The image is a composite of two aerial photographs. The top half shows a large, calm lake surrounded by a dense forest of green trees. The bottom half shows a large, excavated quarry site with a smaller, dark pond in the center, surrounded by brown earth and some sparse vegetation. The text is overlaid on the boundary between the two images.

Millbrook Quarry Zebra Mussel Eradication Project



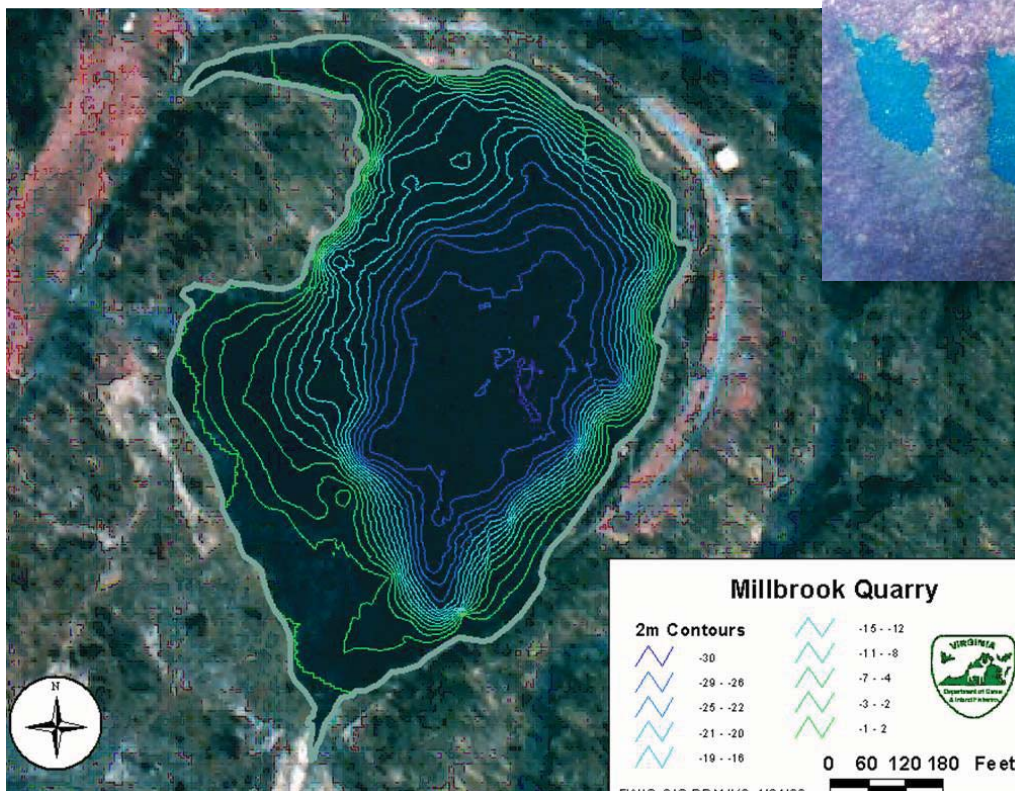
About Zebra Mussels

Zebra mussels (*Dreissena polymorpha*) are freshwater bivalves (clams) native to the Caspian, Black, and Azov seas of eastern Europe. Since the zebra mussel's initial discovery in the United States in 1988, this bivalve has quickly spread throughout the Great Lakes and Mississippi River Basin states. Reproducing zebra mussel populations currently occupy waters in or adjacent to 25 states and extend westward into Nebraska, Kansas, and Oklahoma.

In North America and Europe, zebra mussel populations that colonize open or large water bodies are merely managed to reduce economic and ecological impacts, usually at great financial cost and accompanied by long-term loss of natural resources. Numerous water treatment and power facilities must regularly treat their piping systems to keep them clear of zebra mussels, beaches must periodically remove decaying masses of dead zebra mussels, and bottom-dwelling organisms are often covered by this exotic mussel.



In the United States, congressional researchers estimated that zebra mussels cost the power industry alone \$3.1 billion in the 1993-1999 period, with their impact on industries, businesses, and communities exceeding \$5 billion.



Zebra Mussels at Millbrook Quarry

Millbrook Quarry, located in western Prince William County adjacent to Virginia Highway 55 and Interstate 66, was established in 1947 to produce road stone for construction of Virginia Highway 55. The 12-acre, 93-foot-deep quarry has been inactive since at least February 1963.

A local dive shop in Fairfax first began using the quarry for scuba diving in the early 1970's, and has leased the quarry as a training and recreational dive site since 1978. Through this vendor, the site is accessed by more than a dozen dive shops in the northern Virginia and Washington metropolitan region.

In late August 2002, the Virginia Department of Game and Inland Fisheries (VDGIF) received a report that zebra mussels were present in Millbrook Quarry in Prince William County. Within days, VDGIF confirmed the species' identification; recognizing Millbrook Quarry as the first infestation site of this invasive exotic species in Virginia. Given the proximity of Millbrook Quarry to Broad Run and its extensive use as a dive location, it is highly unlikely that the zebra mussel population could simply have been forever isolated. Broad Run has historically flooded the bank separating it from Millbrook Quarry (1972, Hurricane Agnes),



Aerial view of water clarity at Millbrook Quarry

and unintentional transport of larvae, or veligers, by divers from the quarry to other state waters would be likely.

Diving in Millbrook Quarry could have been prohibited, restricted, or subject to additional costs or regulation if the infestation of zebra mussels was not eradicated.

Many freshwater mussel populations (as well as other aquatic species) have been completely wiped out from areas that zebra mussels now colonize. In Virginia, fifty-four percent (54%) of the native freshwater mussel species in Virginia are currently listed as endangered, threatened, or of special concern. Therefore, if zebra mussels became widely established, the effect on native freshwater mussel populations could be devastating.

In addition, Fairfax Water estimated that they would incur an initial cost of \$2-4 million for chemical feed facilities, in addition to \$500,000 - \$850,000 per year for chemicals and system maintenance. The City of Manassas would likely incur similar expenses to treat zebra mussels at its facility on Lake Manassas, and other private and public facilities throughout the Commonwealth would be at risk.

Since the initial discovery, VDGIF has worked with many federal, state, and local agencies and individuals to pursue eradication of the population. Primary actions included:

- Establishing an interagency Millbrook Quarry Workgroup
- Investigating the hydrologic, geochemical, and biological characteristics of the quarry and infestation
- Inspecting other popular dive sites and reservoirs for zebra mussel infestations
- Evaluating potential avenues for eradicating the infestation
- Surveying other potential infestation sites throughout Virginia
- Surveying Broad Run and Lake Manassas to ensure that zebra mussels had not escaped to those adjacent waters
- Securing funding for the eradication
- Issuing a Request for Proposals to eradicate the infestation
- Selecting a process and contractor to conduct the eradication
- Surveying Broad Run for occurrence of native mussels or other species that might be impacted by potassium seepage from the quarry, and
- Securing environmental review and approvals to eradicate the infestation.



Potash storage facility



How Zebra Mussels were Eradicated at Millbrook Quarry



Diffuser Assembly



Supply Hose with Floatation

Initially Aquatic Sciences reviewed a number of existing control methodologies to determine which one was easily adaptable to open bodies of water. Eventually it was decided that Potassium Chloride, in the form of commercially available Potash, was the best suited for the process of eradication.

A number of factors influenced this decision. First and foremost a large body of water had never been successfully treated with a chemical to remove established populations of zebra mussels. When Potassium is added to water it does not rapidly dissipate nor is it readily consumed in large quantities by organic material. This combined with the static nature of the quarry meant that by using Potash mixing could occur over a longer period of time without the risk of residual loss and that once diffused throughout the quarry a long tenure of control could be realised preventing future re-infestation.

Secondly, Potash is environmentally benign to many aquatic species. Given that several species of aquatic life were present in the quarry and Broad Run this characteristic was of particular importance.

Once Potash was determined to be the best alternative Aquatic Sciences drew upon its significant engineering and marine expertise to formulate a method of application.

Measuring Success of the Zebra Mussel Eradication Project

To kill the zebra mussels through exposure to potassium, the entire quarry was injected with 174,000 gallons of potassium chloride solution over a 3-week period from January 31 to February 17, 2006. The solution was delivered each morning to the site, and then pumped from land-based storage tanks through a floating supply line to a 22-foot work boat outfitted with a specially designed diffuser assembly on its bow. Potassium concentrations throughout the quarry and in adjacent surface waters were measured each weekend during the treatment. The target concentration was 100 milligrams of potassium per liter of water (mg/l, or parts-per-million - ppm); far below the level that would invoke environmental or human health concerns, but more than twice the minimum concentration needed to kill all the zebra mussels. Sampling at various depths and locations in the quarry after treatment revealed potassium concentrations ranging from 98 to 115 ppm, and no potassium leakage from the quarry into adjacent waters has been detected.

No land disturbance was required, as the staging area and setup occurred within the disturbed uplands surrounding the quarry. No disturbance of substrate or bottom sediments within the quarry occurred. No land disturbing activities in or adjacent to Broad Run took place, though Broad Run is being monitored for groundwater infiltration of potassium from Millbrook Quarry.



Bioassay Bags



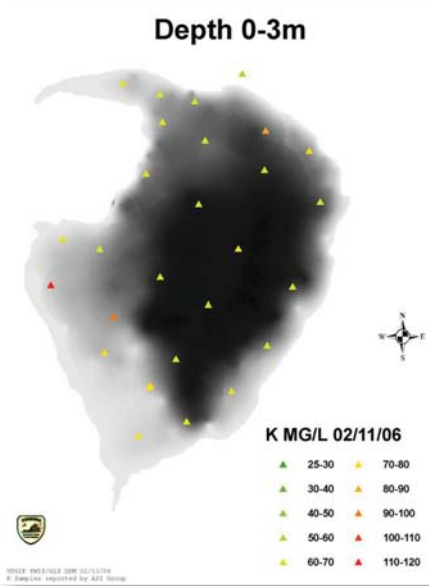
Mortality Determination

Concentrations of potassium were monitored at various depths along transects established throughout the quarry, both during and after “charging” of the quarry, to ensure that lethal concentrations were achieved and maintained. Then, several weeks after treatment was completed, four separate methods of confirming eradication of the infestation were implemented.

First, over a thousand mussels were scraped from rocks at numerous sites around the quarry during informal assessments, revealing no live mussels. Second, VDGIF scuba divers who had documented the extent of the infestation during pre-eradication studies conducted a visual inspection of the quarry, searching for live zebra mussels but finding none. Third, Aquatic Sciences conducted extensive video survey and documentation of the dead zebra mussels through use of a robotic camera. Finally, eighty bioassays of 100 live zebra mussels each were placed at various locations and depths throughout the quarry and thus exposed to the treated quarry water. After 31 days of exposure to the treated quarry water, 100% of the test mussels had died. None of the 100 “control” zebra mussels held in untreated water drawn from Broad Run died during their bioassay period. In dramatic contrast, other aquatic wildlife including turtles, fishes, aquatic insects, and snails continue to thrive in the quarry.

At concentrations used in the quarry (100 parts-per-million) potassium poses no human health risks, nor will it harm any non-molluscan aquatic wildlife, vegetation, or terrestrial wildlife inhabiting the project site. In fact, you would need to drink about 19 gallons of Millbrook Quarry water to consume your daily recommended dose of potassium.

Long term success of Eradicating Zebra Mussels



It is anticipated that there will be negligible, if any, impact on drinking water. There is no federal or Virginia water quality standard for potassium, but potassium chloride is widely used in home water softeners, and many health benefits are attributed to diets rich in potassium. The final chloride

concentration in Millbrook Quarry after treatment has been measured at approximately 90 ppm, well below the EPA/DEQ standard of 250 ppm for potable water.

Potassium will provide long-term (estimated at up to 33 years) protection of Millbrook Quarry against future infestation by zebra mussels.



ROV pilot conducting video inspection of mussel mortality



Turnkey Control Services

INSTALLATION OF PORTABLE SYSTEMS

As an alternative to the extensive costs and effort involved in designing, implementing and operating a chlorination system and a dechlorination system for zebra mussel control, Aquatic Sciences has developed a completely portable and turnkey system using chlorine or potash as control agents. Turnkey services include installation and operation of chemical metering skids, data loggers, chart recorders, analytical instrumentation and dechlorination systems. In addition, Aquatic Sciences provides permits, compliance monitoring and compliance reporting. A typical program includes:

- Installation of chlorination metering skids and tankage
- Installation of analytical instrumentation and loggers
- Installation of dechlorination metering systems and tankage
- Ramp-up and commissioning of both chemical systems
- System operation for 2 to 3 week period
- Compliance sampling
- Breakdown and demobilization
- Compliance reporting

BIOLOGICAL MONITORING SERVICES

Comprehensive biological monitoring services are conducted by ASI staff. On-site personnel training of biological monitoring protocols and procedures can be provided by ASI for clients that choose to complete their own monitoring. Sample analysis and results are available from ASI Ecological Toxicity Laboratory.



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