The Forge River, Problem Identification

A report prepared for the
Town of Brookhaven
Long Island, New York

by

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The Problem

The Forge River is a small, partially mixed estuary discharging into Moriches Bay, a part of the Long Island south shore lagoonal system. The tidal portion of the river is 4 K (3.2 nautical mile) long that ends abruptly at Montauk Highway which serves as a dam. Two freshwater ponds (East Pond and West Pond) continuously discharge to the tidal Forge at this location. The surface watershed of the river is 43.06 km^2 (10.641 acres). About 20 percent of the watershed is in the deep groundwater recharge zone (Zone III).

During the summer months, the water in the Forge has experienced polluted[1] conditions as evidenced by fish and crab kills, foul odors, rotting algal debris in the water, and sections of the river have sporadically turned milky white. These symptoms were especially severe during the summer of 2005 and the river has remained in a deteriorated state ever since.

The New York State Department of Environmental Conservation (NYSDEC), Suffolk County, and the Town of Brookhaven have set an agenda to determine the causes of pollution and to identify potential remediation measures in the Forge River. Investigators at Stony Brook University's School of Marine and Atmospheric Sciences (SoMAS) were initially charged with

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[1] Marine pollution – "the introduction by man, directly or indirectly, of substances or energy to the marine environment resulting in deleterious effects such as: hazards to humans, health; hindrance of marine activities, including fishing, . . ., and reduction of amenities" (Clark, 1992).

studying the Forge River sediments as pollution sources. Our research activities expanded as it quickly became evident that sediments were not the sole cause of the pollution symptoms, and that the Forge River, during summer, was hypereutrophic.

The aim of this report is to provide an overview of the pollution problems in the Forge River as well as to identify the research that SoMAS has conducted as part of this multi-agency project. Data reports (see Appendix) have been prepared for Suffolk County and six interpretive and synthesis reports listed below are being prepared for the Town of Brookhaven.

Reports Prepared for The Town of Brookhaven

1. A report summarizing the problems and possible causes of pollution in the Forge River and the research conducted by SoMAS to address these issues.
2. A report providing an historical review of information about the Forge River that interprets what can be inferred from existing data about the changes in the system and possible changes in nutrients and nutrient sources over time.
3. A report on what is known about water circulation in the tidal Forge River and freshwater flows into the Forge River from ponds, streams, and groundwater based on measurements and modeling of salt balance over tidal cycles, and watershed calculations.
4. An interpretive report on sediments that includes estimates of volumes of contaminated sediments and what sediment contaminant levels mean with respect to ecological risks and an initial assessment of how sediment concentrations relate to dredging options.
5. An interpretative report on nutrient measurements collected in the Forge River – the report will summarize distributions of nutrients in the water column and how they relate to sources and the oxygen and organic matter enrichment problems that are encountered in the system. Initial nitrogen balance and source estimates in the Forge River were made based on a combination of SoMAS and Suffolk County measurements, and include estimates of external inputs from air, streams, ponds and ground waters. It also includes what is known about the sources of nitrogen in ground water. Recommendations will be made for filling data gaps and how to better constrain or estimate nitrogen loadings and sources.
6. A report characterizing the ecological system in the tidal Forge River.

Important Questions

To understand the primary causes of eutrophication, or other pollution problems, in the tidal Forge River and how management actions might best improve water quality, we list some of the over-riding scientific questions that were considered:

- What are the primary sources of nutrients to the system that fuel phytoplankton and plant growth? How might the system respond to various changes in those inputs?
- What are the sources of oxygen demanding organic matter in the tidal Forge?
- What processes affect the internal cycling of various pollutants and oxygen in the tidal Forge? What understanding may be needed to interpret monitoring data or to compare monitoring data with water quality modelling predictions?
- What would be the effects of removing the river's organic rich sediments or the sources of nutrients in the overlying water?
- What is the circulation in the Forge River, the physical forcing factors that affect it, and the rate of flushing of nutrients and oxygen depleting organic matter to Moriches Bay or the Atlantic Ocean?
- How would changes in bathymetry in areas of the Forge River, or elsewhere, affect the circulation and water quality of the tidal Forge?
- How would alterations in Moriches Inlet affect the circulation and water quality within the Forge River?
- What is the sediment quality of the tidal Forge with respect to potentially toxic organic contaminants that might adversely affect resident and transient organisms?
- What is known about populations of organisms in the Forge River and possible impairment from local pollution?

- What is the consequence of *Ulva lactuca* biomass in spring and the impact of its cycling in the system?
- What are the effects of physical structures such as spillways, the town pier, and the constriction in the upper tidal Forge caused by the railroad bridge on water circulation and associated water quality?

Below we provide background and insight relative to these questions and summarize how research conducted by SoMAS is providing information to address them.

Oxygen depletion and eutrophication. There is little doubt that many of the observed pollution effects of the river are a consequence of eutrophication -- a condition caused by excessive nutrient enrichment that stimulates an overabundance of phytoplankton and macroalgal (*Ulva lactuca*) biomass (mass of living material in a given area). As a result, oxygen depletion in the water column and sediments occurs, especially during summer months, primarily from the microbial respiration of decaying biomass. In addition, while photosynthesis produces oxygen during daylight conditions in surface waters, respiration by the same plants, as well as bacteria, consume oxygen in the water at night. These photosynthetic and oxygen utilization processes result in extreme oscillations in dissolved oxygen concentrations seen in time series oxygen measurements. Some of this oxygen demand occurs in the water column (e.g., phytoplankton respiration and rotting algal mats that float to the surface in summer) and some occurs in the sediments that are a large reservoir of labile (constantly undergoing change) organic matter. Another potentially significant source of oxygen demanding organic matter may come from sources external to the tidal Forge River, notably the eutrophied West and East Ponds.

Dissolved oxygen depletion in Forge River waters and sediments likely controls, directly or indirectly, changes in water color and smell that are experienced on the river in summer. The

observed brown and much darker (almost black at times) water in Wills Creek may be associated with the high levels of iron. Reduced iron is released from sediments (and possibly from anoxic ground waters seeping into the Forge and its tributaries) which is then either oxidized (brown rust-like oxides) or forms dark precipitates with reduced sulfide.

At times, the milky white water emanates from the northwestern reaches of the tidal Forge producing odors. We hypothesize that this white water is most likely associated with elemental sulfur precipitated from the oxidation of high levels of sulfide in the water column that persists under low oxygen conditions.

The problem of eutrophication in the Forge River is not new. The historically shallow river was described as "objectionable" and "highly contaminated" some six decades ago (Redfield, 1952). The eutrophication was made worse by the filling and ultimate closing of Moriches Inlet during May 1951 (Redfield, 1952). The impairment of Moriches Bay was linked with the growth of the duck ranching industry decades earlier along the Forge and other tributaries of region. Duck farm activities were identified as a primary source of pollution to Moriches Bay in several studies conducted by Woods Hole Oceanographic Institution (WHOI) investigators between 1950 and 1959. One of several measures used to attribute duck ranching with intense pollution problems was the unusually high amounts of duck-derived phosphorous in waters proximate to duck farming sites. In a 1950 survey, the highest levels of dissolved inorganic phosphorous throughout the Moriches and Great South Bay systems were measured at Forge River stations. Eutrophication, dating back before 1952, was substantiated by observations of high levels of organic enrichment of the black muddy sediments in the Forge (Redfield, 1952; Nichols, 1964). Over the years since, as the duck ranching industry was

reduced or moved from the area and also came under pollution control requirements, Forge River eutrophication has continued.

However, human population has increased dramatically in the local watershed, and there has been an associated increase in human sewage discharged into the drainage basin via cesspools and septic systems. Greater understanding of the current sources and fates of nutrients and oxygen demanding organic matter in the system, and the controlling physics of circulation, will provide clues as to why the pollution problems persist in the Forge.

Sediments: properties, fluxes of nutrients and oxygen, and levels of potentially toxic contaminants. Sediments have accumulated in areas of the Forge River, including the previously dredged navigational channels. In 2006, New York State, Suffolk County, and the Town of Brookhaven, concerned that sediments may have been the cause of the fish and crab kills, discolored and foul-smelling waters, requested that SoMAS undertake research that was focused on the study of sediments and their role in pollution problems of the tidal Forge River. Sediments were a concern in several respects:

- **Sediment toxicity.** Was sediment toxicity from metal or organic contaminants the cause of the die-offs of fishes and crabs? Persistent and potentially toxic contaminants could have entered the Forge from a variety of sources, including stormwater run-off , runoff from residential or agricultural fertilizer use, light industry (i.e., marinas), duck farming activities, and past pesticide applications (e.g., for mosquito control). Sewage, primarily emanating from on-site sewage treatment systems used in the local watershed (cesspools, septic tanks, and small sewage treatment plants discharging to ground water), could also be leaching into the waterway. In addition to problems possibly associated with sediment toxicity in the river, the concentrations of contaminants in sediments may be of

importance with respect to materials management should Forge River sediments be dredged.

- **Sediments as a source of oxygen demand and nutrient inputs. The sediments of the Forge River act as a reservoir of organic matter and nutrients that enter the system.** Forge River sediments are greatly enriched in organic matter and nutrients tied up in that organic matter. Mineral phases in sediments also store iron and phosphorous, and release of those elements is affected by the seasonally variable decomposition of sediment organic matter. The primary source of organic matter to the sediments is from phytoplankton and macroalgal plant growth in the tidal Forge itself. Organic matter also reaches the tidal Forge from external sources, including algae entering from West and East Ponds north of Montauk Highway, in direct discharge of organic matter from duck ranching operations on West Pond, detritus (disintegrated matter) from many sources including the wetlands, and from stormwater runoff in the watershed. The accumulated organic matter is a sink for oxygen in the sediments. Microbial utilization of organic matter in sediments is most intense in warm periods of the year and is a source of oxygen demand and other products of organic matter decomposition. When oxygen is greatly depleted in sediments, there is release of iron and sulfide in the water as well as a concomitant release of phosphorous that is tied up with mineral phases under more oxic conditions that exist before spring or early summer. In many estuarine and marine settings, much of the organic matter decomposition in sediments comes from recent or fresh sources that are relatively easy to degrade. However, the exceptionally high levels of organic matter present in surficial and subsurface sediments of the upper tidal Forge River suggest that there is likely a large excess of labile organic matter compared to what

- **Sediment accumulation, transport and water circulation.** The bathymetry of the Forge affects its circulation and flushing, as well as navigation. The accumulation of silty sediments has occurred at least in dredged navigational channels in the Forge River, as evidenced by changing bathymetry, and inferred by layers of organic rich muds that have accumulated over the past three to four decades (as determined in sediment core data collected as part of this project). The effects of the accumulation of mud on circulation are unclear as are the likely impacts of any sediment dredging. On a local scale, sediment transport has created sills near the mouths of Wills and Poospatuck Creeks that restricts flushing between the creeks and the mainstem of the Forge River. The sill at Wills Creek, in part, is responsible for development of some of the worst pollution conditions observed in the Forge River. The formation of the sill may have been affected by changes in the flow of water and sediment, caused by the Town pier on the north side of the mouth of Wills Creek.

Suffolk County, between 1965-1973, dredged navigation channels in the main stem of the Forge and also in some of its tributaries. The county also removed some duck polluted sediment from these same water bodies. More than 203,300 m^3 (265,900 yd^3) of material were removed in

these operations. Basins were created in Wills, Poospatuck, and Lons Creeks that are deeper than the Forge itself. These basins have reduced flushing, trapping pollutants and organic materials and are prone to eutrophic conditions.

More recent bathymetric data collected by Roger Flood at SoMAS indicate changes in bathymetry that may adversely affect water exchange between the Forge and Moriches Bay. Whether these changes significantly affected circulation and thus pollution conditions in the Forge could be addressed through high resolution hydrodynamic modeling and/or by dredging these features with associated detailed hydrodynamic measurements before and after alterations in the bottom.

Circulation: effects and important physical processes to understand. The circulation within the Forge and Moriches Bay controls the extent of flushing contaminants via dilution and transport both within Moriches Bay and ultimately within the Atlantic Ocean. Circulation and vertical stratification of the water column affect oxygen levels in bottom waters, and the role that sediments play in storing or releasing nutrients. The Forge River is sluggish due to weak estuarine circulation (small tidal range, limited stream flow) and shallow depths within the Forge and Moriches Bay. Further, the groundwater flow throughout the drainage basin is likely an efficient mechanism for flushing septage from both the densely populated residential area and the remaining duck ranches into the river. The sluggish nature of the river limits its carrying capacity for pollutants of all types, resulting in the frequently observed undesirable conditions.

The flushing of the Forge River and Moriches Bay is known to be significantly affected by the exchange of water through the Moriches Inlet as well as changes in precipitation intensity (Redfield, 1952; Ryther et al., 1958). When the inlet closed in 1951, the average salinity of Moriches Bay progressively dropped over time, after 100 days by approximately 8 ppt, at the

mouth of the Forge, with an even greater drop in the western reaches of Moriches Bay (Redfield, 1952). There were corresponding decreases in water clarity and increased nutrient levels in Moriches Bay and the Forge during that same period. Additionally, the water quality in Moriches Bay in 1957 was reported to have worsened following the reopening of the inlet in 1954, and was attributed to increased filling of the inlet and a weaker exchange of water between Moriches Bay and the ocean (Ryther et al., 1958).

Therefore, to understand better why the conditions in the Forge have worsened over recent years, research questions involving changes in circulation as a result of deposition or removal of sediments must be considered. These include the role of sediment deposition and transport of sediment around the mouth of the Forge River on flushing of contaminated water into Moriches Bay; the dredging of the tributaries leading to the river; the effects of any dredging within the Forge that would affect its depth and circulation; and the impact of channel characteristics on tidal exchange through Moriches Inlet on the flushing of both Moriches Bay and the Forge River.

All of these questions require hydrodynamic measurements and modeling of the circulation, including the effects of changing bathymetry and inlet characteristics. To calibrate a physical circulation model, measurements of the effects of various physical forcing processes (e.g., tides, winds, climate, location and amounts of freshwater sources), and bathymetry should be characterized. Boundary conditions must be defined as well. Due to the nature of this lagoonal system, including shallow waters and small tidal range, the effects of weather (winds and precipitation) may be more important in circulation modeling than in other estuarine settings.

Overview of SoMAS Research Activities on the Forge River

The research that SoMAS investigators have undertaken in 2006 to 2008 will provide insight into the complexity of the pollution problems and management challenges in the Forge River. Below is an overview of the research conducted.

Sediment property and contaminant distributions. Sediment grain size, carbon, nitrogen and sulfur content, water content, and depth of muddy sediments above an apparent layer of sand were characterized at 16-19 locations in the system, most of them at or near established monitoring stations of the Suffolk County Department of Health Services. Analyzed metals or metalloids include aluminum, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, silver, vanadium, and zinc. Semivolatile organic contaminants measured included PAHs, PCBs, and a number of chlorinated pesticides. Ten sediment cores were obtained. Sediment cores with depth profiles were characterized for sediment properties down to 40-75 cm. Suffolk County Department of Health Services analyzed for VOCs in surface sediments.

Water column metals. A survey of metal and metalloid levels in filtered seawater was conducted throughout the tidal reaches of the Forge. The concentrations and spatial distributions were analyzed for evidence of point sources, and compared to levels found in other local estuarine and coastal environments.

Sediment flux studies. Sediment cores from several locations within the tidal Forge were collected and incubated on two dates. Oxygen demand was high compared with other highly populated systems. Rates of carbon mineralization and ammonia production were estimated. These fluxes were compared to oxygen respiration rates in the water column conducted in related studies and the fluxes of nitrogen compared to other external inputs of nitrogen to the system.

Bathymetric studies. In December 2007 and January 2008, a high resolution side scan survey of the Forge River and its tributaries was completed. Referenced to mean low water, it was used to estimate the volume of the riverine system and to identify basins where free aquatic exchange with the river and Moriches Bay may be limited.

Physical oceanographic studies. Groundwater discharge rates were estimated by a combination of approaches: 1) estimation of total freshwater flux in the tidal river by computing the salt balance determined by transects of salinity measurements during incoming and outgoing tides, and subtracting flows from East and West Ponds (during dry conditions); and 2) a combination of modeled determinations that rely on estimates of groundwater recharge in the watershed.

Temperature, salinity, dissolved oxygen, and tidal height measurements were collected over a tidal cycle at a section located just south of the mouth of Ely Creek and at a section running along Wills Creek and across the Forge.

The flow from East and West Ponds was estimated on five occasions over the period of August 2006 to January 2007 by measuring the head of water over the box weirs draining the ponds. On January 16, 2007, direct flow meter measurements were made at East and West Pond, Wills Creek, Swift Creek, Ely Creek, Poospatuck Creek, and Old Neck Creek. The flow meter measurements at East and West Ponds were compared with the estimated flow using head measurement over the weirs.

Nutrient sources. A key challenge for management of Forge River impairments is to identify the major sources of nutrients and the best solutions for reducing those inputs into the system. A comparison of nutrient sources to the tidal Forge River was limited to nitrogen.

The assessment of nitrogen loadings relied heavily on surface water and groundwater data collected by Suffolk County in the river since 2005, and informed by freshwater input

measurements from this study. The data were analyzed to ascertain the degree to which duck ranching and human population are contributing nutrients in the Forge. Direct measurements of flow at East and West Ponds, Poospatuck, Ely, Wills, Swift and Old Neck Creeks were made and fluxes of nutrients estimated. Groundwater flows were estimated based on a combination of approaches: salinity and tidal measurements collected over several tidal cycles along with newly collected bathymetric information allow approximations of the flux of fresh water out of the upper reaches of the Forge. The groundwater flow was estimated by comparison with measured surface water flows; additional estimates of groundwater flow and nutrient inputs are derived from watershed infiltration estimates, on-site sewage disposal estimates, and groundwater flow and modeling work being conducted by Suffolk County. The flux of nitrogen species from sediments to water was also reported, and based on a series of benthic flux incubations with sediments collected during the summer of 2006.

Furthermore, spatial and temporal nutrient concentrations and ratios (e.g., N:P) have been collected by Suffolk County during intense monitoring that sheds light on the importance of local sources of nitrogen into the system. The longer-term water quality monitoring data from Suffolk County at the mouth of the Forge over the past three decades provide additional tests and constraints related to how nutrients have changed with land use practices over that time.

Phytoplankton and *Ulva lactuca* studies. During May to October of 2006, bi-weekly time series data were obtained at the Brookhaven Town Pier for nutrients, phytoplankton species, temperature, salinity, and dissolved oxygen to ascertain information about water column structure, phytoplankton community biomass, diversity, and productivity.

Similar studies were conducted from May 2007 to January 2008. Some data were also collected off Old Neck Creek. Several light and dark bottle experiments were also completed.

Research was undertaken to understand the role of the macroalgae *Ulva lactuca* in nutrient cycling in the river. Periodic assessments of abundance (percent cover) were accomplished monthly from April 2007 to March 2008 at Old Neck Creek, Brookhaven Town Pier, southwest of Old Neck Marina, and the mouth of the Forge River.

Ulva growth rate studies were conducted from May 5-30, 2007 at the Brookhaven Town Pier and southwest of the Old Neck Marina.

Conclusions

Although the cause of all the pollution problems in the Forge River and its tributaries is unclear, many of the symptoms appear to be those of eutrophication caused by nutrient enrichment and biomass stimulation. Further, understanding of pollutant sources, transport, and cycling as they contribute to adverse marine environmental consequences can be used to develop and implement remedial measures.

We hypothesize that the problems experienced in the Forge River are not related to toxicological responses to metals or organic contaminants. To that end, TMDLs for nitrogen and phosphorous should be developed. The challenge of course is to devise a cost-effective means for meeting a TMDL criterion that might be established.

Potential remediation measures might include increasing discharge restrictions and requiring septage system upgrades. Zoning modernization, transfer of development rights, and strategic land purchases by government could also reduce pollutant loading to the drainage basin. Finally, construction of sewage treatment facilities, with a variety of designs to optimize effectiveness and minimize costs, might be required.

References

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Appendix

Data Reports for Suffolk County

1. Benthic flux study measurements, including measures of oxygen and nutrient fluxes and estimates of organic carbon re-mineralization rates in sediments.

2. Relative role of sediments in the tidal Forge River in affecting oxygen and nutrient concentrations.

3. Sediment properties (e.g., grain size and organic carbon levels, depth to sand; observations from sediment cores) from surface grabs at 16 stations, and gravity cores at 10 stations.

4. Water column trace metal concentrations and distributions.

5. Sediment metal concentrations in surficial sediments and sediment core samples.

6. Semi-volatile organic contaminants in surficial sediments including PAHs, halogenated pesticides, and PCBs.

7. Sediment core profiles of organic contaminants, including PAHs, halogenated pesticides, and PCBs.