RECLAMATION
Managing Water in the West

Mussel-Related Impacts and Costs at Hoover, Davis, and Parker Dams (Lower Colorado Dams Office Facilities)

Research and Development Office
Science and Technology Program
Final Report ST-2016-1608

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Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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(Signature)

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Executive Summary

The objective of this report is determine mussel-related impacts, quantify associated costs, and establish a process for future tracking of impacts and costs at infested Reclamation facilities along the lower reaches of the Colorado River. This includes Hoover Dam, Davis Dam, and Parker Dam and their respective powerplants.

Quagga mussels were discovered at Lake Mead on January 6, 2007. Since that time, Reclamation has undertaken numerous actions to address the discovery of quagga mussels in the lower Colorado River system.

Costs incurred or planned at Hoover Dam for quagga-related work include:

• Contract Costs, through 2016	$ 1,650,000
• Contract Costs, future (2017 through 2026)	$ 7,500,000
• Supply, materials only (partial), through 2016	$ 78,000
• Supply, materials only (partial), future (2017 through 2020)	$ 277,000
• Service, after 2018	$ 180,000
• In-house O&M Costs, through 2016	$ 53,700
• In-house O&M Costs, future (2017 through 2020)	$ 453,508
• In-house O&M Costs, future (Empty/clean duplex strainers)	$ 39,000

Costs incurred or planned at Davis Dam for quagga-related work include:

• Contract Costs, through 2016	$ 150,000
• Contract Costs, future (2017 through 2020)	$ 800,000
• Supply, materials only (partial), through 2016	$ ---
• Supply, materials only (partial), future (2017 through 2020)	$ ---
• Service, after 2018	$ 60,000
• In-house O&M Costs, through 2016	$ 141,200
• In-house O&M Costs, (yearly/repetitive tasks)	$ 31,200

Costs incurred or planned at Parker Dam for quagga-related work include:

• Contract Costs, through 2016	$ 3,775,000
• Contract Costs, future	$ ---
• Service	$ 45,000
• In-house O&M Costs, through 2016	$ 177,200
• In-house O&M Costs, (yearly/repetitive tasks)	$ 70,560

Objective

The purpose of this Study is to determine the historical costs attributable to the infestation of mussels and to establish a process for future tracking of impacts and costs at infested Reclamation facilities along the lower reaches of the Colorado River. This includes Hoover Dam, Davis Dam, and Parker Dam and their respective powerplants.

Tasks:

1) Identify systems that have been impacted and the effects on O&M;
2) Obtain historical data on past mussel-related costs and analyze pre- and post-cost trends;
3) Identify O&M practices and control measures that have been implemented and their benefits, including costs; and
4) Establish a process for tracking mussel-related costs for future years.

History/Background

Quagga mussels were discovered at Lake Mead on January 6, 2007. This was the first sighting of this mussel west of the Rocky Mountains, although it has been in North America since the late 1980s. Scientists believe it may have arrived at Lake Mead on a boat trailered from infested Midwestern or Eastern water bodies. This introduction of the invasive species may have occurred sometime between 2003 and 2005.

Federal, state and local natural resources and water management agencies immediately conducted inspections of facilities along the lower Colorado River. Mussels were found in extremely low densities at external locations on Hoover, Davis and Parker Dams, but were not found in the water supply or other piping systems inside the dams. Mussels were also found at two fish hatcheries, at marinas on Lakes Mead and Mohave, and at the major Arizona and California diversion points in Lake Havasu. Since January 2007, the mussels also have been found in canals and lakes in southern California, in Arizona, and in the Colorado River as far south as the Imperial Diversion Dam, 20 miles north of Yuma, Arizona.

Mussels can form massive colonies, potentially causing a shift in native species and disrupting the ecological balance of the water body. The colonies also can block water intakes, affecting municipal water supply, irrigation and powerplant operations.

Quagga mussels can survive in waters with temperatures near freezing or as warm as 86 °F. They can also survive at great depths as long as the water is moving and has oxygen, nutrients, and a high level of calcium. The ideal spawning seasons occur in the Spring and Fall when the water temperature is between 60 and 70 °F.

The reproductive rate of mature adult quagga mussels compensates for the low survival rates of quagga mussels at larval stage (veliger). Less than 1% of veligers survive to become reproductive adults. An adult quagga mussel may:

- Have a lifespan of 3 to 5 years
- Spawn all year long if conditions are favorable (potentially 6 cycles per year)
- Produce 30,000 to 40,000 eggs and sperm per cycle

Therefore, significant resources have been expended by state, federal and local agencies on public outreach, monitoring, and some localized eradication programs to try to prevent their further spread.

Since January 2007, Reclamation has undertaken numerous actions to address the discovery of quagga mussels in the lower Colorado River system. The Lower Colorado Region has:

- Conducted an extensive literature search to learn more about the mussels' potential impact on hydroelectric and other infrastructure;

- Conducted research on mussel control/eradication methods;

- Hired a consulting firm experienced in mussel control to perform an in-depth assessment of Hoover, Davis and Parker Dams to:
    - Determine areas most at risk of colonization at each Dam, and
    - Determine preventative or control methods;

- Increased mussel detection strategies and preventative maintenance activities at Hoover, Davis and Parker Dams; and

- Participated in outreach efforts with other regions/facilities to share information, such as:
    - Possible control or preventative methods,
    - Newly available biological information about the invasive species.

Facilities in LC Region Impacted by Quagga Mussels

Non-Reclamation Facilities

Although the following agencies and facilities are not part of this study, they are also impacted by the quagga mussels. The potential costs of responding are staggering and many are seeking Federal funding to offset these previously unforeseen costs.

- Southern Nevada Water Authority (SNWA)
- Lake Mead National Fish Hatchery
- Willow Beach National Fish Hatchery
- National Park Service recreational facilities
- The Metropolitan Water District of Southern California (MWD)
- Central Arizona Project (CAP)
- Headgate Rock Dam and Powerplant (Bureau of Indian Affairs facility)
- Palo Verde Diversion Dam
- Imperial Dam
- Gila Aqueduct
- All-American Canal System
- Coachella Canal System

Each of these agencies has incurred new construction costs and increased operating and maintenance costs. The agencies that are likely affected the most are MWD and CAP, because they take their allotments of Colorado River water from Lake Havasu and because of the extensive and intricate system of tunnels, canals, siphons, pumping plants, and storage reservoirs/lakes necessary to draw, transport and store their allotments serving California and Arizona. In reviewing various documents published by MWD, they have spent at least $20M since 2007 in upgrading their facilities and they anticipate annual costs directly associated with quagga mussels of $10M to maintain, operate, and continue to improve their facilities.

Reclamation Facilities

The following systems and equipment at the Lower Colorado Dams Facilities (Hoover Dam, Davis Dam, and Parker Dam and their respective powerplants) have the potential to be adversely impacted by invasive mussels.

- Intake structures and trash racks
- Penstocks
- Gates and valves
- Cooling water systems
- Raw water fire protection systems
- Service and domestic water systems
- Instrumentation

Options to Minimize Impacts of Quagga Mussels

A Site Assessment Report prepared by RNT Consulting Inc. in 2007 concluded that control or elimination of quagga mussels is not possible. The report also made clear that the circumstances are different at each facility on the lower Colorado River. These reports recommended that each site should fully assess their facility and make pro-active changes to minimize the impacts of the quagga mussels. Recommended methods included:

- Cleaning and chemically treating pipelines and valves;
- Installing duplex strainers;
- Modifying existing duplex strainers to use filter baskets with smaller opening size;
- Installing automated self-cleaning screens;
- Installing UV light systems immediately downstream of the duplex strainers and/or automated self-cleaning screens; or
- Converting cooling water systems from raw water to treated water;
- Converting cooling water systems to closed loop system:
    - Using treated water, or
    - Using cooling oils;
- Adjusting the temperature of the raw water above or below the threshold that veliger can survive and/or spawn (reproduce).

Considerations associated with these options include the following:

- If chemicals are used, chemical monitoring and testing would be required. Disposal of chemicals into the water body may require special permits or the chemically treated water must be contained and disposed of legally.
- Automated self-cleaning screens have a large initial cost but maintenance costs are extremely low.
- If duplex strainers are used, the upfront cost is reduced but there are continual maintenance costs to change filter baskets and periodically empty/clean the baskets. The rate of maintenance is exponential based on the opening size of the filter screen/basket. The risk of shells and debris passing through the filter screen/basket is reduced if the openings are small (less than $1/16^{th}$ of an inch) but the strainer requires more frequent cleaning and maintenance.
- UV light systems have a high initial cost and there is typically an annual service fee to the manufacturer for replacement of bulbs and routine service. In addition, it is imperative that strainers or self-cleaning screens are located upstream of the UV light system.
- Converting a raw water cooling system to a treated water system is the ideal solution, if it is feasible and economically viable. However, this alternative is not viable for the generator cooling (air coolers with finned-tubing) units at Hoover Dam, Davis Dam, or Parker Dam.
- Selecting and implementing a method to minimize the impacts of quagga mussels in pipelines and valves can be time consuming and costly.
- Adjusting the temperature of the raw water may work in theory. However, this is not a practical option and would not be cost effective.

Impacts of Quagga Mussels

Hoover Dam

Intake Structures – The four intake towers at Hoover Dam each supply water to a separate penstock. The towers are over 300 feet tall and the surface area of trash racks on each tower is approximately 44,000 square feet. During a Site Assessment Survey, remote cameras indicated that quagga mussel colonies are attached to the trash racks and to the concrete structures, but only at the upper portion. Water intake occurs at the lower cylindrical gate, which is well below the level at which quagga mussel colonies occur in the range of water levels at which Lake Mead has been operated since 2007; so the impact of quagga mussels at the Hoover Dam intake towers has been negligible to date.

Penstocks – One of the four 30-foot diameter penstocks is taken out of service for inspection each year on a rotating basis. Typically, the invert of the penstocks and the drain valves have been found to be covered with shell debris from dead quagga mussels. Colonies of live quagga mussels inside the penstocks are negligible and do not affect operation of the facilities. After the last turnout to the generators, the penstock decreases to 25-feet diameter and the water becomes still (non-flowing). With no significant movement of the water and a lack of nutrients, survival of the veligers (quagga larvae) and settlement of quagga mussel colonies has not been possible.

Valves – Hoover Dam has hundreds of valves of a variety of sizes and types. In the raw water (untreated) systems, all valves, regardless of size, are affected adversely by the quagga mussels and must be monitored and inspected regularly. Mussel colonies can restrict flow rates and shell debris can make it difficult and sometimes impossible to fully close the valves.

Cooling Water Systems – Each of the 17 generators has two separate water cooling systems. One system of piping and cooling tubes cools the lubricating oil in the oil tub. Failure to sufficiently cool the oil will set off alarms and implement unit shut-down procedures. The second cooling system runs raw water through finned tubes in eight large air coolers. Forced air passes through the air cooler and is used to cool components of the generator. Similarly, failure to sufficiently cool the generator components will set off alarms and implement unit shut-down procedures.

Historically, the raw water used for cooling was taken directly from the penstock laterals. The water was approximately 53 °F and clean. With the quagga infestation of Lake Mead, the cooling water now has a large number of veligers (quagga larvae) searching for a hard surface to attach to and colonize. Also, the amount of shell debris can plug valves and cooling tubes and jeopardize the cooling systems.

Hoover Dam is in the process of modifying the entire cooling water system, which will greatly reduce these risks. These “system changes” will be identified later in the report.

Raw Water Fire Protection Systems – Fire protection system water inside the powerplant and for the transformer deluge system is raw water taken directly from the penstock laterals. With the quagga infestation of Lake Mead, the raw water now has a large number of veligers (quagga larvae) searching for a hard surface to attach to and colonize. Also, the shell debris can plug valves, sprinkler heads, and deluge nozzles (jets, sprayers, and foggers) and jeopardize the fire protection systems. Failure of sprinkler heads and nozzles reduces the efficiency of the fire protection system and is unacceptable.

Since the water in the fire lines is non-moving and there is no food source, the veligers do not survive long enough to colonize. However, the issue of shell debris is a significant concern and the risk is great. Therefore, Hoover Dam is in the process of modifying the fire water system, which will greatly reduce these risks. Potential “system changes” were identified in the Value Planning Report (Value Study completed in December 2015).

Service/Domestic Water Systems – The water treatment plant at Hoover Dam has not yet had issues with quagga mussels. Raw water is taken from the downstream tailrace and is screened and pumped up to the water treatment facility in the Arizona Valve House. The flow rate in the intake pipeline exceeds the velocity at which veliger can settle and attach to the pipeline to form quagga mussel colonies. At the treatment facility, the raw water is treated with the necessary chemicals (primarily chlorine) to kill micro-organisms, including but not limited to bacteria and veligers. The treated water is continually monitored, sampled, and tested to ensure that it meets “Safe Drinking Standards”. The intake system and water treatment facility are inspected regularly as “preventative maintenance” to reduce the risks of potential damage caused by the invasive species.

Costs for Quagga-Related Work

Contract costs incurred or planned at Hoover Dam for quagga-related work include the following:

Construction through 2016:

- Install UV Light System (Unit A2) $ 150,000
- Cooling Water Piping; Units A1- A9; N1-N8 $ 1,500,000 [1]
  (Includes pumps, motors, and electrical work)

[1] Cost data provided by Jeff Ommen, P.E.; Mechanical Engineer for this job

Subtotal	$ 1,650,000

Construction, future:

- Install UV Lights for Remaining 16 Units — $ 2,500,000
  - $ 1,800,000 (UV Lights + Mechanical) [2]
  - $ 700,000 (Electrical) [3, 4]
- Replace pipe and modify fire protection system ($ 500,000/year for 10 years) — $ 5,000,000 [5]

Subtotal	$ 7,500,000

Supply (Materials only, not including "in-house" installation by Reclamation):

- Misc. pipe, fittings, and valves — $ unknown
- Duplex strainers; 2016 — $ 78,000 [6]
- Duplex strainers; 2017 through 2020 — $ 277,000 [7]

Service:

- Contract w/ Atlantium to service UV Lights — $ 180,000 [8, 9]
  (Cost per year after 2018 when installation is complete)

In-house O&M costs for quagga related work include the following:

Through 2016: [10]

W.O. 1320719 Replace duplex strainer	$ 2,405
W.O. 2242621 N2 Cooling; Inst duplex strainer	$ 7,762
W.O. 1607741 AO Cooling Water Piping	$ 8,623
W.O. 3466910 General quagga related work	$ 7,300
Multiple W.O. Install duplex strainers	$ 16,801
Multiple W.O. Install duplex strainer	$ 5,338
W.O. 3870648 Order more duplex strainers	$ 2,968
W.O. 3946674 Order more duplex strainers	$ 1,330
W.O. 3957998 Order more duplex strainers	$ 1,173
Subtotal	$ 53,700

[2] Cost data provided by Jeff Ommen, P.E.; Mechanical Engineer for this job
[3] Cost data provided by Mike Ireland; Electrical Engineer for this job
[4] Per Mike Ireland; Electrical Engineer, could save $260,000 if work was done "in-house"
[5] Cost data provided by Jeff Ommen, P.E.; Mechanical Engineer for this job
[6] Cost data provided by J. R, Roach; Project Planner for this job
[7] Cost data provided by J. R, Roach; Project Planner for this job
[8] Estimate based on rates used for Davis Dam and Parker Dam for same services
[9] For yearly or repetitive tasks, increase cost by 5 percent each year for inflation
[10] Cost data provided by Steve Valderrama, Manager of Operations and Maintenance

Future (2017 through 2020):

▪ W.O., NO Cooling Water Piping	$	10,000 [11]
▪ Multiple W.O. Order more duplex strainers	$	7,508 [12]
▪ Multiple W.O.; Install duplex strainers	$	436,000 [13]
Subtotal	$	453,508

Future (yearly/repetitive tasks): [14]

▪ W.O. 3466910 General quagga related work (Clean existing/new duplex strainers each week)	$	39,000 [15]

Davis Dam

Intakes Structures/Trash Racks – Each of the five intakes at Davis Dam supply water to a separate penstock. Each intake structure is approximately 124 feet high and has six slots for trash rack screens. The surface area of trash racks on each intake is approximately 6,700 square feet. During a Site Assessment Survey, divers reported that quagga mussel colonies are attached to the trash racks and to the concrete structures and may restrict normal flow. The dive team scraped some areas of the trash racks and dislodged large colonies of quagga mussels. This was done primarily to allow them to inspect the metal surface of the trash rack to determine the level of damage caused by corrosion and by the mussel infestation.

There is no easy solution. Alternatives include the following:

- A portable trash rake system could be devised that scrapes off the quagga mussels; however, that creates other problems.
    - The volumes of shell debris released into the penstocks would be massive.
    - The metal surface of the trash rack would now be exposed and the corrosion process would be accelerated.
- To allow better inspection of the trash racks, one segment (10 panels; approximately 12’-6” x 9’ each) could be removed and replaced with a temporary stoplog. Based on inspection results:

[11] Estimate based on W.O. 1607741, added 15% for wage rate increases and contingencies
[12] Cost data provided by J. R, Roach; Project Planner for this job
[13] Cost data provided by J. R, Roach; Project Planner for this job for this job
[14] For yearly or repetitive tasks, increase cost by 5 percent each year for inflation
[15] Cost data provided by Steve Valderrama, Manager of Operations and Maintenance (40 strainers; 1 laborer cleans 4/hour @ $75/hour) -- 40 strainers/week @ 4/hour x $75/hour x 52 weeks

- Option 1 – Salvage and re-use. Sand blast to white metal. Treat with ChlorRid to remove salinity. Recoat with high tech anti-fouling coating.
- Option 2 – Dispose. Replace in kind but coat with anti-fouling coating.
- Option 3 – Dispose. Replace with non-corrosive copper-based metal to which quagga mussels do not readily adhere.

For the options identified, implementation could be accomplished as follows:

- For Option 1, an IDIQ contract with a painting contractor is suggested.
- For Option 2, a five-year contract with a metal fabricator and a painting subcontractor is suggested.
- Option 3 is not viable. There would be dissimilar metal issues with the existing guide channels (steel) and the new trash racks (copper-based). Also, the cost of trash racks manufactured with copper-based metals would be cost-prohibitive.
- Alternatively, for Option 2, installation could be performed under a separate IDIQ contract or could be done “in-house” by Reclamation.

Penstocks – Annually, all penstocks are taken out of service for a general inspection. Additionally, one of the five 22-foot diameter penstocks is taken out of service each year on a rotating basis for several months while major overhaul work is being done on the respective generator. This provides a window of time for coating repair on the penstock and any work needed on the intake structure and trash racks. Typically, the inverts of the penstocks are covered with shell debris from dead quagga mussels. Live quagga mussels are not significant in the penstocks because the flow rate of water exceeds the velocity at which veliger can settle and attach to the penstock to form quagga mussel colonies.

Valves – Davis Dam has hundreds of valves of a variety of sizes and types. In the raw water (untreated) systems, all valves, regardless of size, are affected adversely by the quagga mussels and must be monitored and inspected regularly. Mussel colonies can restrict flow rates and shell debris can make it difficult or impossible to fully close the valves. The goal is to replace raw water supplies with treated water where feasible.

Cooling Water Systems – Each of the five generators has two separate water cooling systems. One system of piping and cooling tubes cools the lubricating oil in the oil tub. Failure to sufficiently cool the oil will set off alarms and implement unit shut-down procedures. The second cooling system runs raw water through finned tubes in eight large air coolers. Forced air passes through the air cooler and is used to cool components of the generator. Similarly, failure to sufficiently cool the generator will set off alarms and implement unit shut-down procedures.

The raw water used for cooling is taken directly from two locations on the forebay structure. The 2013 Facilities Review Inspection revealed that the intake screens/gratings were so badly covered with quagga mussels that the flow rate was severely restricted. This was documented in Power Equipment Bulletin No. 53 (Information on Invasive Mussels for Reclamation Power Facilities Advisory) dated February 2014. The inlets were recently redesigned by Denver Technical Service Center personnel and have been replaced. The system must be continually monitored and requires periodic maintenance and cleaning.

Raw Water Fire Protection Systems – Fire protection system water inside the powerplant and for the transformer deluge system is raw water taken directly from the forebay structure. With the quagga infestation of Lake Mohave, the raw water now has a large number of veligers (quagga larvae) searching for a hard surface to attach to and colonize. Also, the shell debris can plug valves, sprinkler heads, and deluge nozzles (jets, sprayers, and foggers) and jeopardize the fire protection systems. Failure of sprinkler heads and nozzles reduces the efficiency of the fire protection system and is unacceptable.

Since the water in the fire lines is non-moving and there is no food source, the veliger do not survive long enough to colonize. However, the issue of shell debris is a significant concern and the risk is great. Therefore, Davis Dam is preparing to modify the fire water system, which will greatly reduce these risks.

The fire protection system will continue to use raw water to extinguish any fires that trigger activation of the system. The modifications include an isolated connection to the domestic water system (treated water) that will be used to purge raw water out of the fire protection lines. The fire line will remain filled with domestic water which will protect the system against infestation of quagga mussels. A new system will include automated valves, backflow prevention, booster pumps (to increase velocity), duplex strainers to prevent quagga shells from entering the fire water pipelines, and a storage tank to supply the necessary volume of treated water.

Service/Domestic Water Systems – For decades, the water treatment plant at Davis Dam has filtered and screened lake water to remove solids and has chlorinated the water to kill microorganisms. Davis Dam is preparing to eliminate the water treatment plant and construct a new water supply line that connects to a nearby domestic water line operated by the local water district.

The cost savings of eliminating the water treatment plant, purchasing chlorine gas, and testing water samples will offset the cost of installing a new metered supply line and paying for domestic water. Also, eliminating the chlorine injection system will reduce the safety risk of chlorine spills.

Costs for Quagga-Related Work

Construction contract costs incurred or planned at Davis Dam for quagga-related work include the following:

Construction through 2016:

▪ Install UV Light System for One Unit	$	150,000 [16]

Construction, future:

▪ Install UV Lights for Remaining Four Units	$	800,000 [17]
o $ 625,000 (UV Lights + Mechanical)		
o $ 175,000 (Electrical)		
▪ Modify fire protection system	$	unknown

Supply (Materials only, not including "in-house" installation by Reclamation):

▪ Misc. pipe, fittings, and valves	$	unknown

Service:

▪ Contract w/ Atlantium to service UV Light --	$	20,000 [18]
▪ Contract w/ Atlantium to service 4 new UV Lights	$	40,000
Subtotal	$	60,000

In-house O&M costs for quagga related work include the following:

Through 2016:

▪ Cleaning strainers and/or filters (2016)	$	31,200 [19]
▪ Cleaning strainers and/or filters (2009-2015)	$	110,000 [20]
Subtotal	$	141,200

Future (yearly/repetitive tasks): [21]

▪ Cleaning strainers and/or filters each week	$	31,200 [22]

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16 Cost data includes piping, strainer, and electrical work. The supplier (Atlantium) furnished the UV Light as a "prototype" for evaluation

17 Estimate is based on costs established for similar work at Hoover Dam

18 Cost data provided by Vince Lammers, Plant Manager (1 laborer x 4 hours/day x 2 days/week @ $75/hour x 52 weeks)

19 Cost data provided by Vince Lammers, Plant Manager (1 laborer x 4 hours/day x 2 days/week @ $75/hour x 52 weeks)

20 Cleaning strainers/filters: 2008 – Monthly; 2009 – Weekly; 2013 – Twice/week. Data provided by Vince Lammers, Plant Manager. Cost averaged from $0 (2008) to $31,200 (2016)

21 For yearly or repetitive tasks, increase cost by 5 percent each year for inflation

22 Cost data provided by Vince Lammers, Plant Manager (1 laborer x 4 hours/day x 2 days/week @ $75/hour x 52 weeks)

Parker Dam

Lake Havasu, behind Parker Dam, is a shallow lake and has warm water year-round. The warmer temperatures promote growth of aquatic vegetation and algae which provides nutrients needed by the quagga mussels. Therefore, Lake Havasu appears to provide the greatest opportunity for rapid mussel growth and colonization and the potential for quaggas to affect operations at Reclamation facilities on the lower Colorado River is greatest at Parker Dam.

Intakes Structures/Trash Racks – Each of the four intakes at Parker Dam supply water to a separate penstock. Each intake structure is approximately 55 feet high and has a second set of trash rack screens.

The primary trash rack has been overhauled and new trash rack panels were installed for the upper section. In addition, an automated trash rake system was installed to capture and remove debris that clogs the trash rack panels. The volume and weight of debris has increased significantly in the last decade since quagga mussels were discovered in Lake Havasu. The added weight and pressure against the trash rack structure is a risk and the debris needs to be removed at frequent intervals. The highest impact occurs during the summer months (June, July, August, and September). Pre-2007, the trash rack was cleaned once each month. During the summer months in 2016, the trash rack needed to be cleaned at least two times each week.

Penstocks – Annually, all penstocks are taken out of service for a general inspection. Additionally, one of the four 22-foot diameter penstocks is taken out of service each year on a rotating basis for several months while major overhaul work is being done on the respective generator. This provides a window of time for coating repair on the penstock and any work needed on the intake structure and trash racks. Typically, the inverts of the penstocks are covered with shell debris from dead quagga mussels. Live quagga mussels are not significant in the penstocks because the flow rate of water exceeds the velocity at which veligers can settle and attach to the penstock to form quagga mussel colonies.

Valves – Parker Dam has hundreds of valves of a variety of sizes and types. In the raw water (untreated) systems, all valves, regardless of size, are affected adversely by the quagga mussels and must be monitored and inspected regularly. Mussel colonies can restrict flow rates and shell debris can make it difficult or impossible to fully close the valves.

Cooling Water Systems -- Each of the four generators has two separate cooling systems. One system of piping and cooling tubes cools the lubricating oil in the oil tub. Failure to sufficiently cool the oil will set off alarms and implement unit shut-down procedures. The second cooling system runs raw water through finned tubes in eight large air coolers. Forced air passes through the air cooler and is used to cool components of the generator. Similarly, failure to sufficiently cool the generator will set off alarms and implement unit shut-down procedures.

The cooling system that cools the lubricating oil has been replaced with a closed-loop system that uses oil as the coolant. The original valves and cooling tubes were all removed and there are no longer issues with quagga mussels.

The second system that supplies cooling water to the eight air coolers has also been modified recently. The cooling water system to each generator has new piping and valves, automatic self-cleaning strainers, and a "state-of-the-art" UV Light System that kills the veligers. The new system has been working for approximately one year and testing and monitoring verifies that the quagga mussels are no longer a threat to the cooling water systems.

Fire Protection System – The fire protection system at Parker Dam uses domestic water from the onsite water treatment facility.

Costs for Quagga-Related Work

Construction contract costs incurred or planned at Parker Dam for quagga-related work include the following:

Construction through 2016:

▪ Cooling Water Piping (Phase 1)		$ 620,000
▪ Cooling Water Piping (Phase 2)		$ 105,000
▪ Trash Rack Cleaner		$ 900,000
▪ Trash Rack Replacement		$ 430,000
▪ Install UV Light System		$ 995,000
▪ Self-cleaning strainers		$ 725,000
	Subtotal	$ 3,775,000 [23]

Service:

▪ Contract w/ Atlantium to service UV Lights (Cost per year after installation was completed)	$ 45,000 [24, 25]

[23] Sum is for Contract Costs only. Does not include Non-contract Costs (Design, Specifications, Acquisitions, and Inspection Costs)
[24] Cost data provided by John Steffen, Plant Manager
[25] For yearly or repetitive tasks, increase cost by 5 percent each year for inflation

In-house O&M costs for quagga related work include the following:

Through 2016:

▪ Cleaning strainers and/or filters (2016)	$ 31,200	[26]
▪ Cleaning strainers and/or filters (2009-2015)	$ 110,000	[27]
▪ Cleaning/hauling debris from trash racks (2016)	$ 36,000	[28]
Subtotal	$ 177,200	

Future (yearly/repetitive tasks): [29]

▪ Cleaning strainers and/or filters	$ 32,760
▪ Cleaning/hauling debris from trash racks	$ 37,800
Subtotal	$ 70,560

Process for Tracking Mussel-Related Costs

A system is being developed to coordinate with Acquisitions at the end of each fiscal year to identify all construction contracts, supply contracts, and service contracts issued by the Lower Colorado Dams Office (LCDO) that related to control of quagga mussels. A computer-generated spreadsheet will summarize each type of contract and the site (Hoover, Davis, or Parker). This information will be provided to LCDO management.

In addition, a system is in place with Hoover Dam to track costs for “in-house” work for quagga-related maintenance.

- Job-Specific Tasks – A separate and unique Work Order number will be established.
- General Tasks – A Work Order number has been established for quagga-related tasks
- Work Order Reports – At the completion of work, the employee is to add a short summary. If the task was not previously identified as “quagga-related” work but should have been, this will be identified in the summary.

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[26] Cost data provided by John Steffen, Plant Manager (1 laborer x 4 hours/day x 2 days/week @ $75/hour x 52 weeks)

[27] Cleaning strainers/filters: 2008 – Monthly; 2009 – Weekly; 2013 – Twice/week. Data provided by John Steffen, Plant Manager. Cost averaged from $0 (2008) to $31,200 (2016)

[28] Cost data provided by John Steffen, Plant Manager. Volume of debris and number of cleanings has doubled. Assume 24 additional cleanings per year. (2 laborers x 10 hours @ $75/hour x 24 cleanings)

[29] For yearly or repetitive tasks, increase cost by 5 percent each year for inflation

- Educate employees on the importance of documenting any work or task that is "quagga-related".

An annual summary of Work Orders will be compiled at the end of the fiscal year and provided to LCDO management.

A system to track "in-house" work for quagga-related maintenance at Davis Dam and Parker Dam will be developed in 2017 using information gained at Hoover Dam as a proto-type.

References

Bureau of Reclamation. Power Equipment Bulletin No. 53 – Information on Invasive Mussels for Reclamation Power Facilities Advisory (February 2014)

Bureau of Reclamation. Value Engineering Study – Final Report; Ultraviolet Light Treatment System for Generator Cooling Water -- Hoover Dam (May 2016)

Bureau of Reclamation. Value Planning Study – Final Report; Hoover Dam Fire Suppression System (December 2015)

RNT Consultants (Renata Claudi - MS & Tom Prescott – MS, PE); Assessment of the Potential Impact of Quagga Mussels on Davis Dam and Parker Dam and Recommendations for Monitoring and Control (December 17, 2007)

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