with limited exposed bedrock. Some of the Billings Farm is

shown as recent alluvium of the Waits River formation (Doll 1970). Most of the outcroppings are composed of abundant schist and quartzite outcroppings.

In association with the Baseline Water Quality Data Inventory and Analysis Program, the NPS-Water Resources Division has assembled existing water quality data sets in most Park Units. Marsh-Billings-Rockefeller NHP (MABI) was found to have depauperate water quality databases, thereby requiring Level I water quality inventories (USDOI 1997). As defined by the NPS Inventory and Monitoring Program, a Level I water quality inventory includes sampling basic water quality parameters for key water bodies within park boundaries. Key water bodies are either those essential to the cultural, historical, or natural resource management themes of the park or those that provide habitat for rare plants or animals.

The purpose of this project was to collect water quality data at MABI to meet the Level I needs. Moreover, this study identifies key water quality management issues at the park and recommends appropriate long-term water quality monitoring strategies.

Water resource issues

There are continuing water quality concerns in the Park that may affect the water resources therein. The park was once almost entirely cleared for use as upland dairy pastures before it was converted to a forest park in the 1880's. Today, an active cow pasture encloses up to ten heifers from the Billings Farm. They are transported up the carriage road in May and are allowed to graze until September. For about 74 meters, the Pogue Stream runs adjacent to the cow pasture. The nearness of the pasture increases the likelihood of runoff from the cow pasture degrading water quality of the brook.

In contrast to the Pogue Stream, any changes in the water quality of the Pogue are a consequence of the natural conditions in the surrounding forests. Such contributing factors are runoff, organic loading from leaf litter and resuspension of bottom sediments. These factors could change with alteration of the forest cover surrounding the basin.

Sample locations

Two water quality monitoring sites were selected at MABI to establish a baseline for water resource assessments.

The Pogue. The Pogue is located in an elevational depression near the summit of Mount Tom. The contributing watershed is entirely within Park boundaries and is on a topographic high relative to the village center. As there are no residences or commercial development within the basin, present-day anthropogenic impacts to water quality are minimal. One sampling location was selected in the deepest part of the lake (MABI-1). This station characterized the baseline conditions of this water body.

The Pogue Stream. The Pogue Stream follows a topographic low down the slope to its' confluence to a tributary of the Ottaquechee River. It was important to estimate the possible impacts of the proximity of the cow pasture on the water quality of the Pogue Stream. For this reason, a sampling site was established adjacent to a culvert just downstream from the cow pasture (MABI-2).

Existing water quality data

The Water Resources Division produced a water quality scoping report (USDOI 1997). Five sample locations were found in the park. The Pogue stations were found to have moderately good water quality in 1994. Evidence of significant levels of dissolved species were found in 1984, possibly a result of resuspension of bottom sediments or increased runoff from the steep northern side of the basin.

The sampling stations at the Pogue Stream reveal evidence of water quality degradation from foraging cows wading in the stream. Elevated fecal coliform levels were observed downstream from the pasture. The nearest US Geological Survey water gauging station was located at the Ottaquechee River in Woodstock, VT.

The objective of this water quality-monitoring program is not to assemble a comprehensive database, but rather to obtain a baseline of environmental variables. Should degrading trends in these fundamental variables be observed, then management should implement a more comprehensive program to clearly assess the problem.

PROTOCOL

Sampling schedule and water quality parameters

Samples were collected in the fall (October 1998 and 1999), winter (January 1999), spring (June 1999) and summer (August 1999). Parameters were sampled as outlined in Table 1.

Table 1. Sampling parameters for each station

Station	GPS coordinates	Sampling Parameters
The Pogue (MABI-1)	698140.2/4834158.7	Alkalinity, chlorophyll a, conductivity, total and dissolved nutrients, dissolved oxygen, pH, turbidity, temperature, water level
The Pogue Stream (MABI-2)	698804.2/4834265.0	Alkalinity, conductivity, total and dissolved nutrients, dissolved oxygen, pH, temperature, water level, fecal coliform

Field sample collection techniques

Dissolved oxygen, pH, temperature, conductivity and turbidity were measured at both stations with a Hydrolab Mini-Sonde. Only the Pogue was deep enough to allow for surface to bottom profiles. Discrete water samples were collected at both stations 0.25 m below the surface with a Kemmerer bottle.

For alkalinity, 60-ml sample bottles were filled to overflowing, capped and placed on ice for transport to the Cape Cod National Seashore (CACO) laboratory. A one-liter bottle was collected and placed on ice for transport to the CACO laboratory for the chlorophyll a samples. Triplicate 20-ml aliquots were collected in pre-cleaned test tubes and fixed with persulfate oxidizing reagent and transported to the CACO laboratory for total nitrogen and phosphorus analysis. Sixty-ml sample bottles for dissolved nutrients were filled with water filtered through 0.4-micrometer Millipore filters, preserved with 2N hydrochloric acid and iced for transport to CACO. All samples were kept in the dark at 4^{o}C until analysis preparation was

completed. Nutrient samples were not analyzed for four to six months because of mechanical and logistical problems processing these samples at the CACO laboratory that has since been resolved.

Analytical techniques

Field Methods: A Hydrolab that was calibrated according to manufacturers methods before each sample trip collected dissolved oxygen, pH, temperature, conductivity and turbidity. Water levels were established and monitored using the Hydrolab depth recorder.

Laboratory methods: All laboratory analyses were performed at the North Atlantic Coastal Laboratory at the Cape Cod National Seashore.

Alkalinity: Measurement was by potentiometric titration using a bromcresol indicator (American Public Health Association 1992).

Chlorophyll a: The water samples were filtered through a Whatman GFF filter. The filter was ground up and extracted with acetone. Then chlorophyll levels in the acetone extract were measured on a spectrophotometer (Lorenzen 1966).

Dissolved nutrients: Dissolved inorganic nutrients (nitrate, nitrite, ammonia, and phosphate) were determined colorimetrically on a Lachat autoanalyzer (American Public Health Association 1992; Lachat Instruments 1993, 1994).

Total nitrogen and phosphorus: Total nitrogen and phosphorus were determined simultaneously by potassium persulfate digestions followed by colorimetric analysis on the Lachat autoanalyzer (Valderrama 1981).

Fecal coliform: Coliform levels will be determined by the Barnstable County Health Laboratory by A-1 EC medium method (American Public Health Association 1992).

Data management and Archiving

All collected data was entered in the Environmental Protection Agency's national water quality database, STORET.

Results

All results were compared to the state water quality standards, the EPA standards and water body classifications associated with ambient nutrient levels. Vermont water quality standards (Water Quality Policy 10 VSA 1250) are based on functional attributes of water bodies. These standards associate their water quality with the watershed in which they are contained. The Ottaquechee River Basin, by this estimation, is a Class B Warm Water Basin subject to the Class B contaminant levels shown in Table 2. The streams within the park are designated Class B and are subject to the same limits. When specific contaminants aren't mentioned, they are under the purview of EPA water quality standards. As there are no state minimum nutrient loading standards, we will employ a lake trophic classification scheme (Wetzel 1985). This will allow us to evaluate the potential for significant nutrient loading from watershed sources (see Table 2) although it would be an imperfect comparison for brook and stream habitats.

The Pogue. The observed values of these water quality parameters are consistent with those of a naturally mesotrophic lake (see Table 2). Chlorophyll levels are consistently high between 1 – 30 $\mu g\ l^{-1}$. The bottom dissolved oxygen values fell to hypoxic levels in the summer and fall. The Pogue's natural mesotrophy is probably a function of its' geomorphology. The basin's shallow depth, location in a topographic low and small volume would result in higher sedimentation rates and humic levels. In addition, a greater proportion of the bottom would be in the photic zone, which would allow greater water column productivity. Total nitrogen and phosphorus levels are below oligotrophic levels and reveal little likelihood of nutrient loading from the watershed. The alkalinity is much lower than was observed in 1984, indicating that the prior reading may have been associated with some isolated event affecting the buffering capacity of the lake. These low alkalinity levels are to be expected in a lake with glacial till and bedrock comprising the water table. In sum, the water quality here is quite satisfactory.

Pogue Stream. This brook has most water quality parameters of those from a stream with little anthropogenic impact. Dissolved oxygen levels are above 60% year round and chlorophyll levels are at minimal levels (see Table 2). Total nitrogen levels are similar to those observed in the source

waters of the Pogue. Total phosphorus levels are lower, which may reflect natural phosphorus absorption during transport of the waters from the Pogue. Fecal coliform levels were lower than were observed in 1994 before the cows were excluded from watering in the Pogue Stream. Because multiple seasonal samples were not collected, we cannot state whether this represents an improvement over previous conditions. It is likely that coliform input has been significantly reduced by these actions.

Conclusions

The water quality of the Park's water bodies is good. The remote location of the water bodies and the geographical isolation makes it unlikely that there are any immediate threats to water quality by anthropogenic activities. The Pogue's water quality would be significantly affected by any change in runoff engendered by alteration of watershed forest cover.

The Pogue Stream also possesses good water quality. The remote location of the Pogue makes it unlikely that water quality degradation would come from its' source. However, it hasn't been ascertained whether the change in pasturing effected the desired change in coliform levels. Additionally, it would be important to better constrain *E. coli* levels as this parameter will be Vermont's state standard for presence of bacterial contamination (Vermont Water Quality Board, personal communication).

Because of these concerns, we would recommend multiple sampling for fecal coliform and *E. coli* at the Pogue Stream. A minimum effort would consist of collecting five biweekly samples in the late summer and/or early fall at MABI-2. This sampling could be repeated every two or three years to track trends in bacterial contamination. This sampling would serve as an early warning system that would alert Park resource managers to a sudden degradation of water quality.

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Table 2. Marsh-Billings-Rockefeller NHP water quality results at three Level 1 Sample Locations and Vermont Water Quality Standards

Station	Date	Alkalinity ($\mu eq\ l^{-1}$)	Chlorophyll ($\mu g\ l^{-1}$)	Specific conductivity ($\mu S\ cm^{-1}$)	Dissolved NO3 (μM)	Dissolved NH4 (μM)	Total N (μM as NO_3)	Total P (μM as PO_4)
The Pogue (MABI-1)	October 15, 1998	77.63	4.165		3.0	19.75		
	January 6, 1999	91.15	29.08	0.1143				2.9305
	June 10, 1999	87.65	10.70	0.2087			107.82	0.5027
	August 11, 1999	91.6	0.3221	0.2051	1.81	9.32	22.42	0.2235
	October 27, 1999	71.75	1.098	0.2370	1.95	5.98	14.62	0.461
STORET data								
	November 2 1994				60	18		5
	October 23, 1984	1370			0			8.8
Un-named Pogue Stream (MABI-2)	October 15, 1998	106.5	0.3998	0.2160				
	January 6, 1999	95.75	1.2396	0.1958	8.82	18.21		1.589
	June 10, 1999						107.929	0.5353
	August 11, 1999	117.25	2.2580	0.2502	9.46	4.76	13.17	0.5313
	October 27, 1999	111.45		0.1928	1.85	2.73	4.2802	0.4335
STORET data								
	November 2, 1994				150	26		5

Lake trophic classification (Wetzel 1985)								
Oligotrophic			1.7				661	8.0
Mesotrophic			4.7				752	26.7
Eutrophic			14.3				1875	84.4
Class B Warm water					5000			

Station	Date	Bottom DO (mg L^{-1})	Bottom DO (% sat.)	pH	Secchi depth (m)	Water depth (m)	Turbidity (NTU)	Fecal Coliform /100 ml	Total Coliform /100 ml	Discharge (m3/sec)
The Pogue (MABI-1)	October 15, 1998	1.43	14.1	7.48	2.5	2.82				
	January 6, 1999	4.59	40.7	7.22	No reading due to 4" ice cover	2.44				
	June 10, 1999	.36	4.3	7.97	2.1	2.44	0.0			
	August 11, 1999	0.05	0.6	7.65	2.5	2.5	24.51			
	October 27, 1999	0.42	3.8	6.31	2.5	3.00	4.73			
STORET data										
After the cow pasture	November 2 1994							1.5		
Un-named Pogue Stream (MABI-2)	October 15, 1998	10.87	95.9	7.92	0.1	0.1				0.006
	January 6, 1999	12.61	87	7.63	0.04	0.04	1.3	<10	112	
	June 10, 1999	9.26	89.6	7.5	0.04	0.04	0.0			0.0194

	August 11, 1999	7.57	76.4	7.68	0.02	0.02				0.00054
	October 27, 1999	12.14	96	6.15	0.28	0.28	0.0			0.0283
STORET data										
After the cow pasture	November 2 1994							34		
Lake trophic classification (Wetzel 1985)										
Oligotrophic					9.9					
Mesotrophic					4.2					
Eutrophic					2.45					
Class B Warm water		5	60	6.5-8.3				200 1994 standards	1000 1994 standards	

Figure 1. Marsh-Billing NHP sample locations