THE
U.S. ARMY CORPS OF ENGINEERS
TULSA DISTICT, OPERATIONS DIVISION
ZEBRA MUSSEL ACTION PLAN

Prepared By

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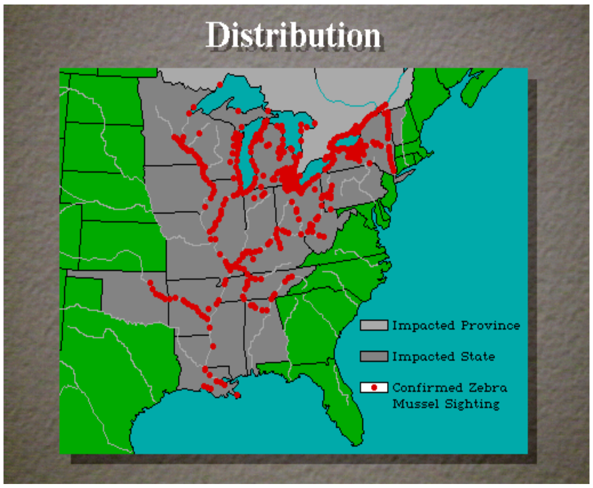
Table of Contents

Background ⇒ Zebra mussels, Dreissena polymorpha, were first found in the United States in St. Clair Lake, Michigan in 1986 and are expected to spread throughout the majority of the U.S. waterways.



They were found in locks 14 (W.D. Mayo), 15 (R.S. Kerr), and 16 (Webbers Falls) from 20 - 22 January 1993. They were found in lock 17 (Chouteau) on 10 June 1993 and in lock 18 (Newt Graham) in mid January 1994. The densities have increased steadily each year and by the fall of 1997 densities are 2,416/M^2 at lock 15, 5.7/M^2 at lock 16, and 54.5/M^2 at lock 17. The highest density at lock 15 was 3,800/M^2. The R.S. Kerr powerhouse had two sites within Unit #1 with densities of 1,400/M^2, with a maximum of 5,200/M^2 at one site.

Biology and Ecology ⇒ Biological characteristics of the Zebra Mussel must be considered when developing control strategies for a facility. Two important aspects of the Zebra Mussel are their strong byssal thread attachment to any firm substrate and the occurrence of Zebra Mussel as microscopic, planktonic veliger larvae in their early life stages. Most adults live 2 - 3 years. Adults are intolerant of low dissolved oxygen (<50% air saturation), high water temperature 30°C (86°F), 32.5°C (90°F) will cause mortality in 5 hours, 34°C (93°F) is lethal, acidic (pH less than 7), low calcium conditions (less than 15 mg/L as divalent cation), brackish water (greater than 5 ppt), turbidity over 50 TDU, and salinity above 4.5.ppt. Biochemical indicators show Zebra Mussel to be their weakest in the Spring and Fall.

Zebra Mussels can be sexually mature when they are about 3mm in length. Females typically produce from 30,000 to 100,000 eggs per season, but can produce 1,000,000 eggs in a single season. Reproduction can occur when water temperature is between 12°C (54°F) and 27°C (80°F). The eggs develop in 7 days and larval life is 7 - 30 days. The eggs and larvae are easily transported by water currents; therefore, facilities downstream of known populations are at immediate risk. Veligers may be abundant in water when temperature exceeds 12°C (54°F) and can settle at any water velocity less than 1.5 mps. They prefer flows of 1.5 to 2.0 mps. (4.8 to 6.6 fps). If faster flows slow down they can attach and stay attached when velocity picks back up.

Due to their high reproduction rate and limited number of natural predators, Zebra Mussels can significantly populate a waterbody in only a few months. They can cluster together with hundreds of thousands per square meter. While native mussels burrow in sand and gravel, Zebra Mussels will attach to any firm object under water, including concrete and metal. This characteristic presents a problem to manmade facilities built in, or that transport, raw water.

<u>Potential Impacts</u> ⇒ Zebra Mussels can become a problem to any surface exposed to raw water. In addition to the direct impacts the accumulation of Zebra Mussels on concrete and metal will increase deterioration of the surfaces. The Tulsa District facilities that can be effected are; powerhouses, locks, stop-logs, boats, barges, buoys, docks, boat ramps, swimming beaches, and other areas. Removing the Zebra Mussels during routine maintenance can protect many of the areas of concern. However, some areas that are less accessible will require installation of a control measure that can protect it.

<u>Powerhouses</u> ⇒ The primary areas of concern in the powerhouses are the cooling water screens, piping, strainers, and drains. Any

accumulation of Zebra Mussels in the cooling systems will diminish the cooling capabilities and reliability of the system to function properly. Historically during the summer, when the river water is warm, we have trouble keeping the units cool. If the amount of water flowing through the system is restricted it will increase the cooling problems. Also of concern are the stop-log rollers and seals. We should not experience any problems from accumulations on the turbine blades or wicket gates due to the high flows during generation periods. Accumulations on the concrete within the penstocks should not be enough to noticeably reduce the flows, or power production, during generation. However, accumulations could increase concrete spalling.

Locks ⇒ The accumulation of Zebra Mussel on the concrete and metal in the lock chamber should not hamper the ability to lock traffic through, but it could accelerate spalding of the surfaces. This would increase the frequency of painting the gates and other metal surfaces. Zebra Mussels should not be able to accumulate on the gate seals since the gates are always closed, except during locking. The only use of raw water within the facilities is the fire system, which could be inoperable if Zebra Mussel plugs the piping.

Trash Racks ⇒ Trash racks are of highest threat of being infested with Zebra Mussels because of the continuous flow of water passing through them. As the zebra mussels accumulate on the trash racks the flow through them will be restricted. This could reduce the efficiency of the turbines and rate of water transfer into/from the locks.

Stop-logs ⇒ Stop-logs that are stored in the river will become infested with Zebra Mussels. We are already experiencing problems placing the stop-logs and are having to physically remove Zebra Mussels from the stop-logs and slots before they can be properly set.

Boats and Barges ⇒ The tugboats and barges are at risk of infestation since they are constantly in the river. The Zebra Mussels will attach to the hull, which will increase spalding, requiring more frequent maintenance for their removal and repainting of the hull. They will also increase the drag on the water, making the tugs and barges harder to move in the water. Any Zebra Mussels within the engines cooling system will jeopardize its ability to keep the engine cool. The smaller boats that are stored on land should not experience problems if properly cleaned when removed from the river after each use.

Buoys ⇒ There has been documentation of Zebra Mussel densities high enough on buoys to sink them. If our densities increase high enough to pose this threat they could threaten the navigation buoys. An increase of Zebra Mussels on the buoys would also increase the drag of the river flow on them and may cause them to be pulled out of position during high flow.

Docks ⇒ Accumulations of Zebra Mussels on fleeting and recreation docks would increase spalding of the surface material and may scratch the hulls of fiberglass recreational boats.

Boat Ramps ⇒ Zebra Mussels could cause problems at boat ramps. They may reduce traction of vehicles, from the Zebra Mussel build up and/or from the slick tissue of crushed Zebra Mussels, and make it hard to drive up the ramps. The thin shells would also be a safety hazard to the public walking barefoot on them.

Swimming Beaches ⇒ Swimming beaches that have a hard substrate for the Zebra Mussels to attach to could become a safety hazard to the public. The thin shells of dead Zebra Mussel are similar to razor blades in thickness and sharpness.

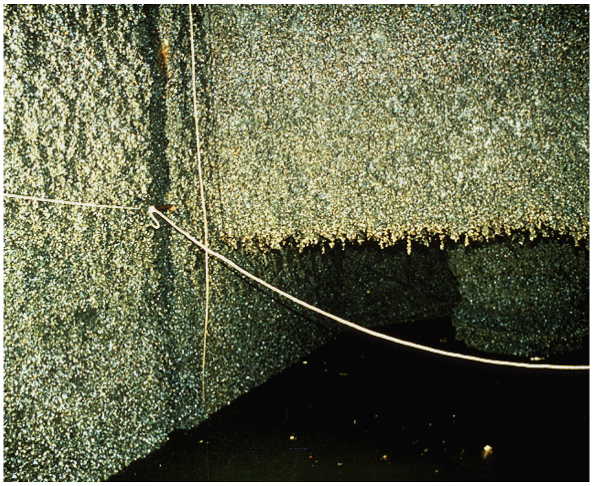
Other Areas ⇒ Others areas that may be of concern are other locations along the shoreline used by the public. There are many isolated locations that are used by campers, fishermen, hunters, hikers, etc. where they could encounter Zebra Mussels, or their shells. These users could be at risk from cuts if they are swimming or wading in the water.

Control Measures ⇒ Each facility will have to be assessed independently to determine which control measures will best reduce Zebra Mussel impacts at the various areas of concern. Control measures can be classified as chemical or non-chemical controls.

Chemical Controls ⇒ There are various oxidizing and non-oxidizing chemicals that can be used to control Zebra Mussels. Some of the more commonly used are chlorine, chlorine dioxide, bromine, potassium, and ammonium nitrate. Chemical treatments are costly and labor intensive to install, operate and maintain. Also, a leak in the control system inside our confined facilities would create a safety hazard. The Environmental Protection Agency requires permits and regulates the effluent from the treated water, therefore, a detoxification system would be required: an additional installation, operation, and maintenance cost.

Non-Chemical Controls ⇒ The non-chemical control options are widely diverse. Some of the more proven techniques include; surface coatings, mechanical/physical removal, filters, cathodic and electric fields, freezing, oxygen deprivation, desiccation, thermal, increasing water velocity, copper ionization, and the use of toxic metal components.

Surface Coatings ⇒ Surface coatings are typically in the form of paints that have a base component that Zebra Mussels do not like. Paints that have a silicone or toxic metal base, such as copper, lead, zinc, etc., will deter settling of Zebra Mussel. Zinc plating is also very effective. These methods would require extensive surface preparation and repetition every few years, requiring additional budget, manpower, and downtime. Not all locations would be accessible to surface coatings.



Mechanical or Physical Removal ⇒ Once Zebra Mussels have settled they can be removed by physically scraping or using a hot water high pressure spray to remove them from the surface. There are also some commercial mechanical devices (such as scrubbers) that are effective. After the Zebra Mussels have been removed those that can not be flushed through the structure will have to be removed from the site and disposed of. This method is labor intensive and requires a suitable disposal site.

Filters ⇒ Filtering of Zebra Mussels from piping systems, such as the cooling water piping for the turbines, require a minimum 40 micron(absolute) filter to prevent passage of veligers. In turbid water pre-filters would be required to remove larger particles. Filter systems would have to be able to provide a continuous flow of raw water, in a sufficient amount, and be self-cleaning. Several manufacturers have stated that they can handle our needs, but at the flows we have the size of the filter system may be extensive. We would likely have problems locating them within the structure, requiring re-routing of the water lines. The piping from the intake to the filter and the backwash water drains would require separate control measures.

Cathodic Protection ⇒ Metal surfaces can be protected with a cathodic current of approximately 50 mA/m^2. This technique is site specific but can be effective at specific locations, especially where cathodes are already being used.

Electric Fields ⇒ Some studies have shown that electrical fields can be used to protect metal, concrete, wood, and open water. Electrical fields of 10 mA/ft^2 at 40 V have been applied to concrete surfaces by installing an electrically charged metal mesh to the concrete surface.

Another study used 1/8 inch electrodes spaced 2 inches apart over concrete and steel surfaces with 8.05 V/in. Installing such a network of metal mesh or electrodes would be extensive and its durability would be unlikely for most of our applications. The system would be costly to install, maintain, and supply electric for.

Open water areas of our systems (such as within pipes) may be able to be protected for some distance with pulses of electric at a rate of 6.5 kV/cm for 770 nanoseconds. The Zebra Mussels are stunned and pass through the system without settling. Modeling results indicate that efficiencies of more than 50,000 gallons/kWh may be reached. The expense to install this system would likely be acceptable but the electric supply to operate it could be substantial (the Webbers Falls Powerhouse cooling system is 550 GPM and would therefore require 0.66 kw). The effectiveness of this system could be lost when flows cease, possibly allowing the Zebra Musseld to recover, settle, and remain established beyond the electrical field.

Freezing ⇒ Exposure to freezing conditions will kill Zebra Mussel. This technique would be effective and inexpensive on surfaces that can be de-watered during the winter.

Oxygen Deprivation ⇒ If oxygen levels can be maintained low enough and long enough Zebra Mussels can be suffocated. Oxygen depletion can be promoted in water systems with a variety of chemical additives. If chemicals are used EPA permits would likely be required and the system would have to be out of service for an estimated 20 - 120 days. After the Zebra Mussels have died they would then have to be physically removed from sensitive areas.

Desiccation ⇒ Exposure to warm and dry conditions can kill Zebra Mussels over time. They can survive in open-air conditions over seven days, depending on humidity and ambient air conditions. After they have died they would then have to be physically removed from sensitive areas.

Increasing Water Velocity ⇒ Zebra Mussels are not capable of settling on substrate if the mean water velocity is higher that 4.5 fps. If higher velocities can be maintained during operation it could prevent Zebra Mussel establishment.

Thermal ⇒ Water temperatures over 35°C (95°F) for one hour will kill Zebra Mussels. Higher temperatures will reduce

the time needed for 100% mortality. Using this technique requires a hot water source and the ability to hold the water in the system during the treatment. Areas that can not be enclosed for thermal treatment can be cleaned with a high-pressure, hot water 60°C(140°F) sprayer that will kill the Zebra Mussels instantly and remove them from the surface being cleaned.

Copper Ionization ⇒ Controlled releases of copper ions will inhibit the establishment of Zebra Mussels. When used in conjunction with a highly hydrated aluminum hydroxide flow that settles in low and laminar flow areas that are most susceptible to Zebra Mussel settlement, its anti-fouling properties are increased. The initial cost for the system and O&M is relatively low. The installation of a feeder line to the cooling water intake may be difficult. The technology for fresh water use is relatively new, but proven.

Toxic Metal Components ⇒ Toxic metals such as copper, zinc, brass, lead, mercury, silver, etc. are less susceptible to Zebra Mussel infestations. Use of copper, brass, or zinc-plated metal instead of steel will deter settlement at those locations.

No Action ⇒ Some locations can be left without control measures if the impacts are insignificant, or installation of controls would not be cost efficient.

Recommendations ⇒ The first line of defense that can be taken against Zebra Mussels is to try to prevent their introduction. Operations Division should keep informed of current events and maintain a level of expertise to sufficiently coordinate this action plan. By supporting and promoting information and education efforts it may be possible to delay, or even prevent, infestations. Once

Zebra Mussels have become established in a waterbody there is no feasible way to eradicate them. The challenge at that point is to control their impacts.

Establishment of a monitoring program will allow early detection so that control measures can be implemented before accumulations begin impacting operations. The control methods can be categorized as chemical controls and non-chemical controls. Most often facilities require a combination of methods to deal with the different areas exposed to Zebra Mussels.

<u>Monitoring</u> ⇒ Projects, powerhouses, and locks should monitor during routine operations around their facilities for the presence of Zebra Mussels. Resident and project offices should look around submerged structures such as rocks, docks, cables, debris, etc. Powerhouses and locks should check tubes, tunnels, gauges, seals, etc.

The District Office will provide information to the Area and Lake Managers for guidance to lake customers in assisting to monitor for Zebra Mussels. If Zebra Mussels are found a few should be collected and Everett Laney should be contacted as soon as possible at 918-669-7411 so that proper notifications, coordination, and recommendations can be taken.

<u>Powerhouses</u> ⇒ A copper and aluminum ionization system has been used successfully at several generating stations. The system applies an electrolytic dissolution of toxic copper into the water that kills the veligers and inhibits adult settlement by reducing their ability to attach to the sub-

stratum as they become increasingly unable to secrete byssus threads. The dissolution can be applied into the cooling water intake where it will be drawn through the entire cooling system. The target level of copper added to the water is 10 ppb above the background levels. This system can treat 5,000 gpm at ≤100 watts, 10,000 gpm at ≤200 watts, etc., therefore, one system that is available commercially can treat all the raw water needs of a powerhouse. The estimated cost per system is $50,000 - $75,000. The Oklahoma Department of Environmental Quality has approved, in writing, our use of the system with no permit requirements and only standard monitoring requirements. The intake grate should be replaced with a toxic metal, or be zinc plated.

The *turbine blades* and *wicket gates* should not experience any problems from accumulations due to the high flows during generation periods. Any Zebra Mussels found during routine maintenance should be physically removed. Accumulations on the concrete within the *penstocks* should not be enough to noticeably reduce the flows, or power production, during generation. Heavy accumulations could increase concrete spalling, therefore, physical removal may be required.

Locks ⇒ When the locks are not in use the chamber should be kept empty to prevent accumulations (by desiccation and freezing) on the upper portions of the *lock walls*, *ladders*, and *mooring bit tracks*. Those in the lower portions of the lock walls, floor, and drains can be left since they should not hinder operation of the lock. The cathodic systems on the *mooring bits* and *gates* should be replaced and maintained. During scheduled de-watering of the lock all Zebra Mussels should be removed and disposed of at an appropriate location on Corps property. The metal works in the *valve chambers* and the river side of the *gates* should be painted with an appropriate silicone or copper based marine paint. The current *fire system*, which uses river water, should be abandoned, supplied with rural water, or a portable system adopted. A portable system could be fire extinguishers or a portable pump with a dry storage intake that can be quickly lowered into the river when needed.

Trash Racks ⇒ If the *trash racks* can be removed, or accessed during dewatering, they can be protected by periodic physical removal of the Zebra Mussels, surface coatings, or reconstructed with a toxic metal. For those trash racks that can not be removed, or accessed during dewatering, the only means to remove the Zebra Mussels will likely be with divers physically removing them.

Stop Logs ⇒ The s*top-logs* should be dry docked when not in use, if possible. If not, the Zebra Mussels will need to be physically removed from the rollers, tracks, and seals before each use, along with the stop-log *slots*. If they can be removed from the water they should be painted with an appropriate silicone or copper based marine paint. If a power supply can be provided to the floating stop-logs a cathodic or electric field system could be installed.

Boats and Barges ⇒ All portions of the *tugboats* and *barges* should be painted below the water line with an appropriate silicone or copper based marine paint. This includes the *treasure chest and any other areas* that can be painted. All non-toxic *components* exposed to raw water should be replaced with toxic metal components, if able. Those that can not be replaced will require monitoring to ensure Zebra Mussels do not impact proper function. The smaller craft should be dry docked except when in use. When removed from use they should be washed with a mild chlorine solution (tap water) or high pressure hot water (140° F) spray (car wash).

Buoys ⇒ The incidence of buoys being sunk by heavy accumulations of Zebra Mussels are rare. Preventive measures should not be taken until the buoys are threatened. When accumulations do threaten the buoys the Zebra Mussels should be physically removed and an appropriate silicone or toxic metal based marine paint should be applied to prevent re-infestations.

Docks ⇒ Fleeting and pole supported recreation docks should not be so adversely impacted by accumulations that control measures would be warranted. Metal floating docks should be zinc plated or painted with an appropriate silicone or toxic metal based marine paint below the water line. Styrofoam floatation should be replaced, as needed, with hard surface floatation painted with an appropriate silicone or copper based marine paint.

Boat Ramps ⇒ Traffic on some boat ramps may keep the Zebra Mussel accumulations to a minimum. Most of the direct use of the ramps, such as foot traffic and the rear tires of the vehicle backing the trailer, are in the upper few feet of the water level. Typically, most of the Zebra Mussels accumulate in depths below three feet, therefore, no control measures should be needed. If accumulations become a problem they should be physically removed.

Swimming Beaches ⇒ Removal of Zebra Mussel shells from beaches would not eliminate the safety hazard since small broken shells would be impossible to separate from the sand. Shells that are washed up onto the shore should be physically removed and the beach posted as hazardous. Beaches that are littered with shells should be closed to the public or restricted to use with shoes only. The shell deposits could be covered with an appropriate layer of new sand, but would eventually have new shells wash back up on the shore.

Other Areas ⇒ Information should be disseminated to the visiting public of Zebra Mussel infestations and educated to the potential hazards they may impose, including non-maintained areas. Areas with more severe wave action will not likely experience heavy accumulations in the wave zone. Therefore, Zebra Mussels should pose less of a threat to boat ramps, non-floating docks, or the public in those high wave zones.

Conclusions ⇒ Specific control measures and estimated budgets for each potentially impacted facility should be determined and budgeted. Development of the control measures and budget requirements will be coordinated jointly between district and field personnel. The Tulsa District point of contact is Everett Laney.