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*Managing Water in the West*

# Facility Assessment for McNary Lock & Dam

## Invasive Quagga and Zebra Mussels

**U.S. Army Corps of Engineers**
**Walla Walla District**


**U.S. Department of the Interior**
**Bureau of Reclamation**
**Technical Service Center**
**Denver, Colorado**



**August 2015**

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*Prepared for U.S. Army Corps of Engineers Walla Walla District and McNary Lock & Dam Project Office*

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Cover Photo: Photo of McNary Dam.

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# Executive Summary

The purpose of this assessment is to provide U.S. Army Corps of Engineers (USACE) management and project staff with information regarding the vulnerability of facility features to invasive mussel impacts. This report is not intended to be a risk assessment or prediction of the potential for a future mussel infestation. Instead it is intended to assist project management and staff in anticipating and planning for impacts should a future infestation occur.

## Findings

McNary Lock and Dam facilities are relatively complex and an invasive mussel infestation would likely significantly impact facility operations and maintenance. Impacts would generally be expected to include fouling of trashracks, grates, gates, screens, bar racks, raw fire water systems, cooling water systems piping, valves, associated equipment and instrumentation as well as impacts from heavy shell debris loads which can overwhelm strainers and filters. Fish passage, handling, and transport facilities also appear susceptible to impacts which could include mussel fouling on screens, diffusers, separators, instrumentation and equipment along with clogging of piping and associated systems from shell debris. However, the annual shutdown and unwatering of the fish facilities will likely reduce or eliminate long-term settlement. Shell debris during operation would likely be the most significant impact for the fish facilities.

Based on information from Ice Harbor, calcium and pH levels would suggest that conditions may only be suitable for supporting moderate levels of infestation. Additional data on seasonal variability would be helpful to better assess potential infestation levels and assist in prioritizing response actions.

## Recommendations

The following recommendations are provided for consideration:

- In conjunction with this assessment, consideration should be given to development of site-specific response actions that build upon the Columbia River Basin response plan to address a future infestation as soon as possible (if not already in place). While there is no accurate way to predict whether McNary will become infested, planning ahead will allow time for budgeting and implementation of response actions if needed. Management options have been included in Appendix B along with links to other response plans and response planning guidelines developed by the National Parks Service.

- It is recommended that seasonal (spring-fall) monitoring for mussel larvae via plankton net sampling be continued for the earliest possible detection. Although substrate monitoring can detect the presence of adult mussels, it is not considered an effective early detection method. An infestation is typically already in the advanced stages by the time settlement on substrates is observed, thereby substantially reducing the available time before mussels begin impacting facilities. The primary advantage of early detection is to allow lead time for planning, budgeting, and implementation of response actions.

- It is also recommended that future water quality sampling and analyses be conducted to further ascertain the potential for mussel survival, establishment, and associated infestation potential at McNary.

# Introduction

## Purpose and Objectives

The purpose of this assessment is to provide U.S. Army Corps of Engineers (USACE) management and project staff with information regarding the vulnerability of facility features to invasive mussel impacts. This report is not intended to be a risk assessment or prediction of the potential for future mussel infestation. Instead, it is intended to assist project management and staff in anticipating and planning for impacts should a future infestation occur.

## Brief Project Description

McNary Lock and Dam consist of a navigation lock, a concrete dam with an earthfill embankment at the south abutment, a spillway section, a powerhouse, and fish passage facilities. The project provides hydroelectric generation, navigation, recreation, habitat, and incidental irrigation. The facilities are owned, operated, and maintained by the U.S. Army Corps of Engineers.

The lock is located between the concrete gravity and the earthfill embankment sections and is 86-ft wide by 683-ft long with a total lift of approximately 75 ft. The downstream end of the lock is equipped with an arch gate while the upstream end is equipped with a miter gate that is raised and lowered accordingly. Waterways, controlled by culvert tainter valves, are used to fill and drain the lock.

The concrete gravity section contains a 1,300-ft-long radial gated spillway with twenty-two vertical lift gates. Two spillway weirs were installed to improve downstream passage. The powerplant is adjacent to the spillway and consists of fourteen 70-MW Kaplan turbine and generator units with a combined rated capacity of 980 MW. The powerplant operates year round with varying number of operating units as needed to meet demand. The fish facilities include two upstream passage ladders and a juvenile bypass and fish facility.

## Background on Potential Invasive Mussel Impacts

Quagga and zebra mussels (adult lengths typically average about 1 in) are unique in that they can firmly attach to the underwater surfaces using byssal threads. They begin spawning by emitting eggs and sperm into the water column when water temperatures reach about 10ºC (50ºF); though spawning has been observed at slightly lower temperatures in some cases. On a population-wide basis, egg production occurs in astronomical levels (on the order of 30,000 eggs/female/reproductive cycle). Depending on temperature and environmental suitability, multiple reproductive cycles may occur in a single year. Fertilized eggs develop into freely swimming larvae or veligers (ranging in sizes from 60 to 250 micron) which may be transported by water currents for many miles. Within a few weeks and if water conditions are suitable, the veligers will settle (i.e., attach to hard surfaces) and continue growth to adulthood.

Successful settlement is mediated by a number of environmental conditions inherent in the natural water system. These include calcium, alkalinity/hardness, pH, nutrients, dissolved oxygen, temperature and conductivity. It should be noted that some of these parameters are indirect measures of others. For example, alkalinity/hardness is presumptive for calcium and magnesium. It is generally accepted that highly successful mussel colonization occurs when calcium levels exceed about 24 mg/L. Successful establishment is more in question when calcium values fall below about 10 mg/L. With the possible exception of nutrients (implied indicators of food supply) in high mountain lakes, the remainder of listed parameters seems fairly well represented as having adequate levels in most Western waters where data are available. Table 1 provides water quality parameters suitability criteria for invasive mussels. It should be noted that this information may not be entirely applicable to all water bodies in the Western U.S. Nevertheless it provides an approximate indication of suitability requirements.

**Table 1.** Presumptive infestation-level suitability criteria for invasive mussels.

| **Parameter** | Low Probability of Survival | **Infestation Levels** | | |
|---|---|---|---|---|
| | | Low | Moderate | High |
| Calcium (mg/L) | <10 (QM)<br><8 (ZM) | 10-12 (QM)<br>8-15 (ZM) | 12-30 (QM)<br>15-30 (ZM) | >30 |
| Alkalinity/Total Hardness (mg $CaCO_3$/L) | <35 (QM)<br><30 (ZM) | 35-42 (QM)<br>30-55 (ZM) | 42-100 (QM)<br>55-100 (ZM) | >100 |
| pH | <7.0<br>>9.5 | 7.0-7.8<br>9.0-9.5 | 7.8-8.2<br>8.8-9.0 | 8.2-8.8 |
| Dissolved Oxygen (mg/L) | <3 | 5-7 | 7-8 | >8 |
| Dissolved Oxygen (% saturation) | <25% | 25-50% | 50-75% | >75% |
| Mean Summer Temperature ($^{o}$F) | <64<br>>86 | 64-68<br>83-86 | 68-72<br>77-83 | 72-75 |
| Conductivity (µS/cm) | <30 | 30-60 | 60-110 | >110 |
| Salinity (g/L) | >10 | 8-10 | 5-8 | <5 |
| Secchi depth (m) | <0.1<br>>8 | 0.1-0.2<br>2.5-8 | 0.2-0.4 | 0.4-2.5 |
| Chlorophyll a (µg/L) | <2.0<br>>25 | 2.0-2.5<br>20-25 | 8-20 | 2.5-8 |
| Total phosphorous (µg/L) | <5<br>>50 | 5-10<br>35-50 | 10-25 | 25-35 |

It is also important to note that mean summer temperature does not imply temperature thresholds. Adult mussels have been observed to survive at temperatures near freezing. The low-temperature threshold for mussel growth is thought to be around 45 ºF. This would imply that mussels are more likely to colonize systems with raw water temperatures greater than about 45 ºF, with a lower probability of colonization for sustained temperatures below this threshold. On the upper end, temperatures greater than about 84-86 ºF for extended periods are not generally expected to support mussel survival. For additional information see Mackie G. & R. Claudi, Monitoring and Control of Macrofouling Mollusks, 2nd Ed., CRC Press, 2010.

Environmental and operational conditions of the structures themselves may also influence veliger settlement and subsequent colonization. Within a facility, veliger settlement is prohibited or greatly reduced in pipes where water velocities continuously exceed 6 feet per second (ft/s). However, intermittent operations or lower velocities may lead to successful settlement. Once attached, mussels can sustain that attachment even when flow velocities are well above 6 ft/s. Ideal areas for mussel colonization are those areas with continuous flows of moderate velocities (<6 ft/s) and ample supplies of food and oxygen. Piped systems which are seldom utilized or idle for prolonged periods and which have depleted oxygen are not generally supportive of successful colonization. A major exception is a situation where leaking valves allow constant flows and replenishment to such seldom used systems.

Invasive mussels pose serious threats to water resources infrastructure and operations. Of major importance to facilities is the ability of mussels to rapidly colonize hard surfaces at densities of tens of thousands per square meter. Heavy accumulation can lead to costly operations and maintenance problems. Flow restriction is the foremost concern because mussels can clog water intake structures, such as trashracks, pipes and screens, thereby threatening water delivery to critical systems at hydropower plants and reducing pumping and conveyance capacities of water distribution systems.

# Assessment Findings

## Potential Infestation Levels

### Water Quality

Of importance for estimating potential infestation levels are those parameters necessary for establishment and growth of mussel populations discussed above (namely calcium, pH, dissolved oxygen, temperature, and nutrients). Though it should not be construed as a complete water quality analysis or prediction of future conditions, based on limited available water quality information that was provided for Ice Harbor, calcium levels appear to be in the range of 18-21 mg/L. These levels would be considered conducive to supporting moderate levels of infestation. Similarly, pH was indicated to be about 7.4 which would be considered conducive for low levels of infestation. Without information regarding frequency and duration, it is difficult to assess potential infestation levels. Additional water quality data are needed to further assess suitability for mussel survival, establishment, and associated infestation levels.

## Vulnerability of Features

### Lock

The lock appears susceptible to mussel related impacts with perhaps some mitigating effects due to operating conditions. Fluctuating water levels during lockages, which can occur several times per day, would be expected to significantly reduce (and likely prevent) mussel settlement on surfaces that do not remain submerged. Conversely, mussel settlement and fouling of surfaces that remain submerged for extend periods of time would be expected; the degree to which would depend on levels of infestation.

The waterways, trashracks, and tainter valves for filling and draining the lock may be exposed to greater impacts. Mussel fouling on the tainter valves has the potential to degrade seals over time. Frequent operation may considerably reduce mussel settlement along sealing surfaces. The most significant impacts may result from mussel shell debris which can be drawn into the gate sections during operations and may affect seating of the gates upon closure.

Bulkhead slots for servicing the gates are also generally susceptible to long term mussel fouling which can lead to seal damage during installation and affect the ability to fully seat bulkheads. If deployed for extended periods of time, mussel fouling on the bulkheads themselves may occur, affecting drain holes (if so equipped) and making removal difficult. Furthermore, bypass or fill piping may be susceptible to complete clogging with the potential for inoperability which would also make bulkhead removal problematic.

Other mechanical components may be exposed to increased wear and operational problems due to mussel fouling and associated shell debris. Regularly scheduled shutdowns with unwatering for inspection and maintenance are expected to reduce long term accumulation of mussels, but unwatering sumps and pumps would also likely be impacted with the potential for mussel accumulation in sumps affecting pumps operation (i.e., suction screens as well as cooling/lub and seal water if so equipped).

**Figure 1.** Navigation lock

### Dam & Spillway

Although it is currently uncertain (i.e., hypothetical), structural drainage systems may also be impacted by mussels depending on the design of the systems, size of seepage passages, and potential for backflooding of outlets. Typically flow passages to drain systems are extremely small, but if they are sufficiently large for larval mussels (> 60µm) to enter and the water chemistry is suitable for survival, then mussel colonization and clogging of portions of the drainage systems may be possible. Asian clam shell debris in drainage galleries would be an indicator for the possibility of mussel larvae to also enter the drainage systems.

**Figure 2.** Asian clam shell debris in drainage gallery

### *Spillway Gates & Stoplogs*

The spillway gates remain partially submerged more or less continuously. Impacts can range from increased friction along sealing surfaces and degraded seal performance to accelerated corrosion on submerged metallic surfaces (e.g., the gates themselves and embedded seal plates). Depending on the seats design, it may also be possible for shell debris to accumulate in recesses which could make fully seating the gates difficult.

Stoplogs to provide access for inspection and maintenance are not expected to be directly impacted if stored in the dry. However, the guides, seats, and sealing surfaces would likely be susceptible to fouling which could result in seal damage or incomplete seating during installation. If deployed for extended periods of time (i.e., months) direct fouling of the stoplogs may occur. Impacts can include clogging of bypass fill passages which could complicate stoplogs removal.

### *Spillway Weirs*

The spillway weirs provide improved downstream passage for juvenile fish and generally appear susceptible to mussel related impacts which may include fouling of the entire structure. Long term fouling along flow boundaries could impact fish passage performance by roughening flow surfaces and potentially exposing fish to injury during passage.

## Powerplant

### *Intake Trashracks*

The powerplant intakes are equipped with trashracks with 6-in bar spacing which appear highly susceptible to mussel related impacts owing primarily to intermittent operations. Experience at Reclamation facilities that are heavily infested with quagga mussels suggests that portions of powerplant intake trashracks can become heavily fouled with significant reductions in open area resulting in increased headlosses. Depending on trashrack design and existing condition there may also be a remote potential for trashrack failure. The trashracks are removable (though they typically remain in place) and a raking system is available which can reduce mussel fouling along leading edges of trashrack bars, but if rake head penetration is not sufficient, mussel fouling between bars can persist.  The trashrack slots also appear susceptible to long term mussel fouling which could make future removal difficult.  Furthermore, long term fouling on submerged metal work can accelerate corrosion if not adequately protected.

**Figure 3.**  Trash rake

***Extended Submersible Barrier Screens***

The intakes ESBS are deployed in the bulkhead slots and also appear somewhat susceptible to mussel fouling. Locally higher velocities may mitigate impacts to some degree, but intermittent operation of units would likely allow mussel fouling on the wedgewire screens and internal component which would reduce open area and alter velocity distributions with the potential for increased fish impingement and injury potential.  However, considerable mitigation would be expected through annual removal of the screens for cleaning to reduce long term fouling and associated impacts.

**Figure 4.**  Intake screen panels and brush system

### *Gatewells & Vertical Barrier Screens*

Surfaces in the gate wells and on the vertical barrier screens (VBS) appear quite susceptible to mussel fouling. The vertical barrier screens consist of fixed panels and rotating sections, both of which appear quite susceptible to mussel fouling which has further potential for adverse impacts to downstream passage. The rotating sections may be less susceptible to mussel attachment, but lodged shell debris may be problematic. Increased impingement and injury potential from mussel settlement on the screens would be the primary concern, but heavy fouling of the screens could also make removal for cleaning difficult. Impacts from long term mussel attachment would be mitigated through annual removal and cleaning.

### *Intake Gates & Bulkheads*

The roller gates for each of the powerplant intakes appear generally susceptible to long term mussel fouling since they typically remain submerged. Mussel fouling has the potential to damage seals and sealing surfaces leading to degraded seal performance. Although not likely to render the gates inoperable, mussel fouling of the mechanical components may cause abrasion damage along bearing surfaces with some potential for incomplete seating on closure depending on design, infestation levels and operating conditions.

Bulkheads for the powerplant intakes are not directly susceptible to mussel fouling if they are stored in the dry. However, the bulkhead slots are likely susceptible to varying degrees of mussel fouling which may impact ESBS removal and could affect bulkhead seals and seats during installation. Like the intake gates, mussel fouling along the slots can damage seals and sealing surfaces with the possibility for incomplete seating during installation. If the bulkhead remains installed for extended periods of time then direct fouling may occur which can impact lifting equipment. Fouling of bypass fill lines may also occur which could further complicate removal unless other means of balancing are available.

**Figure 5.** Roller gate and bulkhead gate

### *Cooling Water Systems*

The cooling water systems supply the thrust bearing oil coolers, generator air coolers, transformers and HVAC system with raw water. Packing and compressor cooling water is supplied with potable water, but have raw water backup. Fire water for the transformers deluge system is raw. Raw cooling water is supplied via takeoffs from the spiral cases. Cooling water systems of this type are some of the most susceptible features to mussel related impacts due mainly to the small size of piping and flow passages. Although these systems appear to have some measure of protection from shell debris afforded by strainers, they can still become clogged and excessive shell debris drawn into the system can overwhelm strainers and filters if not adequately maintained. Strainers alone will not exclude mussel larvae (veligers) which can pass and settle in downstream portions of the system. Live mussels and dead mussel shell debris have the potential to clog distribution lines and small flow passages (i.e., heat exchangers) reducing or cutting off water flow at multiple points in the system. Clogging can cause increased operating temperatures and has the obvious potential for costly outages until cooling water flows can be restored. Turbine pit drains may also be exposed to clogging from mussels with the potential for turbine pit flooding. The HVAC system which utilizes raw water also appears susceptible to impacts similar to the units cooling water system.


**Figure 6.** Cooling water system duplex strainers


**Figure 7.** Cooling water strainer baskets


**Figure 8.** Oil cooler heat exchangers


**Figure 9.** Deluge system firewater pumps


**Figure 10.** Transformer deluge system distribution piping and nozzles

### ***Waterways & Draft Tubes***

The internal surfaces of the intakes, casings, and draft tubes are not generally susceptible to heavy mussel fouling due mainly to high velocities and perhaps high turbulence intensities which is thought to be prohibitive for mussel settlement. However, mussel fouling has been observed on portions of the draft tubes (with excessive fouling on recesses in access hatches) at powerplants which are exposed to heavy quagga mussel infestations. Such limited settlement is not expected to significantly impact operation of the units. Conversely, waterways and draft tube drain lines and valves would be susceptible to clogging from live mussels or mussel shell debris. Furthermore, draining to the powerplant unwatering sump would be a source of live mussels and shell debris which would adversely affect sump operations.


**Figure 11.** Station power penstock drain

### ***Draft Tube Bulkheads***

Draft tube bulkheads are typically stored in the dry above the tailrace water surface elevation and used when needed to dewater for inspection and maintenance. As such they will generally not be directly susceptible to mussel fouling. However, the guides and seats are likely to experience some degree of mussel fouling or shell debris accumulation which could lead to difficulty during installation including seal damage and/or incomplete seating during installation. Like other bulkheads, if installed for extended periods of time, mussel fouling of drain holes in structural members can also adversely affect hoisting and operability of bypass fill valves which could further complicate removal.

### ***Drainage & Unwatering Sumps & Pumps***

The sump systems collect drainage and unwatering flows. Leakage from or draining of waterways to the sump would expose the system to colonization by live mussels and contamination from dead mussel shell debris. Impacts will likely include mussel attachment on submerged surfaces and equipment which could affect sump pump operability. Fouling of pumps intake screens (if so equipped) would reduce capacity and may even lead to inoperability of the pumps under extreme conditions.  Raw water lubricated/cooled bearings and seals for the sump pumps could also be impacted by clogging of the relatively small diameter supply lines. Furthermore, fouling of the float switch/level alarm arrangements could render the automated system inoperable.


**Figure 12.**  Unwatering sump pumps

### *Air Vents*
Air vents can be impacted by mussel fouling at connections resulting in blockage which would reduce vent capacities. Air vents typically serve multiple purposes including air release during filling, air admission during draining, prevention of negative pressures downstream of the gate to ensure smooth operation, or in certain cases to prevent downstream pipe collapse during an unbalanced gate closure.  In some cases, venting is also required to prevent cavitation damage. Impacts will vary depending on operating conditions and levels of infestation, but are likely to be more prevalent for smaller diameter vent lines.

### *Service & Domestic Water Systems*
Due to the relatively small diameters, raw service water piping and hose taps (e.g., gate and deck wash supply) are generally susceptible to clogging from live mussel settlement and/or mussel shell debris with the potential for inoperability depending on levels of infestation and associated shell debris loads.

## Fish Facilities

### *Fish Ladders*
Adult fish passage is accomplished by means of conventional fish ladder systems at north and south sides of the dam.  Multiple entrances are available along the downstream side of the dam. The north powerhouse entrances are connected to a fish transport channel that leads across the tailrace below the tailrace deck to a junction pool and the fish ladder on the left abutment.  Both ladders have exit trashracks.  The south ladder is equipped with a traveling water screen intake and tainter valve for auxiliary water and irrigation.  The upstream most ladder pools also contain a counting station with picketed leads and tilting weirs that adjust to changes in forebay elevation.  Auxiliary water for attraction is also supplied from auxiliary water pumps (AWS) to diffusers in the lower pools of the ladder and transport channel.  The pumped AWS pulls water

from the tailrace through trashracks along the south side. A small PUD powerplant is located near the north ladder entrance.

The relative complexity of waterways, equipment, and operations for the adult fish passage facilities will likely be problematic in a number of ways should an infestation occur. Mussel fouling of trashracks, weirs, orifices, and diffusers could increase fish injury potential. Water level sensors or automated systems instrumentation exposed to raw water would be equally susceptible which could result in misoperation. The traveling water screen may be less susceptible to fouling due mainly to the operating scheme, but the wash water supply pump and lines may be exposed to clogging from live mussels and shell debris. However, the fish ladders are dewatered annually for inspection and maintenance during the winter which allows opportunities for cleaning to reduce long term fouling and associated impacts.

Mussel fouling on the AWS intakes trashracks would likely also be problematic which could affect discharge capacity. If pumps are equipped with cooling or seal water systems, mussel related clogging could lead to degraded seal performance or inoperability. Mussel fouling on diffuser bar racks could further reduce capacity and alter function of diffusers. While the equipment arrangements for the ladder entrances are not entirely clear, any mechanical components that remain submerged would also likely be impacted which can include increased wear on seal elements and/or operational difficulties with adjustable weirs or orifices, particularly those that are automated. Like other bulkheads and stoplogs, the ladder entrance bulkhead slots may be susceptible to long term fouling which can make bulkhead installation difficult with the possibility for incomplete seating.

**Figure 13.** South fish ladder pools

**Figure 14.** South intake traveling water screen spray water supply


**Figure 15.** Traveling water screen wash supply pump

### ***Juvenile Collection Channel & Bypass Conduit***

Fish excluded at the powerplant intakes are diverted to a collection channel and then transported to the juvenile fish facility via the bypass conduit. The outfall passages and valves from the gatewells could be impacted by mussel fouling depending on operating conditions. Mussel settlement in the gatewells, orifices, collection channel, and transport conduit would be expected to increase fish injury potential. Mussel fouling in the upstream portion of the system would become a source of dead mussel shell debris that can adversely impact the downstream juvenile fish facility. However, the annual shutdowns will likely mitigate impacts and preclude long term accumulation of mussels as well as afford opportunities to clean waterways and associated systems.

The collection channel transports fish to a dewatering system and then onto the juvenile fish facility. It’s unlikely that significant live mussel settlement will occur in the bypass pipe that transports fish from the collection channel to the JFF. Velocities are generally larger than 6 ft/s and would likely limit or preclude settlement. The annual dewatering of the system would also reduce or eliminate any long term mussel attachment. However, shell debris accumulation on and live mussel settlement beneath floor screens and in other areas that are not fully dewatered may be problematic. Like most other systems, the main impacts are likely to result for shell debris drawn into the collection system during operation.

**Figure 16.** Outfall from orifice at juvenile fish collection channel

**Figure 17.** Juvenile bypass pipe

### *Juvenile Fish Facility*

The juvenile fish facility and transport operations appear broadly susceptible to mussel related impacts due primarily to complexity and the relatively small sizes of piping, bar racks, screens, equipment and related systems. Shell debris from upstream may be most problematic to deal with from an operations standpoint. Any small diameter piping (less than about 6-in) would be susceptible to complete clogging depending on levels of infestation, shell debris loads, and operating conditions. Separator bar racks, screens (wedgewire or perforated plate), gates and crowders all have the potential to become fouled to some degree during the operating season. The most significant affects would be fouling of separators which may increase fish injury potential. Excessive accumulation of mussels could also impact valves, instrumentation, and related equipment.

**Figure 18.** Bypass flume just upstream from JFF


**Figure 19.** Juvenile fish separator bar rack

### Instrumentation

Pressure, temperature, flow and level measurement instrumentation (including forebay and tailrace float wells and perhaps even pit tag detectors) in contact with raw water are susceptible to errors or inoperability due to mussel fouling.  This also includes stilling wells, bubbler systems, piezometer rings, pressure transducers, pressure and temperature gauges and switches, and acoustic flowmeters.

# Conclusions

McNary Lock and Dam facilities are relatively complex and a heavy invasive mussel infestation would likely significantly impact facility operations and maintenance.  Impacts would generally be expected to include fouling of trashracks, grates, gates, screens, bar racks, raw fire water systems, cooling water systems, valves, associated equipment and instrumentation as well as impacts from heavy shell debris loads which can overwhelm strainers and filters. Fish passage, handling, and transport facilities also appear susceptible to impacts which could include mussel fouling on screens, diffusers, separators, instrumentation and equipment along with clogging of piping and associated systems from shell debris.  However, the annual shutdown and unwatering of the fish facilities will likely reduce or eliminate long-term settlement and provide opportunities for cleaning.  Shell debris during operation would likely be the most significant impact for the fish facilities.

Based on information from Ice Harbor, calcium and pH levels would suggest that conditions may only be suitable for supporting moderate levels of infestation.  Additional data on seasonal variability would be helpful to better assess potential infestation levels and assist in prioritizing response actions.

# Recommendations

## Monitoring and Detection

To date mussels have not been detected in the Snake or Columbia River systems. However, it is recommended that seasonal (spring-fall) sampling and analyses for larval detection (plankton tow sampling) be continued for the earliest possible detection of mussels. Larval detection potentially allows for 2-3 years of lead time to enable planning, budgeting, and implementation of response actions for facilities protection should mussels be detected. If invasive mussels are detected in the future and suitability appears adequate for survival and establishment, emphasis should transition to monitoring for settlement using substrates. This post-introduction monitoring provides information on the evolution of the infestation. Typically settlement on intake structures will be observed first followed by impacts to internal piping and related systems and equipment. Continued monitoring can also be used to refine maintenance schedules, further inform facility protection strategies, or anticipate future changes in population dynamics as well as ecological impacts attributable to mussels, as needed.

## Response Planning

It is recommended that this report be used in conjunction with the Columbia River Basin Response Plan to develop site-specific actions for the possibility of a future mussel infestation at McNary Lock and Dam facilities. One specific response action worth considering would be the inclusion of mussel impacts and associated requirements into SOPs and O&M schedules where possible. Appendix B provides some management options for response planning, including links to various response planning guidelines and online examples.

## Facility Protection Options

While a variety of solutions may be possible (or new technologies may become available), not all solutions are applicable to all situations or all facility components. Some options may be as straightforward as routine cleaning while submerged or inaccessible structures and systems may require unique measures, including redesign or retrofit, to deal effectively with invasive mussels. The options provided below are suggestions on where to begin should a future infestation occur, but they do not substitute for thorough planning and engineering.

### Lock, Dam & Spillway

Regularly scheduled shutdowns for unwatering and inspection of the lock afford the opportunity to access waterways and equipment for inspection and removal of mussels and shell debris as needed. Servicing of gates involves bulkhead installation which will likely require a means for cleaning of bulkhead slots and seats prior to installation to achieve adequate sealing.

Depending on levels of infestation, the unwatering pumps may become difficult to operate if live mussel fouling or shell debris accumulation around pump intake strainers occurs. Options for reducing settlement on the strainers could include the use of foul release coatings, but the system would still be susceptible to clogging from shell debris if accumulations around the intakes become excessive. For pump cooling and seal water systems, where so equipped, installation of self-cleaning filtration may provide adequate protection by excluding live mussels and dead mussel shell debris that could otherwise clog supply lines.

Mussel fouling on submerged surfaces of the dam would not be expected to require corrective actions. However, long term settlement would become a source of mussel shell debris which could be drawn into downstream systems depending on location. If an invasive mussel infestation occurs, more frequent monitoring and inspection of structural drainage systems would be warranted. If mussel fouling or changes in drainage system flows are observed, frequent inspections and cleanout of accessible portions of the systems may be required.

Few options are available to proactively protect the spillway gates and long term fouling is likely to occur without more frequent servicing of gate seals. Like bulkheads, provisions for cleaning stoplog slots and seats prior to installation may be required to achieve adequate seating and seal performance. Foul release coatings may also be an option to reduce mussel settlement on upstream surfaces of the gates if needed.

The spillway weirs will also be difficult to proactively protect. The use of foul release coatings to minimize fouling may be an option worth considering. Recognizing the difficulties and expense of coating the entire structure, coatings could at least be considered to reduce fouling along flow boundaries for which fish may come in contact.

## Powerplant

### *Trashracks*

One option for trashracks throughout the facilities includes removal and replacement with backup sets followed by manual cleaning where possible. However, depending on the level of infestation, frequent cleaning could become expensive. Foul-release coatings could also be considered as a proactive strategy to reduce the maintenance frequency and facilitate cleaning. Various coatings for metallic structures have been tested at Reclamation’s Parker Dam which is heavily infested with quagga mussels. Results to date are promising, but limitations in durability have been identified. Nevertheless, more durable coatings systems may become available in the near future which could provide solutions for reducing fouling in many cases.

Other options involve retrofit of the rake heads with high pressure water jetting to remove mussels between bars during raking operations. In such cases, a mussel free water supply would be needed to eliminate impacts to water delivery piping and nozzles for the water jetting system.

### *Extended Submersible Bar Screens*

Lodged shell debris may require more frequent removal and manual cleaning. Foul release coatings would afford some measure of proactive protection to reduce fouling, but potential problems with lodged mussel shell debris in the screen would likely remain.

### *Vertical Barrier Screens*

Options for the vertical barrier screens could include removal and replacement with back up sets for cleaning at regular intervals. Targeted use of foul release coatings may also be worth consideration to reduce or minimize fouling and lengthen the period of time between removal and cleaning cycles.

### *Intake Gates & Bulkheads*

Available options for proactively protecting the intake gates are generally limited to removal and manual cleaning at regular intervals. Regularly exercising the gates may reduce mussel attachment along the guides but doing so can also increase wear on seal elements and mechanical components. A means for cleaning bulkhead slots and seats prior to installation may be required for adequate sealing.

### *Cooling Water Systems*

The supply strainers for the generator air coolers, bearing oil coolers and other portions of the cooling water system would benefit from reducing strainer media to 1/8-in to exclude most of the shell debris. Self-cleaning filtration and ultraviolet (UV) light treatment systems may also be options worth consideration. UV equipment with sufficient dose capability could be installed just downstream of the existing strainers to kill veligers passing through the strainers. It should be noted that portions of the cooling water supply piping upstream of the strainers to the inlets at the gate slots (including grates) would remain susceptible to mussel fouling which may require frequent manual cleanout, depending on levels of infestation.

Conversion of the HVAC system to closed loop is another proactive step that would be expected to reduce or mussel-related impacts to that system. Although makeup water would be periodically needed, there are substantially more treatment options available for closed loop cooling systems as compared to single-pass or once-through systems.

### *Draft Tube Bulkheads*

As with other bulkheads, options are limited to manual cleaning of guides and seats prior to installation of the bulkheads in order to prevent seal damage and ensure adequate seating. Storage of bulkheads in the dry is recommended when and where possible. Alternative materials may also be considered for the guides to reduce mussel fouling and facilitate cleaning.

### *Drainage & Unwatering Sump*

The sumps will likely require regular manual cleanout to manage mussel fouling on continuously submerged surfaces and remove accumulated mussel shell debris. Increased inspection and maintenance frequencies for the float switch arrangements and pump intake screens (where so equipped) will also likely be required to ensure reliable operation of the system. Consideration could also be given to replacing float switch arrangements with a noncontact level sensor/switching arrangements (e.g., downlooking acoustic water level sensor), if possible, to ensure reliable operation of pumps and sump system. Additional provisions for protecting pump cooling/seal water supply lines may be needed. Filtration, treated water, or well water would be options worth considering.

### *Air Vents*
Periodic inspection and cleaning of all air vents throughout the facility will likely be required at more frequent intervals and should be a high priority if an infestation occurs. While there are few options available for ensuring that air vents operate reliably for the intended purpose, more frequent inspections will provide information on the extent of the problem. If significant blockage is observed, retrofit of the vent systems, perhaps using copper-based materials of construction to reduce mussel fouling, could be considered.

### *Service & Domestic Water Systems*
For domestic water systems, options for proactively protecting supply and distribution piping beyond the use of strainers, filtration, and UV would include moving treatment processes as far upstream as possible. Station service water lines, equipment, and taps utilizing raw water will likely require frequent disassembly and cleaning to maintain operability.

### *Fire Protection Systems*
The best available proactive strategy for maintaining reliable operation of water-based fire protection systems is conversion to a treated or well water supply where possible, or use of alternative suppression technology that does not rely on raw water. Any fire system solution utilizing infested water should be considered highly susceptible to acute impacts from heavy mussel shell debris loads which can, even for dry deluge systems, overwhelm strainers upon activation.

## Fish Facilities

### *Fish Ladders*
Options for reducing settlement on trashracks, pickets, and diffusers are likely limited to foul release coatings. Where possible (and if not already the case), consideration for retrofit of structures to facilitate removal and cleaning or replacement with back up sets would be worthwhile should an infestation occur. The auxiliary water supply pumped systems may be difficult to proactively protect. Any lubrication, cooling, or seal water supply systems for the auxiliary water pumps could potentially be protected by self-cleaning filtration systems. Additional dewatering may be required for inspection and cleaning of portions of the system that are not typically dewatered on an annual basis. Targeted use of foul release coatings may be worth consideration, but frequent cleanout may still be required to minimize fish injury potential. Ladder entrances and associated equipment will also likely require frequent inspection and cleaning to minimize fouling.

### *Juvenile Bypass*
There are few options for preventing mussel settlement in the juvenile collection channel and separator systems except for the targeted use of foul release coatings where possible. While annual shutdowns afford opportunities for mussel removal to reduce long term fouling, provisions for ensuring portions of the system do not become fouled during the operating season would appear to be a high priority.

### *Juvenile Fish Facility*

Although impacts from long term mussel attachment are not expected due to annual shutdowns of the fish facilities, as with other fish passage systems, targeted use of foul release coatings may the best proactive means of reducing settlement during operations. This would include use on separator racks and screens. Regardless of proactive settlement prevention, provisions for shell debris removal and handling will likely be required. Other equipment including valves, pumps, and piping would be expected to require frequent inspection and cleaning.

## Instrumentation

The forebay and tailrace level monitoring systems will likely require frequent inspection and cleaning. Other instrumentation including pressure taps, gages, temperature sensors, pressure and temperature switches, and flow measurement devices will also likely also require frequent inspection and disassembly for cleaning to maintain accurate and reliable operation. In the event of an infestation, all critical instrumentation for safe systems operation should be inventoried and prioritized for inspection and cleaning to ensure reliable operation.

## Crane & Hoist Certification

If water weight bags are used for crane or hoist testing, the contract statement of work should include language for preventing the spread of invasive species from one site to another. Information about decontamination procedures can be found in Appendix B with a link to Reclamation's Equipment Inspection and Cleaning Manual.

# Appendix A

## Facility Assessment Checklist

| | | | |
|---|---|---|---|
| **Project Name:** | **McNary Lock & Dam, USACE** | | |
| **Prepared by:** | Kubitschek & Willett | **Date of Preparation:** | 8/4/2015 |

**2. Preparation (Step 1)**

| *Item No.* | *Item* | Status [1] | Comments / Plan to Resolve |
|---|---|---|---|
| **1** | **Planning** | | |
| 1.1 | Has the project scope – including definition and objectives – been prepared? | Y | |
| 1.2 | Has the *Project Scope Statement* been approved? | Y | |
| 1.3 | Is there a *Project Plan* against which to measure progress? | Y | Project Management Plan (PMP) |
| 1.4 | Does the *Project Plan* address the following areas: | | |
| 1.4.1 | • Project Scope and Deliverables | Y | |
| 1.4.2 | • Project Schedule | Y | |
| 1.4.3 | • Project Budget | Y | |
| 1.4.4 | • Project Organization and Resources | Y | |
| 1.5 | Were key project stakeholders brought into the *Project Plan*? | Y | |
| 1.6 | Were potential customers involved early in the planning process? | N/A | |
| 1.7 | If there are vendors, have they signed off on the *Project Plan*? | N/A | |
| 1.8 | If there is an independent oversight contractor, have they signed off on the *Project Plan*? | N/A | |
| 1.9 | Is the Project Sponsor function identified and defined? | Y | |
| 1.10 | Are there alternate persons if key members of the project are not available or become reassigned? | Y | |
| 1.11 | Other organization items (*please list*): | N/A | |
| **2** | **Tracking & Monitoring** | | |
| 2.1 | Are the various types of reports, their contents, frequency, and audience defined and communicated to the Project Team? | Y | |
| 2.2 | Are the input requirements from Project Team members clearly documented and communicated? | Y | |
| **3** | **Meetings and Input Data** | | |
| 3.1 | Have the various meetings, purpose, context, frequency, and participants been defined and communicated? | Y | |
| 3.2 | Have the drawings and documents from the facility sites been requested? | Y | |

[1] *Enter one of the following:* **C** (Complete), **P** (Partially Complete), **Y** (Yes), **N** (No); **NA** (Not Applicable)

## 2. Preparation (Step 1)

| *Item No.* | *Item* | Status [1] | Comments / Plan to Resolve |
|---|---|---|---|
| **4** | **Project Assumptions and Constraints** | | |
| 4.1 | Are there any key assumptions upon which the assessment is based and have these assumptions been documented? | Y | |
| 4.2 | Does the Project have any Constraints such as: | | |
| 4.2.1 | • Facility shutdown schedules? | Y | Facilities operating at time of site visit |
| 4.2.2 | • Facility access limitations and ventilation requirements? | Y | Access limited to structures, systems, and equipment without requiring shutdown |
| 4.2.3 | • Monitoring issues such as availability of reports from sampling plates set out in previous seasons? | N | |
| 4.2.4 | • Any training needed for key project staff? | N | |
| 4.2.5 | • Any pre-project procurement needed for portable field equipment? | N | |

## 3. In-house Review and Preparation for Field Visits (Step 2)

| *Item No.* | *Item* | Status [2] | Comments / Plan to Resolve |
|---|---|---|---|
| **1** | **Reviewing** | | |
| 1.1 | Have drawings and documents from the facility site been reviewed? | Y | Review of limited available dwgs |
| 1.2 | Have questions arising from the document review been communicated to and discussed with the site experts? | Y | Generally during site visit |
| 1.3 | Did the document review identify any pre-site-visit activities that should be done such as video inspections requiring divers or shutdown of equipment that needs to be scheduled? | N | |
| 1.4 | Are all pre-site-visit tasks needed to be done at site completed? | Y | |
| 1.5 | Has the deliverables list been updated based on the information from the site documents? | Y | |
| 1.6 | Have all system checklist sheets been prepared? | Y | |

[2] *Enter one of the following:* **C** (Complete), **P** (Partially Complete), **Y** (Yes), **N** (No); **NA** (Not Applicable)

## 4. Site Visits, Follow-up and Reporting (Step 3)

The general approach should be to follow the path of the water through the site facility. The water path will become more complicated each time the water branches into a specific system. Follow each system in turn and you will have covered the complete flow of water through the facility.

| *Item No.* | *Item* | Status | *Comments / Plan to Resolve* |
|---|---|---|---|
| **1** | **Field Walkthroughs** | | |
| 1.1 | Has the pre-meeting at site been completed? | Y | Presentation on mussels given to project staff and brief discussions with project personnel on purpose/intent of the assessment |
| 1.2 | Were all necessary site staff available? | Y | |
| 1.3 | Have follow-up discussions with staff not available during the site visit been scheduled and completed? | N/A | |
| 1.4 | Have all the system walkthrough checklists been completed? | Y | |
| 1.5 | Have all actions arising from the site meeting and system walkthroughs been documented and communicated to the person responsible for the action? | Y | |
| 1.6 | Has the draft project report been reviewed by all contributors? | N/A | Will be completed following site visit |
| 1.7 | Has the final report been approved for issue? | N/A | Will be completed following site visit |
| 1.10 | Has the final report been distributed? | N/A | Will be completed following site visit |
| | | | |

## 5. Mussel Vulnerability Evaluation - Project Team Contact List

**Project Name: McNary Lock & Dam, USACE**

**Project Lead: Kubitschek & Willett**

Some suggestions for the roles of the various team members and the skills or knowledge that would be helpful for each team member are contained in Appendix A.

| ***Name*** | ***Title*** | ***Location*** | ***Office Phone & E-mail*** |
|---|---|---|---|
| Joe Kubitschek | Hydraulic Engineer | Reclamation, TSC – Hydraulic Investigations and Laboratory Services, Denver, CO | (303) 445-2148<br>jkubitschek@usbr.gov |
| Leonard Willett | LC Region Mussel Task Force Coordinator | Reclamation, LC Region, LC Dams Office, Boulder City, NV | (702) 494-2216<br>lwillett@usbr.gov |
| Damian Walter | Wildlife Biologist | USACE – Walla Walla District | (509) 527-7136<br>Damian.J.Walter@usace.army.mil |
| | | | |
| | | | |

## 6. Mussel Vulnerability Evaluation – Sample Facility Deliverables List

**Facility Name: McNary Lock & Dam, USACE**

The deliverables are internal document packages prepared for each system or major structure. Once all deliverables are completed, they are then used to prepare the overall assessment report which would be the only external deliverable. It will be helpful when preparing this list to refer to Appendix D for additional detail about typical systems and components at risk that should be considered.

| *Major Structure or System* | *Reference drawings Used* | *Deliverables* |
|---|---|---|
| Dam & Appurtenances | Avail dwgs provided by USACE | |
| eg2: pump station unit cooling water system | N/A – No pumping plant | |
| eg3: powerplant & fire water system | Avail dwgs provided by USACE | |
| Continue with systems or structures until all areas in contact with raw water are covered. | | |
| | | |
| | | |

# System Walkthrough Checklist

| | |
|---|---|
| **System or Structure Name:** | **McNary Lock & Dam, USACE** |
| **Prepared by:** | Kubitschek & Willett |
| **Date of Preparation:** | 8/4/2015 |

## 1. Instructions for Using this Document

- Prepare one of these sheets for each system or major structure identified in the Deliverables list.
- For each *Item No.* below, complete all blank fields (see footnotes for *Status* and *At Risk of Mussels* columns).
- For some of the components such as valves and strainers there may be several in one system. If more than one component needs to be considered add an extra sheet for that particular component group.
- Refer to Appendix C for additional information and suggestions about various systems and components.
- Add additional rows as required where you identify items that need to be considered and are not covered elsewhere in the list.

## 2. Walkthrough Checklist

| *Item No.* | *Item* | *Status* [3] | *At Risk (yes/no)* | *Comments* |
|---|---|---|---|---|
| **1** | **General for Dams, Reservoirs, Aqueducts** | | | |
| 1.1 | Are there any membranes, control joints, permeable construction media, drains, etc. that will let raw water pass? | Y | Y | Potential for mussel related impacts to drainage systems currently unknown |
| 1.2 | Are there any air vents? | Y | Y | Various throughout the facility |
| 1.3 | Check if the spillway and appurtenances are always wet or dry and record duration of dry period. | | | Spillway operates seasonally and vertical lift gates typically submerged |
| 1.4 | How much does the water level (i.e. reservoir water surface elevation) fluctuate? | | | Varies slightly, typically about 5 ft. |
| 1.5 | Are all potential water seepage paths inspected on a regular basis? | Y | | |
| 2 | **Water Intake Structures** | | | |
| 2.1 | Types of intake structures present (more than one may be present): | | | |
| 2.1.1 | • Open Canal Direct into Facility (concrete) | N | | |
| 2.1.2 | • Open Canal Direct into Facility (other material-specify) | N | | |
| 2.1.3 | • Forebay (specify lining material) | N | | |
| 2.1.4 | • Tower (specify construction material) | N | | |
| 2.1.5 | • Submerged Tunnel or pipe intake (specify construction material) | N | | |
| 2.1.6 | • Penstock intakes (specify construction material) | Y | Y | Separate intakes |
| 2.1.7 | • Fish Barriers | Y | Y | Power plant intakes ESBS and vertical barrier screens |
| 2.2 | Is the floor of any intake structures likely to be covered with silt or sediment? | N | | |
| 2.3 | Are any structures duplicated to provide a backup? | N | | |
| 2.4 | What is the flow velocity range in the structure? | | | Velocities will likely range from 0-5 ft/s at the intakes and exceed 20 ft/s depending on operating conditions. |

[3] *Enter one of the following:* **C** (Complete), **P** (Partially Complete), **A** (Absent); **Y** (Yes), **N** (No); **NA** (Not Applicable)

## 2. Walkthrough Checklist

| Item No. | Item | Status [3] | At Risk (yes/no) | Comments |
|---|---|---|---|---|
| 2.5 | Is the structure accessible for inspection? | N | | Intakes submerged and operating at time of site visit |
| 2.6 | Are there any shutdowns to provide easy access and what is their frequency? | Y | | For regularly scheduled inspection and maintenance cycles. |
| 2.7 | Are there scheduled maintenance cycles and what are their frequencies? | Y | | Varies depending on the system/equip, but typically annual |
| **3** | **Trash Racks, Grates, Screens** | | | |
| 3.1 | Record spacing, size and material of trash rack bars. | | Y | Staff indicated intake trashracks bar spacing 6 in |
| 3.2 | Are trash racks fixed or easily removable for maintenance? | | Y | Powerplant intake trashracks removable, but typically remain in place |
| 3.3 | Is there a planned maintenance frequency for the trash racks? If so what is interval? | N | Y | Typically remain in place |
| 3.4 | Is there a trash rake or other style of cleaning system? | Y | Y | Trashracks raking system |
| 3.5 | Are the rake fingers sufficiently large to remove mussels from sides of trash rack bars? | N | Y | |
| 3.6 | Record location, material, size and grid spacing of any small intake grates. | | Y | |
| 3.7 | Are grates fixed or removable for easy maintenance? | | Y | |
| 3.8 | Check if grates at bottom of pipes or channels get covered with silt or sediment. | N/A | | |
| 3.9 | Record location, material, size and grid spacing of any screens. | | Y | ESBS and vertical barrier screens appear to be wedgewire and perf plate. Various screens in JFF |
| 3.10 | Are screens fixed or removable for easy maintenance? | Y | Y | |
| **4** | **Wells and Sumps** | | | |
| 4.1 | Location and material of constructions of wells. | N/A | | |
| 4.2 | Identify level fluctuations in pump wells. | N/A | | |
| 4.3 | Distance of pump suction from bottom of wells. Will pump ingest shells that are transported along the floor into the well? | N/A | | |
| 4.4 | Location and material of constructions of sumps. | | Y | Drainage and unwatering sumps - concrete |
| 4.5 | Is there a float or other instrumentation in sump that could become covered with mussels? | Y | Y | Float switches |
| 4.6 | Frequency of sump inspection by plant staff. | | Y | Monthly (assumed) |
| **5** | **Pumps and Turbines** | | | |
| 5.1 | Is pump motor or turbine generator water or air cooled? Water cooled motors are at risk. | | Y | Generator air coolers, thrust bearing oil coolers, transformers, and HVAC systems utilize raw water |
| 5.2 | Can mussel shells get into wear ring gaps? | Y | Y | Assumed possible |
| 5.3 | Does pump have a mechanical seal? | Y | Y | Various pumps throughout facility (sumps and auxiliary water) |
| 5.4 | How is the seal flushed during start-up? | | | On startup |
| 5.5 | How is the seal flushed during normal running? | | | Continuously |
| 5.6 | Does the turbine have a stuffing box? | Y | N | Turbine packing uses potable water |
| 5.7 | Is there a stuffing box lantern ring or other cavity for cooling and flushing water? | N/A | | |
| 5.8 | How is the ring flushed during start-up? | N/A | | |

## 2. Walkthrough Checklist

| Item No. | Item | Status [3] | At Risk (yes/no) | Comments |
|---|---|---|---|---|
| 5.9 | How is the ring flushed during normal running? | N/A | | |
| 5.10 | Check if the turbine bearings have water cooled lubrication? | Y | Y | Bearing oil coolers for all units use raw water |
| 5.11 | Check if the pump has water cooled bearings? | N | | |
| 5.12 | Can mussel shells get into the water lubricated bearing passages? | N/A | | |
| 5.13 | Do seal or stuffing box cavities have a means of monitoring or inspection? | N/A | | |
| 5.14 | Can seals or stuffing box be cleaned without removing generator? | N/A | | |
| **6** | **Piping** | | | |
| 6.1 | Identify materials of construction for piping. | | Y | Steel, copper |
| 6.2 | What is flow velocity range in piping? | | Y | Varies depending on system & operating conditions |
| 6.3 | How much time is velocity above 6 ft/sec? | | Y | Varies depending on system |
| 6.4 | How much time is velocity below 6 ft/sec? | | Y | Varies depending on system |
| 6.5 | Are there any offsets or changes in pipe diameter? | Y | Y | Offsets, bends, fittings, etc... throughout the facility |
| **7** | **Instrument Tubing and Instruments** | | | |
| 7.1 | Identify any small diameter lines (2" diameter or less) including material of construction such as: | | Y | Service water taps, portions of the cooling water supply lines, fish facilities, etc… |
| 7.1.1 | • Flow measurement taps | N | | |
| 7.1.2 | • Piezometer taps | N | | |
| 7.1.3 | • Pressure taps | Y | Y | Pressure taps/gages/switches throughout the facility |
| 7.1.4 | • Sample lines | N | | |
| 7.1.5 | • Pressure balance lines | N | | |
| 7.1.6 | • Other – Outlet works flowmeter | N | | |
| | • Other – Reservoir El. gauge | Y | Y | Stilling well and float arrangements |
| **8** | **Heat Exchangers** | | | |
| 8.1 | Identify material of construction of plenum. | | Y | Generator air coolers and bearing oil coolers heat exchangers. Assumed steel |
| 8.2 | Identify material of construction of tubing. | | Y | Assumed copper |
| 8.3 | What is diameter of tubing? | | Y | Smallest diameters ~¾-in tubing |
| 8.4 | What is flow velocity range in tubing? | | Y | Depends on operating conditions, but likely less than 6 ft/s |
| **9** | **Valves** | | | |
| 9.1 | Identify all normally open (NO) valves. | | Y | Juvenile collection channel, cooling water supply when operating, various throughout the facility |
| 9.2 | Can NO valves fail to seal properly if valve seat or valve face becomes mussel coated? | Y | Y | May be possible depending on size, operational frequency, and levels of infestation |
| 9.3 | Identify all normally closed (NC) valves | | Y | Various throughout the facility, particularly the fish facilities |

## 2. Walkthrough Checklist

| *Item No.* | *Item* | *Status* [3] | *At Risk (yes/no)* | *Comments* |
|---|---|---|---|---|
| 9.4 | Can NC valves fail to open if valve face becomes coated with mussels? | Y | Y | May be possible depending on size, operational frequency, and levels of infestation |
| 9.5 | What is throat diameter of valve? Is it small enough to become plugged by mussel shells? | | Y | Various valves through facility |
| **10** | **Strainers and Filters** | | | |
| 10.1 | Identify the style of strainer, material of construction of strainer body and basket as well as the size of the basket pores. Typical styles are: | | | Various strainers on cooling water supply lines |
| 10.1.1 | • Fixed In-line strainer | Y | Y | Fire pumps |
| 10.1.2 | • Duplex strainer | Y | Y | Cooling water supply lines |
| 10.1.3 | • Self-cleaning strainer | N | | |
| 10.1.4 | • Wye (Y) strainer | N | | |
| 10.1.5 | • Other type - specify | | | |
| 10.2 | Identify the style of filter, material of construction of body and filter element, as well as the size of the filter pores. Typical styles are: | | | |
| 10.2.1 | • Self-cleaning filter | N/A | | |
| 10.2.2 | • Replaceable cartridge filter | N/A | | |
| 10.2.3 | • Other type - specify | N/A | | |

# Appendix B

## Management Options for Quagga & Zebra Mussel Infestations

Concurrent with Prevention & Public Outreach/Education Activities

Most water bodies in the western United States are at risk of infestation by invasive quagga and zebra mussels. While actions taken to prevent or respond to infestation must be tailored to each specific location, the following activities represent options for consideration as part of any readiness planning as well as options for dealing with mussels following detection. Information on preventing the spread of invasive mussels can be found at the 100$^{th}$ Meridian Initiative website http://100thmeridian.org/ and http://protectyourwaters.net.

Guidance has also been developed by Reclamation and is documented in Technical Memorandum No. 86-68220-07-05 *Inspection and Cleaning Manual for Equipment and Vehicles to Prevent the Spread of Invasive Species* which provides information for inspecting and cleaning vehicles and equipment to help prevent the spread of invasive species. The manual can be found at http://www.usbr.gov/mussels/prevention/docs/EquipmentInspectionandCleaningManual2012.pdf

## Actions to consider prior to detection of mussels:

1. **Develop Coordinated Response Plan(s) -** This plan would detail policies, command and authority structure, strategies, communications, roles and responsibilities, and response actions to be implemented – Involves multiple federal, state, and local agencies and stakeholders. An example Response Plan for the Columbia River Basin may be found at the 100$^{th}$ Meridian website http://www.100thmeridian.org/Columbia_RBT.asp. The National Parks Service also has information and guidelines for prevention and response planning that can be found at http://www.nature.nps.gov/biology/Quagga/index.cfm.

2. **Perform Infestation Risk Assessment(s) –** This activity may be completed as standalone or as part of the Coordinated Response Plan. The purpose is to identify which water bodies are most at-risk of infestation within the geographic region of interest or management jurisdiction. The likelihood of infestation is typically based upon recreational usage, the nearest known infestation, and the extent to which environmental conditions (including calcium, pH, dissolved oxygen, temperature, etc…) are likely to support mussel establishment. This information can be used to prioritize facility vulnerability assessments (below). A variety of examples for risk assessments are available on the web. Information specific to environmental suitability based risk assessments is available at the U.S. Army Corps of Engineers Zebra Mussel Information System (ZMIS) website http://el.erdc.usace.army.mil/zebra/zmis/zmishelp.htm.

3. **Perform Facility Vulnerability Assessment(s) –** This activity may be completed as standalone or following the infestation risk assessment(s) and consists of a detailed inventory of critical water related infrastructure and how each component is likely to be affected by mussels should infestation occur. The results can be used to prioritize facility protection needs and actions. A facility vulnerability assessment template can be found at www.usbr.gov/mussels/.

4. **Implement Monitoring Program(s) –** Monitoring programs should be considered for high priority water bodies where infestation is either likely or would cause significant impacts to water systems or other key resources. Monitoring programs, designed to provide early detection of mussel larvae (through water sampling and lab analysis), potentially provide 2-3 years of lead time for planning and implementing protective actions before the infestation impairs operations via adult settlement on hydraulic structures or within critical systems. Additional information on monitoring can be found at the U.S. Army Corps of Engineers Zebra Mussel Information System (ZMIS) website http://el.erdc.usace.army.mil/zebra/zmis/zmishelp.htm.

## Actions to consider following detection of mussels:

1. **Execute Coordinated Response Plan –** Involves notification, information exchange, and implementation of containment and control actions (i.e., components of the response plan).

2. **Increase Monitoring –** Transition from monitoring for detection to monitoring with increased frequency to confirm detection, identify or locate the presence of adults, and track infestation levels. This activity may also include regular facilities inspections to determine when facilities are being impacted by adult colonization. The information obtained can guide facilities protection actions and assists in anticipating ecological impacts for future mitigation planning and budgeting.

3. **Identify and Implement Appropriate Facilities Protection Measures –** Identify which actions or technologies are best suited for maintaining operations and reducing O&M costs or other expenses. Various conventional technologies have been used with reasonable success. The table below provides some conventional as well as experimental options, each of which has advantages and disadvantages. It should be noted that there are a number of commercial treatment products that have not been listed, but may be applicable in various situations.

**Table 1** – Control and facilities protection options for various applications

| **Technology** | **Potential Applications** |
|---|---|
| **Filtration to prevent mussel entry to piped systems** – Self-cleaning 40-80 micron filters may be more than adequate depending on exclusion requirements. Exclusion avoids the need for treating infested systems. | Low volume systems - Facilities service water, unit or transformer cooling water, HVAC, pumped systems, and piping |
| **Ultraviolet (UV) Treatment of water in piped systems** – In-line UV systems are being evaluated to prevent mussel settlement. UV has additional water treatment benefits and is not expected to require discharge permitting † | Low volume systems - Facilities service water, unit or transformer cooling water, HVAC, pumped systems, and piping |
| **Chemical Treatment** – Injection or delivery of chemicals (oxidizing and nonoxidizing) to kill mussels or impair ability to attach to surfaces<br>• Bromine<br>• Chlorine<br>• Chlorine dioxide | Low and medium volume systems - Facilities service water, unit or transformer cooling water, HVAC, pumped systems, and delivery pipelines. Permitting required for chemical treatment methods |

| | |
|---|---|
| • Hydrogen peroxide<br>• Ozone<br>• Potassium salts<br>• Potassium permanganate<br>• Sodium Hypochlorite | |
| **Alternative Treatments** – Alternatives to kill mussels or impair ability to attach<br>• Thermal<br>• Biological<br>• Desiccation | Low and medium volume systems – Facilities service water, unit or transformer cooling water, HVAC, pumped systems and delivery pipelines. Desiccation requires capability to dewater system for extended durations |
| **Coatings to protect exposed surfaces** – Prevents mussel attachment or facilitates cleaning (anti-fouling & foul-release) † | Hydraulic Structures & Equipment - Gates, valves, penstocks, intake structures, trashracks, fish screens |
| **Alternative Materials** – To prevent mussel attachment or facilitate cleaning<br>• Copper<br>• Galvanizing (requires high zinc content) | Intake grating, piping/tubing, heat exchangers, HVAC systems |
| **Mechanical Removal** – Routine maintenance<br>• Mechanical raking/scraping<br>• Hydrojetting<br>• Pipeline pigging<br>• Traveling intake screens (self-cleaning) | Structures, systems, equipment, and instrumentation where access is possible – Diversion structures, pipelines, trashracks, intakes, fish screens. For instrumentation, noncontact methods should be considered where possible |
| **Redundant Systems** – Multiple intakes or duplicate systems for switching during treatment or cleaning to provide uninterrupted service | Systems for which retrofit is possible/practical |

† - Under development or being field tested.

Technologies selection for each application depends on a number of considerations including periodic or continuous mussel exclusion requirements, operations and maintenance requirements, permitting requirements, environmental impacts, and cost; to name a few. If conventional technologies are not applicable then alternatives should be developed and demonstrated as early as possible to meet unique facilities requirements. Operational strategies may also be available to reduce or eliminate mussel impacts. However, such strategies are often limited depending on the type of system and available flexibility. Additional information on control strategies and facilities protection methods may be found in Mackie & Claudi, Monitoring and Control of Macrofouling Mollusks in Fresh Water Systems, 2010 and at the U.S. Army Corps of Engineers Zebra Mussel Information System (ZMIS) website http://el.erdc.usace.army.mil/zebra/zmis/zmishelp.htm

**Identify Ecological Impacts –** Involves developing and initiating actions to track ecological changes, develop mitigation plans, and implement long-term mitigation actions (considers endangered species, food webs, aquatic weeds, water quality, etc…)