# The GLMRIS Report

## Appendix A - Alternative Development Analyses

USACE
01/06/2014

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# LIST OF ATTACHMENTS

# A.1 ALTERNATIVE PLAN DEVELOPMENT

## A.1.1 Introduction

This appendix of the GLMRIS Report provides a series of attachments used in the GLMRIS Report planning process. These attachments vary in their contents, but all were vital in the development of the GLMRIS Report Alternatives.

# ATTACHMENT A

# NONSTRUCTURAL ALTERNATIVE REPORT


# Nonstructural Measures for Consideration by the GLMRIS Program

Final Draft

January 2014

**US Army Corps of Engineers®**

*Product of the GLMRIS Team*

The Great Lakes and Mississippi River Interbasin Study (GLMRIS) Team consists of a regional, collaborative effort led by the U.S. Army Corps of Engineers (Corps), including various District and Division offices, as well as Corps Centers of Expertise and Research Laboratories. Products of the GLMRIS Team are also made possible in collaboration with various federal, state, local, and non-governmental stakeholders.


# Nonstructural Measures for Consideration by the GLMRIS Program

Final Draft
January 2014

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# NONSTRUCTURAL MEASURES FOR CONSIDERATION BY THE GLMRIS PROGRAM

## 1 INTRODUCTION

As part of the overall U.S. Army Corps of Engineers (USACE) Great Lakes Mississippi River Interbasin Study (GLMRIS) program and its objectives, a technology report was prepared that identified and evaluated technological approaches that may reduce the potential for the movement of aquatic nuisance species (ANS) between the Great Lakes and Mississippi River basins (GLMRIS 2012). This technology evaluation considered both engineering-based structural approaches (i.e., those that require the construction and operation of technology-based infrastructure) and nonstructural measures (i.e., those that do not require engineered construction for implementation and operation) for controlling interbasin transfer of ANS through the Chicago Area Waterways System (CAWS).

The GLMRIS program also prepared a risk assessment report (Grippo et al. 2013) that evaluated the potential risks of ANS for undergoing successful interbasin transfer through the CAWS and causing unacceptable environmental, economic, and sociopolitical consequences. The risk assessment evaluated potential establishment over four time steps encompassing a 50-year time period:

Time 0 ($T_0$) = potential for establishment in the immediate future based on the current distribution of the ANS;

Time 10 ($T_{10}$) = potential for establishment within 10 years from present time;

Time 25 ($T_{25}$) = potential for establishment within 25 years from present time; and

Time 50 ($T_{50}$) = potential for establishment within 50 years from now.

The use of these time steps is intended to capture changes in the distribution of ANS species that may occur during a time step and thus affect the likelihood of establishment.

The risk assessment identified 13 ANS that pose potentially medium to high risks of adverse impacts within the next 50 years, should they undergo successful interbasin transfer between the Great Lakes and Mississippi River basins.

This report presents the findings of a study that was conducted to identify and evaluate the potential applicability of nonstructural measures to reduce the interbasin transfer of the 13 medium- and high-risk ANS identified in the GLMRIS risk assessment (Grippo et al. 2013). The nonstructural measures evaluated are ones that (1) may be implemented relatively quickly ($T_0$); (2) pose little or no risk to human health or safety; (3) would require no construction of any type of infrastructure; (4) could act to stop or reduce (slow) the arrival at and passage of at least some ANS; and (5) have been or are currently being implemented for other ANS elsewhere in North America (as evidence that the control is consistent with U.S. laws and regulations). Examples of nonstructural measures include removal (e.g., netting), chemical control (e.g., use of aquatic herbicides), controlled waterway use (e.g., inspection and cleaning of watercraft before or after entry to a water body), and educational programs.

# 2 METHODS

The GLMRIS technology report (GLMRIS 2012) identified and evaluated over 90 available controls for possible use in addressing the transfer of ANS species between the Great Lakes and Mississippi River basins through the CAWS. The current study examined the control measures listed in the GLMRIS technology report (GLMRIS 2012) that are nonstructural in nature (i.e., do not require engineered construction), and further evaluated these with regard to applicability to the 13 medium- and high-risk ANS identified in the risk assessment (Grippo et al. 2013). While the technology report identified a number of nonstructural measures, a number were removed from further consideration because it was deemed improbable that they could be implemented quickly (e.g., $T_0$). For example, fish species gene manipulation and chemical sterility control measures were removed from consideration because these approaches are not likely to be available in the near future for the species under consideration by the GLMRIS program (for additional information on deleterious gene spread, see http://glmris.anl.gov/documents/docs/anscontrol/DeleteriousGeneSpread.pdf).

The evaluation presented in this report also considered, when data were available: (1) the perceived effectiveness and success of each control measure; (2) implementability; (3) the application frequency; (4) public acceptance; and (5) cost of each control measure.

## 2.1 SPECIES AND SPECIES GROUPINGS

The GLMRIS risk assessment (Grippo et al. 2013) identified 13 ANS that pose potentially medium to high risks of adverse impacts within the next 50 years in either the Great Lakes or Mississippi River basins (Table 2.1). This study evaluated control methods that could target these species or their taxonomic groupings.

## 2.2 DATA SOURCES

For this study, data were obtained from a number of sources, including peer-reviewed scientific literature (i.e., *Biological Conservation*, *BioControl*, the *North American Journal of Fisheries Management*, and *Fisheries*), and reports and publications from state and federal agencies and non-governmental organizations (NGOs) with active ANS programs or activities. Public Web sites of state and federal agencies, as well as those of NGOs, with ANS programs or activities were also examined for useful information on nonstructural measures. Table 2.2 lists the state and federal agencies and the NGOs from which control measure information was obtained.

**TABLE 2.1 Aquatic Nuisance Species Posing Medium or High Risks of Adverse Impacts Following Interbasin Transfer through the Chicago Area Waterways System (Grippo et al. 2013)**

| Taxonomic Category | Common Name | Scientific Name | Basin Currently Inhabited[a] | Risk Level | Time Period to Attain Risk Level[b] |
|---|---|---|---|---|---|
| Virus | VHSv (viral hemorrhagic septicemia virus) | *Novirhabdovirus* sp. (Family *Rhabdoviridae)* | GL | Medium | $T_{10}$ |
| Algae | Grass kelp | *Enteromorpha flexuosa* | GL | Medium | $T_{10}$ |
| | Red algae | *Bangia atropurpurea* | GL | Medium | $T_0$ |
| | Diatom | *Stephanodiscus binderanus* | GL | Medium | $T_0$ |
| Plants | Reed sweetgrass | *Glyceria maxima* | GL | Medium | $T_{50}$ |
| Crustaceans | Fishhook waterflea | *Cercopagis pengoi* | GL | High | $T_{25}$ |
| | Bloody red shrimp | *Hemimysis anomala* | GL | High | $T_0$ |
| | Scud | *Apocorophium lacustre* | MR | Medium | $T_0$ |
| Fish | Bighead carp | *Hypophthalmichthys nobilis* | MR | Medium | $T_{25}$ |
| | Silver carp | *Hypophthalmichthys molitrix* | MR | Medium | $T_{25}$ |
| | Threespine stickleback | *Gasterosteus aculeatus* | GL | Medium | $T_0$ |
| | Ruffe | *Gymnocephalus cernuus* | GL | Medium | $T_{50}$ |
| | Tubenose goby | *Proterorhinus semilunaris* | GL | Medium | $T_{10}$ |

**TABLE 2.2 Organizations, Programs, and Agencies Providing Information on Nonstructural Measures for Possible ANS Control**

| | | |
|---|---|---|
| **Non-Governmental Organizations** | | |
| National Ballast Information Clearinghouse | Maryland Native Plant Society | Sea Grant New York |
| New Jersey Invasive Species Strike Team | Maine Volunteer Lake Monitoring Program | Great Lakes Fishery Commission |
| 100th Meridian Initiative | | |
| **State Agencies, Programs, and Organizations** | | |
| New Hampshire Department of Environmental Services | Massachusetts Department of Environmental Protection | Massachusetts Department of Conservation and Recreation |
| Wisconsin Department of Natural Resources | Massachusetts Office of Water Resources | Rhode Island Department of Environmental Management |
| Rhode Island Aquatic Invasive Species Working Group | Michigan Department of Environmental Quality | South Carolina Department of Natural Resources |
| State of Washington Department of Ecology | New York Department of Environmental Conservation | Pennsylvania Fish and Boat Commission |
| Minnesota Department of Natural Resources | Wyoming Game and Fish Commission | Colorado Parks and Wildlife |
| Missouri Department of Conservation | Colorado Department of Natural Resources | Idaho State Department of Agriculture |
| Illinois Aquatic Nuisance Species Program | Indiana Department of Natural Resources | Iowa Department of Natural Resources |
| Kansas Department of Wildlife, Parks, and Tourism | Louisiana Department of Wildlife and Fisheries | Montana Fish, Wildlife, and Parks |
| Utah Division of Wildlife Resources | New Mexico Department of Game and Fish | North Dakota Game and Fish Department |
| Ohio Department of Natural Resources | Oklahoma Department of Wildlife Conservation | Oregon Department of Fish and Wildlife |
| South Dakota Game, Fish, and Parks | Texas Parks and Wildlife | Nebraska Game and Parks |
| Washington Department of Fish and Wildlife | Massachusetts Office of Coastal Zone Management, Massachusetts Aquatic Invasive Species Working Group | University of Florida |
| **Federal Agencies, Programs, and Organizations** | | |
| U.S. Geological Survey | U.S. Fish and Wildlife Service | United States Coast Guard |
| U.S. Department of Agriculture, Forest Service | Department of Defense, Invasive Species Management | Congressional Research Service |
| U.S. Environmental Protection Agency, Great Lakes Nonindigenous Invasive Species Workshop | Aquatic Nuisance Species Task Force, Asian Carp Working Group | Department of Commerce, National Oceanic and Atmospheric Administration, National Invasive Species Council |
| Aquatic Nuisance Species Task Force | U.S. Army Corps of Engineers, Aquatic Nuisance Species Research Program | |

# 3 NONSTRUCTURAL ANS MEASURES AND THEIR APPLICABILITY TO GLMRIS

Examination of available information regarding ANS control measures identified a number of approaches that have been, or are currently being, applied in attempts to or limit the introduction or spread of ANS. These approaches include activities such as monitoring, the use of pesticides, and public education campaigns (Table 3.1). Some approaches may be applicable to a variety of species or taxonomic groups, while others apply to a specific species or taxonomic group. This section provides an overview of each of the control approaches and evaluates the potential applicability of the approaches for controlling transfer of the ANS of concern for GLMRIS.

## 3.1 EDUCATION AND OUTREACH

### 3.1.1 Overview

The principal objective of any education and outreach approach is to raise public awareness regarding ANS issues and concerns, and to inform members of the public about how to become involved in helping address those concerns. Raising public awareness will be related to increasing knowledge regarding the ANS and why they are of concern, increasing the public's ability to correctly recognize an ANS when encountered; increasing knowledge regarding what

**TABLE 3.1 General Nonstructural Measures Potentially Applicable for Addressing the Interbasin Transfer of the ANS of GLMRIS Concern**

| | ANS Taxonomic Grouping | | | | |
|---|---|---|---|---|---|
| General Approach | Virus | Algae | Rooted Semi-Aquatic Vegetation | Crustaceans | Fish |
| Education and Outreach | √[a] | √ | √ | √ | √ |
| Monitoring | √ | √ | √ | √ | √ |
| Pesticides/Anti-microbial | √ | √ | √ | √ | √ |
| Antifouling Materials | √ | √ | √ | √ | |
| Biological Control | | | | | |
| Manual/Mechanical Removal | | | √ | | √ |
| Habitat Alteration | | √ | √ | √ | √ |
| Ballast and Bilge Water Management | √ | √ | √ | √ | √ |
| Laws and Regulations | √ | √ | √ | √ | √ |

[a] √ = the approach has been applied in the United States to one or more species within the specified taxonomic group.

to do if an ANS is encountered; and providing the public with simple actions to take to reduce the potential for inadvertently spreading the ANS (e.g., Putnam 2013a).

The primary target of most education and outreach activities is the recreational water body user, namely boaters and anglers, and any commercial activities that support recreational water use. With regard to the CAWS, another target audience would be commercial water body users (i.e., barge operators). Examples of education and outreach components include the following:

- educating the public on how to identify an ANS and report any encounters;
- educating the public on being careful to not transfer ANS between water bodies;
- reminding boaters to inspect and clean their watercraft before and/or after each visit to a water body where an ANS is known or suspected;
- reminding anglers to inspect and clean their gear (e.g., rods, reels, lines, nets, waders) before and/or after each visit to a water body;
- educating anglers on the potential for transferring an ANS when using live bait, and on the proper disposal of live bait;
- encouraging aquarium hobbyists and water garden owners to use native species, and not dispose of unwanted plants and animals in the wild; and
- educating the public regarding existing restrictions on the possession, sale, transport, and release of ANS.

Examples of education and outreach programs that incorporate many of these components include the Wisconsin Department of Natural Resources Invasive Species Program (http://dnr.wi.gov/topic/Invasives) and the Minnesota Sea Grant Aquatic Invasive Species Program (http://www.seagrant.umn.edu/ais/index).

Education and outreach materials for implementing such approaches can include any of the following:

- printed materials such as brochures and posters;
- press releases on local newspapers, radio, and TV;
- permanent signage at water bodies, especially in high-use areas such as boat ramps and fishing piers; and
- educational programs at schools and community organizations (e.g., Boy Scout and Girl Scout clubs, church groups, boat and gun clubs).

In general, these measures are relatively low in cost and easy to implement. However, the actual cost and effectiveness of any education and outreach program will depend on the size of the program, the quantity of printed materials, the degree of involvement from the public, and the actual funding provided.

### 3.1.2 Applicability to the CAWS

Education and outreach methods could be implemented for any of the 13 GLMRIS medium- and high-risk ANS. Whether efforts to educate recreational waterway users would be effective for controlling passage of the ANS through the CAWS or their subsequent establishment in the Mississippi River Basin is unknown.

There is relatively minimal recreational waterway use in many portions of the CAWS. Because of the size of the algal and crustacean ANS, observations of these ANS by waterway users may be expected to be minimal. While directly observing VHSv would not be possible, it may be possible to observe affected fish. Voluntary inspections and cleaning of watercraft and angling equipment would likely have limited effectiveness on the algae, crustaceans, and seeds and fragments of reed sweetgrass that could be transported by attachment to watercraft, because these ANS are relatively difficult to detect unless present in high numbers.

An education and outreach program for the CAWS could be an effective measure to reduce the probability of interbasin transfer of the four fish ANS and of VHSv. Specific programs may include the following:

- Providing information to commercial and recreational baitfish harvesters on reducing accidental and deliberate unlawful introduction of the ANS—this could include the distribution of printed materials at bait shops, marinas, and boat ramp facilities, as well as in-person training;

- Providing information to anglers and boaters on how to prevent accidental introduction of the fish, and to encourage voluntary action to reduce this risk;

- Providing information to the public on how to identify all life stages of the fish ANS, and how to report sightings (ANS Taskforce 2007; Putnam 2013a); and

- Providing information to the public on how to identify fish that may be infected by VHSv, and how to report such sightings.

The degree of effectiveness in reducing the probability of the fish ANS from arriving in and passing through the CAWS is not known, and would depend on the scope of the program, public involvement, and participation and coordination among stakeholders. For example, the state of Montana has a comprehensive education and outreach program that includes most of the techniques described above. In 2012, over 64,000 boaters and anglers were questioned about aquatic invasive species awareness. Only 6% were unaware, compared to 17% the previous year.

This suggests that Montana's outreach program has been successful raising ANS awareness of recreational waterway users in that state (MT FWP 2012b). Providing boat washing stations at high-use boat launches would make vessel cleaning more convenient for boaters and may increase compliance with voluntary programs.

## 3.2 MONITORING

### 3.2.1 Overview

Monitoring is used to provide early warning that an ANS has spread beyond its current known distribution and has moved into a new area. While such information will not by itself control or limit the spread of an ANS into a new water body, if coupled with a rapid response plan (such as a quick and well-coordinated eradication plan), some control of further spread of the ANS may be possible (Hänfling et al. 2011). For example, reed sweetgrass is an ANS of concern in the Great Lakes, currently occurring in Wisconsin along the western shore of Lake Michigan (WDNR 2013b). An isolated population was discovered growing out of a recently replaced manhole cover at Illinois Beach State Park, just north of Waukegan, Illinois; this population was treated with aquatic herbicide and subsequent monitoring has indicated this population to have to have been eradicated (Berent and Howard 2013).

Some ANS are large enough to be observed and are relatively easy to observe and identify (e.g., large fish, rooted semiaquatic vegetation); thus it may be possible for such species to be monitored by local groups and volunteer "citizen scientists." However, because of the small (i.e., microscopic) size of some of the ANS (algae, crustacean), and the nature of their habitats (e.g., living on bottom surfaces, in deep or turbid waters), adequate monitoring would most likely require the use of specialized sampling equipment (including watercraft). As a result, the monitoring would most likely be conducted by local, state, or federal agencies. Voluntary occurrence reporting (a form of monitoring) and agency monitoring would be beneficial in informing agencies how far a species has spread. Monitoring efforts also contribute to understanding the factors that may control the abundance of ANS, and thus may provide valuable information for predicting how likely an ANS is to become established in a new location (DFO 2010).

Several state agencies and local groups have established voluntary occurrence reporting and voluntary watercraft inspections for ANS. For example, the state of Vermont trains boat access greeters through the Department of Environmental Conservation's (VTDEC's) Boat Access Greeter Program. This program offers visual inspections of boats and equipment for ANS, and provides education to the public on the importance of preventing ANS spread (VDEC 2012).

### 3.2.2 Applicability to the CAWS

Agency monitoring and voluntary occurrence reporting alone would not affect the passage of any of the ANS through the CAWS. Monitoring can, however, inform agencies about how far a species has spread; provide early warning regarding passage through the CAWS and establishment either below Brandon Road Lock and Dam or in Lake Michigan; and trigger a response action to implement a control action. Monitoring costs would vary based on the frequency of monitoring events, the monitoring equipment, and the number of staff required.

The effectiveness of volunteer monitoring programs is unknown, but may be expected to depend on the number of volunteers and inspection sites. Because of the small size of many of the algal and crustacean ANS, successful monitoring for these species would most likely need to be conducted by staff from local, state, and federal agencies rather than by volunteers and citizen scientists. Successful monitoring of the fish ANS, especially of smaller fish (such as the tubenose goby) in deep or turbid waters, as well as monitoring for fish potentially infected with VHSv, would also likely be restricted to agency programs and staff.

## 3.3 PESTICIDES

### 3.3.1 Overview

Control of ANS using pesticides involves the application of chemicals directly to the ANS or its habitat. Before the use of any pesticides, non-target organisms that may be affected by exposure at the treatment area must be considered. Many, if not all, pesticides lack specificity and their use may reduce the abundance of ANS, but it may also reduce the abundance of native biota. Regardless of which type of pesticide is to be used, care must also be taken during application to minimize drift or runoff to non-target areas where non-target vegetation and other biota may be affected. Because most pesticides do not target individual species, wherever the chemical is applied either directly to the water column or by broadcast spraying, it will likely affect non-target species. This makes pesticide application infeasible across large water bodies or for prolonged periods of time.

Control of invasive algal populations may be achieved with the application of algaecides. Algaecides can be applied as a spray directed onto floating mats of algae; sprayed or injected directly into the water column for suspended or attached phytoplankton; or applied as granular crystals or pellets (USACE 2012a). Algaecides can be effective at controlling the spread of a population of algae by reducing abundance (density) in the treated area, but may not be effective in complete eradication. In addition, environmental conditions such as high pH, high alkalinity, or water temperatures below 15°C may act to reduce the effectiveness of some algaecide formulations (USACE 2012a).

Control of invasive rooted semiaquatic vegetation may be achieved with the application of various aquatic herbicides. Aquatic herbicides such as glyphosate that are translocated through all parts of the plant, including the deep rhizomes, are ideal for controlling species such as reed sweetgrass (DPIPWE 2002). In general, aquatic herbicides may be applied directly to individual plants (the preferred method for minimizing exposure of non-target species) or by spraying directly onto stands of vegetation. Application of aquatic herbicides should be timed to coincide with the flowering period of the target plant, thereby limiting or preventing seed production.

Reed sweetgrass that have more than about one-third of their stems below water may not be killed by aquatic herbicide (DPIPWE 2002). Aquatic herbicide application may be most effective when used in combination with manual harvest and/or physical removal measures. The cost of aquatic herbicide application depends on the market price of the aquatic herbicide used and the size of area where aquatic herbicide application is planned. Additional fees may be incurred for permitting and sample/analysis (NH DES 2005).

Pesticide treatment may be effective in controlling invasive crustaceans, although resting eggs may pose a problem in some cases. For example, chemical agents such as chlorine bleach, saltwater, common boat cleaner, and vinegar have been shown to successfully kill as much as 90–100% of the resting eggs of some planktonic crustacean species (New York Sea Grant 2004). However, resting eggs enclosed in a female parent's body were about 5–10% more resistant to treatment by some agents than the "free" resting eggs, while enclosed resting eggs treated with boat cleaner were about 50% more resistant than the same treatments applied to free resting eggs (New York Sea Grant 2004).

Piscicides for controlling fish populations can be used in a variety of aquatic environments, including lakes and rivers, but are most effective in impoundments and areas with little or no flow. Rotenone and antimycin are two commonly used piscicides (Brown et al. 2011). As with most pesticides, piscicide effectiveness is affected by factors such as water temperature, alkalinity, and sunlight (USACE 2013). Depending on the type, concentration, method and timing of application, and length of exposure to the piscicide used, it could be toxic to other aquatic biota (i.e., invertebrates). Because piscicides do not target individual species, their use across large water bodies or for prolonged periods of time may would likely affect non-target species.

### 3.3.2 Applicability to the CAWS

The current distribution of the ANS of GLMRIS concern, as well as the environments associated with the CAWS and associated portions of the Great Lakes and Mississippi River basins, likely will limit the use of pesticides to localized areas. Pesticides applied on coastal or open water habitats in the Great Lakes would likely be quickly diluted (by wave action in coastal areas and by simple dilution in open water column settings). Within the CAWS and below Brandon Road Lock and Dam, it may be possible to maintain desired concentrations for longer periods of time than in the Great Lakes, but with current transport there will be a strong likelihood of affecting non-target areas and species.

Use of algaecides has been shown to be an effective method to control invasive algae populations. It is unknown how effective any particular algaecide might be on any of the three algal ANS of concern, or how much they would reduce the probability of passage through the CAWS or establishment below Brandon Road Lock and Dam. For the red algae *Bangia atropurpurea*, endothall and chelated copper-based algaecides (such as K-Tea™ [triethanolamine; SePRO Corporation] and Captain™ [copper carbonate; SePRO Corporation]) could be effective. Many diatom species are susceptible to copper sulfate and chelated copper formulations. The diatom ANS of concern to the GLMRIS program is *Stephanodiscus binderus*, and the genus *Stephanodiscus* is included on many copper sulfate- and chelated copper-based product labels as a sensitive genera that can be controlled by their use. Similarly, the genus *Enteromorpha*, to which grass kelp (*E. flexuosa*) belongs, is included on many copper sulfate- and chelated copper-based product labels as being susceptible to these algaecides (USACE 2012a). The algaecides would be applied directly to the water column, and non-target habitats and species may be affected.

The use of aquatic herbicides has been shown to be an effective method to control reed sweetgrass, and may be most effective when used in combination with manual or mechanical removal (see Section 3.5). A foliar spray of glyphosate (3% solution) applied in early to late summer has been shown to control populations of *reed sweetgrass*, although rhizomes in the sediment may survive after initial spraying (King County 2012). The aquatic herbicide imazapyr has also been reported to be effective on reed sweetgrass, especially when applied in summer or early fall and when water levels are low and plant stems are not submerged (King County 2012). While direct application to individual plants would greatly limit exposure of non-target biota, foliar spraying could expose both plant and animal non-target species and their habitats.

Chemical solutions, such as chlorine bleach, may be effective in controlling the crustacean ANS of concern as well as VHSv, but there would be concerns regarding non-target biota (New York Sea Grant 2004). Because any such chemical solutions would be applied in a manner similar to that used for algaecide applications, application in the Great Lakes (targeting arrival of the fishhook water flea and bloody red shrimp to the CAWS), below Brandon Road Lock and Dam (targeting arrival of the scud to the CAWS), or within the CAWS (targeting passage of all three species) would likely expose non-target biota and habitats. In addition, dilution issues associated with water volume and current/wave action would make effective application difficult. Thoroughly cleaning boat hulls, trailers, nets, and other equipment may be effective for limited transfer of VHSv between the basins; the U.S. Environmental Protection Agency (EPA) has approved the disinfectant Virkon AQUATIC$^{TM}$ for use against VHSv. There is no known biological or antiviral treatment to rid fish of VHSv (Kipp 2013).

Piscicides are commonly used to manage fish populations in lentic environments, and they could be effective in controlling passage through the CAWS of the four fish ANS of concern. The piscicide rotenone has been suggested as potentially effective for bighead carp and silver carp in the Chicago Ship and Sanitary Canal; it was effective at killing common carp and 10 other fish species during a 2009 CAWS application, and over 40 fish species during a 2010 CAWS application (USACE 2010, 2013). Another study examined the potential effectiveness of rotenone and antimycin A to prevent bighead and silver carp from passing through the Chicago Ship and Sanitary Canal (USGS 2003). In that study, rotenone was reported to be effective on bighead and silver carp (all exposed carp killed within 4 hours), but antimycin A was judged to be relatively poor for controlling carp because the time to mortality was considered too long to be effective. Piscicides may be effective in reducing numbers of fish ANS in areas of the CAWS and the two basins where current and wave action are minimal (e.g., small embayments and coves, quiet side channels and pools), and where application could be controlled and closely monitored to minimize potential impacts on non-target biota.

## 3.4 ANTIFOULING MATERIALS

### 3.4.1 Overview

Antifouling materials, such as paints and other surface coating, limit the attachment of organisms onto submerged surfaces by creating a surface that is inhospitable to biota. Antifouling paints are applied to the hulls of boats and any other vessel submerged in water and act to slow and limit the buildup of unwanted organisms (biofoul) that can affect a vessel's efficiency and integrity. They may also serve as a tool by which to reduce the potential for indigenous and nonindigenous biota to be transported between water bodies. Some antifouling materials incorporate one or more biocides, while others are biocide-free. Historically, antifouling paints incorporated copper or organotin (such as tributyltin [TBT]) compounds as biocides to limit attachment by aquatic biota. Such paints expose biota to the biocides either by slowly releasing the biocide, or by slowly wearing away and continually exposing fresh layers of biocide (i.e., self-polishing paints).

Due to concerns about effects on non-target biota, as well as potential concerns regarding human health, TBT-based paints were banned by the International Maritime Organization (IMO 2002). As a consequence, paint manufacturers have been developing more environmentally friendly biocide-based antifouling paints. In general, these can be grouped into three categories: (1) controlled depletion paints (CDPs); (2) tin-free self-polishing paints (TF-SPCs); and (3) hybrid systems (Almeida et al. 2007).

Controlled depletion paints use biocides in combination with a physically drying, nontoxic, binder that acts to control the relative rate of the dissolution/erosion of the paint and associated biocide release. There are several varieties of CDPs:

- Ablative antifouling paints, wherein the surface of the paint is continually sloughed off, exposing fresh biocide;
- Sloughing antifouling paints, wherein the paint is lost in flakes rather than continuously;
- Modified epoxy antifouling paints, which contain copper particles that slowly dissolve, exposing more copper until the copper is completely lost;
- Vinyl antifouling paints, which form a smooth, hard surface from which the biocide slowly leaches; and
- Copolymer antifouling paints, in which the biocide is bound to the pigment and the surface slowly dissolves.

Metal-based antifouling paints most commonly employ copper, while some are aluminum- or zinc-based (Wells and Sytsma 2009), and thus also carry a concern about affecting non-target biota and/or human health. In general, CDPs may need to be applied every 3 years or even less frequently depending on hull wear (Almeida et al. 2007; EPA 2011).

Tin-free self-polishing paints are similar in nature to TBT-based self-polishing paints but no longer use tin-based compounds. Instead, TF-SPCs are based on copper or zinc acrylates, along with other biocides, and these biocides are thought to be released upon contact with seawater. This group of paints is not thought to be as effective as traditional TBT-based paints and, similar to CDPs, has a service life of around 3 years (Almeida et al. 2007; EPA 2011). Hybrid system paints contain some combination of CDP and TF-SPC, with copper- or zinc-based biocides; their mechanism of functioning is not well understood (Almeida et al. 2007).

All three types of antifouling paints, while free of TBT, are always based on the release of incorporated biocides, so there is a continual concern regarding effects on non-target biota as well as human health concerns. As a consequence, in recent years there has been a tendency toward the development of fully biocide-free antifouling paints. These newer products differ from the more traditional antifouling paints in that they act by producing an ultra-smooth hydrophobic surface with very low friction to which marine organisms cannot adhere (Almeida et al. 2007). Examples of such newer products include the following:

- Polymers (such as silicon) that are applied in thick layers to a vessel surface. While these have been found to prevent the attachment of marine organisms, their effectiveness may be limited. Attachment by fouling organisms has been reported to be prevented on only around 20% of the exposed surface after 3 years of exposure (Almeida et al. 2007); and

- Antifouling paints with fine synthetic fibers in their formulations. Such paints form a three-dimensional structure that produces an extremely strong and flexible coating, while at the same time maintaining the smoothness of a self-polishing antifouling paint. Such products may have a functional life span of 3 to 5 years (Almeida et al. 2007).

Considerable research is ongoing regarding the development of nontoxic antifouling materials, including approaches that incorporate slime coatings that prevent attachment, or coatings that continually wear away, limiting attachment and transport (e.g., Ganguli et al. 2009). In contrast to biocide-based products, the longevity of non-biocide-based products may range from less than 2 years to as long as 10 years (EPA 2011).

Any new such products must be registered for use by the EPA. For example, ePaint is a company that began developing antifouling coatings with funding from the U.S. Navy in 1985 and was the first company to have an antifouling coating free of copper- and tin-based pesticides and registered with the EPA. Their products are free of copper and TBT, and work by combining water and dissolved oxygen molecules using visible light in the water column to form a hydrogen peroxide layer that blankets the boat hull to create a surface inhospitable to biofouling organisms (ePaint 2013).

Initial application costs of antifouling materials may range from less than $1,000 to more than $7,000, depending on the size of the vessel being treated, the application requirements, and method of application (e.g., does the hull need to be bare metal or not, is the material sprayed on or applied by roller). Additional costs would be incurred during product-specific inspection and reapplication rates.

### 3.4.2 Applicability to the CAWS

Among the 13 medium- and high-risk GLMRIS ANS (Table 2.1), algae, crustaceans (excluding the bloody red shrimp), and VHSv are most likely to be transported through the CAWS via hull attachment (Grippo et al. 2013). As a result, it is these species whose transfer through the CAWS may be most affected through the use of antifouling materials. While the algae may directly grow on wetted surfaces of watercraft, the crustaceans and VHSv would need to find rough hull surfaces and other attached biota (e.g., zebra mussels, algae, or hosts in the case of VHSv) onto which they could cling and be carried into or through the CAWS. Similar to the crustaceans, seeds and fragments of reed sweetgrass would also need rough surfaces or attached biota to be carried into or through the CAWS. The antifouling materials that include biocides work by exposing attached biota to toxic levels of the biocides, and thus likely require some minimum exposure period for attaching biota to be affected. It is not known what level of exposure could be expected in the CAWS. The crustaceans in particular are not hull fouling organisms, but rather grab directly onto rough surfaces on the hull, or onto any objects (biotic or abiotic) that are already attached. As a result, they may drop off before sufficient exposure has occurred. Seeds and fragments of reed sweetgrass, as well as VHSv would be similar; these would passively be caught on surface irregularities on the vessel hull, and could drop off at any time. Thus the effectiveness of any biocide-based antifouling material for limiting or controlling hull-mediated transfer is unknown, but may be very limited in effectiveness for some taxa.

In contrast, antifouling materials that do not employ biocides but work to reduce attachment may be more effective for the CAWS. However, it is unknown how effective such materials would be for these particular ANS. In addition, the level of effectiveness would also be a function of how willing owners and operators of commercial and recreational watercraft would be to apply such materials to their watercraft, and the reapplication schedule that would be required. Voluntary use may become reduced if application would be required with a less than annual frequency.

Antifouling materials are only temporarily effective at controlling the attachment of ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include the type of hull paint (toxic [with biocide] or nontoxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommend cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require hull paints on commercial and recreational vessels. Nonabrasive techniques for connecting barges and docking vessels must be developed to reduce surface wear or paint formulas must be developed that can withstand damage from operations. Before hull paints can be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation are required. Consequently, antifouling materials will be most effective if combined with new regulations requiring regular application and hull maintenance. Because of the uncertainty regarding the practicality of maintaining a treated hull surface, hull paints are considered ineffective at completely preventing the transport of the ANS of concern.

## 3.5 BIOLOGICAL CONTROL

### 3.5.1 Overview

Biological control methods may include the use of herbivorous or predatory invertebrates or fish, and the introduction of disease agents. Insect and fish herbivores have been used to control invasive plants (e.g., weevils to control purple loosestrife [MDNR 2013]), while predator introductions have been used in attempts to control invasive molluscs, crustaceans, and fish. For example, the European eel has been used in Italy in attempts to control an invasive crayfish species (Aquiloni et al. 2010). Introducing predatory fish species and targeted disease agents has been identified as a potential control for controlling Asian carp, but such biological controls are only in the conceptual stage of development (GLMRIS 2012).

### 3.5.2 Applicability to the CAWS

No reports were found regarding biological control of invasive algae, crustacean zooplankton such as the fishhook water flea, or small benthic crustaceans such as the scud. There are no biological controls for VHSv. Reed sweetgrass may be controlled biologically through the use of herbivorous fish or livestock. For example, grass carp feed on the species in aquatic habitats, while at the waters' edge cattle may be used to graze on the plant (Sundblad and Wittgren 1989). The use of such biological control approaches for controlling reed sweetgrass is not recommended for the CAWS. Introduction of grass carp to feed on the plant would be undesirable, given that grass carp is an ANS in the United States, and the addition of another ANS to the aquatic habitats of the CAWS and adjoining basins would not be acceptable. Control of reed sweetgrass by cattle grazing is similarly not a feasible option for control of this ANS. Land use surrounding the CAWS is mostly industrial, residential, or commercial, and providing cattle access to the edge of the waterway would not be practicable. In addition, several instances of cattle poisoning have been reported due to cyanide production in the young shoots of reed sweetgrass, and as a consequence grazing is not recommended (Sundblad and Wittgren 1989). Targeted disease agents are in the conceptual stage of development; however, no such agents are currently available for use in controlling the spread of ANS fish species in the CAWS. New developments in the biological control of the ANS of concern will be investigated for potential future use in reducing the probability of ANS interbasin transfer.

## 3.6 MANUAL OR MECHANICAL REMOVAL

### 3.6.1 Overview

Manual or mechanical removal involves the physical removal of biota. Manual or mechanical removal of algae and semiaquatic rooted vegetation may include mowing and removal of the aboveground portions of plants, the cutting and removal of floating mats of aquatic vegetation, and the excavation or dredging of areas with stands of vegetation. Advantages of manual and mechanical plant removal are that there are no aquatic herbicide residues left behind, nor are there problems arising from decomposition of dying plant material (DPIPWE 2002). Physical removal of vegetation may be labor intensive, and the overall cost of this control measure will depend on the cost of labor used, the size of the area undergoing removal activities, the frequency of removal activities, the types of mechanical removal equipment employed, and costs of disposal of removed vegetation, soil and, sediment (NH DES 2005).

Mowing or cutting several times during the growing season may act to deplete the energy reserves in the roots and rhizomes of some rooted aquatic plants. This in turn may reduce plant growth and reproduction, as well as reducing its competitive abilities, and allow other vegetation to expand into the site (King County 2012). In open water, cutting and removing floating rafts of aquatic vegetation has been used as a temporary method for reducing abundance and biomass of the target ANS, and repeated cutting during the growing season has been found to inhibit growth in some species. Removal of mats of filamentous algae using rakes can control such species (especially in small water bodies), but is typically an ongoing activity that must be repeated throughout the growing season (Lynch 2009). No reports regarding manual or mechanical removal of algae were found.

For rooted semiaquatic vegetation, large stands of plants may be removed through mechanical means involving dredging or soil excavation (Melbourne Water 2003), while small stands may be removed by hand pulling. The removal of large plants in their entirety is difficult, because roots and rhizomes can from the parent plant be very wide and deep, and thus may be missed during removal activities. As a consequence, the soils or sediments of the area will probably serve as a seed bank for the ANS, especially if it has been established and reproducing for several years (DPIPWE 2002). Thus, monitoring followed by removal of seedlings and regrowths will likely be necessary (King County 2012). In addition, soils or sediments excavated during mechanical plant removal will likely contain viable seeds and rhizomes, and thus will need to be disposed of in a manner that does not further spread the ANS of interest. It is critical that whenever mechanical means are used for plant control, the machinery be inspected and decontaminated to ensure any seeds and viable plant fragments are removed from the machinery prior to leaving the site (USBOR 2012).

Covering the area containing rooted semi-aquatic plants with black plastic for 5 to 6 weeks can achieve 100% control for some plant species (Forest Health Staff 2006). Such an approach may be especially suitable for small areas where the plastic can be securely fixed in place.

For invertebrates and fish, removal approaches may include controlled harvest and overfishing. Controlled harvest is the removal of a species to a level where it can no longer maintain a viable population. Controlled harvest implies that the captured organisms are consumed or used for some purpose other than just disposal, whereas overfishing means that captured organisms are discarded and not necessarily used beneficially. Both of these control measures require intensive harvest over a long period of time, using nets, traps, and electrofishing approaches (GLMRIS 2012). Controlled harvest and overfishing can be effective, but are generally most effective in smaller water bodies such as ponds and small lakes. Species have longer lifespans and produce few offspring are particularly susceptible to controlled harvest and overfishing methods. While traps have been used with limited success for large invertebrates (i.e., North

American crayfish in Europe) (Hänfling et al. 2011), they would not likely be effective for small planktonic and benthic crustaceans.

### 3.6.2 Applicability to the CAWS

Because of the very small size of the algal and crustacean ANS, manual or mechanical removal of these species is not a likely option. There are also no removal methods for addressing VHSv. Physical removal of reed sweetgrass can be effective in controlling this species, especially for small, localized populations. This method may be most effective in combination with the use of aquatic herbicides. Effectiveness in the CAWS will depend on the location of the infestation. However, physical removal of seedlings drifting through the CAWS is likely not feasible.

Controlled harvest and overfishing of the four fish ANS would be difficult to implement in the CAWs because of its many pathways. The small size of the tubenose goby, threespine stickleback, and ruffe, together with the shoreline habitats they occupy, make capture problematic. Controlled harvest and overfishing may, however, be effective in controlling the two carp species in areas below Brandon Road Lock and Dam, and could be effective in the CAWS should these species successfully enter the CAWS.

## 3.7 HABITAT ALTERATION

### 3.7.1 Overview

Habitat alteration involves measures to limit ANS spread via changes in the chemical or physical quality of the habitats where the ANS occur or are colonizing. Some ANS are opportunistic species that invade areas where anthropogenic activities have resulted in reduced habitat quality for the resident species. For example, invasive algae thrive in water bodies with water quality that has been degraded by nutrient runoff (USACE 2012c). In such cases, the ANS may be better suited to the degraded conditions, and thus are able to outcompete the resident biota.

Algae thrive in waters with high nutrient (especially phosphorus) content. For such species, reductions in water pollution and nutrient runoff may reduce suitable habitat and limit their establishment in new habitats. Management of nutrient content can also be achieved with the application of alum (aluminum sulfate). Alum forms an aluminum hydroxide precipitate on contact with water. This precipitate reacts with phosphorus to form an aluminum phosphate compound, making this essential nutrient unavailable to algae. Alum application is commonly used in lakes to control invasive algae populations (USACE 2012b).

For rooted semiaquatic plants, habitat alteration may include direct physical disturbance of the habitat by tilling. Tilling the affected media in autumn may expose the roots and rhizomes to winter temperatures that may be cold enough to kill the roots and to desiccate the rhizomes (NWCB 2010). Some rooted semiaquatic vegetation may be sensitive to shade, and could be outcompeted by resident vegetation if an adequate cover of overstory vegetation can be established using suitable indigenous species to increase the shade-producing canopy. This type of approach can be effective as a long-term control method (Melbourne Water 2003).

The application of chemical compounds to alter water quality may limit or control the movement of crustaceans or fish species to new areas. Chemicals that may be applied for such purposes include carbon dioxide ($CO_2$), ozone, nitrogen, and sodium thiosulfate; depending on the location to be treated, the installation of application infrastructure would be necessary for some of these to ensure regular adequate delivery to the water body (USACE 2012b). The effectiveness of such compounds will depend on the chemical concentrations required to effectively block movement, the required duration of the chemical application, the habitat where the application occurs, and the species and life stages being targeted. Maintaining effective concentrations in an open environment (such as an offshore area of the Great Lakes) could be problematic. Overall effectiveness will be affected by factors such as water level, current, water temperature, wave action, sediment composition, water chemistry, and weather conditions.

Another habitat alteration approach involves the drawdown of water levels in areas where the ANS occurs or is colonizing. Such drawdowns would expose and desiccate semiaquatic vegetation, attached algae, benthic invertebrates, shoreline fish nests, and fish eggs and larvae. This approach requires the availability of some sort of water control structure in the target area (NHDES 2005). Because water drawdowns are not species specific, water drawdowns may also be expected to affect non-target biota that inhabit the target water body.

### 3.7.2 Applicability to the CAWS

Some habitat alteration approaches may be applicable for 13 of the GLMRIS ANS, the exception being VHSv. The distributions of the diatom *Stephanodiscus binderus*, grass kelp, and the red alga (*B. atropurpurea)* are associated with elevated salinity and eutrophic conditions (Grippo et al. 2013). Managing nutrient loads to waterways in order to reduce water pollution and nutrient runoff into Lake Michigan, the CAWS, and the waters below Brandon Road Lock and Dam could reduce the abundance of these ANS and the suitability of available habitat. These actions could in turn reduce the likelihood of the arrival and passage these species, and their colonization of the Mississippi River Basin. Improvements in water quality might be achievable through the regulation of point source pollution (through the Clean Water Act); stormwater management best practices such as fertilizer restrictions; buffer zones around water bodies for controlling runoff; and other stormwater runoff controls such as retention ponds, native plant landscaping, or rainwater harvesting. However, it is unknown how quickly such measures could be implemented and improvements in water quality realized.

The use of alum to reduce phosphorus levels in Great Lakes waters would likely be problematic, because of the large areas that would need to be treated. However, in the more isolated environment of the CAWS, alum application has a potential to be effective for the diatom and red algae. Alum application is commonly used in lakes to control invasive algae populations, but no documentation has been found regarding its use in large, flowing systems such as the CAWS.

While water drawdown may be effective in small water bodies such as ponds or small lakes, it is not an option in the Great Lake, or below Brandon Road Lock and Dam, without preexisting water control structures in areas where ANS are encountered. Similarly, while flooding cut stubble has been reported to drown reed sweetgrass (Sundblad and Wittgren 1989), flooding would also require preexisting water control structures. In addition, sufficient water drawdown in either the CAWS or below Brandon Road Lock and Dam could adversely affect navigation.

## 3.8 BALLAST AND BILGE WATER MANAGEMENT

### 3.8.1 Overview

Algae, rooted semiaquatic vegetation, crustaceans, and fish eggs or larvae may be introduced to new areas as a result of transport in, and subsequent discharge of, ballast and bilge water. Ballast water is pumped onto large (e.g., commercial) ships at various ports to add weight to ships that may be carrying little or no cargo. As the ballast water is pumped into the ship, it will bring along with it any living organisms (including seeds, spores, and eggs) that may be present in the water column. The bilge is the lowest compartment of a ship, and collects water from rough seas or rain than drains from the deck, or from hull leaks. Because the bilge collects surface runoff from the deck, it may contain living organisms as well. Limiting discharge of ballast and bilge water to minimize collection of water in one basin and discharge in another basin may greatly reduce ballast and bilge water as vectors for interbasin transfer of ANS. Such management, however, would require regulatory oversight.

### 3.8.2 Applicability to the CAWS

It is possible that the viral, algal, and crustacean ANS, as well as seeds or fragments of reed sweetgrass, could be present in ballast or bilge water in commercial or recreational watercraft that that enter and/or traverse the CAWS between the two basins. The ANS originating in the Great Lakes Basin could be carried into the CAWS, subsequently discharged, and then be passively transported via current to the Mississippi River basin. In the case of the scud, the ANS would need to be carried through the CAWS and directly discharged into the Great Lakes Basin. Restricting ballast and bilge water discharge from watercraft could reduce the probability of interbasin transfer through this mechanism. However, it is unknown how effective such ballast and bilge water management could be at reducing passage through of any of the ANS through the CAWS.

It is possible for small fish and fish eggs to be transported in ballast or bilge water; however, fish cannot live for long time periods in such conditions. While the potential for transport of fish or eggs between the two basins exists, it is unknown how likely such transport might be or how well eggs and fish could survive such transport. Similarly, it is unknown whether ballast and bilge water exchange programs would have a measurable effect on the probability of arrival and passage of fish species to and through the CAWS. In addition, ballast or bilge management programs would not address accidental ballast or bilge releases that would occur as a result of accidental hull breaches.

## 3.9 LAWS AND REGULATIONS

### 3.9.1 Overview

Laws and regulations can help control and limit the spread of ANS, and in some cases, may allow the designation of funds to carry out monitoring or other management programs. Laws and regulations can be passed at the federal, state, or local levels to address the spread of ANS. For example, the Lacey Act is a law that authorizes the Secretary of the Interior to "regulate the importation and transport of species determined to be injurious to the health and welfare of humans, the interests of agriculture, horticulture or forestry, and the welfare and survival of wildlife resources of the U.S." (USFWS 2013). Species listed under the Lacey Act, including viable eggs or hybrids of the species, must not be transported across state lines, except by permit for zoological, education, medical, or scientific purposes. Among the 13 medium- and high-risk ANS identified by the GLMRIS risk assessment (Grippo et al. 2013), only the silver carp and bighead carp are listed as injurious wildlife under the Lacey Act (50 CFR 16). The silver carp was listed in 2007 and the bighead carp was listed in 2011.

Many states regulate the possession, sale, or transport of nuisance plant species by listing such species on a Noxious Weed List, Prohibited Plant List, or equivalent. For example, Massachusetts, Wisconsin, New Hampshire, Connecticut, and Washington have each listed reed sweetgrass as prohibited in some or all parts of the state (USDA 2013). These laws make it illegal to move, sell, purchase, transplant, cultivate, or distribute banned plants into or within the state. In addition, the law in Washington declares that public and private landowners are required to control this plant when it occurs on their land (King County 2012). States can adopt their own regulations prohibiting the sale, ownership, transport and release of specific live fish species. These regulations may remove the likelihood of infestation in waterways where the fish species have not already spread. The efficacy of these regulations depends on how much the transfer of live fish contributes to the overall spread of the species. Many states have adopted live baitfish restrictions. These restrictions include designations of specific fish species as unlawful use for baitfish, designations of which fish species are allowable as live baitfish, designations of specific water bodies as "artificial bait only" angling areas, and rules about selling and transporting live bait between states. For example, the state of New York identifies species that may be purchased to be used in New York water bodies, and identifies several species as not allowed for use as bait within the state (NYDEC 2013). The state of Indiana prohibits the use of live carp and gizzard shad as baitfish (INDNR 2013).

Watercraft inspections described earlier (see Sections 3.1 and 3.2) may be made mandatory by law, and access to a water body denied without the proper paperwork or a permit indicating that the watercraft has been inspected and decontaminated. Access to water bodies infected by an ANS may also be restricted from recreational use as a way to control or limit transport of an

ANS to other water bodies. Examples of states that have established mandatory watercraft inspections include Oregon and Montana (ODFW 2012; MTFWP 2012a).

Improvement in water quality was previously discussed (Section 3.6) as a possible approach for reducing habitat quality for some ANS. Such improvement can be achieved through regulations regarding point source pollution such as those set forth in the Clean Water Act.

Mandatory ballast and bilge exchange laws may also limit or control the arrival and passage of these organisms. In the United States, the National Invasive Species Act of 1996 has directed the Coast Guard and the Smithsonian Environmental Research Center to develop a clearinghouse (the National Ballast Information Clearinghouse) to gather and disseminate information on ballast-water invasions, regulations, and practices so legislation can be implemented to reduce marine invasions.

### 3.9.2 Applicability to the CAWS

The implementation of laws for mandatory watercraft inspection and decontamination, restrictions on ballast and bilge water discharge, restrictions on nutrient loading, and restrictions on baitfish use may act to slow the interbasin transfer of the GLMRIS species. However, implementation of new laws and regulations by themselves would not limit or control potential interbasin transfer, owing to transfer mechanisms associated with current drift. In addition, depending on the nature or specifics of new legislation, it is uncertain how quickly new laws and regulations could be implemented, or how successful any new laws and regulations may be in actually controlling interbasin transfer of the ANS.

## 3.10 COST CONSIDERATIONS OF NONSTRUCTURAL MEASURES

At this time, it is not possible to estimate costs that could be incurred with the implementation of a comprehensive nonstructural alternative that includes one or more of the nonstructural measures discussed in this report (Table 3.1). Costs will be affected by specific implementation requirements of the approaches selected; the more involved an approach and the more frequently it must be applied, the greater the expected cost. However, annual costs for a nonstructural program that employs several of the nonstructural measures considered may be expected to be in the millions of dollars within any one state.

Annual expenditures on invasive species management varies widely by state and management activity. For example, annual expenditures for Wisconsin have been estimated at $8,500,000 for an overall program that includes education and outreach, monitoring, pesticide application, removal, biological control, ballast and bilge inspection, watercraft inspection, and research (Putnam 2013). For the Wisconsin program, education and outreach activities account for approximately half (about $4,000,000) of the estimated $8,500,000 annual cost, while monitoring and pesticides combined accounted for nearly as much (about $1,000,000 and $2,000,000, respectively). In contrast, Ohio expenditures for ANS management were less than

$300,000 and activities included only monitoring, education and outreach, and physical removal of invasive species (Lesher 2013).

Expenditures for individual nonstructural measures also vary between states and agencies. For example, monitoring expenditures were $1,000,000 in Wisconsin, compared to less than $500,000 in Ohio. Monitoring by the Great Lakes Fishery Commission (GLFC) and EPA Region 5 cost between $1,000,000 and $5,000,000 and presumably covered a larger area than Wisconsin or Ohio activities (Bolen 2013; Dettmers 2013). Similarly, Wisconsin spent approximately $4,000,000 on education and outreach, while the state of Ohio, the National Oceanic and Atmospheric Administration (NOAA) (Martinez 2013), and the Great Lakes Fishery Commission each spent $100,000 or less. Wisconsin and the GLFC each spent less than $350,000 on watercraft inspections (including ballast and bilge water), while EPA Region 5 spent over $1,000,000 on watercraft inspections. For nonstructural measures to address ballast water treatment, data provided by the Great Lakes Maritime Administration and the U.S. Department of Transportation indicated a $2,300,000 expenditure on ballast water treatment methods and technology verification in fresh water (Miras 2013). With regard to other nonstructural measures, costs for pesticide application were over $1,000,000 for both the state of Wisconsin and the GLFC, and EPA Region 5 spent between $2,500,000 and $5,000,000 on manual or mechanical removal of invasive species. Assuming the implementation of programs similar to Wisconsin's, and the associated costs for Minnesota, Ohio, Illinois, Indiana, and Michigan (the other Great Lakes States closest to the CAWS), an estimated annual cost for a nonstructural alternative encompassing the six states may be as high as $51,000,000. Nationwide, the National Invasive Species Council (NISC) allocates over two billion dollars across eight NISC member agencies to fund invasive species activities. These activities include programs for prevention, early detection and rapid response, control and management, research, restoration, education and public awareness, and leadership and international cooperation (NISC 2013).

# 4 SUMMARY AND RECOMMENDATIONS

## 4.1 SUMMARY OF NONSTRUCTURAL MEASURES

Several nonstructural measures could potentially be applied to the 13 ANS of concern. Table 4.1 summarizes the potential effectiveness of the various categories of nonstructural approaches for controlling the interbasin transfer of ANS of concern. The Nonstructural Measures Alternative consists of implementing all of the applicable nonstructural measures in Table 4.1. It is recommended that all of the applicable nonstructural measures be implemented because they represent best management practices that may reduce the speed or potential for ANS interbasin transfer at a given time.

Each of the 13 ANS of concern has the potential to be transported by watercraft, which could facilitate the arrival of ANS at the CAWS or their passage through the CAWS. Thus, ballast and bilge management and the application of antifouling agents are two ways to limit the movement of ANS through aquatic pathways. Ballast water management would be most applicable to commercial vessels operating in the Great Lakes and would involve treating ballast water to kill ANS or restricting the discharge of ballast and bilge water from ports known to have ANS. The application of antifouling paints to commercial and recreational watercraft could reduce the spread of hull-fouling ANS species like crustaceans, algae, and plants. However, the effectiveness of antifouling coatings is greatly dependent on the type of coating, the frequency and method of application, and the ability of the coating to withstand damage from normal operations. The efficacy of these vessel-related control measures in reducing ANS transport depends on the extent to which the control measures are adopted by the public. Consequently, laws and regulations regarding ballast and bilge water treatment and the required application of antifouling paints would be necessary to make these measures as effective as possible.

Education programs targeting recreational boaters, anglers, and aquarium hobbyists could also reduce the probability of interbasin ANS transfer. Education and outreach programs may be most effective for species like reed sweetgrass, ruffe, or Asian carp that can be more easily seen and identified by the public. Educating the public on the importance of cleaning boats and fishing gear could reduce the potential for spreading smaller, more difficult to see species of crustaceans and algae. However, because educational programs rely on adequate funding and implementation, as well as voluntary compliance and participation, there is a high level of uncertainty regarding effectiveness.

Monitoring programs coupled with a response plan may be critical in limiting and reducing the probability of arrival and potential passage of ANS through the CAWS. Public and private monitoring efforts, aided by education programs, could identify the location of ANS. Once identified by monitoring programs, nonstructural measures for removing or killing localized populations of ANS could reduce the probability of interbasin transfer. These measures include pesticide application and manual or mechanical removal. Following removal, additional monitoring could also be implemented to detect additional or future colonies. Consequently, monitoring and removal efforts may be successful in reducing the numbers of species arriving at the CAWS, potentially reducing the likelihood of passage. However, small, mobile species like

**TABLE 4.1 Potential Effectiveness of Nonstructural Measures for Controlling Interbasin Transfer of the ANS of GLMRIS Concern**

| Taxon | Nonstructural Approach | Potential Effectiveness |
|---|---|---|
| Virus (VHSv) | Education and Outreach | Educating public to identify and not use infected baitfish may reduce likelihood of spread via baitfish. Voluntary cleaning of watercraft and other recreational equipment may slow transfer via these vectors. |
| | Monitoring | Would only provide early identification of spread and would not affect transfer. Monitoring would require agency involvement. |
| | Pesticides/Anti-microbials | Use of pesticides with active ingredients that are registered by the EPA to clean boat hulls, trailers, nets, and other equipment may slow transfer. |
| | Antifouling Materials | May reduce transport on hulls of watercraft. |
| | Biological Control | Not applicable. |
| | Manual or Mechanical Removal | Not applicable. |
| | Habitat Alteration | Not applicable. |
| | Ballast and Bilge Management | May reduce passage via this vector. |
| | Laws and Regulations | Mandatory disinfection of water craft and live bait restrictions may slow spread. Uncertain how quickly new laws and regulations could be passed and implemented. |
| Algae (Diatom; Grass Kelp; Red Algae) | Education and Outreach | Educating public to perform voluntary cleaning of watercraft and other recreational equipment may limit slow transfer via these vectors. |
| | Monitoring | Would provide early identification of spread but unlikely to affect transfer. Monitoring would require agency involvement. |
| | Pesticides | Algaecides may be effective in localized areas, but the inability to maintain needed concentrations in large or flowing water bodies limits effectiveness. Concerns regarding impacts on non-target species. |
| | Antifouling Materials | Both biocide- and non-biocide-based materials may reduce transport on hulls of watercraft. |
| | Biological Control | Not applicable. |
| | Manual or Mechanical Removal | Not applicable. |
| | Habitat Alteration | Improving water quality may reduce suitable habitat and limit occurrence and spread. Limited applicability to the CAWS; possible below Brandon Road Lock and Dam. |
| | Ballast and Bilge Management | May limit passage via this vector. |
| | Laws and Regulations | Little effect anticipated, although mandatory disinfection of water craft and ballast and bilge water management may slow spread. Uncertain how quickly new laws and regulations could be passed and implemented. |

**TABLE 4.1 (Cont.)**

| Taxon | Nonstructural Approach | Potential Effectiveness |
|---|---|---|
| Rooted Semiaquatic Vegetation (Reed Sweetgrass) | Education and Outreach | Educating public to perform voluntary cleaning of watercraft and other recreational equipment may limit spread via these vectors. Public identification of new populations, if linked with aggressive response action, could control spread. |
| | Monitoring | Would provide early identification of spread but unlikely to affect transfer. Monitoring would require agency involvement. Early identification of new populations, if linked with aggressive response action, could control spread and transfer. |
| | Pesticides | Aquatic herbicides may be very effective, especially if application occurs quickly following discovery of new invasions. Application in large or flowing water bodies may limit effectiveness. Concerns regarding impacts on non-target species. |
| | Antifouling Materials | Non-biocide-based materials may reduce transport on hull soft watercraft. |
| | Biological Control | Not applicable. |
| | Manual or Mechanical Removal | A variety of approaches may be applicable, and could be successful in controlling spread if implemented soon after new populations are reported. May limit establishment of new populations. |
| | Habitat Alteration | May limit establishment of new populations. |
| | Ballast and Bilge Management | May reduce passage via this vector, but effectiveness is unknown. |
| | Laws and Regulations | Little effect anticipated, although mandatory disinfection of watercraft and ballast and bilge water management may slow spread. Uncertain how quickly new laws and regulations could be passed and implemented. |
| Crustaceans (Fishhook Waterflea; Scud; Bloody Red Shrimp) | Education and Outreach | Educating public to perform voluntary cleaning of watercraft and other recreational equipment may limit spread. |
| | Monitoring | Would provide early identification of spread but unlikely to affect transfer. Monitoring would require agency involvement. |
| | Pesticides | Pesticides may be effective in localized areas, but maintaining needed concentrations in large or flowing water bodies limits effectiveness. Disinfection of boat hulls and other recreational equipment may slow spread via this vector. Concerns regarding impacts on non-target species. |
| | Antifouling Materials | Non-biocide-based materials may reduce transport on hulls of watercraft. Effectiveness of biocide-based materials is unknown. |
| | Biological Control | Not applicable. |
| | Manual or Mechanical Removal | Not applicable. |

**TABLE 4.1 (Cont.)**

| Taxon | Nonstructural Approach | Potential Effectiveness |
|---|---|---|
| | Habitat Alteration | The application of chemical compounds to alter water quality may limit movement of the species. |
| | Ballast and Bilge Management | May reduce passage via this vector, but effectiveness is unknown. |
| | Laws and Regulations | Mandatory disinfection of watercraft and ballast and bilge water management may slow spread. Uncertain how quickly new laws and regulations could be passed and implemented. |
| Fish (Bighead Carp; Silver Carp; Tubenose Goby; Ruffe; Threespine Stickleback) | Education and Outreach | Educating public to not use the ANS as baitfish may reduce likelihood of accidental introduction via baitfish use and disposal. |
| | Monitoring | Would provide early identification of spread but unlikely to affect transfer. Monitoring would require agency involvement. Early identification of new populations, if linked with aggressive response action, may limit spread and transfer. |
| | Pesticides | Piscicides may be effective in localized areas, but maintaining needed concentrations in large or flowing water bodies limits effectiveness. Concerns regarding impacts on non-target species. |
| | Antifouling Materials | Not applicable. |
| | Biological Control | Not applicable. |
| | Manual or Mechanical Removal | Controlled harvest and overfishing may be effective in maintaining low numbers in localized area, potentially slowing the advance into new areas. |
| | Habitat Alteration | Limited applicability in localized areas. |
| | Ballast and Bilge Management | Importance of transfer via ballast or bilge water is unknown but may be very limited. Effectiveness of management is also unknown. |
| | Laws and Regulations | Unknown whether new legislation would be effective. Uncertain how quickly new laws and regulations could be passed and implemented. |

VHSv, crustaceans, fish, and the diatom, would be difficult to remove in numbers sufficient to reduce their abundance and would be difficult to eradicate with pesticides in large water bodies. For these species, pesticide application and physical removals are not expected to be effective at reducing the probability of interbasin transfer.

Biological control is another potential tool to eliminate or reduce ANS abundance. However, biological controls are difficult to implement effectively because of the uncertain outcomes, existing regulations regarding species introductions, and uncertainty regarding the most appropriate species to introduce. Therefore, biological control measures are not likely to be used to control any of the 13 ANS of concern.

Habitat alteration may be effective for ANS requiring highly specific habitat conditions. For example, among the 13 ANS of concern, red algae and grass kelp require rather specific nutrient and halide concentrations for establishment and growth. Similarly, the diatom (*S. binderanus*) is most productive under high nutrient conditions. Therefore, controlling runoff and municipal discharges into the Great Lakes Basin could reduce the abundance of these species and with it the potential for their arrival and passage through the CAWS. Other habitat alteration approaches like the drawdown of water levels are not expected to be practical in large water bodies.

Finally, laws and regulations could be applied to some degree to all of the 13 ANS, alone or in conjunction with the nonstructural control measures described above. For example, new laws and regulations restricting the sale and possession of the 13 ANS could reduce the potential for new introductions of these species. New laws and regulations to limit vessel transport could also be implemented that would specify the frequency of antifouling paint application, require that recreational boaters inspect and decontaminate watercraft, and require mandatory ballast and bilge exchange and\or treatment. In addition, improvements in water quality designed to reduce habitat suitability for some algal ANS can be achieved through the regulation of point source pollution as set forth in the Clean Water Act. The nonstructural measures backed by laws and regulations could increase the efficacy of these measures, because they would be required by law rather than relying on voluntary compliance.

## 4.2 NONSTRUCTURAL MEASURES EXPECTED TO REDUCE THE PROBABILITY OF ESTABLISHMENT

Although all of the applicable nonstructural measures are recommended, certain measures are expected to reduce the probability of interbasin transfer of five ANS between the Mississippi River Basin and Great Lakes Basin at some time during the 50-year planning horizon (Table 4.2). These species include grass kelp, reed sweetgrass, silver carp, bighead carp, and tubenose goby.

### 4.2.1 Grass Kelp

Grass kelp have been documented in Muskegon Lake and surrounding water bodies. Grass kelp are not considered to have arrived at the CAWS pathway. Consequently, arrival is currently limiting the potential for interbasin transfer, and this species is considered to have a low probability of arrival at the CAWS until $T_{10}$. Because the current location of this species has been documented, it may be possible, using nonstructural measures, to significantly reduce the abundance of grass kelp at its current location, thereby reducing its probability of arrival at CAWS entry points in southern Lake Michigan. Nonstructural measures to be applied at the current location of grass kelp include algaecides, manual harvest and mechanical controls, and desiccation. Managing nutrient loads to waterways may also reduce the productivity of the grass kelp by reducing habitat suitability. The nonstructural measures would also include agency monitoring to locate additional areas where grass kelp is established and to monitor future reoccurrences. Together, the elements of the Nonstructural Measures Alternative could maintain the probability of grass kelp arriving at the CAWS at a low level, compared to the medium probability of arrival at $T_{10}$ under the No Federal Action Alternative.

**Probability of Arrival for Grass Kelp**

| **Time Step** | $T_0$ | $T_{10}$ | $T_{25}$ | $T_{50}$ |
|---|---|---|---|---|
| No Federal Action Alternative | Low | Medium | Medium | Medium |
| With Nonstructural Measures Alternative | Low | Low | Low | Low |

### 4.2.2 Reed Sweetgrass

The current distribution of reed sweetgrass within the Great Lakes Basin is thought to be limited to several counties in Wisconsin (Howard 2012). Therefore, the reed sweetgrass is not considered to have arrived at the CAWS pathway, and this species is considered to have a low probability of arrival until $T_{50}$. Consequently, arrival is currently limiting the potential for interbasin transfer. Monitoring could be conducted to determine the current range of existing populations followed by rapid implementation of physical removal and pesticide application plans to reduce reed sweetgrass abundance and distribution. Additional regulations on the nursery industry and education and outreach targeting recreational boaters could reduce the potential for the spread of the species. Voluntary occurrence reports and continued agency monitoring would occur to evaluate the effectiveness of nonstructural measures and to identify new populations of reed sweetgrass. The combination of these nonstructural measures are expected to keep the probability of arrival at the CAWS at low for the 50-year planning horizon.

**Probability of Arrival for Reed Sweetgrass**

| **Time Step** | $T_0$ | $T_{10}$ | $T_{25}$ | $T_{50}$ |
|---|---|---|---|---|
| No Federal Action Alternative | Low | Low | Low | Medium |
| With Nonstructural Measures Alternative | Low | Low | Low | Low |

### 4.2.3 Bighead and Silver Carp (Asian Carp)

Asian carp are considered to have arrived at the beginning of the CAWS pathway at Brandon Road Lock and Dam. As Asian carp population levels increase, so will the probability of passage through the CAWS for individuals within that population. Nonstructural measures, including contracted commercial fishing for Asian carp coupled with local, state, and federal monitoring and removal efforts are likely to have a counteracting effect on expected population increases of Asian carp. In addition, the Asian Carp Monitoring and Response Working Group would continue to refine and improve harvest methods to control Asian carp populations in the CAWS. Consequently, these nonstructural measures are expected to maintain the probability of Asian carp passing through the CAWS at a low level, compared to the medium probability of passage at $T_{25}$ under the No Federal Action Alternative.

**Probability of Passage for Asian Carp**

| **Time Step** | $T_0$ | $T_{10}$ | $T_{25}$ | $T_{50}$ |
|---|---|---|---|---|
| No Federal Action Alternative | Low | Low | Medium | Medium |
| With Nonstructural Measures Alternative | Low | Low | Low | Low |

### 4.2.4 Tubenose Goby

The tubnose goby is commonly collected in the Duluth-Superior harbor of Lake Superior (Kocovsky et al. 2011), but there are no records of this species being collected in Lake Michigan. Consequently, the tubenose goby is not considered to have arrived at the CAWS pathway. The tubenose goby has been documented to spread in bilge and ballast water (Dopazo et al. 2008). The implementation of a ballast/bilge water exchange program is likely to increase the time it may take for the tubenose goby to arrive at the CAWS pathway, because it would require the tubenose goby to spread by natural dispersal to southern Lake Michigan. Additional nonstructural measures such as monitoring and education and outreach could also help to slow arrival of tubenose goby at the CAWS. Therefore, the Nonstructural Measures Alternative is expected to reduce the probability of arrival for the tubenose goby to low through $T_{10,}$ compared to medium under the No Federal Action Alternative.

**Probability of Arrival for Tubenose Goby**

| **Time Step** | $T_0$ | $T_{10}$ | $T_{25}$ | $T_{50}$ |
|---|---|---|---|---|
| No Federal Action Alternative | Low | Medium | Medium | Medium |
| With Nonstructural Measures Alternative | Low | Low | Medium | Medium |

At this time, no nonstructural measures alone or in combination with other nonstructural measures are expected to reduce the probability of establishment for any of the other eight ANS over the 50-year planning horizon.

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# ATTACHMENT B

# GLMRIS ALTERNATIVES

# Mid-System Control Technologies without a Buffer Zone - Flow Bypass Alternative

| | ALTERNATIVE FEATURES | | MITIGATION FEATURES | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Location** | **Alternative Project Features (Part of Total Cost of the Alternative)** | **Mitigation - Part of USACE Base Project (Part of Total Cost of the Alternative)** | **Mitigation - Paid by Others or Added to USACE Project by Congress (Part of Total Cost of the Alternative)** | **Mitigation - Paid by Others (Part of Total Cost of the Alternative)** | **Mitigation - Qualitative Description only** | **Cost info** | **Variation** | **Unmitigated Impacts** |
| Measures | Basin Wide | Nonstructural Measures | | | Nonstructural Measures | | | | |
| Measures | Stickney (IL) | GLMRIS Lock | | | | | USACE | | |
| Measures | Stickney (IL) | WW Treatment Plant. Plant will treat flow in CSSC and provide ANS free water for lockages - 778 MGD, 2.6 ac | | | | | | | |
| Measures | Stickney (IL) | An Electric Barrier in 950 ft' Engineered Approach Channel on the downstream and upstream sides of the GLMRIS Lock | | | | | | | |
| Measures | Alsip (IL) | GLMRIS Lock | | | | | | | |
| Measures | Alsip (IL) | WW Treatment Plant. Plant will treat the Cal Sag flow and provide water for lockages - 959 MGD, 3.1 ac | | | | | | | |
| Measures | Alsip (IL) | An Electric Barrier in 950 ft' Engineered Approach Channel on the downstream and upstream sides of the GLMRIS Lock | | | | | USACE | | |

# Mid-System Control Technologies without a Buffer Zone - Flow Bypass Alternative

| | ALTERNATIVE FEATURES | | MITIGATION FEATURES | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Location** | **Alternative Project Features (Part of Total Cost of the Alternative)** | **Mitigation - Part of USACE Base Project (Part of Total Cost of the Alternative)** | **Mitigation - Paid by Others or Added to USACE Project by Congress (Part of Total Cost of the Alternative)** | **Mitigation - Paid by Others (Part of Total Cost of the Alternative)** | **Mitigation - Qualitative Description only** | **Cost info** | **Variation** | **Unmitigated Impacts** |
| Water Quality | Basin Wide | Nonstructural Measures | | | Nonstructural Measures | | | | |
| | Stickney (IL) | | This plan assumes treatment of the entire volume of water in the CSSC. Diversion flows captured by project features so mitigation needed. No additional volume is needed. | | | | MWRD | | |
| | Alsip (IL) | | This plan assumes treatment of the entire volume of water in the Cal-Sag Channel. Diversion flows captured by project features so mitigation needed. No additional volume is needed. | | | | MWRD | | |

# Mid-System Control Technologies without a Buffer Zone - Flow Bypass Alternative

| | ALTERNATIVE FEATURES | | MITIGATION FEATURES | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Location | Alternative Project Features (Part of Total Cost of the Alternative) | Mitigation - Part of USACE Base Project (Part of Total Cost of the Alternative) | Mitigation - Paid by Others or Added to USACE Project by Congress (Part of Total Cost of the Alternative) | Mitigation - Paid by Others (Part of Total Cost of the Alternative) | Mitigation - Qualitative Description only | Cost info | Variation | Unmitigated Impacts |
| FRM | Basin Wide | Nonstructural Measures | | | Nonstructural Measures | | | | |
| FRM | Stickney (IL) | | Conveyance Tunnel (water diverted from channel into tunnel and reservoir system) from CSSC Barrier to McCook area for a total of 4.9 miles and 14 ft diameter | | | | MWRD | | |
| FRM | McCook (IL) | | RESERVOIR near McCook - 35,000 acre-feet with aeration system and Pump Station to empty Reservoir | | | | MWRD - USACE | | |
| FRM | Alsip (IL) | | Conveyance Tunnel (water diverted from channel into tunnel and reservoir system) from Cal-Sag Barrier to Thornton area for a total of 5 miles and 16 ft diameter | | | | | | |

# Mid-System Control Technologies without a Buffer Zone - Flow Bypass Alternative

| | ALTERNATIVE FEATURES | | MITIGATION FEATURES | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Location** | **Alternative Project Features (Part of Total Cost of the Alternative)** | **Mitigation - Part of USACE Base Project (Part of Total Cost of the Alternative)** | **Mitigation - Paid by Others or Added to USACE Project by Congress (Part of Total Cost of the Alternative)** | **Mitigation - Paid by Others (Part of Total Cost of the Alternative)** | **Mitigation - Qualitative Description only** | **Cost info** | **Variation** | **Unmitigated Impacts** |
| FRM (Cont.) | Basin Wide | Nonstructural Measures | | | Nonstructural Measures | | | | |
| | Thornton (IL) | | RESERVOIR near Thornton - 48,500 acre-feet with aeration system and Pump Station to empty Reservoir | | | | | | |
| | Oak Lawn (IL) | | RESERVOIR near Stony Creek - 540 acre-feet with aeration system and Pump Station to empty Reservoir | | | | MWRD - USACE | | |
| | | | | | | | | | |
| Navigation | | | | | | | | | |
| | | | | | | | | | |

# Mid-System Control Technologies without a Buffer Zone - Flow Bypass Alternative

| | ALTERNATIVE FEATURES | | MITIGATION FEATURES | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Location** | **Alternative Project Features (Part of Total Cost of the Alternative)** | **Mitigation - Part of USACE Base Project (Part of Total Cost of the Alternative)** | **Mitigation - Paid by Others or Added to USACE Project by Congress (Part of Total Cost of the Alternative)** | **Mitigation - Paid by Others (Part of Total Cost of the Alternative)** | **Mitigation - Qualitative Description only** | **Cost info** | **Variation** | **Unmitigated Impacts** |
| Natural Resources | Basin Wide | Nonstructural Measures | | | Nonstructural Measures | | | | |
| | Stickney (IL) | | No mitigation would be needed for impeding migration of native species. Mitigation measures to restore lost habitat due to construction activities and facilities may be unnecessary as well since the riparian zone is ruined and the canal is manmade. | | | | | | |
| | Alsip (IL) | | | | | | | | |

# ATTACHMENT C

# TECHNOLOGY TEAM SCREENING CHARTS WITH STATUS WATERMARK

# Scud

| | A | B/C | D | E | I | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Fact Sheet | ANS Control | Selective for ANS of Concern – CAWS | Status [2] | crustacean | Comments Refer to fact sheets for additional information on each Control | Level of R&D | Biocides for Industrial Use - Conventional, municipal drinking water or wastewater treatment technologies | Effective on Scud (all life stages) | Comments | Effective with Downstream Flow | Effective with Upstream Flow | Effective on Scud (Adhered to boat) | Comments on Adhered to Boat | Effective on Scud (Ballast Water) | Comments on Ballast Water |
| 3 | Accelerated Water Velocity | Accelerated Water Velocity | N | Available | X | • Not effective in preventing downstream ANS movement<br>• Must have a length and speed of flow greater than the organism's leaping ability and swimming endurance | | NA | Y | | N | Y | | | N | |
| 4 | Acoustic Fish Deterrents | Continuous Wave | N | Experimental | | • Under development for control of fish<br>• May not be effective on all fish species | T | NA | | | | | | | | |
| 5 | | Pulsed Pressure Wave | N | Experimental | | • Not lethal unless an organism is very close to sound source | A | NA | | | | | | | | |
| 6 | Algaecides § | Copper Sulfate and Chelated Copper Formulations (ethanolamines, ethylene diamines, triethanolamines, triethanolamine+ethylene diamine, and copper citrate/gluconate) | N | Available, Registered | | • May be effective on diatoms (*S. binderanus* ) and grass kelp (*Enteromorpha flexuosa* )<br>• Chelated copper formulations may be effective on red macro-algae (Bangia atropupurea)<br>• Reduced efficacy in waters with high pH and water temperatures < 15 °C<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 7 | | Endothall (as the mono(N,N-dimethylalkylamine) salt) CAS #: 66330-88-9 | N | Available, Registered | | • May be effective on red macro-algae (*B. atropupurea* ) and diatoms (*S. binderanus* )<br>• Can be harmful to fish<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 8 | | Algaecides containing Sodium Carbonate Peroxyhydrate CAS #: 15630-89-4 | N | Available, Registered | | • May be effective on diatoms (*S. binderanus* ), and grass kelp (*E. flexuosa* )<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 9 | Alteration of Water Quality §<br><br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/10/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided. | Carbon Dioxide ($CO_2$) | N | Available, When Not Registered for a Use | X | • May repel fish at sub-lethal levels<br>• Lowers pH<br>• Creates irreversible cell damage and death<br>• Effectiveness dependent upon dose and exposure | | NA | Y | Scud is a benthic organism and technology may not be effective at targeting similar species, Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |

2 Status
Available - An option or technology that has been implemented in the field.
Experimental - A novel option or technology, or a chemical that is not a U.S. Environmental Protection Agency (USEPA)-registered pesticide under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).
Registered - A chemical that is a USEPA-registered pesticide under FIFRA for the fact sheet use in compliance with the USEPA-approved product label.
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# Scud

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| 10 | | Gases | Ozone | N | Available | X | • Rendered ineffective in the presence of organic matter<br>• Used commercially to decontaminate water<br>• Ozone oxidation is toxic to most small waterborne organisms<br>• Destroys the epithelium covering the gill lamella in fish<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | NA | Y | Scud is a benthic organism and technology may not be effective at targeting similar species, Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 11 | | | Nitrogen | N | Available | X | • Adult fish are more tolerant than young fish<br>• Nitrogen supersaturation is a cause of gas bubble disease in fish<br>• Effectiveness dependent upon dose and exposure<br>• Not effective on eggs | | NA | N | Not effective on this species | | | | | | |
| 12 | | Solids | Alum | N | Available | | • Creates a solid precipitate from suspended solids within the water column which settles<br>• Alum is not classified as a pesticide, therefore does not require FIFRA registration<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 13 | | | Sodium Thiosulfate<br>CAS #: 7772-98-7 | N | Experimental | X | • Deoxygenated compound<br>• Effectiveness dependent upon dose and exposure | T | NA | | | | | | | | |
| 14 | **Aquatic Herbicides** §<br><br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/13/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided. | 2,4-D (both the amine and butoxy-ethyl ester formulations)<br>CAS #: 94-75-7 | | N | Available, Registered | | • Tank mixing with other herbicides improves plant control<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 15 | | Diquat<br>CAS #: 85-00-7 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 16 | | Fluridone<br>CAS #: 59756-60-4 | | N | Available, Registered | | • Plants must be exposed to a lethal dose for a minimum of 45 days for optimal results<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 17 | | Glyphosate<br>CAS #: 1071-83-6 | | N | Available, Registered | | • May be effective on reed sweetgrass (Glyceria maxima)<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 18 | | Imazapyr<br>CAS #: 81334-34-1 | | N | Available, Registered | | • May be effective on reed sweetgrass (*G. maxima* )<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 19 | | Triclopyr<br>CAS #: 55335-06-3 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 20 | | | | | | | | | NA | | | | | | | | |

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| 21 | **Benthic Barriers** | Textile or Plastic | | N | Available | | | | NA | | | | | | | | |
| 22 | | Silt | | N | Available | | • Created by applying excessive silt/sand to smother bottom-dwelling organism<br>• Application to control aquatic nuisance species has not been widely studied | | NA | | | | | | | | |
| 23 | **Biocides for Industrial Use** §<br><br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br><br>The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Isothiazolone (Sea-Nine®) CAS #: 64359-81-5 | | N | When Not Registered for a Use | X | • Antifouling agent used in hull coatings<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 24 | | 2-(thiocyanomethylthio) benzothiazole (TCMTB) CAS #: 21564-17-0 | | N | When Not Registered for a Use | X | • Antifouling agent<br>• Disinfection of industrial water systems<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 25 | | Benzalkonium Chloride CAS #: 8001-54-5 | | N | When Not Registered for a Use | X | • Corrosive<br>• Disinfection of industrial water systems<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 26 | | Bromine CAS #: 7726-95-6 | | N | When Not Registered for a Use | | • Purification of drinking water, cooling systems, and surfaces<br>• Corrosive<br>• Requires a controlled application; reacts quickly<br>• Effectiveness dependent upon dose and exposure<br>• Presence of organic matter limits effectiveness | | N | | | | | | | | |
| 27 | | Chlorine (free chlorine, hypochlorous acid, hypochlorite salts) CAS #: 7782-50-5 | | N | When Not Registered for a Use | X | • Residuals remain in water after treatment<br>• Requires frequent applications<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | Y | Y | | Y | Y | | | Y | |
| 28 | | Chlorine Dioxide CAS #: 10049-04-4 | | N | When Not Registered for a Use | | • Effectiveness dependent upon dose and exposure | | Y | | | | | | | | |
| 29 | | Chlorothalonil CAS #: 1897-45-6 | | N | When Not Registered for a Use | X | • Registered under FIFRA as a fungicide<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 30 | | Dibromonitrilopropionamide (DBNPA) CAS #: 10222-01-2 | | N | When Not Registered for a Use | X | • Pulp and paper water treatment systems<br>• Disinfection of industrial water systems<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 31 | | Dichlofluanid CAS #: 1085-98-9 | | N | Experimental | | • Antifouling agent<br>• Effectiveness dependent upon dose and exposure | A | N | | | | | | | | |
| 32 | | N-(3-Chloroallyl) Hexamethylenetetrmine chloroallyl chloride (Dowicil® 75) | | N | When Not Registered for a Use | X | • Not persistent and degrades rapidly under acidic conditions<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 33 | | Glutaraldehyde CAS #: 111-30-8 | | N | When Not Registered for a Use | | • Slight to moderate efficiency in presence of organic matter<br>• Some residuals remain in water after treatment<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 34 | **Biocides for Industrial Use** § **(continued)**<br><br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. | Hydrogen Peroxide CAS #: 7722-84-1 CAS #: 79-21-0 | | N | When Not Registered for a Use | X | • Disinfection of drinking water, cooling systems and surfaces<br>• Presence of organic matter limits effectiveness<br>• Moderately corrosive<br>• Some residuals remain in water after treatment<br>• Effective on algal spores | | Y | Y | | Y | Y | | | Y | |

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| 35 | Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br><br>The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Iodine<br>CAS #: 7553-56-2 | | N | When Not Registered for a Use | X | • Disinfection of drinking water, cooling systems and surfaces<br>• Requires a controlled application and reacts quickly<br>• Corrosive<br>• Presence of organic matter limits effectiveness<br>• Residuals remain in water after treatment<br>• Requires frequent applications<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 36 | | 2-methylthio-4-tertbutylamino-6-cyclo-propylamino-striazine (Irgarol®) CAS #: 28159-98-0 | | N | When Not Registered for a Use | | • Antifouling agent<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 37 | | Fatty Amines<br>(Mexel® 432) | | N | Experimental | | • Rapid degradation in the environment<br>• Scale dispersant & corrosion inhibitor<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 38 | | Peracetic Acid (Peraclean®)<br>CAS #: 79-21-0<br>CAS #: 7722-84-1 | | N | When Not Registered for a Use | | • No known toxic residual; more potent than hydrogen peroxide<br>• Rapidly active at low concentrations against a wide range of microorganisms<br>• Corrosive<br>• Highly efficient in presence of organic matter<br>• Wastewater treatment | | Y | | | | | | | | |
| 39 | | Phenol<br>CAS #: 108-95-2 | | N | When Not Registered for a Use | | • Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 40 | **Biocides for Industrial Use § (continued)**<br><br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br><br>The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Polyhexamethylene Biguanide (PHMB) CAS #: 32289-58-0 | | N | When Not Registered for a Use | | • Disinfection of industrial water systems<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 41 | | Potassium Permanganate<br>CAS #: 7722-64-7 | | N | Experimental | X | • Organic matter limits effectiveness & moderately corrosive<br>• Some residuals remain in water after treatment<br>• Effectiveness dependent upon dose and exposure | A | Y | Y | | Y | Y | | | Y | |
| 42 | | Vitamin K<br>(SeaKleen®)<br>CAS #: 11032-49-8 | | N | Experimental | X | • Ballast water treatment<br>• Toxic to a broad spectrum of marine and freshwater organisms (fish larvae and eggs, planktonic crustaceans, bivalve larvae, Vibrio bacteria, and dinoflagellates)<br>• Effectiveness dependent upon dose and exposure | A | N | Y | | Y | Y | | | Y | |
| 43 | | Silver (Ionic or Salts)<br>Ions CAS #: 15046-91-0 | | N | Experimental | | • Disinfection of industrial water systems<br>• Limited applications of metal ions or salts<br>• Not generally used due to human side effect risk<br>• Effectiveness dependent upon dose and exposure | A | N | | | | | | | | |
| 44 | | Sodium Chlorite<br>CAS #: 7758-19-2 | | N | When Not Registered for a Use | X | • Disinfection of drinking water, cooling systems and surfaces<br>• Presence of organic matter limits effectiveness<br>• Residuals remain in water after treatment<br>• Requires frequent applications and corrosive<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | Y | Y | | Y | Y | | | Y | |
| 45 | | Sodium Hydroxide [B, GS]<br>CAS #: 1310-73-2 | | N | When Not Registered for a Use | X | • Under consideration for use in ballast water treatment<br>• <1% survival of test organisms including algae, annelids, crustaceans and fish with 48-hr exposure to pH adjustments of 11.5 to 12.5 using NaOH (TenEyek, M. 2009. Great Ships Initiative Bench-Scale Test Findings, Technical Report – Public, Sodium Hydroxide (NaOH). GSI/BS/5.) | | Y | Y | | Y | Y | | | Y | |

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| 46 | | Triclosan CAS #: 3380-34-5 | | N | When Not Registered for a Use | | • Stable and incompatible with strong oxidizing agents • Wastewater treatment • Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 47 | | Zineb (Thiocarbamate) CAS #: 12122-67-7 | | N | Experimental | | • Antifouling agent & disinfection of industrial water systems • Effectiveness dependent upon dose and exposure | A | N | | | | | | | | |
| 48 | **Biological Controls** § | Introduced Predatory Fish Species | | N | Available | | • Includes both carnivorous and herbivorous fish species • Best used in waters with no outflows • Predatory fish are non-selective feeders and may eat native species • Predatorsare size selective feeders and may not eat eggs or larger organisms | | NA | | | | | | | | |
| 49 | | Introduced Predatory Insect Species | | N | Experimental | | • United States Department of Agriculture (USDA) has not approved of any insects for use as biological controls of plants identified as ANS of Concern – CAWS • Predators may be selective feeders (may not eat seeds) | T | NA | | | | | | | | |
| 50 | | *Pseudomonas fluorescens* CL 145A | | N | Registered | | • Active ingredient (Pseudomonas fluorescens CL 145A) approved by the United States Environmental Protection Agency (USEPA) in July 2011(Reg. No. 84059-4) • Formulation of commercial product as Zequanox™ is pending review by USEPA as of October 2010; Section 3 registration expected in March 2012 • Ongoing research to assess impacts to non-target mollusks | | NA | | | | | | | | |
| 51 | | Targeted Disease Agents | | N | Experimental | | • Under consideration for carp species | T | NA | | | | | | | | |
| 52 | **Controlled Harvest and Overfishing** | Controlled Harvest and Overfishing | | N | Available | | • Requires sorting and returning of native fish species • Requires continual capture over a long period of time, or intensive harvest during critical periods of concentration and reproduction (e.g., migration and spawning season) • Once harvesters, processors, and communities become economically dependent on harvesting nuisance fish, pressure to manage a sustainable population of these fish may conflict with the original purpose of removing them from the environment • Typically for organisms larger than eggs and larvae. | | NA | | | | | | | | |
| 53 | **Deleterious Gene Spread** | Daughterless Gene | | Y | Experimental | | • Researched as a Control for silver carp (*H. molitrix* ), bighead carp (*H. nobilis* ), black carp (*Mylopharyngodon piceus* ), and sea lamprey (*Petromyzon marinus* ) • Researched as a Control for common carp • Manipulation of genes can manifest unforeseen and significant undesirable side effects and would require extensive research before being accepted as a Control | T | NA | | | | | | | | |
| 54 | | Trojan Y Chromosome | | Y | Experimental | | • The Food and Drug Administration regulates genetically engineered animals | T | NA | | | | | | | | |
| 55 | **Dredging and Diver Dredging** | Dredging and Diver Dredging | | N | Available | | • Requires careful disposal or reuse of dredged material to prevent the transfer of ANS to a new location • May remove other ANS of Concern – CAWS and non-target organisms that reside in sediment | | NA | | | | | | | | |

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| 56 | **Electron Beam Irradiation** | Electron Beam Irradiation | N | Available | X | • Used in irradiation of food, environmental waste, medical sterilization, and water treatment<br>• Requires a closed system and not appropriate for open water application<br>• May require pretreatment to remove suspended solids<br>• Used in irradiation of food, environmental waste, medical sterilization, and water treatment | | NA | Y | | Y | Y | | | | |
| 57 | **Hydrologic Separation** | Physical Barriers | N | Available | X | • Modifies flow within waterway, including stormwater and combined sewer overflow discharge, and conveyance and commercial water dischargers and withdrawal of water | | NA | Y | | Y | Y | | | | |
| 58 | **Irrigation Water Chemicals** § | Acrolein<br>CAS #: 107-02-8 | N | Available, Registered, Restricted Use Product* | | • For control of submersed and floating weeds and algae only in irrigation canal systems in western states, provided the appropriate state registrations are also in place<br>• Toxic to fish and other aquatic organisms at labeled use rates | | NA | | | | | | | | |
| 59 | | Xylene<br>CAS #: 1330-20-7 | N | Registered | | • For use only in irrigation and drainage canals designated by the Bureau of Reclamation and cooperating water user organizations<br>• For use in Programs of the Bureau of Reclamation and Cooperating Water User Organizations within the following states, provided that the appropriate state registrations are also in place: AZ, CA, CO, ID, KS, MT, NE, NM, NV, ND, OK, OR, SD, TX, UT, WA, and WY<br>• For control of submerged weeds in irrigation and drainage canals<br>• Toxic to fish and other aquatic organisms at labeled use rates<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | |
| 60 | **Lethal Temperature** | Pressurized Hot Water/Steam Treatment | N | Available | X | • Hot water has been used to kill zebra and quagga mussels at municipal and industrial facilities, and high pressure hot water is used to clean ANS off of recreational boats<br>• Treated area (i.e. boat hull) must be above the surface. | | NA | Y | | Y | Y | | | | |
| 61 | | Hot Water Thermal Barrier | N | Available | X | • Difficult to manage in open water system, must be completely mixed throughout the water column | | | | | | | | | | |
| 62 | | Freezing | N | Available | X | air temperatures<br>• Cluster mussels are more tolerant of reduced air temperatures than individual organisms<br>• Can be applied to static water. | | NA | N | Not effective on this species | | | | | | |
| 63 | | Carbon Dioxide ($CO_2$) Pellet (dry ice) Blasting | N | Available | X | • Method used extensively to remove organics from aircrafts producing no deterioration of surfaces<br>• CO2 pellets convert to a gas at ambient temperatures, leaving no residue. | | NA | Y | Requires proper treatment of material | Y | Y | | | | |
| 64 | | Desiccation | N | Available | X | • Desiccation can only be achieved in areas where water levels can be controlled<br>• Exposure to air quickly leads to death for active water-breathing organism—mollusks and plants are more tolerant and require longer drying period | | NA | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |

Removed During Nov 2012 ANS Controls Screening Charette

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| 65 | **Light Attenuating Dyes** § | Light Attenuating Dyes | | N | Registered | | • Not effective for suppressing growth of floating aquatic plants or emergent shoreline vegetation identified as ANS of Concern – CAWS<br>• Not effective on floating algal mats<br>• May suppress the growth of non-target plants and algae<br>• Only for use in contained waterbodies with little or no outflow<br>• Do not apply to waters used for human consumption | | NA | | | | | | | | |
| 66 | **Manual Harvest** | Manual Harvest | | Y | Available | | • Labor-intensive<br>• Selectively dependent upon training and skill of staff | | NA | | | | | | | | |
| 67 | **Mechanical Control Methods** | Mechanical Harvesting | | N | Available | | • May disturb non-target organisms in equipment path | | NA | | | | | | | | |
| 68 | | Shredding | | N | Available | | | | NA | | | | | | | | |
| 69 | | Mowing | | N | Available | | | | NA | | | | | | | | |
| 70 | | Chaining | | N | Available | | | | NA | | | | | | | | |
| 71 | | Roto-tilling | | N | Available | | | | NA | | | | | | | | |
| 72 | | Rotovating | | N | Available | | • Used for submersed vegetation rooted in the substrate<br>• May have applications on emergent plants<br>• May disturb non-target organisms in equipment path | | NA | | | | | | | | |
| 73 | **Molluscicides** § | Quaternary and Polyquaternary Ammonium Compounds; Aromatic Hydrocarbons; Endothall as the Mono (N,N-imethylalkylamine) Salt (TD2335 Industrial Biocide-Molluscicide) | | N | Registered | | • Used for recirculating and once-through cooling water systems<br>• For control of established populations of freshwater and saltwater mollusks in closed systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | |
| 74 | | Metals and their salts (Copper Sulfate and Chelated Copper Formulations) | | N | Registered | | • Can be used to control mollusks in open water systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | |
| 75 | | Niclosamide<br>CAS #: 1420-04-8 | | N | Available, Registered, Restricted Use Product* | | • First developed as a lampricide<br>• Used for control of snails in aquaculture ponds<br>• Toxic to fish and aquatic invertebrates at recommended use rates for control of snails in aquaculture ponds | | NA | | | | | | | | |
| 76 | **Pheromones** | Repellant and Attractant Pheromones | | Y | Experimental | | • Under investigation as an attractant and/or deterrent for silver carp (*H. molitrix* ), bighead carp (*H. nobilis* ), black carp (*M. piceus* ), and sea lamprey (*P. marinus* ) | T | NA | | | | | | | | |
| 77 | **Piscicides** § | Antimycin A<br>CAS #: 1397-94-0 | | N | Available, Registered, Restricted Use Product* | | • Effectiveness can vary with the surfactant used.<br>• Requires approximately 8 to 32 hours to kill cyprinid species such as bighead carp (H. nobilis) and silver carp (H. molitrix)<br>• Restricted use pesticide due to aquatic toxicity and need for highly specialized applicator training | | NA | | | | | | | | |

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# Scud

| | A | B | C | D | E | I | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 78 | | Niclosamide<br>CAS #: 1420-04-8 | | N | Available, Registered, Restricted Use Product* | | • First developed as a lampricide<br>• Toxic to aquatic invertebrates; non-target organisms may be killed at rates recommended for sea lamprey control<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by United States Department of Interior, United States Fish & Wildlife Service (USFWS), state fish and game, Fisheries and Oceans Canada, and Provincial Certified Applicators trained in sea lamprey control<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 79 | | Rotenone (Both Standard Application and Via Oral Delivery Platforms)<br>CAS #: 83-79-4 | | N | Available, Registered, Restricted Use Product* | | • Kills bighead (*H. nobilis* ) carp and silver carp (*H. molitrix* ) within approximately 4 hours<br>• May be toxic to other aquatic organisms<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 80 | | TFM (3-Trifluoromethyl-4-nitrophenol)<br>CAS #: 88-30-2 | | N | Available, Registered, Restricted Use Product* | | • Designed only to control sea lamprey (*P. marinus* )<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by certified applicators of USFWS, Fisheries and Oceans Canada, and provincial and state fish and game employees<br>• Non-target organisms may be killed at labeled use rates<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 81 | **Screens** | Non-Mechanical Screens | Fences | N | Available | | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent movement of non-target organisms, depending on their size | | NA | | | | | | | | |
| 82 | | | Bar Screens | N | Available | | | | NA | | | | | | | | |
| 83 | | | Trash Racks | N | Available | | | | NA | | | | | | | | |
| 84 | | | Curtains | N | Available | | | | NA | | | | | | | | |
| 85 | | Mechanical Screens | Chain Bar Screens | N | Available | | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent the movement of non-target organisms, depending on their size | | NA | | | | | | | | |
| 86 | | | Reciprocating Rake Bar Screens | N | Available | | | | NA | | | | | | | | |
| 87 | | | Catenary Bar Screens | N | Available | | | | NA | | | | | | | | |
| 88 | | | Continuous Belt Bar Screens | N | Available | | | | NA | | | | | | | | |
| 89 | | | Rotating Drum Screens (Paddle Wheel Or Power) | N | Available | | | | NA | | | | | | | | |
| 90 | | | Wedge-Wire Cylinders | N | Available | | | | NA | | | | | | | | |
| 91 | | | Louvered Screens | N | Available | | | | NA | | | | | | | | |
| 92 | | | Mechanical Climber Screens | N | Available | | | | NA | | | | | | | | |
| 93 | | Filters | | N | Available | X | • Generally used to treat small volumes of water<br>• Constrained by resistance through filter membrane and filter fouling<br>• Filters may prevent the movement of non-target organisms, depending on their size | | NA | Y | For scud suspended in the water column, may not be effective for scud established on the bottom of channel | Y | Y | | | | |
| 94 | **Sensory Deterrent Systems** | Underwater Strobe lights | | N | Experimental | | • Used to prevent upstream movement of fish | A | NA | | | | | | | | |

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# Scud

| | A | B | C | D | E | I | N | O | P | Q | R | S | T | U | V | W | X |
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| 95 | | Underwater Sound | | N | Experimental | | • May not prevent downstream movement of aquatic organisms | A | NA | | | | | | | | |
| 96 | | Acoustic Air Bubble Curtain | | N | Experimental | | | A | NA | | | | | | | | |
| 97 | | Electric Barrier | | N | Available | | • Must be configured to stop upstream and downstream movement of fish<br>• May impact non-target aquatic organisms | A | NA | | | | | | | | |
| 98 | **Ultrasound** | Ultrasound | | N | Available | | • Used in small water bodies and water treatment plants<br>• Ultrasound may be effective on diatoms (*S. binderanus* )<br>• Most effective on enclosed bodies of water<br>• Additional research may be needed to investigate potential impacts on non-target organisms<br>• Under investigation for use against aquatic vascular plants (non-algae)<br>• Requires continuous application to maintain effectiveness | | NA | | | | | | | | |
| 99 | **Ultraviolet Light** | Ultraviolet (UV) Light | | N | Available | X | • Used in fish hatcheries and water treatment facilities<br>• Used to treat contained flowing systems<br>• Best used after suspended solids, iron and manganese have been filtered from water<br>• May impact non-target aquatic organisms<br>• Under investigation for use against aquatic vascular plants (non-algae) | | NA | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 100 | **Vertical Drop Barrier** | Vertical Drop Barrier | | N | Available | X | • Does not prevent aquatic organism movement downstream<br>• May impact upstream movement of non-target organisms | | NA | Y | | N | Y | | | | |
| 101 | **Williams' Cage**<br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Williams' Cage | | Y | Experimental | | • May be effective on silver carp *(H. molitrix)* and sea lamprey *(P. marinus)*<br>• Does not prevent aquatic organism movement downstream | A | NA | | | | | | | | |

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# Bighead Carp

| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Fact Sheet | ANS Control | | Selective for ANS of Concern – CAWS | Status [2] | fish | Comments<br>Refer to fact sheets for additional information on each Control | Level of R&D | Biocides for Industrial Use - Conventional, municipal drinking water or wastewater treatment technologies | Effective on Bighead Carp (eggs) | Comments on eggs | Effective on Bighead Carp (larvae) | Comments on larvae | Effective on Bighead Carp (adult) | Comments on adult | Effective with Downstream Flow | Effective with Upstream Flow |
| 3 | **Accelerated Water Velocity** | Accelerated Water Velocity | | N | Available | X | • Not effective in preventing downstream ANS movement<br>• Must have a length and speed of flow greater than the organism's leaping ability and swimming endurance | | NA | Y | | Y | | Y | | N | Y |
| 4 | **Acoustic Fish Deterrents** | Continuous Wave | | N | Experimental | X | • Under development for control of fish<br>• May not be effective on all fish species | T | NA | N | Eggs not impacted by sound waves because they lack swim bladder | Y | | Y | | | |
| 5 | | Pulsed Pressure Wave | | N | Experimental | X | • Not lethal unless an organism is very close to sound source | A | NA | N | Eggs not impacted by sound waves because they lack swim bladder | Y | | Y | | Y | Y |
| 6 | **Algaecides** § | Copper Sulfate and Chelated Copper Formulations (ethanolamines, ethylene diamines, triethanolamines, triethanolamine+ethylene diamine, and copper citrate/gluconate) | | N | Available, Registered | | • May be effective on diatoms (*S. binderanus*) and grass kelp (*Enteromorpha flexuosa*)<br>• Chelated copper formulations may be effective on red macro-algae (Bangia atropupurea)<br>• Reduced efficacy in waters with high pH and water temperatures < 15 °C<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 7 | | Endothall (as the mono(N,N-dimethylalkylamine) salt)<br>CAS #: 66330-88-9 | | N | Available, Registered | | • May be effective on red macro-algae (*B. atropupurea*) and diatoms (*S. binderanus*)<br>• Can be harmful to fish<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | |
| 8 | | Algaecides containing Sodium Carbonate Peroxyhydrate<br>CAS #: 15630-89-4 | | N | Available, Registered | | • May be effective on diatoms (*S. binderanus*), and grass kelp (*E. flexuosa*)<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | |
| 9 | **Alteration of Water Quality** §<br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/10/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided. | Gases | Carbon Dioxide ($CO_2$) | N | Available, When Not Registered for a Use | X | • May repel fish at sub-lethal levels<br>• Lowers pH<br>• Creates irreversible cell damage and death<br>• Effectiveness dependent upon dose and exposure | | NA | Y | | Y | | Y | | Y | Y |
| 10 | | | Ozone | N | Available | X | • Rendered ineffective in the presence of organic matter<br>• Used commercially to decontaminate water<br>• Ozone oxidation is toxic to most small waterborne organisms<br>• Destroys the epithelium covering the gill lamella in fish | | NA | Y | | Y | | Y | | Y | Y |
| 11 | | | Nitrogen | N | Available | X | • Adult fish are more tolerant than young fish<br>• Nitrogen supersaturation is a cause of gas bubble disease in fish<br>• Effectiveness dependent upon dose and exposure<br>• Not effective on eggs | | NA | M | Uncertain of toxicity of nitrogen across egg membrane | Y | | Y | | Y | Y |

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# Bighead Carp

| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | | Solids | Alum | N | Available | | • Creates a solid precipitate from suspended solids within the water column which settles<br>• Alum is not classified as a pesticide, therefore does not require FIFRA registration | | NA | | | | | | | | |
| 13 | | | Sodium Thiosulfate<br>CAS #: 7772-98-7 | N | Experimental | X | • Deoxygenated compound<br>• Effectiveness dependent upon dose and | T | NA | Y | | Y | | Y | | Y | Y |
| 14 | **Aquatic Herbicides** §<br><br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/13/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided. | 2,4-D (both the amine and butoxy-ethyl ester formulations)<br>CAS #: 94-75-7 | | N | Available, Registered | | • Tank mixing with other herbicides improves plant control<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 15 | | Diquat<br>CAS #: 85-00-7 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 16 | | Fluridone<br>CAS #: 59756-60-4 | | N | Available, Registered | | • Plants must be exposed to a lethal dose for a minimum of 45 days for optimal results<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 17 | | Glyphosate<br>CAS #: 1071-83-6 | | N | Available, Registered | | • May be effective on reed sweetgrass (Glyceria maxima)<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 18 | | Imazapyr<br>CAS #: 81334-34-1 | | N | Available, Registered | | • May be effective on reed sweetgrass (*G. maxima* )<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | |
| 19 | | Triclopyr<br>CAS #: 55335-06-3 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 20 | | | | | | | | | NA | | | | | | | | |
| 21 | **Benthic Barriers** | Textile or Plastic | | N | Available | | | | NA | | | | | | | | |
| 22 | | Silt | | N | Available | X | • Created by applying excessive silt/sand to smother bottom-dwelling organism<br>• Application to control aquatic nuisance species has not been widely studied | | NA | M | Floating eggs may not be affected by silt | Y | | N | Adults would likely avoid areas of high turbidity | Y | Y |
| 23 | **Biocides for Industrial Use** §<br><br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br><br>The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained | Isothiazolone<br>(Sea-Nine®) | | N | When Not Registered for a Use | | • Antifouling agent used in hull coatings<br>• Effectiveness dependent upon dose and | | N | | | | | | | | |
| 24 | | 2-(thiocyanomethylthio) benzothiazole<br>(TCMTB)<br>CAS #: 21564-17-0 | | N | When Not Registered for a Use | X | • Antifouling agent<br>• Disinfection of industrial water systems<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 25 | | Benzalkonium Chloride<br>CAS #: 8001-54-5 | | N | When Not Registered for a Use | X | • Corrosive<br>• Disinfection of industrial water systems<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 26 | | Bromine<br>CAS #: 7726-95-6 | | N | When Not Registered for a Use | X | • Purification of drinking water, cooling systems, and surfaces<br>• Corrosive<br>• Requires a controlled application; reacts quickly<br>• Effectiveness dependent upon dose and exposure<br>• Presence of organic matter limits effectiveness | | N | | | | | | | | |

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# Bighead Carp

| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27 | herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Chlorine (free chlorine, hypochlorous acid, hypochlorite salts) CAS #: 7782-50-5 | | N | When Not Registered for a Use | X | • Residuals remain in water after treatment<br>• Requires frequent applications<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | Y | Y | | Y | | Y | | Y | Y |
| 28 | | Chlorine Dioxide CAS #: 10049-04-4 | | N | When Not Registered for a Use | X | • Effectiveness dependent upon dose and exposure | | Y | Y | | Y | | Y | | Y | Y |
| 29 | | Chlorothalonil CAS #: 1897-45-6 | | N | When Not Registered for a Use | | • Registered under FIFRA as a fungicide<br>• Effectiveness dependent upon dose and | | N | | | | | | | | |
| 30 | | Dibromonitrilopropionamide (DBNPA) | | N | When Not Registered for a Use | | • Pulp and paper water treatment systems<br>• Disinfection of industrial water systems | | N | | | | | | | | |
| 31 | | Dichlofluanid CAS #: 1085-98-9 | | N | Experimental | X | • Antifouling agent<br>• Effectiveness dependent upon dose and exposure | A | N | | | | | | | | |
| 32 | | N-(3-Chloroallyl) Hexamethylenetetrmine chloroallyl | | N | When Not Registered for a Use | | • Not persistent and degrades rapidly under acidic conditions | | N | | | | | | | | |
| 33 | | Glutaraldehyde CAS #: 111-30-8 | | N | When Not Registered for a Use | | • Slight to moderate efficiency in presence of organic matter<br>• Some residuals remain in water after treatment<br>• Effectiveness dependent upon dose and | | N | | | | | | | | |
| 34 | **Biocides for Industrial Use** § **(continued)**<br><br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br><br>The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Hydrogen Peroxide CAS #: 7722-84-1 CAS #: 79-21-0 | | N | When Not Registered for a Use | | • Disinfection of drinking water, cooling systems and surfaces<br>• Presence of organic matter limits effectiveness<br>• Moderately corrosive<br>• Some residuals remain in water after treatment<br>• Effective on algal spores | | Y | | | | | | | | |
| 35 | | Iodine CAS #: 7553-56-2 | | N | When Not Registered for a Use | X | • Disinfection of drinking water, cooling systems and surfaces<br>• Requires a controlled application and reacts quickly<br>• Corrosive<br>• Presence of organic matter limits effectiveness<br>• Residuals remain in water after treatment<br>• Requires frequent applications<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 36 | | 2-methylthio-4-tertbutylamino-6-cyclopropylamino-striazine (Irgarol®) CAS #: 28159-98-0 | | N | When Not Registered for a Use | X | • Antifouling agent<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 37 | | Fatty Amines (Mexel® 432) | | N | Experimental | | • Rapid degradation in the environment<br>• Scale dispersant & corrosion inhibitor | | N | | | | | | | | |
| 38 | | Peracetic Acid (Peraclean®) CAS #: 79-21-0 CAS #: 7722-84-1 | | N | When Not Registered for a Use | X | • No known toxic residual; more potent than hydrogen peroxide<br>• Rapidly active at low concentrations against a wide range of microorganisms<br>• Corrosive<br>• Highly efficient in presence of organic matter<br>• Wastewater treatment | | Y | Y | | Y | | Y | | Y | Y |
| 39 | | Phenol CAS #: 108-95-2 | | N | When Not Registered for a Use | X | • Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 40 | **Biocides for Industrial Use §** **(continued)**<br><br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br><br>The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on | Polyhexamethylene Biguanide (PHMB) CAS #: 32289-58-0 | | N | When Not Registered for a Use | | • Disinfection of industrial water systems<br>• Effectiveness dependent upon dose and | | N | | | | | | | | |
| 41 | | Potassium Permanganate CAS #: 7722-64-7 | | N | Experimental | | • Organic matter limits effectiveness & moderately corrosive<br>• Some residuals remain in water after treatment<br>• Effectiveness dependent upon dose and | A | Y | | | | | | | | |
| 42 | | Vitamin K (SeaKleen®) CAS #: 11032-49-8 | | N | Experimental | X | • Ballast water treatment<br>• Toxic to a broad spectrum of marine and freshwater organisms (fish larvae and eggs, planktonic crustaceans, bivalve larvae, Vibrio bacteria, and dinoflagellates)<br>• Effectiveness dependent upon dose and exposure | A | N | | | | | | | | |

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# Bighead Carp

| | A | B / C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
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| 43 | 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Silver (Ionic or Salts)<br>Ions CAS #: 15046-91-0 | N | Experimental | | • Disinfection of industrial water systems<br>• Limited applications of metal ions or salts<br>• Not generally used due to human side effect risk | A | N | | | | | | | | |
| 44 | | Sodium Chlorite<br>CAS #: 7758-19-2 | N | When Not Registered for a Use | X | • Disinfection of drinking water, cooling systems and surfaces<br>• Presence of organic matter limits effectiveness<br>• Residuals remain in water after treatment<br>• Requires frequent applications and corrosive<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | Y | Y | | Y | | Y | | Y | Y |
| 45 | | Sodium Hydroxide [B, GS]<br>CAS #: 1310-73-2 | N | When Not Registered for a Use | X | • Under consideration for use in ballast water treatment<br>• <1% survival of test organisms including algae, annelids, crustaceans and fish with 48-hr exposure to pH adjustments of 11.5 to 12.5 using NaOH (TenEyek, M. 2009. Great Ships Initiative Bench-Scale Test Findings, Technical Report – Public, Sodium Hydroxide (NaOH). GSI/BS/5.) | | Y | Y | | Y | | Y | | Y | Y |
| 46 | | Triclosan<br>CAS #: 3380-34-5 | N | When Not Registered for a Use | X | • Stable and incompatible with strong oxidizing agents<br>• Wastewater treatment<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 47 | | Zineb (Thiocarbamate)<br>CAS #: 12122-67-7 | N | Experimental | X | • Antifouling agent & disinfection of industrial water systems<br>• Effectiveness dependent upon dose and exposure | A | N | | | | | | | | |
| 48 | **Biological Controls** § | Introduced Predatory Fish Species | N | Available | X | • Includes both carnivorous and herbivorous fish species<br>• Best used in waters with no outflows<br>• Predatory fish are non-selective feeders and may eat native species<br>• Predatorsare size selective feeders and may not eat eggs or larger organisms | | NA | Y | | Y | | N | Adults too large to be consumed by most predators | Y | Y |
| 49 | | Introduced Predatory Insect Species | N | Experimental | | • United States Department of Agriculture (USDA) has not approved of any insects for use as biological controls of plants identified as ANS of Concern – CAWS<br>• Predators may be selective feeders (may not eat seeds) | T | NA | | | | | | | | |
| 50 | | *Pseudomonas fluorescens* CL 145A | N | Registered | | • Active ingredient (Pseudomonas fluorescens CL 145A) approved by the United States Environmental Protection Agency (USEPA) in July 2011(Reg. No. 84059-4)<br>• Formulation of commercial product as Zequanox™ is pending review by USEPA as of October 2010; Section 3 registration expected in March 2012<br>• Ongoing research to assess impacts to non-target mollusks | | NA | | | | | | | | |

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# Bighead Carp

| | A | B/C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 51 | | Targeted Disease Agents | N | Experimental | X | • Under consideration for carp species | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |
| 52 | **Controlled Harvest and Overfishing** | Controlled Harvest and Overfishing | N | Available | X | • Requires sorting and returning of native fish species<br>• Requires continual capture over a long period of time, or intensive harvest during critical periods of concentration and reproduction (e.g., migration and spawning season)<br>• Once harvesters, processors, and communities become economically dependent on harvesting nuisance fish, pressure to manage a sustainable population of these fish may conflict with the original purpose of removing them from the | | NA | N | Eggs are too small to harvest | N | Larvae are too small to harvest | Y | | Y | Y |
| 53 | **Deleterious Gene Spread** | Daughterless Gene | Y | Experimental | X | • Researched as a Control for silver carp (*H. molitrix*), bighead carp (*H. nobilis*), black carp (*Mylopharyngodon piceus*), and sea lamprey (*Petromyzon marinus*)<br>• Researched as a Control for common carp<br>• Manipulation of genes can manifest unforeseen and significant undesirable side effects and would require extensive research before being accepted as a Control | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |
| 54 | | Trojan Y Chromosome | Y | Experimental | X | • The Food and Drug Administration regulates genetically engineered animals | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |
| 55 | **Dredging and Diver Dredging** | Dredging and Diver Dredging | N | Available | | • Requires careful disposal or reuse of dredged material to prevent the transfer of ANS to a new location<br>• May remove other ANS of Concern – CAWS and non-target organisms that reside in sediment | | NA | | | | | | | | |
| 56 | **Electron Beam Irradiation** | Electron Beam Irradiation | N | Available | | • Used in irradiation of food, environmental waste, medical sterilization, and water treatment<br>• Requires a closed system and not appropriate for open water application<br>• May require pretreatment to remove suspended solids<br>• Used in irradiation of food, environmental | | NA | | | | | | | | |
| 57 | **Hydrologic Separation** | Physical Barriers | N | Available | X | • Modifies flow within waterway, including stormwater and combined sewer overflow discharge, and conveyance and commercial water dischargers and withdrawal of water<br>• Must be designed to handle storm flows | | NA | Y | | Y | | Y | | Y | Y |
| 58 | **Irrigation Water Chemicals** § | Acrolein<br>CAS #: 107-02-8 | N | Available, Registered, Restricted Use Product* | | • For control of submersed and floating weeds and algae only in irrigation canal systems in western states, provided the appropriate state registrations are also in place<br>• Toxic to fish and other aquatic organisms at labeled use rates | | NA | | | | | | | | |

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# Bighead Carp

| | A | B/C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 59 | | Xylene<br>CAS #: 1330-20-7 | N | Registered | | • For use only in irrigation and drainage canals designated by the Bureau of Reclamation and cooperating water user organizations<br>• For use in Programs of the Bureau of Reclamation and Cooperating Water User Organizations within the following states, provided that the appropriate state registrations are also in place: AZ, CA, CO, ID, KS, MT, NE, NM, NV, ND, OK, OR, SD, TX, UT, WA, and WY<br>• For control of submerged weeds in irrigation and drainage canals<br>• Toxic to fish and other aquatic organisms at | | NA | | | | | | | | |
| 60 | **Lethal Temperature** | Pressurized Hot Water/Steam Treatment | N | Available | X | • Hot water has been used to kill zebra and quagga mussels at municipal and industrial facilities, and high pressure hot water is used to clean ANS off of recreational boats<br>• Treated area (i.e. boat hull) must be above the surface. | | NA | N | Eggs are found in free floating in the current and do not adhere to boat hulls | N | Larvae do not adhere to boat hulls | N | Fish do not adhere to boat hulls | | |
| 61 | | Hot Water Thermal Barrier | N | Available | X | • Difficult to manage in open water system, must be completely mixed throughout the water column | | | | | | | | | | |
| 62 | | Freezing | N | Available | X | air temperatures<br>• Cluster mussels are more tolerant of reduced air temperatures than individual organisms<br>• Can be applied to static water. | | NA | Y | | Y | | Y | | Y | Y |
| 63 | | Carbon Dioxide ($CO_2$) Pellet (dry ice) Blasting | N | Available | X | • Method used extensively to remove organics from aircrafts producing no deterioration of surfaces<br>• CO2 pellets convert to a gas at ambient temperatures, leaving no residue.<br>• Treated area (i.e. boat hull) must be above the surface. | | NA | N | Eggs are found in free floating in the current and do not adhere to boat hulls | N | Larvae do not adhere to boat hulls | N | Fish do not adhere to boat hulls | | |
| 64 | | Desiccation | N | Available | X | • Desiccation can only be achieved in areas where water levels can be controlled<br>• Exposure to air quickly leads to death for active water-breathing organism—mollusks and plants are more tolerant and require longer drying period | | NA | Y | | Y | | Y | | Y | Y |
| 65 | **Light Attenuating Dyes §** | Light Attenuating Dyes | N | Registered | | • Not effective for suppressing growth of floating aquatic plants or emergent shoreline vegetation identified as ANS of Concern – CAWS<br>• Not effective on floating algal mats<br>• May suppress the growth of non-target plants and algae<br>• Only for use in contained waterbodies with little or no outflow<br>• Do not apply to waters used for human consumption | | NA | | | | | | | | |
| 66 | **Manual Harvest** | Manual Harvest | Y | Available | | • Labor-intensive<br>• Selectively dependent upon training and skill of staff | | NA | | | | | | | | |
| 67 | **Mechanical Control Methods** | Mechanical Harvesting | N | Available | | | | NA | | | | | | | | |

Removed During Nov 2012 ANS Controls Screening Charette

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# Bighead Carp

| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 68 | | | Shredding | N | Available | | • May disturb non-target organisms in equipment path | | NA | | | | | | | | |
| 69 | | | Mowing | N | Available | | | | NA | | | | | | | | |
| 70 | | | Chaining | N | Available | | | | NA | | | | | | | | |
| 71 | | | Roto-tilling | N | Available | | | | NA | | | | | | | | |
| 72 | | | Rotovating | N | Available | | • Used for submersed vegetation rooted in the substrate<br>• May have applications on emergent plants<br>• May disturb non-target organisms in equipment path | | NA | | | | | | | | |
| 73 | **Molluscicides** § | | Quaternary and Polyquaternary Ammonium Compounds; Aromatic Hydrocarbons; Endothall as the Mono (N,N-imethylalkylamine) Salt (TD2335 Industrial Biocide-Molluscicide) | N | Registered | | • Used for recirculating and once-through cooling water systems<br>• For control of established populations of freshwater and saltwater mollusks in closed systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | |
| 74 | | | Metals and their salts (Copper Sulfate and Chelated Copper Formulations) | N | Registered | | • Can be used to control mollusks in open water systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | |
| 75 | | | Niclosamide<br>CAS #: 1420-04-8 | N | Available, Registered, Restricted Use Product* | | • First developed as a lampricide<br>• Used for control of snails in aquaculture ponds<br>• Toxic to fish and aquatic invertebrates at recommended use rates for control of snails in aquaculture ponds | | NA | | | | | | | | |
| 76 | **Pheromones** | | Repellant and Attractant Pheromones | Y | Experimental | X | • Under investigation as an attractant and/or deterrent for silver carp (*H. molitrix*), bighead carp (*H. nobilis*), black carp (*M. piceus*), and sea lamprey (*P. marinus*) | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |
| 77 | **Piscicides** § | | Antimycin A<br>CAS #: 1397-94-0 | N | Available, Registered, Restricted Use Product* | X | • Effectiveness can vary with the surfactant used.<br>• Requires approximately 8 to 32 hours to kill cyprinid species such as bighead carp (H. nobilis) and silver carp (H. molitrix)<br>• Restricted use pesticide due to aquatic toxicity and need for highly specialized applicator training | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |
| 78 | | | Niclosamide<br>CAS #: 1420-04-8 | N | Available, Registered, Restricted Use Product* | X | • First developed as a lampricide<br>• Toxic to aquatic invertebrates; non-target organisms may be killed at rates recommended for sea lamprey control<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by United States Department of Interior, United States Fish & Wildlife Service (USFWS), state fish and game, Fisheries and Oceans Canada, and Provincial Certified Applicators trained in sea lamprey control<br>• Effectiveness dependent upon dose and exposure | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |
| 79 | | | Rotenone (Both Standard Application and Via Oral Delivery Platforms)<br>CAS #: 83-79-4 | N | Available, Registered, Restricted Use Product* | X | • Kills bighead (*H. nobilis*) carp and silver carp (*H. molitrix*) within approximately 4 hours<br>• May be toxic to other aquatic organisms<br>• Effectiveness dependent upon dose and exposure | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |

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# Bighead Carp

| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80 | | TFM (3-Trifluoromethyl-4-nitrophenol)<br>CAS #: 88-30-2 | | N | Available, Registered, Restricted Use Product* | X | • Designed only to control sea lamprey (*P. marinus*)<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by certified applicators of USFWS, Fisheries and Oceans Canada, and provincial and state fish and game employees<br>• Non-target organisms may be killed at labeled use rates<br>• Effectiveness dependent upon dose and exposure | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |
| 81 | **Screens** | Non-Mechanical Screens | Fences | N | Available | X | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent movement of non-target organisms, depending on their size | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 82 | | | Bar Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 83 | | | Trash Racks | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | N | Y |
| 84 | | | Curtains | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 85 | | Mechanical Screens | Chain Bar Screens | N | Available | X | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent the movement of non-target organisms, depending on their size | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 86 | | | Reciprocating Rake Bar Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 87 | | | Catenary Bar Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 88 | | | Continuous Belt Bar Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 89 | | | Rotating Drum Screens (Paddle Wheel Or Power) | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 90 | | | Wedge-Wire Cylinders | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 91 | | | Louvered Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 92 | | | Mechanical Climber Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 93 | | Filters | | N | Available | X | • Generally used to treat small volumes of water<br>• Constrained by resistance through filter membrane and filter fouling<br>• Filters may prevent the movement of non-target organisms, depending on their size | | NA | Y | | Y | | Y | | Y | Y |
| 94 | **Sensory Deterrent Systems** | Underwater Strobe lights | | N | Experimental | X | | A | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | M | Future research is needed to determine if this species is susceptible to this technology | Y | Y |

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# Bighead Carp

| | A | B/C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 95 | | Underwater Sound | N | Experimental | X | • Used to prevent upstream movement of fish<br>• May not prevent downstream movement of aquatic organisms | A | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | M | Future research is needed to determine if this species is susceptible to this technology | Y | Y |
| 96 | | Acoustic Air Bubble Curtain | N | Experimental | X | | A | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | M | Future research is needed to determine if this species is susceptible to this technology | Y | Y |
| 97 | | Electric Barrier | N | Available | X | • Must be configured to stop upstream and downstream movement of fish<br>• May impact non-target aquatic organisms | | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | Y | | N | Y |
| 98 | **Ultrasound** | Ultrasound | N | Available | | • Used in small water bodies and water treatment plants<br>• Ultrasound may be effective on diatoms (*S. binderanus* )<br>• Most effective on enclosed bodies of water<br>• Additional research may be needed to investigate potential impacts on non-target organisms<br>• Under investigation for use against aquatic vascular plants (non-algae)<br>• Requires continuous application to maintain effectiveness | | NA | | | | | | | | |
| 99 | **Ultraviolet Light** | Ultraviolet (UV) Light | N | Available | | • Used in fish hatcheries and water treatment facilities<br>• Used to treat contained flowing systems<br>• Best used after suspended solids, iron and manganese have been filtered from water<br>• May impact non-target aquatic organisms<br>• Under investigation for use against aquatic vascular plants (non-algae) | | NA | | | | | | | | |

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# Bighead Carp

| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | **Vertical Drop Barrier** | Vertical Drop Barrier | | N | Available | X | • Does not prevent aquatic organism movement downstream<br>• May impact upstream movement of non-target organisms | | NA | Y | | Y | | Y | | N | Y |
| 101 | **Williams' Cage**<br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Williams' Cage | | Y | Experimental | X | • May be effective on silver carp *(H. molitrix)* and sea lamprey *(P. marinus)*<br>• Does not prevent aquatic organism movement downstream | A | NA | N | Eggs incapable of directed movement | N | Larvae have limited directed movement | M | Future research is needed to determine if this specis is susceptible to this | N | Y |

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# Silver Carp

| | A | B | C | D | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | **Fact Sheet** | **ANS Control** | | Selective for ANS of Concern – CAWS | **fish** | **Comments<br>Refer to fact sheets for additional information on each Control** | **Level of R&D** | **Biocides for Industrial Use - Conventional, municipal drinking water or wastewater treatment technologies** | **Effective on Silver Carp (eggs)** | **Comments on eggs** | **Effective on Silver Carp (larvae)** | **Comments on larvae** | **Effective on Silver Carp (adult)** | **Comments on adult** | **Effective with Downstream Flow** | **Effective with Upstream Flow** |
| 3 | **Accelerated Water Velocity** | Accelerated Water Velocity | | N | X | • Not effective in preventing downstream ANS movement<br>• Must have a length and speed of flow greater than the organism's leaping ability and swimming endurance | | NA | Y | | Y | | Y | | N | Y |
| 4 | **Acoustic Fish Deterrents** | Continuous Wave | | N | X | • Under development for control of fish<br>• May not be effective on all fish species | T | NA | N | Eggs not impacted by sound waves because they lack swim bladder | Y | | Y | | | |
| 5 | | Pulsed Pressure Wave | | N | X | • Not lethal unless an organism is very close to sound source | A | NA | N | Eggs not impacted by sound waves because they lack swim bladder | Y | | Y | | Y | Y |
| 6 | **Algaecides** § | Copper Sulfate and Chelated Copper Formulations (ethanolamines, ethylene diamines, triethanolamines, triethanolamine+ethylene diamine, and copper citrate/gluconate) | | N | | • May be effective on diatoms (*S. binderanus*) and grass kelp (*Enteromorpha flexuosa*)<br>• Chelated copper formulations may be effective on red macro-algae (Bangia atropupurea)<br>• Reduced efficacy in waters with high pH and water temperatures < 15 °C<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 7 | | Endothall (as the mono(N,N-dimethylalkylamine) salt)<br>CAS #: 66330-88-9 | | N | | • May be effective on red macro-algae (*B. atropupurea*) and diatoms (*S. binderanus*)<br>• Can be harmful to fish<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | |
| 8 | | Algaecides containing Sodium Carbonate Peroxyhydrate<br>CAS #: 15630-89-4 | | N | | • May be effective on diatoms (*S. binderanus*), and grass kelp (*E. flexuosa*)<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | |
| 9 | **Alteration of Water Quality** §<br><br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on | | Carbon Dioxide ($CO_2$) | N | X | • May repel fish at sub-lethal levels<br>• Lowers pH<br>• Creates irreversible cell damage and death<br>• Effectiveness dependent upon dose and exposure | | NA | Y | | Y | | Y | | Y | Y |

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# Silver Carp

| | A | B | C | D | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 11/10/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided. | Gases | Ozone | N | X | • Rendered ineffective in the presence of organic matter<br>• Used commercially to decontaminate water<br>• Ozone oxidation is toxic to most small waterborne organisms<br>• Destroys the epithelium covering the gill lamella in fish<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | NA | Y | | Y | | Y | | Y | Y |
| 11 | | | Nitrogen | N | X | • Adult fish are more tolerant than young fish<br>• Nitrogen supersaturation is a cause of gas bubble disease in fish<br>• Effectiveness dependent upon dose and exposure<br>• Not effective on eggs | | NA | M | Uncertain of toxicity of nitrogen across egg membrane | Y | | Y | | Y | Y |
| 12 | | Solids | Alum | N | | • Creates a solid precipitate from suspended solids within the water column which settles<br>• Alum is not classified as a pesticide, therefore does not require FIFRA registration | | NA | | | | | | | | |
| 13 | | | Sodium Thiosulfate CAS #: 7772-98-7 | N | X | • Deoxygenated compound<br>• Effectiveness dependent upon dose and | T | NA | Y | | Y | | Y | | Y | Y |
| 14 | **Aquatic Herbicides** § <br><br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/13/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided. | 2,4-D (both the amine and butoxy-ethyl ester formulations) CAS #: 94-75-7 | | N | | • Tank mixing with other herbicides improves plant control<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 15 | | Diquat CAS #: 85-00-7 | | N | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 16 | | Fluridone CAS #: 59756-60-4 | | N | | • Plants must be exposed to a lethal dose for a minimum of 45 days for optimal results<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 17 | | Glyphosate CAS #: 1071-83-6 | | N | | • May be effective on reed sweetgrass (Glyceria maxima)<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 18 | | Imazapyr CAS #: 81334-34-1 | | N | | • May be effective on reed sweetgrass (*G. maxima* )<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | |
| 19 | | Triclopyr CAS #: 55335-06-3 | | N | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 20 | | | | | | | | NA | | | | | | | | |
| 21 | **Benthic Barriers** | Textile or Plastic | | N | | | | NA | | | | | | | | |
| 22 | | Silt | | N | X | • Created by applying excessive silt/sand to smother bottom-dwelling organism<br>• Application to control aquatic nuisance species has not been widely studied | | NA | M | Floating eggs may not be affected by silt | Y | | N | Adults would likely avoid areas of high turbidity | Y | Y |
| 27 | **Biocides for Industrial Use** § <br><br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of | Chlorine (free chlorine, hypochlorous acid, hypochlorite salts) CAS #: 7782-50-5 | | N | X | • Residuals remain in water after treatment<br>• Requires frequent applications<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | Y | Y | | Y | | Y | | Y | Y |

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# Silver Carp

| | A | B | C | D | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 28 | and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004) | | Chlorine Dioxide CAS #: 10049-04-4 | N | X | • Effectiveness dependent upon dose and exposure | | Y | Y | | Y | | Y | | Y | Y |
| 34 | **Biocides for Industrial Use § (continued)** Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004) | | Hydrogen Peroxide CAS #: 7722-84-1 CAS #: 79-21-0 | N | | • Disinfection of drinking water, cooling systems and surfaces • Presence of organic matter limits effectiveness • Moderately corrosive • Some residuals remain in water after treatment • Effective on algal spores | | Y | | | | | | | | |
| 38 | The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided. | | Peracetic Acid (Peraclean®) CAS #: 79-21-0 CAS #: 7722-84-1 | N | X | • No known toxic residual; more potent than hydrogen peroxide • Rapidly active at low concentrations against a wide range of microorganisms • Corrosive • Highly efficient in presence of organic matter • Wastewater treatment | | Y | Y | | Y | | Y | | Y | Y |
| 41 | **Biocides for Industrial Use § (continued)** | | Potassium Permanganate CAS #: 7722-64-7 | N | | • Organic matter limits effectiveness & moderately corrosive • Some residuals remain in water after treatment • Effectiveness dependent upon dose and | A | Y | | | | | | | | |
| 44 | Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004) The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided. | | Sodium Chlorite CAS #: 7758-19-2 | N | X | • Disinfection of drinking water, cooling systems and surfaces • Presence of organic matter limits effectiveness • Residuals remain in water after treatment • Requires frequent applications and corrosive • Effectiveness dependent upon dose and exposure • Effective on algal spores | | Y | Y | | Y | | Y | | Y | Y |
| 45 | Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | | Sodium Hydroxide [B, GS] CAS #: 1310-73-2 | N | X | • Under consideration for use in ballast water treatment • <1% survival of test organisms including algae, annelids, crustaceans and fish with 48-hr exposure to pH adjustments of 11.5 to 12.5 using NaOH (TenEyek, M. 2009. Great Ships Initiative Bench-Scale Test Findings, Technical Report – Public, Sodium Hydroxide (NaOH). GSI/BS/5.) | | Y | Y | | Y | | Y | | Y | Y |
| 48 | **Biological Controls §** | | Introduced Predatory Fish Species | N | X | • Includes both carnivorous and herbivorous fish species • Best used in waters with no outflows • Predatory fish are non-selective feeders and may eat native species • Predatorsare size selective feeders and may not eat eggs or larger organisms | | NA | Y | | Y | | N | Adults too large to be consumed by most predators | Y | Y |
| 49 | | | Introduced Predatory Insect Species | N | | • United States Department of Agriculture (USDA) has not approved of any insects for use as biological controls of plants identified as ANS of Concern – CAWS • Predators may be selective feeders (may not eat seeds) | T | NA | | | | | | | | |

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# Silver Carp

| | A | B | C | D | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 | | *Pseudomonas fluorescens* CL 145A | | N | | • Active ingredient (Pseudomonas fluorescens CL 145A) approved by the United States Environmental Protection Agency (USEPA) in July 2011(Reg. No. 84059-4)<br>• Formulation of commercial product as Zequanox™ is pending review by USEPA as of October 2010; Section 3 registration expected in March 2012<br>• Ongoing research to assess impacts to non-target mollusks | | NA | | | | | | | | |
| 51 | | Targeted Disease Agents | | N | X | • Under consideration for carp species | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |
| 52 | **Controlled Harvest and Overfishing** | Controlled Harvest and Overfishing | | N | X | • Requires sorting and returning of native fish species<br>• Requires continual capture over a long period of time, or intensive harvest during critical periods of concentration and reproduction (e.g., migration and spawning season)<br>• Once harvesters, processors, and communities become economically dependent on harvesting nuisance fish, pressure to manage a sustainable population of these fish may conflict with the original purpose of removing them from the environment<br>• Typically for organisms larger than eggs and larvae. | | NA | N | Eggs are too small to harvest | N | Larvae are too small to harvest | Y | | Y | Y |
| 53 | **Deleterious Gene Spread** | Daughterless Gene | | Y | X | • Researched as a Control for silver carp (*H. molitrix*), bighead carp (*H. nobilis*), black carp (*Mylopharyngodon piceus*), and sea lamprey (*Petromyzon marinus*)<br>• Researched as a Control for common carp<br>• Manipulation of genes can manifest unforeseen and significant undesirable side effects and would require extensive research before being accepted as a Control | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |
| 54 | | Trojan Y Chromosome | | Y | X | • The Food and Drug Administration regulates genetically engineered animals | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |
| 55 | **Dredging and Diver Dredging** | Dredging and Diver Dredging | | N | | • Requires careful disposal or reuse of dredged material to prevent the transfer of ANS to a new location<br>• May remove other ANS of Concern – CAWS and non-target organisms that reside in sediment | | NA | | | | | | | | |

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# Silver Carp

| | A | B | C | D | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 56 | **Electron Beam Irradiation** | Electron Beam Irradiation | | N | | • Used in irradiation of food, environmental waste, medical sterilization, and water treatment<br>• Requires a closed system and not appropriate for open water application<br>• May require pretreatment to remove suspended solids<br>• Used in irradiation of food, environmental | | NA | | | | | | | | |
| 57 | **Hydrologic Separation** | Physical Barriers | | N | X | • Modifies flow within waterway, including stormwater and combined sewer overflow discharge, and conveyance and commercial water dischargers and withdrawal of water<br>• Must be designed to handle storm flows. | | NA | Y | | Y | | Y | | Y | Y |
| 58 | **Irrigation Water Chemicals** § | Acrolein<br>CAS #: 107-02-8 | | N | | • For control of submersed and floating weeds and algae only in irrigation canal systems in western states, provided the appropriate state registrations are also in place<br>• Toxic to fish and other aquatic organisms at labeled use rates | | NA | | | | | | | | |
| 59 | | Xylene | | N | | • For use only in irrigation and drainage canals | | NA | | | | | | | | |
| 60 | **Lethal Temperature** | Pressurized Hot Water/Steam Treatment | | N | X | • Hot water has been used to kill zebra and quagga mussels at municipal and industrial facilities, and high pressure hot water is used to clean ANS off of recreational boats | | | | Eggs are found in free floating in the | | | | | | |
| 61 | | Hot Water Thermal Barrier | | N | X | be completely mixed throughout the water column<br>• During cold weather conditions, warm water temperatures may attract fish | | NA | Y | | Y | | Y | | Y | Y |
| 62 | | Freezing | | N | X | • Freezing is often combined with winter water level drawdowns to expose the ANS to freezing air temperatures<br>• Cluster mussels are more tolerant of reduced air temperatures than individual organisms<br>• Can be applied to static water. | | NA | Y | | Y | | Y | | Y | Y |
| 63 | | Carbon Dioxide ($CO_2$) Pellet (dry ice) Blasting | | N | X | • Method used extensively to remove organics from aircrafts producing no deterioration of surfaces<br>• CO2 pellets convert to a gas at ambient temperatures, leaving no residue.<br>• Treated area (i.e. boat hull) must be above the surface. | | NA | N | Eggs are found in free floating in the current and do not adhere to boat hulls | N | Larvae do not adhere to boat hulls | N | Fish do not adhere to boat hulls | | |
| 64 | | Desiccation | | N | X | • Desiccation can only be achieved in areas where water levels can be controlled<br>• Exposure to air quickly leads to death for active water-breathing organism—mollusks and plants are more tolerant and require longer drying period | | NA | Y | | Y | | Y | | Y | Y |

Removed During Nov 2012 ANS Controls Screening Charette

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# Silver Carp

| | A | B | C | D | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 65 | **Light Attenuating Dyes** § | | Light Attenuating Dyes | N | | • Not effective for suppressing growth of floating aquatic plants or emergent shoreline vegetation identified as ANS of Concern – CAWS<br>• Not effective on floating algal mats<br>• May suppress the growth of non-target plants and algae<br>• Only for use in contained waterbodies with little or no outflow<br>• Do not apply to waters used for human consumption | | NA | | | | | | | | |
| 66 | **Manual Harvest** | | Manual Harvest | Y | | • Labor-intensive<br>• Selectively dependent upon training and skill of staff | | NA | | | | | | | | |
| 67 | **Mechanical Control Methods** | | Mechanical Harvesting | N | | • May disturb non-target organisms in equipment path | | NA | | | | | | | | |
| 68 | | | Shredding | N | | | | NA | | | | | | | | |
| 69 | | | Mowing | N | | | | NA | | | | | | | | |
| 70 | | | Chaining | N | | | | NA | | | | | | | | |
| 71 | | | Roto-tilling | N | | | | NA | | | | | | | | |
| 72 | | | Rotovating | N | | • Used for submersed vegetation rooted in the substrate<br>• May have applications on emergent plants<br>• May disturb non-target organisms in equipment path | | NA | | | | | | | | |
| 73 | **Molluscicides** § | | Quaternary and Polyquaternary Ammonium Compounds; Aromatic Hydrocarbons; Endothall as the Mono (N,N-imethylalkylamine) Salt (TD2335 Industrial Biocide-Molluscicide) | N | | • Used for recirculating and once-through cooling water systems<br>• For control of established populations of freshwater and saltwater mollusks in closed systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | |
| 74 | | | Metals and their salts (Copper Sulfate and Chelated Copper Formulations) | N | | • Can be used to control mollusks in open water systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | |
| 75 | | | Niclosamide<br>CAS #: 1420-04-8 | N | | • First developed as a lampricide<br>• Used for control of snails in aquaculture ponds<br>• Toxic to fish and aquatic invertebrates at recommended use rates for control of snails in aquaculture ponds | | NA | | | | | | | | |
| 76 | **Pheromones** | | Repellant and Attractant Pheromones | Y | X | • Under investigation as an attractant and/or deterrent for silver carp (*H. molitrix*), bighead carp (*H. nobilis*), black carp (*M. piceus*), and sea lamprey (*P. marinus*) | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |
| 77 | **Piscicides** § | | Antimycin A<br>CAS #: 1397-94-0 | N | X | • Effectiveness can vary with the surfactant used.<br>• Requires approximately 8 to 32 hours to kill cyprinid species such as bighead carp (H. nobilis) and silver carp (H. molitrix)<br>• Restricted use pesticide due to aquatic toxicity and need for highly specialized applicator training | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |

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# Silver Carp

| | A | B | C | D | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 78 | | Niclosamide<br>CAS #: 1420-04-8 | | N | X | • First developed as a lampricide<br>• Toxic to aquatic invertebrates; non-target organisms may be killed at rates recommended for sea lamprey control<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by United States Department of Interior, United States Fish & Wildlife Service (USFWS), state fish and game, Fisheries and Oceans Canada, and Provincial Certified Applicators trained in sea lamprey control<br>• Effectiveness dependent upon dose and exposure | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |
| 79 | | Rotenone (Both Standard Application and Via Oral Delivery Platforms)<br>CAS #: 83-79-4 | | N | X | • Kills bighead (*H. nobilis* ) carp and silver carp (*H. molitrix* ) within approximately 4 hours<br>• May be toxic to other aquatic organisms<br>• Effectiveness dependent upon dose and exposure | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |
| 80 | | TFM (3-Trifluoromethyl-4-nitrophenol)<br>CAS #: 88-30-2 | | N | X | • Designed only to control sea lamprey (*P. marinus* )<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by certified applicators of USFWS, Fisheries and Oceans Canada, and provincial and state fish and game employees<br>• Non-target organisms may be killed at labeled use rates<br>• Effectiveness dependent upon dose and exposure | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |
| 81 | **Screens** | Non-Mechanical Screens | Fences | N | X | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent movement of non-target organisms, depending on their size | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 82 | | | Bar Screens | N | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 83 | | | Trash Racks | N | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | N | Y |
| 84 | | | Curtains | N | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 85 | | Mechanical Screens | Chain Bar Screens | N | X | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent the movement of non-target organisms, depending on their size | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 86 | | | Reciprocating Rake Bar Screens | N | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 87 | | | Catenary Bar Screens | N | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 88 | | | Continuous Belt Bar Screens | N | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 89 | | | Rotating Drum Screens (Paddle Wheel Or Power) | N | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 90 | | | Wedge-Wire Cylinders | N | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 91 | | | Louvered Screens | N | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 92 | | | Mechanical Climber Screens | N | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |

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# Silver Carp

| | A | B | C | D | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 93 | | Filters | | N | X | • Generally used to treat small volumes of water<br>• Constrained by resistance through filter membrane and filter fouling<br>• Filters may prevent the movement of non-target organisms, depending on their size | | NA | Y | | Y | | Y | | Y | Y |
| 94 | **Sensory Deterrent Systems** | Underwater Strobe lights | | N | X | | A | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | M | Future research is needed to determine if this species is susceptible to this technology | Y | Y |
| 95 | | Underwater Sound | | N | X | • Used to prevent upstream movement of fish<br>• May not prevent downstream movement of aquatic organisms | A | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | M | Future research is needed to determine if this species is susceptible to this technology | Y | Y |
| 96 | | Acoustic Air Bubble Curtain | | N | X | | A | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | M | Future research is needed to determine if this species is susceptible to this technology | Y | Y |
| 97 | | Electric Barrier | | N | X | • Must be configured to stop upstream and downstream movement of fish<br>• May impact non-target aquatic organisms | | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | Y | | N | Y |

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# Silver Carp

| | A | B | C | D | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 98 | **Ultrasound** | | Ultrasound | N | | • Used in small water bodies and water treatment plants<br>• Ultrasound may be effective on diatoms (*S. binderanus* )<br>• Most effective on enclosed bodies of water<br>• Additional research may be needed to investigate potential impacts on non-target organisms<br>• Under investigation for use against aquatic vascular plants (non-algae)<br>• Requires continuous application to maintain effectiveness | | NA | | | | | | | | |
| 99 | **Ultraviolet Light** | | Ultraviolet (UV) Light | N | | • Used in fish hatcheries and water treatment facilities<br>• Used to treat contained flowing systems<br>• Best used after suspended solids, iron and manganese have been filtered from water<br>• May impact non-target aquatic organisms<br>• Under investigation for use against aquatic vascular plants (non-algae) | | NA | | | | | | | | |
| 100 | **Vertical Drop Barrier** | | Vertical Drop Barrier | N | X | • Does not prevent aquatic organism movement downstream<br>• May impact upstream movement of non-target organisms | | NA | Y | | Y | | Y | | N | Y |
| 101 | **Williams' Cage**<br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | | Williams' Cage | Y | X | • May be effective on silver carp *(H. molitrix)* and sea lamprey *(P. marinus)*<br>• Does not prevent aquatic organism movement downstream | A | NA | N | Eggs incapable of directed movement | N | Larvae have limited directed movement | M | Future research is needed to determine if this specis is susceptible to this technology | N | Y |

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# Grass Kelp

| | A | B / C | D | E | F | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | **Fact Sheet** | **ANS Control** | Selective for ANS of Concern – CAWS | **Status** [2] | **algae** | **Comments Refer to fact sheets for additional information on each Control** | **Level of R&D** | **Biocides for Industrial Use - Conventional, municipal drinking water or wastewater treatment technologies** | **Effective on Grass Kelp (spores)** | **Comments on Spores in Water** | **Effective on Grass Kelp (adult)** | **Comments on adults in Water** | **Effective with Downstream Flow** | **Effective with Upstream Flow** | **Effective on Grass Kelp adhered to boat hulls** | **Comments** | **Effective on Grass Kelp in ballast water** | **Comments** |
| 3 | **Accelerated Water Velocity** | Accelerated Water Velocity | N | Available | X | • Not effective in preventing downstream ANS movement<br>• Must have a length and speed of flow greater than the organism's leaping ability and swimming endurance | | NA | Y | | Y | | N | Y | | | | |
| 4 | **Acoustic Fish Deterrents** | Continuous Wave | N | Experimental | | • Under development for control of fish<br>• May not be effective on all fish species | T | NA | | | | | | | | | | |
| 5 | | Pulsed Pressure Wave | N | Experimental | | • Not lethal unless an organism is very close to sound source | A | NA | | | | | | | | | | |
| 6 | **Algaecides** § | Copper Sulfate and Chelated Copper Formulations (ethanolamines, ethylene diamines, triethanolamines, triethanolamine+ethylene diamine, and copper citrate/gluconate) | N | Available, Registered | X | • May be effective on diatoms (*S. binderanus* ) and grass kelp (*Enteromorpha flexuosa* )<br>• Chelated copper formulations may be effective on red macro-algae (Bangia atropupurea)<br>• Reduced efficacy in waters with high pH and water temperatures < 15 °C<br>• Effectiveness dependent upon dose and exposure<br>• Minimum exposure requirement is 1 to 3 hours | | NA | N | Algaecides are not effective on spores | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 7 | | Endothall (as the mono(N,N-dimethylalkylamine) salt)<br>CAS #: 66330-88-9 | N | Available, Registered | X | • May be effective on red macro-algae (*B. atropupurea* ) and diatoms (*S. binderanus* )<br>• Can be harmful to fish<br>• Effectiveness dependent upon dose and exposure<br>• Minimum exposure requirement is 3 to 8 hours | | NA | N | Algaecides are not effective on spores | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 8 | | Algaecides containing Sodium Carbonate Peroxyhydrate<br>CAS #: 15630-89-4 | N | Available, Registered | X | • May be effective on diatoms (*S. binderanus* ), and grass kelp (*E. flexuosa* )<br>• Effectiveness dependent upon dose and exposure<br>• Minimum exposure requirement is 1 to 3 hours | | NA | N | Algaecides are not effective on spores | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 9 | **Alteration of Water Quality** §<br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/10/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query | Carbon Dioxide ($CO_2$) | N | Available, When Not Registered for a Use | | • May repel fish at sub-lethal levels<br>• Lowers pH<br>• Creates irreversible cell damage and death<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |

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# Grass Kelp

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| 10 | and for convenience have been provided. | Gases | Ozone | N | Available | X | • Rendered ineffective in the presence of organic matter<br>• Used commercially to decontaminate water<br>• Ozone oxidation is toxic to most small waterborne organisms<br>• Destroys the epithelium covering the gill lamella in fish<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | NA | Y | | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 11 | | | Nitrogen | N | Available | | • Adult fish are more tolerant than young fish | | NA | | | | | | | | | | |
| 12 | | Solids | Alum | N | Available | X | • Creates a solid precipitate from suspended solids within the water column which settles<br>• Alum is not classified as a pesticide, therefore does not require FIFRA registration<br>• Effectiveness dependent upon dose and exposure | | NA | N | Not effective on spores | Y | | Y | Y | | | | |

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| 13 | | | Sodium Thiosulfate<br>CAS #: 7772-98-7 | N | Experimental | | • Deoxygenated compound<br>• Effectiveness dependent upon dose and | T | NA | | | | | | | | | | |
| 14 | **Aquatic Herbicides** § <br><br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/13/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided | 2,4-D (both the amine and butoxy-ethyl ester formulations)<br>CAS #: 94-75-7 | | N | Available, Registered | | • Tank mixing with other herbicides improves plant control<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 15 | | Diquat<br>CAS #: 85-00-7 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 16 | | Fluridone<br>CAS #: 59756-60-4 | | N | Available, Registered | | • Plants must be exposed to a lethal dose for a minimum of 45 days for optimal results<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 17 | | Glyphosate<br>CAS #: 1071-83-6 | | N | Available, Registered | | • May be effective on reed sweetgrass (Glyceria maxima)<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 18 | | Imazapyr<br>CAS #: 81334-34-1 | | N | Available, Registered | | • May be effective on reed sweetgrass (*G. maxima* )<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | | | |
| 19 | | Triclopyr<br>CAS #: 55335-06-3 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 20 | | | | | | | | | NA | | | | | | | | | | |
| 21 | **Benthic Barriers** | Textile or Plastic | | N | Available | | | | NA | | | | | | | | | | |
| 22 | | Silt | | N | Available | | • Created by applying excessive silt/sand to smother bottom-dwelling organism<br>• Application to control aquatic nuisance species has not been widely studied | | NA | | | | | | | | | | |
| 27 | **Biocides for Industrial Use** § <br><br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br><br>The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its | Chlorine (free chlorine, hypochlorous acid, hypochlorite salts)<br>CAS #: 7782-50-5 | | N | When Not Registered for a Use | X | • Residuals remain in water after treatment<br>• Requires frequent applications<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | Y | Y | | M | Future research is needed to determine if this species is susceptible to this technology | | | | | | |
| 28 | | Chlorine Dioxide<br>CAS #: 10049-04-4 | | N | When Not Registered for a Use | | • Effectiveness dependent upon dose and exposure | | Y | Y | | M | Future research is needed to determine if this species is susceptible to this technology | | | | | | |
| 34 | **Biocides for Industrial Use** § **(continued)**<br><br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br><br>The status of these chemicals is based on | Hydrogen Peroxide<br>CAS #: 7722-84-1<br>CAS #: 79-21-0 | | N | When Not Registered for a Use | X | • Disinfection of drinking water, cooling systems and surfaces<br>• Presence of organic matter limits effectiveness<br>• Moderately corrosive<br>• Some residuals remain in water after treatment<br>• Effective on algal spores | | Y | Y | | M | Future research is needed to determine if this species is susceptible to this technology | | | | | | |

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# Grass Kelp

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| 38 | results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein | Peracetic Acid (Peraclean®)<br>CAS #: 79-21-0<br>CAS #: 7722-84-1 | | N | When Not Registered for a Use | | • No known toxic residual; more potent than hydrogen peroxide<br>• Rapidly active at low concentrations against a wide range of microorganisms<br>• Corrosive<br>• Highly efficient in presence of organic matter<br>• Wastewater treatment | | Y | | | | | | | | | | |
| 41 | **Biocides for Industrial Use § (continued)**<br><br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br><br>The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Potassium Permanganate<br>CAS #: 7722-64-7 | | N | Experimental | X | • Organic matter limits effectiveness & moderately corrosive<br>• Some residuals remain in water after treatment<br>• Effectiveness dependent upon dose and exposure | A | Y | N | Not effective on spores | M | Future research is needed to determine if this species is susceptible to this technology | | | | | | |
| 44 | | Sodium Chlorite<br>CAS #: 7758-19-2 | | N | When Not Registered for a Use | X | • Disinfection of drinking water, cooling systems and surfaces<br>• Presence of organic matter limits effectiveness<br>• Residuals remain in water after treatment<br>• Requires frequent applications and corrosive<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | Y | Y | | M | Future research is needed to determine if this species is susceptible to this technology | | | | | | |
| 45 | | Sodium Hydroxide [B, GS]<br>CAS #: 1310-73-2 | | N | When Not Registered for a Use | X | • Under consideration for use in ballast water treatment<br>• <1% survival of test organisms including algae, annelids, crustaceans and fish with 48-hr exposure to pH adjustments of 11.5 to 12.5 using NaOH (TenEyek, M. 2009. Great Ships Initiative Bench-Scale Test Findings, Technical Report – Public, Sodium Hydroxide (NaOH). GSI/BS/5.) | | Y | N | Not effective on spores | M | Future research is needed to determine if this species is susceptible to this technology | | | | | | |
| 48 | **Biological Controls** § | Introduced Predatory Fish Species | | N | Available | | • Includes both carnivorous and herbivorous fish species<br>• Best used in waters with no outflows<br>• Predatory fish are non-selective feeders and | | NA | | | | | | | | | | |
| 49 | | Introduced Predatory Insect Species | | N | Experimental | | • United States Department of Agriculture (USDA) has not approved of any insects for use as biological controls of plants identified as ANS of Concern – CAWS<br>• Predators may be selective feeders (may not eat seeds) | T | NA | | | | | | | | | | |
| 50 | | *Pseudomonas fluorescens* CL 145A | | N | Registered | | • Active ingredient (Pseudomonas fluorescens CL 145A) approved by the United States Environmental Protection Agency (USEPA) in July 2011(Reg. No. 84059-4)<br>• Formulation of commercial product as Zequanox™ is pending review by USEPA as of October 2010; Section 3 registration expected in March 2012<br>• Ongoing research to assess impacts to non-target mollusks | | NA | | | | | | | | | | |
| 51 | | Targeted Disease Agents | | N | Experimental | | • Under consideration for carp species | T | NA | | | | | | | | | | |

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| 52 | **Controlled Harvest and Overfishing** | Controlled Harvest and Overfishing | | N | Available | | • Requires sorting and returning of native fish species<br>• Requires continual capture over a long period of time, or intensive harvest during critical periods of concentration and reproduction (e.g., migration and spawning season)<br>• Once harvesters, processors, and communities become economically dependent on harvesting nuisance fish, pressure to manage a sustainable population of these fish may conflict with the original purpose of removing them from the environment | | NA | | | | | | | | | | |
| 53 | **Deleterious Gene Spread** | Daughterless Gene | | Y | Experimental | | • Researched as a Control for silver carp (*H. molitrix*), bighead carp (*H. nobilis*), black carp (*Mylopharyngodon piceus*), and sea lamprey (*Petromyzon marinus*)<br>• Researched as a Control for common carp<br>• Manipulation of genes can manifest unforeseen and significant undesirable side effects and would require extensive research before being accepted as a Control | T | NA | | | | | | | | | | |
| 54 | | Trojan Y Chromosome | | Y | Experimental | | • The Food and Drug Administration regulates genetically engineered animals | T | NA | | | | | | | | | | |
| 55 | **Dredging and Diver Dredging** | Dredging and Diver Dredging | | N | Available | | • Requires careful disposal or reuse of dredged material to prevent the transfer of ANS to a new location<br>• May remove other ANS of Concern – CAWS and non-target organisms that reside in sediment | | NA | | | | | | | | | | |
| 56 | **Electron Beam Irradiation** | Electron Beam Irradiation | | N | Available | | • Used in irradiation of food, environmental waste, medical sterilization, and water treatment<br>• Requires a closed system and not appropriate for open water application<br>• May require pretreatment to remove suspended solids<br>• Used in irradiation of food, environmental waste, medical sterilization, and water treatment | | NA | | | | | | | | | | |
| 57 | **Hydrologic Separation** | Physical Barriers | | N | Available | X | • Modifies flow within waterway, including stormwater and combined sewer overflow discharge, and conveyance and commercial water dischargers and withdrawal of water<br>• Must be designed to handle storm flows. | | NA | Y | | Y | | Y | Y | | | | |
| 58 | **Irrigation Water Chemicals** § | Acrolein<br>CAS #: 107-02-8 | | N | Available, Registered, Restricted Use Product* | X | • For control of submersed and floating weeds and algae only in irrigation canal systems in western states, provided the appropriate state registrations are also in place<br>• Toxic to fish and other aquatic organisms at labeled use rates<br>• Effectiveness dependent upon dose and exposure<br>• Minimum exposure requirement is 1 to 3 hours | | NA | M | Future research is needed to determine if spores are susceptible to this technology | Y | | Y | Y | | | | |

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| 59 | | Xylene CAS #: 1330-20-7 | | N | Registered | X | • For use only in irrigation and drainage canals designated by the Bureau of Reclamation and cooperating water user organizations • For use in Programs of the Bureau of Reclamation and Cooperating Water User Organizations within the following states, provided that the appropriate state registrations are also in place: AZ, CA, CO, ID, KS, MT, NE, NM, NV, ND, OK, OR, SD, TX, UT, WA, and WY • For control of submerged weeds in irrigation and drainage canals • Toxic to fish and other aquatic organisms at labeled use rates • Effectiveness dependent upon dose and exposure • Minimum exposure requirement is 1 to 3 hours | | NA | M | Future research is needed to determine if spores are susceptible to this technology | Y | | Y | Y | | | | |
| 60 | **Lethal Temperature** | Pressurized Hot Water/Steam Treatment | | N | Available | X | • Hot water has been used to kill zebra and quagga mussels at municipal and industrial facilities, and high pressure hot water is used to clean ANS off of recreational boats • Treated area (i.e. boat hull) must be above the surface. | | NA | Y | Requires proper treatment of wash water | Y | | Y | Y | | | | |
| 61 | | Hot Water Thermal Barrier | | N | Available | X | • Difficult to manage in open water system, must be completely mixed throughout the water column | | | | Spore temperature | | | | | | | | |
| 62 | | Freezing | | N | Available | X | air temperatures • Cluster mussels are more tolerant of reduced air temperatures than individual organisms • Can be applied to static water. | | NA | N | Spore resistant to freezing temperatures | Y | | Y | Y | | | | |
| 63 | | Carbon Dioxide ($CO_2$) Pellet (dry ice) Blasting | | N | Available | X | • Method used extensively to remove organics from aircrafts producing no deterioration of surfaces • CO2 pellets convert to a gas at ambient temperatures, leaving no residue. • Treated area (i.e. boat hull) must be above the surface. | | NA | Y | Requires proper treatment of material | Y | | Y | Y | | | | |
| 64 | | Desiccation | | N | Available | X | • Desiccation can only be achieved in areas where water levels can be controlled • Exposure to air quickly leads to death for active water-breathing organism—mollusks and plants are more tolerant and require longer drying period | | NA | M | Spore dry out period unknown | Y | | Y | Y | | | | |
| 65 | **Light Attenuating Dyes** § | Light Attenuating Dyes | | N | Registered | X | • Not effective for suppressing growth of floating aquatic plants or emergent shoreline vegetation identified as ANS of Concern – CAWS • Not effective on floating algal mats • May suppress the growth of non-target plants and algae • Only for use in contained waterbodies with little or no outflow • Do not apply to waters used for human | | NA | N | Not effective on spores | N | Species can survive over 100 days in complete darkness | | | | | | |
| 66 | **Manual Harvest** | Manual Harvest | | Y | Available | | • Labor-intensive • Selectively dependent upon training and skill of staff | | NA | | | | | | | | | | |

Removed During Nov 2012 ANS Controls Screening Charette

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| 67 | **Mechanical Control Methods** | Mechanical Harvesting | | N | Available | | • May disturb non-target organisms in equipment path | | NA | | | | | | | | | | |
| 68 | | Shredding | | N | Available | | | | NA | | | | | | | | | | |
| 69 | | Mowing | | N | Available | | | | NA | | | | | | | | | | |
| 70 | | Chaining | | N | Available | | | | NA | | | | | | | | | | |
| 71 | | Roto-tilling | | N | Available | | | | NA | | | | | | | | | | |
| 72 | | Rotovating | | N | Available | | • Used for submersed vegetation rooted in the substrate<br>• May have applications on emergent plants<br>• May disturb non-target organisms in equipment path | | NA | | | | | | | | | | |
| 73 | **Molluscicides** § | Quaternary and Polyquaternary Ammonium Compounds; Aromatic Hydrocarbons; Endothall as the Mono (N,N-imethylalkylamine) Salt (TD2335 Industrial Biocide-Molluscicide) | | N | Registered | | • Used for recirculating and once-through cooling water systems<br>• For control of established populations of freshwater and saltwater mollusks in closed systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | | | |
| 74 | | Metals and their salts (Copper Sulfate and Chelated Copper Formulations) | | N | Registered | | • Can be used to control mollusks in open water systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | | | |
| 75 | | Niclosamide CAS #: 1420-04-8 | | N | Available, Registered, Restricted Use Product* | | • First developed as a lampricide<br>• Used for control of snails in aquaculture ponds<br>• Toxic to fish and aquatic invertebrates at recommended use rates for control of snails in aquaculture ponds | | NA | | | | | | | | | | |
| 76 | **Pheromones** | Repellant and Attractant Pheromones | | Y | Experimental | | • Under investigation as an attractant and/or deterrent for silver carp (*H. molitrix* ), bighead carp (*H. nobilis* ), black carp (*M. piceus* ), and sea lamprey (*P. marinus* ) | T | NA | | | | | | | | | | |
| 77 | **Piscicides** § | Antimycin A CAS #: 1397-94-0 | | N | Available, Registered, Restricted Use Product* | | • Effectiveness can vary with the surfactant used.<br>• Requires approximately 8 to 32 hours to kill cyprinid species such as bighead carp (H. nobilis) and silver carp (H. molitrix)<br>• Restricted use pesticide due to aquatic toxicity and need for highly specialized applicator training | | NA | | | | | | | | | | |
| 78 | | Niclosamide CAS #: 1420-04-8 | | N | Available, Registered, Restricted Use Product* | | • First developed as a lampricide<br>• Toxic to aquatic invertebrates; non-target organisms may be killed at rates recommended for sea lamprey control<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by United States Department of Interior, United States Fish & Wildlife Service (USFWS), state fish and game, Fisheries and Oceans Canada, and Provincial Certified Applicators trained in sea lamprey control<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | | | |
| 79 | | Rotenone (Both Standard Application and Via Oral Delivery Platforms) CAS #: 83-79-4 | | N | Available, Registered, Restricted Use Product* | | • Kills bighead (*H. nobilis* ) carp and silver carp (*H. molitrix* ) within approximately 4 hours<br>• May be toxic to other aquatic organisms | | NA | | | | | | | | | | |
| 80 | | TFM (3-Trifluoromethyl-4-nitrophenol) CAS #: 88-30-2 | | N | Available, Registered, Restricted Use Product* | | • Designed only to control sea lamprey (*P. marinus* )<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by certified applicators of USFWS, Fisheries and Oceans Canada, and provincial and state fish and game employees<br>• Non-target organisms may be killed at labeled use rates | | NA | | | | | | | | | | |

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# Grass Kelp

| | A | B | C | D | E | F | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 81 | **Screens** | Non-Mechanical Screens | Fences | N | Available | | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent movement of non-target | | NA | | | | | | | | | | |
| 82 | | | Bar Screens | N | Available | | | | NA | | | | | | | | | | |
| 83 | | | Trash Racks | N | Available | | | | NA | | | | | | | | | | |
| 84 | | | Curtains | N | Available | | | | NA | | | | | | | | | | |
| 85 | | Mechanical Screens | Chain Bar Screens | N | Available | | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent the movement of non-target organisms, depending on their size | | NA | | | | | | | | | | |
| 86 | | | Reciprocating Rake Bar Screens | N | Available | | | | NA | | | | | | | | | | |
| 87 | | | Catenary Bar Screens | N | Available | | | | NA | | | | | | | | | | |
| 88 | | | Continuous Belt Bar Screens | N | Available | | | | NA | | | | | | | | | | |
| 89 | | | Rotating Drum Screens (Paddle Wheel Or Power) | N | Available | | | | NA | | | | | | | | | | |
| 90 | | | Wedge-Wire Cylinders | N | Available | | | | NA | | | | | | | | | | |
| 91 | | | Louvered Screens | N | Available | | | | NA | | | | | | | | | | |
| 92 | | | Mechanical Climber Screens | N | Available | | | | NA | | | | | | | | | | |
| 93 | | Filters | | N | Available | X | • Generally used to treat small volumes of water<br>• Constrained by resistance through filter membrane and filter fouling<br>• Filters may prevent the movement of non-target organisms, depending on their size | | NA | Y | 0.16 micrometers spore size | Y | 3.5 millimeters diameter filaments, 20 centimeters in length | Y | Y | | | | |
| 94 | **Sensory Deterrent Systems** | Underwater Strobe lights | | N | Experimental | | • Used to prevent upstream movement of fish<br>• May not prevent downstream movement of aquatic organisms | A | NA | | | | | | | | | | |
| 95 | | Underwater Sound | | N | Experimental | | | A | NA | | | | | | | | | | |
| 96 | | Acoustic Air Bubble Curtain | | N | Experimental | | | A | NA | | | | | | | | | | |
| 97 | | Electric Barrier | | N | Available | | • Must be configured to stop upstream and downstream movement of fish<br>• May impact non-target aquatic organisms | A | NA | | | | | | | | | | |
| 98 | **Ultrasound** | Ultrasound | | N | Available | X | • Used in small water bodies and water treatment plants<br>• Ultrasound may be effective on diatoms (*S. binderanus* )<br>• Most effective on enclosed bodies of water<br>• Additional research may be needed to investigate potential impacts on non-target organisms<br>• Under investigation for use against aquatic vascular plants (non-algae)<br>• Requires continuous application to maintain effectiveness | | NA | N | Not effective on spores | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 99 | **Ultraviolet Light** | Ultraviolet (UV) Light | | N | Available | X | • Used in fish hatcheries and water treatment facilities<br>• Used to treat contained flowing systems<br>• Best used after suspended solids, iron and manganese have been filtered from water<br>• May impact non-target aquatic organisms<br>• Under investigation for use against aquatic vascular plants (non-algae) | | NA | M | Future research is needed to determine if this species' spores are susceptible to this technology | Y | | Y | Y | | | | |
| 100 | **Vertical Drop Barrier** | Vertical Drop Barrier | | N | Available | | • Does not prevent aquatic organism movement downstream<br>• May impact upstream movement of non-target organisms | | NA | | | | | | | | | | |

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# Red Algae

| | A | B | C | D | E | F | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Fact Sheet | ANS Control | | Selective for ANS of Concern – CAWS | Status [2] | algae | Comments Refer to fact sheets for additional information on each Control | Level of R&D | Biocides for Industrial Use - Conventional, municipal drinking water or wastewater treatment technologies | Effective on Red Algae (spores) | Comments on Spores in Water | Effective on Red Algae (adult) | Comments on adults in Water | Effective with Downstream Flow | Effective with Upstream Flow | Effective on Red Algae adhered to boat hulls | Comments | Effective on Red Algae in ballast water | Comments |
| 3 | **Accelerated Water Velocity** | Accelerated Water Velocity | | N | Available | X | • Not effective in preventing downstream ANS movement<br>• Must have a length and speed of flow greater than the organism's leaping ability and swimming endurance | | NA | Y | | Y | | N | Y | | | | |
| 4 | **Acoustic Fish Deterrents** | Continuous Wave | | N | Experimental | | • Under development for control of fish<br>• May not be effective on all fish species | T | NA | | | | | | | | | | |
| 5 | | Pulsed Pressure Wave | | N | Experimental | | • Not lethal unless an organism is very close to sound source | A | NA | | | | | | | | | | |
| 6 | **Algaecides** § | Copper Sulfate and Chelated Copper Formulations (ethanolamines, ethylene diamines, triethanolamines, triethanolamine+ethylene diamine, and copper citrate/gluconate) | | N | Available, Registered | X | • May be effective on diatoms (*S. binderanus* ) and grass kelp (*Enteromorpha flexuosa* )<br>• Chelated copper formulations may be effective on red macro-algae (Bangia atropupurea)<br>• Reduced efficacy in waters with high pH and water temperatures < 15 °C<br>• Effectiveness dependent upon dose and exposure | | NA | N | Algaecides are not effective on spores | M | Chelated Copper Formulations are effective against other filamentous algae; there is not data on its effectiveness with this species | Y | Y | | | | |
| 7 | | Endothall (as the mono(N,N-dimethylalkylamine) salt) CAS #: 66330-88-9 | | N | Available, Registered | X | • May be effective on red macro-algae (*B. atropupurea* ) and diatoms (*S. binderanus* )<br>• Can be harmful to fish<br>• Effectiveness dependent upon dose and exposure<br>• Minimum exposure requirement is 3 to 8 hours | | NA | N | Algaecides are not effective on spores | M | Endothall is effective against other filamentous algae; there is not data on its effectiveness with this species | Y | Y | | | | |
| 8 | | Algaecides containing Sodium Carbonate Peroxyhydrate CAS #: 15630-89-4 | | N | Available, Registered | X | • May be effective on diatoms (*S. binderanus* ), and grass kelp (*E. flexuosa* )<br>• Effectiveness dependent upon dose and exposure | | NA | N | Algaecides are not effective on spores | N | Not effective on this species | | | | | | |
| 9 | **Alteration of Water Quality** §<br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/10/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided. | Gases | Carbon Dioxide ($CO_2$) | N | Available, When Not Registered for a Use | | • May repel fish at sub-lethal levels<br>• Lowers pH<br>• Creates irreversible cell damage and death<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 10 | | | Ozone | N | Available | X | • Rendered ineffective in the presence of organic matter<br>• Used commercially to decontaminate water<br>• Ozone oxidation is toxic to most small waterborne organisms<br>• Destroys the epithelium covering the gill lamella in fish<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | NA | Y | | Y | | Y | Y | | | | |

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# Red Algae

| | A | B | C | D | E | F | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | | Nitrogen | N | Available | | • Adult fish are more tolerant than young fish<br>• Nitrogen supersaturation is a cause of gas bubble disease in fish<br>• Effectiveness dependent upon dose and exposure<br>• Not effective on eggs | | NA | | | | | | | | | | |
| 12 | | Solids | Alum | N | Available | X | • Creates a solid precipitate from suspended solids within the water column which settles<br>• Alum is not classified as a pesticide, therefore does not require FIFRA registration<br>• Effectiveness dependent upon dose and exposure | | NA | N | Not effective on spores | Y | | Y | Y | | | | |
| 13 | | | Sodium Thiosulfate<br>CAS #: 7772-98-7 | N | Experimental | | • Deoxygenated compound<br>• Effectiveness dependent upon dose and exposure | T | NA | | | | | | | | | | |
| 14 | **Aquatic Herbicides** §<br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/13/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided | 2,4-D (both the amine and butoxy-ethyl ester formulations)<br>CAS #: 94-75-7 | | N | Available, Registered | | • Tank mixing with other herbicides improves plant control<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 15 | | Diquat<br>CAS #: 85-00-7 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 16 | | Fluridone<br>CAS #: 59756-60-4 | | N | Available, Registered | | • Plants must be exposed to a lethal dose for a minimum of 45 days for optimal results<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 17 | | Glyphosate<br>CAS #: 1071-83-6 | | N | Available, Registered | | • May be effective on reed sweetgrass (Glyceria maxima)<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 18 | | Imazapyr<br>CAS #: 81334-34-1 | | N | Available, Registered | | • May be effective on reed sweetgrass (*G. maxima* )<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 19 | | Triclopyr<br>CAS #: 55335-06-3 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 20 | | | | | | | | | NA | | | | | | | | | | |
| 21 | **Benthic Barriers** | Textile or Plastic | | N | Available | | | | NA | | | | | | | | | | |
| 22 | | Silt | | N | Available | | • Created by applying excessive silt/sand to smother bottom-dwelling organism<br>• Application to control aquatic nuisance species has not been widely studied | | NA | | | | | | | | | | |
| 27 | **Biocides for Industrial Use** §<br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br>The status of these chemicals is based on | Chlorine (free chlorine, hypochlorous acid, hypochlorite salts)<br>CAS #: 7782-50-5 | | N | When Not Registered for a Use | X | • Residuals remain in water after treatment<br>• Requires frequent applications<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | Y | Y | | M | Future research is needed to determine if this species is susceptible to this technology | | | | | | |

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# Red Algae

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 28 | results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. | Chlorine Dioxide CAS #: 10049-04-4 | | N | When Not Registered for a Use | | • Effectiveness dependent upon dose and exposure | | Y | | | | | | | | | | |
| 34 | **Biocides for Industrial Use § (continued)**<br><br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004) | Hydrogen Peroxide CAS #: 7722-84-1 CAS #: 79-21-0 | | N | When Not Registered for a Use | X | • Disinfection of drinking water, cooling systems and surfaces<br>• Presence of organic matter limits effectiveness<br>• Moderately corrosive<br>• Some residuals remain in water after treatment<br>• Effective on algal spores | | Y | Y | | M | Future research is needed to determine if this species is susceptible to this technology | | | | | | |
| 38 | The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein | Peracetic Acid (Peraclean®) CAS #: 79-21-0 CAS #: 7722-84-1 | | N | When Not Registered for a Use | | • No known toxic residual; more potent than hydrogen peroxide<br>• Rapidly active at low concentrations against a wide range of microorganisms<br>• Corrosive<br>• Highly efficient in presence of organic matter<br>• Wastewater treatment | | Y | | | | | | | | | | |
| 41 | **Biocides for Industrial Use § (continued)**<br><br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004) | Potassium Permanganate CAS #: 7722-64-7 | | N | Experimental | X | • Organic matter limits effectiveness & moderately corrosive<br>• Some residuals remain in water after treatment<br>• Effectiveness dependent upon dose and exposure | A | Y | N | Not effective on spores | M | Future research is needed to determine if this species is susceptible to this technology | | | | | | |
| 44 | The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Sodium Chlorite CAS #: 7758-19-2 | | N | When Not Registered for a Use | X | • Disinfection of drinking water, cooling systems and surfaces<br>• Presence of organic matter limits effectiveness<br>• Residuals remain in water after treatment<br>• Requires frequent applications and corrosive<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | Y | Y | | M | Future research is needed to determine if this species is susceptible to this technology | | | | | | |
| 45 | | Sodium Hydroxide [B, GS] CAS #: 1310-73-2 | | N | When Not Registered for a Use | X | • Under consideration for use in ballast water treatment<br>• <1% survival of test organisms including algae, annelids, crustaceans and fish with 48-hr exposure to pH adjustments of 11.5 to 12.5 using NaOH (TenEyek, M. 2009. Great Ships Initiative Bench-Scale Test Findings, Technical Report – Public, Sodium Hydroxide (NaOH). GSI/BS/5.) | | Y | N | Not effective on spores | M | Future research is needed to determine if this species is susceptible to this technology | | | | | | |
| 48 | **Biological Controls §** | Introduced Predatory Fish Species | | N | Available | | • Includes both carnivorous and herbivorous fish species<br>• Best used in waters with no outflows<br>• Predatory fish are non-selective feeders and may eat native species<br>• Predatorsare size selective feeders and may not eat eggs or larger organisms | | NA | | | | | | | | | | |
| 49 | | Introduced Predatory Insect Species | | N | Experimental | | • United States Department of Agriculture (USDA) has not approved of any insects for use as biological controls of plants identified as ANS of Concern – CAWS<br>• Predators may be selective feeders (may not eat seeds) | T | NA | | | | | | | | | | |

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# Red Algae

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 | | *Pseudomonas fluorescens* CL 145A | | N | Registered | | • Active ingredient (Pseudomonas fluorescens CL 145A) approved by the United States Environmental Protection Agency (USEPA) in July 2011(Reg. No. 84059-4)<br>• Formulation of commercial product as Zequanox™ is pending review by USEPA as of October 2010; Section 3 registration expected in March 2012<br>• Ongoing research to assess impacts to non-target mollusks | | NA | | | | | | | | | | |
| 51 | | Targeted Disease Agents | | N | Experimental | | • Under consideration for carp species | T | NA | | | | | | | | | | |
| 52 | **Controlled Harvest and Overfishing** | Controlled Harvest and Overfishing | | N | Available | | • Requires sorting and returning of native fish species<br>• Requires continual capture over a long period of time, or intensive harvest during critical periods of concentration and reproduction (e.g., migration and spawning season)<br>• Once harvesters, processors, and communities become economically dependent on harvesting nuisance fish, pressure to manage a sustainable population of these fish may conflict with the original purpose of removing them from the environment<br>• Typically for organisms larger than eggs and larvae. | | NA | | | | | | | | | | |
| 53 | **Deleterious Gene Spread** | Daughterless Gene | | Y | Experimental | | • Researched as a Control for silver carp (*H. molitrix* ), bighead carp (*H. nobilis* ), black carp (*Mylopharyngodon piceus* ), and sea lamprey (*Petromyzon marinus* )<br>• Researched as a Control for common carp<br>• Manipulation of genes can manifest unforeseen and significant undesirable side effects and would require extensive research before being accepted as a Control | T | NA | | | | | | | | | | |
| 54 | | Trojan Y Chromosome | | Y | Experimental | | • The Food and Drug Administration regulates genetically engineered animals | T | NA | | | | | | | | | | |
| 55 | **Dredging and Diver Dredging** | Dredging and Diver Dredging | | N | Available | | • Requires careful disposal or reuse of dredged material to prevent the transfer of ANS to a new location<br>• May remove other ANS of Concern – CAWS and non-target organisms that reside in sediment | | NA | | | | | | | | | | |
| 56 | **Electron Beam Irradiation** | Electron Beam Irradiation | | N | Available | | • Used in irradiation of food, environmental waste, medical sterilization, and water treatment<br>• Requires a closed system and not appropriate for open water application<br>• May require pretreatment to remove suspended solids<br>• Used in irradiation of food, environmental waste, medical sterilization, and water treatment | | NA | | | | | | | | | | |
| 57 | **Hydrologic Separation** | Physical Barriers | | N | Available | X | • Modifies flow within waterway, including stormwater and combined sewer overflow discharge, and conveyance and commercial water dischargers and withdrawal of water<br>• Must be designed to handle storm flows. | | NA | Y | | Y | | Y | Y | | | | |

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# Red Algae

| | A | B | C | D | E | F | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 58 | **Irrigation Water Chemicals** § | | Acrolein<br>CAS #: 107-02-8 | N | Available, Registered, Restricted Use Product* | X | • For control of submersed and floating weeds and algae only in irrigation canal systems in western states, provided the appropriate state registrations are also in place<br>• Toxic to fish and other aquatic organisms at labeled use rates<br>• Effectiveness dependent upon dose and exposure<br>• Minimum exposure requirement is 1 to 3 hours | | NA | M | Future research is needed to determine if this species' spores are susceptible to this technology | Y | | Y | Y | | | | |
| 59 | | | Xylene<br>CAS #: 1330-20-7 | N | Registered | X | • For use only in irrigation and drainage canals designated by the Bureau of Reclamation and cooperating water user organizations<br>• For use in Programs of the Bureau of Reclamation and Cooperating Water User Organizations within the following states, provided that the appropriate state registrations are also in place: AZ, CA, CO, ID, KS, MT, NE, NM, NV, ND, OK, OR, SD, TX, UT, WA, and WY<br>• For control of submerged weeds in irrigation and drainage canals<br>• Toxic to fish and other aquatic organisms at labeled use rates<br>• Effectiveness dependent upon dose and exposure<br>• Minimum exposure requirement is 1 to 3 hours | | NA | M | Future research is needed to determine if this species' spores are susceptible to this technology | Y | | Y | Y | | | | |
| 60 | **Lethal Temperature** | | Pressurized Hot Water/Steam Treatment | N | Available | X | • Hot water has been used to kill zebra and quagga mussels at municipal and industrial facilities, and high pressure hot water is used to clean ANS off of recreational boats<br>• Treated area (i.e. boat hull) must be above the surface. | | NA | Y | Requires proper treatment of wash water | Y | | Y | Y | | | | |
| 61 | | | Hot Water Thermal Barrier | N | Available | X | • Difficult to manage in open water system, must be completely mixed throughout the water column | | | | Spore temperature | | | | | | | | |
| 62 | | | Freezing | N | Available | X | air temperatures<br>• Cluster mussels are more tolerant of reduced air temperatures than individual organisms<br>• Can be applied to static water. | | NA | N | Spore resistant to freezing temperatures | Y | | Y | Y | | | | |
| 63 | | | Carbon Dioxide ($CO_2$) Pellet (dry ice) Blasting | N | Available | X | • Method used extensively to remove organics from aircrafts producing no deterioration of surfaces<br>• CO2 pellets convert to a gas at ambient temperatures, leaving no residue.<br>• Treated area (i.e. boat hull) must be above the surface. | | NA | Y | Requires proper treatment of material | Y | | Y | Y | | | | |
| 64 | | | Desiccation | N | Available | X | • Desiccation can only be achieved in areas where water levels can be controlled<br>• Exposure to air quickly leads to death for active water-breathing organism—mollusks and plants are more tolerant and require longer drying period | | NA | M | Spore dry out period unknown | Y | | Y | Y | | | | |

Removed During Nov 2012 ANS Controls Screening Charette

2 Status
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# Red Algae

| | A | B | C | D | E | F | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 65 | **Light Attenuating Dyes** § | | Light Attenuating Dyes | N | Registered | X | • Not effective for suppressing growth of floating aquatic plants or emergent shoreline vegetation identified as ANS of Concern – CAWS<br>• Not effective on floating algal mats<br>• May suppress the growth of non-target plants and algae<br>• Only for use in contained waterbodies with little or no outflow<br>• Do not apply to waters used for human consumption | | NA | N | Not effective on spores | N | Only able to suppress growth | | | | | | |
| 66 | **Manual Harvest** | | Manual Harvest | Y | Available | | • Labor-intensive<br>• Selectively dependent upon training and skill of staff | | NA | | | | | | | | | | |
| 67 | **Mechanical Control Methods** | | Mechanical Harvesting | N | Available | | • May disturb non-target organisms in equipment path | | NA | | | | | | | | | | |
| 68 | | | Shredding | N | Available | | | | NA | | | | | | | | | | |
| 69 | | | Mowing | N | Available | | | | NA | | | | | | | | | | |
| 70 | | | Chaining | N | Available | | | | NA | | | | | | | | | | |
| 71 | | | Roto-tilling | N | Available | | | | NA | | | | | | | | | | |
| 72 | | | Rotovating | N | Available | | • Used for submersed vegetation rooted in the substrate<br>• May have applications on emergent plants<br>• May disturb non-target organisms in equipment path | | NA | | | | | | | | | | |
| 73 | **Molluscicides** § | | Quaternary and Polyquaternary Ammonium Compounds; Aromatic Hydrocarbons; Endothall as the Mono (N,N-imethylalkylamine) Salt (TD2335 Industrial Biocide-Molluscicide) | N | Registered | | • Used for recirculating and once-through cooling water systems<br>• For control of established populations of freshwater and saltwater mollusks in closed systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | | | |
| 74 | | | Metals and their salts (Copper Sulfate and Chelated Copper Formulations) | N | Registered | | • Can be used to control mollusks in open water systems<br>• Is non-selective at use rates to control mollusks<br>• Minimun exposure requirement is 1 to 3 hours | | NA | | | | | | | | | | |
| 75 | | | Niclosamide<br>CAS #: 1420-04-8 | N | Available, Registered, Restricted Use Product* | | • First developed as a lampricide<br>• Used for control of snails in aquaculture ponds<br>• Toxic to fish and aquatic invertebrates at recommended use rates for control of snails in aquaculture ponds | | NA | | | | | | | | | | |
| 76 | **Pheromones** | | Repellant and Attractant Pheromones | Y | Experimental | | • Under investigation as an attractant and/or deterrent for silver carp (*H. molitrix* ), bighead carp (*H. nobilis* ), black carp (*M. piceus* ), and sea lamprey (*P. marinus* ) | T | NA | | | | | | | | | | |
| 77 | **Piscicides** § | | Antimycin A<br>CAS #: 1397-94-0 | N | Available, Registered, Restricted Use Product* | | • Effectiveness can vary with the surfactant used.<br>• Requires approximately 8 to 32 hours to kill cyprinid species such as bighead carp (H. nobilis) and silver carp (H. molitrix)<br>• Restricted use pesticide due to aquatic toxicity and need for highly specialized applicator training | | NA | | | | | | | | | | |

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# Red Algae

| | A | B | C | D | E | F | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 78 | | Niclosamide<br>CAS #: 1420-04-8 | | N | Available, Registered, Restricted Use Product* | | • First developed as a lampricide<br>• Toxic to aquatic invertebrates; non-target organisms may be killed at rates recommended for sea lamprey control<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by United States Department of Interior, United States Fish & Wildlife Service (USFWS), state fish and game, Fisheries and Oceans Canada, and Provincial Certified Applicators trained in sea lamprey control<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 79 | | Rotenone (Both Standard Application and Via Oral Delivery Platforms)<br>CAS #: 83-79-4 | | N | Available, Registered, Restricted Use Product* | | • Kills bighead (*H. nobilis* ) carp and silver carp (*H. molitrix* ) within approximately 4 hours<br>• May be toxic to other aquatic organisms<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 80 | | TFM (3-Trifluoromethyl-4-nitrophenol)<br>CAS #: 88-30-2 | | N | Available, Registered, Restricted Use Product* | | • Designed only to control sea lamprey (*P. marinus* )<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by certified applicators of USFWS, Fisheries and Oceans Canada, and provincial and state fish and game employees<br>• Non-target organisms may be killed at labeled use rates<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 81 | **Screens** | Non-Mechanical Screens | Fences | N | Available | | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent movement of non-target | | NA | | | | | | | | | | |
| 82 | | | Bar Screens | N | Available | | | | NA | | | | | | | | | | |
| 83 | | | Trash Racks | N | Available | | | | NA | | | | | | | | | | |
| 84 | | | Curtains | N | Available | | | | NA | | | | | | | | | | |
| 85 | | Mechanical Screens | Chain Bar Screens | N | Available | | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent the movement of non-target organisms, depending on their size | | NA | | | | | | | | | | |
| 86 | | | Reciprocating Rake Bar Screens | N | Available | | | | NA | | | | | | | | | | |
| 87 | | | Catenary Bar Screens | N | Available | | | | NA | | | | | | | | | | |
| 88 | | | Continuous Belt Bar Screens | N | Available | | | | NA | | | | | | | | | | |
| 89 | | | Rotating Drum Screens (Paddle Wheel Or Power) | N | Available | | | | NA | | | | | | | | | | |
| 90 | | | Wedge-Wire Cylinders | N | Available | | | | NA | | | | | | | | | | |
| 91 | | | Louvered Screens | N | Available | | | | NA | | | | | | | | | | |
| 92 | | | Mechanical Climber Screens | N | Available | | | | NA | | | | | | | | | | |
| 93 | | Filters | | N | Available | X | • Generally used to treat small volumes of water<br>• Constrained by resistance through filter membrane and filter fouling<br>• Filters may prevent the movement of non-target organisms, depending on their size | | NA | Y | 15.5 micrometers spore size | Y | 75 micrometer diameter filaments | Y | Y | | | | |
| 94 | **Sensory Deterrent Systems** | Underwater Strobe lights | | N | Experimental | | • Used to prevent upstream movement of fish<br>• May not prevent downstream movement of aquatic organisms | A | NA | | | | | | | | | | |
| 95 | | Underwater Sound | | N | Experimental | | | A | NA | | | | | | | | | | |
| 96 | | Acoustic Air Bubble Curtain | | N | Experimental | | | A | NA | | | | | | | | | | |
| 97 | | Electric Barrier | | N | Available | | • Must be configured to stop upstream and downstream movement of fish<br>• May impact non-target aquatic organisms | A | NA | | | | | | | | | | |

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# Red Algae

| | A | B | C | D | E | F | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 98 | **Ultrasound** | Ultrasound | | N | Available | X | • Used in small water bodies and water treatment plants<br>• Ultrasound may be effective on diatoms (*S. binderanus* )<br>• Most effective on enclosed bodies of water<br>• Additional research may be needed to investigate potential impacts on non-target organisms<br>• Under investigation for use against aquatic vascular plants (non-algae)<br>• Requires continuous application to maintain effectiveness | | NA | N | Not effective on spores | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 99 | **Ultraviolet Light** | Ultraviolet (UV) Light | | N | Available | X | • Used in fish hatcheries and water treatment facilities<br>• Used to treat contained flowing systems<br>• Best used after suspended solids, iron and manganese have been filtered from water<br>• May impact non-target aquatic organisms<br>• Under investigation for use against aquatic vascular plants (non-algae) | | NA | M | Future research is needed to determine if this species' spores are susceptible to this technology | Y | | Y | Y | | | | |

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# Diatom

| | A | B–C | D | E | F | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Fact Sheet | ANS Control | Selective for ANS of Concern – CAWS | Status [2] | algae | Comments<br>Refer to fact sheets for additional information on each Control | Level of R&D | Biocides for Industrial Use - Conventional, municipal drinking water or wastewater treatment technologies | Effective on Diatom | Comments | Effective with Downstream Flow | Effective with Upstream Flow | Effective on Diatom adhered to boat hulls | Comments | Effective on Diatom in ballast water | Comments |
| 3 | **Accelerated Water Velocity** | Accelerated Water Velocity | N | Available | X | • Not effective in preventing downstream ANS movement<br>• Must have a length and speed of flow greater than the organism's leaping ability and swimming endurance | | NA | Y | | N | Y | | | | |
| 4 | **Acoustic Fish Deterrents** | Continuous Wave | N | Experimental | | • Under development for control of fish<br>• May not be effective on all fish species | T | NA | | | | | | | | |
| 5 | | Pulsed Pressure Wave | N | Experimental | | • Not lethal unless an organism is very close to sound source | A | NA | | | | | | | | |
| 6 | **Algaecides** § | Copper Sulfate and Chelated Copper Formulations (ethanolamines, ethylene diamines, triethanolamines, triethanolamine+ethylene diamine, and copper citrate/gluconate) | N | Available, Registered | X | • May be effective on diatoms (*S. binderanus* ) and grass kelp (*Enteromorpha flexuosa* )<br>• Chelated copper formulations may be effective on red macro-algae (Bangia atropupurea)<br>• Reduced efficacy in waters with high pH and water temperatures < 15 °C<br>• Effectiveness dependent upon dose and exposure<br>• Minimum exposure requirement is 1 to 3 hours | | NA | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 7 | | Endothall (as the mono(N,N-dimethylalkylamine) salt)<br>CAS #: 66330-88-9 | N | Available, Registered | X | • May be effective on red macro-algae (*B. atropupurea* ) and diatoms (*S. binderanus* )<br>• Can be harmful to fish<br>• Effectiveness dependent upon dose and exposure<br>• Minimum exposure requirement is 3 to 8 hours | | NA | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 8 | | Algaecides containing Sodium Carbonate Peroxyhydrate<br>CAS #: 15630-89-4 | N | Available, Registered | X | • May be effective on diatoms (*S. binderanus* ), and grass kelp (*E. flexuosa* )<br>• Effectiveness dependent upon dose and exposure<br>• Minimum exposure requirement is 1 to 3 hours | | NA | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 9 | **Alteration of Water Quality** §<br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/10/2011. The Chemical Abstracts Service | Carbon Dioxide ($CO_2$) | N | Available, When Not Registered for a Use | | • May repel fish at sub-lethal levels<br>• Lowers pH<br>• Creates irreversible cell damage and death<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |

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# Diatom

| | A | B | C | D | E | F | N | O | P | Q | R | S | T | U | V | W | X |
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| 10 | (CAS) numbers were used to enter the query and for convenience have been provided. | Gases | Ozone | N | Available | X | • Rendered ineffective in the presence of organic matter<br>• Used commercially to decontaminate water<br>• Ozone oxidation is toxic to most small waterborne organisms<br>• Destroys the epithelium covering the gill lamella in fish<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | NA | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 11 | | | Nitrogen | N | Available | | • Adult fish are more tolerant than young fish<br>• Nitrogen supersaturation is a cause of gas bubble disease in fish<br>• Effectiveness dependent upon dose and exposure<br>• Not effective on eggs | | NA | | | | | | | | |
| 12 | | Solids | Alum | N | Available | X | • Creates a solid precipitate from suspended solids within the water column which settles<br>• Alum is not classified as a pesticide, therefore does not require FIFRA registration<br>• Effectiveness dependent upon dose and exposure | | NA | Y | | Y | Y | | | | |

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# Diatom

| | A | B | C | D | E | F | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | | | Sodium Thiosulfate CAS #: 7772-98-7 | N | Experimental | | • Deoxygenated compound • Effectiveness dependent upon dose and exposure | T | NA | | | | | | | | |
| 14 | **Aquatic Herbicides** § The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/13/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided | 2,4-D (both the amine and butoxy-ethyl ester formulations) CAS #: 94-75-7 | | N | Available, Registered | | • Tank mixing with other herbicides improves plant control • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 15 | | Diquat CAS #: 85-00-7 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 16 | | Fluridone CAS #: 59756-60-4 | | N | Available, Registered | | • Plants must be exposed to a lethal dose for a minimum of 45 days for optimal results • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 17 | | Glyphosate CAS #: 1071-83-6 | | N | Available, Registered | | • May be effective on reed sweetgrass (Glyceria maxima) • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 18 | | Imazapyr CAS #: 81334-34-1 | | N | Available, Registered | | • May be effective on reed sweetgrass (*G. maxima* ) • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 19 | | Triclopyr CAS #: 55335-06-3 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 20 | | | | | | | | | NA | | | | | | | | |
| 21 | **Benthic Barriers** | Textile or Plastic | | N | Available | | | | NA | | | | | | | | |
| 22 | | Silt | | N | Available | | • Created by applying excessive silt/sand to smother bottom-dwelling organism • Application to control aquatic nuisance species has not been widely studied | | NA | | | | | | | | |
| 27 | **Biocides for Industrial Use** § Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004) | Chlorine (free chlorine, hypochlorous acid, hypochlorite salts) CAS #: 7782-50-5 | | N | When Not Registered for a Use | X | • Residuals remain in water after treatment • Requires frequent applications • Effectiveness dependent upon dose and exposure • Effective on algal spores | | Y | Y | | | | | | | |
| 28 | | Chlorine Dioxide CAS #: 10049-04-4 | | N | When Not Registered for a Use | | • Effectiveness dependent upon dose and exposure | | Y | | | | | | | | |
| 34 | **Biocides for Industrial Use** § **(continued)** Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004) The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided. Manufacturers and products mentioned are examples only. Nothing contained herein | Hydrogen Peroxide CAS #: 7722-84-1 CAS #: 79-21-0 | | N | When Not Registered for a Use | X | • Disinfection of drinking water, cooling systems and surfaces • Presence of organic matter limits effectiveness • Moderately corrosive • Some residuals remain in water after treatment • Effective on algal spores | | Y | Y | | | | | | | |
| 38 | | Peracetic Acid (Peraclean®) CAS #: 79-21-0 CAS #: 7722-84-1 | | N | When Not Registered for a Use | | • No known toxic residual; more potent than hydrogen peroxide • Rapidly active at low concentrations against a wide range of microorganisms • Corrosive • Highly efficient in presence of organic matter • Wastewater treatment | | Y | | | | | | | | |
| 41 | **Biocides for Industrial Use §** **(continued)** Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) | Potassium Permanganate CAS #: 7722-64-7 | | N | Experimental | X | • Organic matter limits effectiveness & moderately corrosive • Some residuals remain in water after treatment • Effectiveness dependent upon dose and exposure | A | Y | M | Future research is needed to determine if this species is susceptible to this technology | | | | | | |

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# Diatom

| | A | B/C | D | E | F | N | O | P | Q | R | S | T | U | V | W | X |
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| 44 | Washington, DC, 2004)<br><br>The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Sodium Chlorite<br>CAS #: 7758-19-2 | N | When Not Registered for a Use | X | • Disinfection of drinking water, cooling systems and surfaces<br>• Presence of organic matter limits effectiveness<br>• Residuals remain in water after treatment<br>• Requires frequent applications and corrosive<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | Y | Y | | | | | | | |
| 45 | | Sodium Hydroxide [B, GS]<br>CAS #: 1310-73-2 | N | When Not Registered for a Use | X | • Under consideration for use in ballast water treatment<br>• <1% survival of test organisms including algae, annelids, crustaceans and fish with 48-hr exposure to pH adjustments of 11.5 to 12.5 using NaOH (TenEyek, M. 2009. Great Ships Initiative Bench-Scale Test Findings, Technical Report – Public, Sodium Hydroxide (NaOH). GSI/BS/5.) | | Y | M | Future research is needed to determine if this species is susceptible to this technology | | | | | | |
| 48 | **Biological Controls** § | Introduced Predatory Fish Species | N | Available | | • Includes both carnivorous and herbivorous fish species<br>• Best used in waters with no outflows<br>• Predatory fish are non-selective feeders and may eat native species<br>• Predatorsare size selective feeders and may not eat eggs or larger organisms | | NA | | | | | | | | |
| 49 | | Introduced Predatory Insect Species | N | Experimental | | • United States Department of Agriculture (USDA) has not approved of any insects for use as biological controls of plants identified as ANS of Concern – CAWS<br>• Predators may be selective feeders (may not eat seeds) | T | NA | | | | | | | | |
| 50 | | *Pseudomonas fluorescens* CL 145A | N | Registered | | • Active ingredient (Pseudomonas fluorescens CL 145A) approved by the United States Environmental Protection Agency (USEPA) in July 2011(Reg. No. 84059-4)<br>• Formulation of commercial product as Zequanox™ is pending review by USEPA as of October 2010; Section 3 registration expected in March 2012<br>• Ongoing research to assess impacts to non-target mollusks | | NA | | | | | | | | |
| 51 | | Targeted Disease Agents | N | Experimental | | • Under consideration for carp species | T | NA | | | | | | | | |
| 52 | **Controlled Harvest and Overfishing** | Controlled Harvest and Overfishing | N | Available | | • Requires sorting and returning of native fish species<br>• Requires continual capture over a long period of time, or intensive harvest during critical periods of concentration and reproduction (e.g., migration and spawning season)<br>• Once harvesters, processors, and communities become economically dependent on harvesting nuisance fish, pressure to manage a sustainable population of these fish may conflict with the original purpose of removing them from the environment<br>• Typically for organisms larger than eggs and larvae. | | NA | | | | | | | | |

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# Diatom

| | A | B | C | D | E | F | N | O | P | Q | R | S | T | U | V | W | X |
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| 53 | **Deleterious Gene Spread** | Daughterless Gene | | Y | Experimental | | • Researched as a Control for silver carp (*H. molitrix*), bighead carp (*H. nobilis*), black carp (*Mylopharyngodon piceus*), and sea lamprey (*Petromyzon marinus*)<br>• Researched as a Control for common carp<br>• Manipulation of genes can manifest unforeseen and significant undesirable side effects and would require extensive research before being accepted as a Control | T | NA | | | | | | | | |
| 54 | | Trojan Y Chromosome | | Y | Experimental | | • The Food and Drug Administration regulates genetically engineered animals | T | NA | | | | | | | | |
| 55 | **Dredging and Diver Dredging** | Dredging and Diver Dredging | | N | Available | | • Requires careful disposal or reuse of dredged material to prevent the transfer of ANS to a new location<br>• May remove other ANS of Concern – CAWS and non-target organisms that reside in sediment | | NA | | | | | | | | |
| 56 | **Electron Beam Irradiation** | Electron Beam Irradiation | | N | Available | | • Used in irradiation of food, environmental waste, medical sterilization, and water treatment<br>• Requires a closed system and not appropriate for open water application<br>• May require pretreatment to remove suspended solids<br>• Used in irradiation of food, environmental waste, medical sterilization, and water treatment | | NA | | | | | | | | |
| 57 | **Hydrologic Separation** | Physical Barriers | | N | Available | X | • Modifies flow within waterway, including stormwater and combined sewer overflow discharge, and conveyance and commercial water dischargers and withdrawal of water<br>• Must be designed to handle storm flows. | | NA | Y | | Y | Y | | | | |
| 58 | **Irrigation Water Chemicals** § | Acrolein<br>CAS #: 107-02-8 | | N | Available, Registered, Restricted Use Product* | X | • For control of submersed and floating weeds and algae only in irrigation canal systems in western states, provided the appropriate state registrations are also in place<br>• Toxic to fish and other aquatic organisms at labeled use rates<br>• Effectiveness dependent upon dose and exposure<br>• Minimum exposure requirement is 1 to 3 hours | | NA | Y | | Y | Y | | | | |
| 59 | | Xylene<br>CAS #: 1330-20-7 | | N | Registered | X | • For use only in irrigation and drainage canals designated by the Bureau of Reclamation and cooperating water user organizations<br>• For use in Programs of the Bureau of Reclamation and Cooperating Water User Organizations within the following states, provided that the appropriate state registrations are also in place: AZ, CA, CO, ID, KS, MT, NE, NM, NV, ND, OK, OR, SD, TX, UT, WA, and WY<br>• For control of submerged weeds in irrigation and drainage canals<br>• Toxic to fish and other aquatic organisms at labeled use rates<br>• Effectiveness dependent upon dose and exposure<br>• Minimum exposure requirement is 1 to 3 hours | | NA | Y | | Y | Y | | | | |

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# Diatom

Removed During Nov 2012 ANS Controls Screening Charette

| | A | B | C | D | E | F | N | O | P | Q | R | S | T | U | V | W | X |
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| 60 | **Lethal Temperature** | Pressurized Hot Water/Steam Treatment | | N | Available | X | • Hot water has been used to kill zebra and quagga mussels at municipal and industrial facilities, and high pressure hot water is used to clean ANS off of recreational boats<br>• Treated area (i.e. boat hull) must be above the surface. | | NA | Y | Requires proper treatment of wash water | Y | Y | | | | |
| 61 | | Hot Water Thermal Barrier | | N | Available | X | • Difficult to manage in open water system, must be completely mixed throughout the water column | | | | | | | | | | |
| 62 | | Freezing | | N | Available | X | air temperatures<br>• Cluster mussels are more tolerant of reduced air temperatures than individual organisms<br>• Can be applied to static water. | | NA | Y | | Y | Y | | | | |
| 63 | | Carbon Dioxide ($CO_2$) Pellet (dry ice) Blasting | | N | Available | X | • Method used extensively to remove organics from aircrafts producing no deterioration of surfaces<br>• CO2 pellets convert to a gas at ambient temperatures, leaving no residue.<br>• Treated area (i.e. boat hull) must be above the surface | | NA | Y | Requires proper treatment of material | Y | Y | | | | |
| 64 | | Desiccation | | N | Available | X | • Desiccation can only be achieved in areas where water levels can be controlled<br>• Exposure to air quickly leads to death for active water-breathing organism—mollusks and plants are more tolerant and require longer drying period | | NA | Y | | Y | Y | | | | |
| 65 | **Light Attenuating Dyes** § | Light Attenuating Dyes | | N | Registered | X | • Not effective for suppressing growth of floating aquatic plants or emergent shoreline vegetation identified as ANS of Concern – CAWS<br>• Not effective on floating algal mats<br>• May suppress the growth of non-target plants and algae<br>• Only for use in contained waterbodies with little or no outflow<br>• Do not apply to waters used for human consumption | | NA | N | Only able to suppress growth | | | | | | |
| 66 | **Manual Harvest** | Manual Harvest | | Y | Available | | • Labor-intensive<br>• Selectively dependent upon training and skill of staff | | NA | | | | | | | | |
| 67 | **Mechanical Control Methods** | Mechanical Harvesting | | N | Available | | • May disturb non-target organisms in equipment path | | NA | | | | | | | | |
| 68 | | Shredding | | N | Available | | | | NA | | | | | | | | |
| 69 | | Mowing | | N | Available | | | | NA | | | | | | | | |
| 70 | | Chaining | | N | Available | | | | NA | | | | | | | | |
| 71 | | Roto-tilling | | N | Available | | | | NA | | | | | | | | |
| 72 | | Rotovating | | N | Available | | • Used for submersed vegetation rooted in the substrate<br>• May have applications on emergent plants<br>• May disturb non-target organisms in equipment path | | NA | | | | | | | | |
| 73 | **Molluscicides** § | Quaternary and Polyquaternary Ammonium Compounds; Aromatic Hydrocarbons; Endothall as the Mono (N,N-imethylalkylamine) Salt (TD2335 Industrial Biocide-Molluscicide) | | N | Registered | | • Used for recirculating and once-through cooling water systems<br>• For control of established populations of freshwater and saltwater mollusks in closed systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | |

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| 74 | | Metals and their salts (Copper Sulfate and Chelated Copper Formulations) | | N | Registered | | • Can be used to control mollusks in open water systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | |
| 75 | | Niclosamide CAS #: 1420-04-8 | | N | Available, Registered, Restricted Use Product* | | • First developed as a lampricide<br>• Used for control of snails in aquaculture ponds<br>• Toxic to fish and aquatic invertebrates at recommended use rates for control of snails in aquaculture ponds | | NA | | | | | | | | |
| 76 | **Pheromones** | Repellant and Attractant Pheromones | | Y | Experimental | | • Under investigation as an attractant and/or deterrent for silver carp (*H. molitrix* ), bighead carp (*H. nobilis* ), black carp (*M. piceus* ), and sea lamprey (*P. marinus* ) | T | NA | | | | | | | | |
| 77 | **Piscicides** § | Antimycin A CAS #: 1397-94-0 | | N | Available, Registered, Restricted Use Product* | | • Effectiveness can vary with the surfactant used.<br>• Requires approximately 8 to 32 hours to kill cyprinid species such as bighead carp (H. nobilis) and silver carp (H. molitrix)<br>• Restricted use pesticide due to aquatic toxicity and need for highly specialized applicator training | | NA | | | | | | | | |
| 78 | | Niclosamide CAS #: 1420-04-8 | | N | Available, Registered, Restricted Use Product* | | • First developed as a lampricide<br>• Toxic to aquatic invertebrates; non-target organisms may be killed at rates recommended for sea lamprey control<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by United States Department of Interior, United States Fish & Wildlife Service (USFWS), state fish and game, Fisheries and Oceans Canada, and Provincial Certified Applicators trained in sea lamprey control<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 79 | | Rotenone (Both Standard Application and Via Oral Delivery Platforms) CAS #: 83-79-4 | | N | Available, Registered, Restricted Use Product* | | • Kills bighead (*H. nobilis* ) carp and silver carp (*H. molitrix* ) within approximately 4 hours<br>• May be toxic to other aquatic organisms<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 80 | | TFM (3-Trifluoromethyl-4-nitrophenol) CAS #: 88-30-2 | | N | Available, Registered, Restricted Use Product* | | • Designed only to control sea lamprey (*P. marinus* )<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by certified applicators of USFWS, Fisheries and Oceans Canada, and provincial and state fish and game employees<br>• Non-target organisms may be killed at labeled use rates<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 81 | **Screens** | Non-Mechanical Screens | Fences | N | Available | | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent movement of non-target | | NA | | | | | | | | |
| 82 | | | Bar Screens | N | Available | | | | NA | | | | | | | | |
| 83 | | | Trash Racks | N | Available | | | | NA | | | | | | | | |
| 84 | | | Curtains | N | Available | | | | NA | | | | | | | | |
| 85 | | Screens | Chain Bar Screens | N | Available | | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or | | NA | | | | | | | | |
| 86 | | | Reciprocating Rake Bar Screens | N | Available | | | | NA | | | | | | | | |
| 87 | | | Catenary Bar Screens | N | Available | | | | NA | | | | | | | | |
| 88 | | | Continuous Belt Bar Screens | N | Available | | | | NA | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 89 | | Mechanical | Rotating Drum Screens (Paddle Wheel Or Power) | N | Available | | • Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent the movement of non-target organisms, depending on their size | | NA | | | | | | | | |
| 90 | | | Wedge-Wire Cylinders | N | Available | | | | NA | | | | | | | | |
| 91 | | | Louvered Screens | N | Available | | | | NA | | | | | | | | |
| 92 | | | Mechanical Climber Screens | N | Available | | | | NA | | | | | | | | |
| 93 | | Filters | | N | Available | X | • Generally used to treat small volumes of water<br>• Constrained by resistance through filter membrane and filter fouling<br>• Filters may prevent the movement of non-target organisms, depending on their size | | NA | Y | 830 cubic micrometers | Y | Y | | | | |
| 94 | **Sensory Deterrent Systems** | Underwater Strobe lights | | N | Experimental | | • Used to prevent upstream movement of fish<br>• May not prevent downstream movement of aquatic organisms | A | NA | | | | | | | | |
| 95 | | Underwater Sound | | N | Experimental | | | A | NA | | | | | | | | |
| 96 | | Acoustic Air Bubble Curtain | | N | Experimental | | | A | NA | | | | | | | | |
| 97 | | Electric Barrier | | N | Available | | • Must be configured to stop upstream and downstream movement of fish<br>• May impact non-target aquatic organisms | A | NA | | | | | | | | |
| 98 | **Ultrasound** | Ultrasound | | N | Available | X | • Used in small water bodies and water treatment plants<br>• Ultrasound may be effective on diatoms (*S. binderanus* )<br>• Most effective on enclosed bodies of water<br>• Additional research may be needed to investigate potential impacts on non-target organisms<br>• Under investigation for use against aquatic vascular plants (non-algae)<br>• Requires continuous application to maintain effectiveness | | NA | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 99 | **Ultraviolet Light** | Ultraviolet (UV) Light | | N | Available | X | • Used in fish hatcheries and water treatment facilities<br>• Used to treat contained flowing systems<br>• Best used after suspended solids, iron and manganese have been filtered from water<br>• May impact non-target aquatic organisms<br>• Under investigation for use against aquatic vascular plants (non-algae) | | NA | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 100 | **Vertical Drop Barrier** | Vertical Drop Barrier | | N | Available | | • Does not prevent aquatic organism movement downstream<br>• May impact upstream movement of non-target organisms | | NA | | | | | | | | |
| 101 | **Williams' Cage**<br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Williams' Cage | | Y | Experimental | | • May be effective on silver carp *(H. molitrix)* and sea lamprey *(P. marinus)*<br>• Does not prevent aquatic organism movement downstream | A | NA | | | | | | | | |

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# Reed Sweetgrass

| | A | B | C | D | E | L | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Fact Sheet | ANS Control | | Selective for ANS of Concern – CAWS | Status [2] | plant | Comments<br>Refer to fact sheets for additional information on each Control | Level of R&D | Biocides for Industrial Use - Conventional, municipal drinking water or wastewater treatment technologies | Effective on Reed Sweetgrass (seeds in water) | Comments on Seeds in Water | Effective on Reed Sweetgrass (root or rhizome fragment in water) | Comments on Root or Rhizome fragment in Water | Effective on Reed Sweetgrass (rooted plant) | Comments on Rooted Plant | Effective with Downstream Flow | Effective with Upstream Flow |
| 3 | **Accelerated Water Velocity** | Accelerated Water Velocity | | N | Available | X | • Not effective in preventing downstream ANS movement<br>• Must have a length and speed of flow greater than the organism's leaping ability and swimming endurance | | NA | Y | | Y | | Y | | N | Y |
| 4 | **Acoustic Fish Deterrents** | Continuous Wave | | N | Experimental | | • Under development for control of fish<br>• May not be effective on all fish species | T | NA | | | | | | | | |
| 5 | | Pulsed Pressure Wave | | N | Experimental | | • Not lethal unless an organism is very close to sound source | A | NA | | | | | | | | |
| 6 | **Algaecides** § | Copper Sulfate and Chelated Copper Formulations (ethanolamines, ethylene diamines, triethanolamines, triethanolamine+ethylene diamine, and copper citrate/gluconate) | | N | Available, Registered | | • May be effective on diatoms (*S. binderanus* ) and grass kelp (*Enteromorpha flexuosa* )<br>• Chelated copper formulations may be effective on red macro-algae (Bangia atropupurea)<br>• Reduced efficacy in waters with high pH and water temperatures < 15 °C<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 7 | | Endothall (as the mono(N,N-dimethylalkylamine) salt)<br>CAS #: 66330-88-9 | | N | Available, Registered | | • May be effective on red macro-algae (*B. atropupurea* ) and diatoms (*S. binderanus* )<br>• Can be harmful to fish<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 8 | | Algaecides containing Sodium Carbonate Peroxyhydrate<br>CAS #: 15630-89-4 | | N | Available, Registered | | • May be effective on diatoms (*S. binderanus* ), and grass kelp (*E. flexuosa* )<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 9 | **Alteration of Water Quality** §<br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/10/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided. | Gases | Carbon Dioxide ($CO_2$) | N | Available, When Not Registered for a Use | | • May repel fish at sub-lethal levels<br>• Lowers pH<br>• Creates irreversible cell damage and death<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 10 | | | Ozone | N | Available | | • Rendered ineffective in the presence of organic matter<br>• Used commercially to decontaminate water<br>• Ozone oxidation is toxic to most small waterborne organisms<br>• Destroys the epithelium covering the gill lamella in fish<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 11 | | | Nitrogen | N | Available | | • Adult fish are more tolerant than young fish<br>• Nitrogen supersaturation is a cause of gas bubble disease in fish<br>• Effectiveness dependent upon dose and exposure<br>• Not effective on eggs | | NA | | | | | | | | |

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# Reed Sweetgrass

| | A | B | C | D | E | L | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | | Solids | Alum | N | Available | | • Creates a solid precipitate from suspended solids within the water column which settles<br>• Alum is not classified as a pesticide, therefore does not require FIFRA registration<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 13 | | | Sodium Thiosulfate<br>CAS #: 7772-98-7 | N | Experimental | | • Deoxygenated compound<br>• Effectiveness dependent upon dose and exposure | T | NA | | | | | | | | |
| 14 | **Aquatic Herbicides** § | 2,4-D (both the amine and butoxy-ethyl ester formulations)<br>CAS #: 94-75-7 | | N | Available, Registered | X | • Tank mixing with other herbicides improves plant control<br>• Effectiveness dependent upon dose and exposure | | NA | N | Not effective on seeds | N | Not effective on this species | N | Not effective on this species | | |
| 15 | The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/13/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided | Diquat<br>CAS #: 85-00-7 | | N | Available, Registered | X | • Effectiveness dependent upon dose and exposure | | NA | N | Not effective on seeds | N | Not effective on root or rhizome fragments | N | Herbicide will not kill underground roots/rhizomes of perennial plants; recovery/re-growth of plants will occur | | |
| 16 | | Fluridone<br>CAS #: 59756-60-4 | | N | Available, Registered | X | • Plants must be exposed to a lethal dose for a minimum of 45 days for optimal results<br>• Effectiveness dependent upon dose and exposure | | NA | N | Not effective on seeds | N | Not effective on root or rhizome fragments | N | Not effective on emergent plant species | | |
| 17 | | Glyphosate<br>CAS #: 1071-83-6 | | N | Available, Registered | X | • May be effective on reed sweetgrass (Glyceria maxima)<br>• Effectiveness dependent upon dose and exposure<br>• Avoid wash-off of sprayed foliage for 6 hours after application | | NA | N | Not effective on seeds | N | Herbicide cannot be applied directly to water and is ineffective in water | Y | | Y | Y |
| 18 | | Imazapyr<br>CAS #: 81334-34-1 | | N | Available, Registered | X | • May be effective on reed sweetgrass (*G. maxima* )<br>• Effectiveness dependent upon dose and exposure<br>• Avoid wash-off of sprayed foliage for 1 hour after application | | NA | N | Not effective on seeds | N | Herbicide cannot be applied directly into water | Y | | Y | Y |
| 19 | | Triclopyr<br>CAS #: 55335-06-3 | | N | Available, Registered | X | • Effectiveness dependent upon dose and exposure | | NA | N | Not effective on seeds | N | Not effective on this species | N | Not effective on this species | | |
| 20 | | | | | | | | | NA | | | | | | | | |
| 21 | **Benthic Barriers** | Textile or Plastic | | N | Available | X | | | NA | N | Barrier only controls those seeds which are present at time of barrier placement | N | Will not affect floating root/rhizome fragments | N | | | |
| 22 | | Silt | | N | Available | | • Created by applying excessive silt/sand to smother bottom-dwelling organism<br>• Application to control aquatic nuisance species has not been widely studied | | NA | | | | | | | | |
| 23 | **Biocides for Industrial Use** § | Isothiazolone<br>(Sea-Nine®)<br>CAS #: 64359-81-5 | | N | When Not Registered for a Use | | • Antifouling agent used in hull coatings<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 24 | Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for | 2-(thiocyanomethylthio) benzothiazole (TCMTB)<br>CAS #: 21564-17-0 | | N | When Not Registered for a Use | | • Antifouling agent<br>• Disinfection of industrial water systems<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |

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# Reed Sweetgrass

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| 25 | Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br><br>The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Benzalkonium Chloride<br>CAS #: 8001-54-5 | N | When Not Registered for a Use | | • Corrosive<br>• Disinfection of industrial water systems<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 26 | | Bromine<br>CAS #: 7726-95-6 | N | When Not Registered for a Use | | • Purification of drinking water, cooling systems, and surfaces<br>• Corrosive<br>• Requires a controlled application; reacts quickly<br>• Effectiveness dependent upon dose and exposure<br>• Presence of organic matter limits effectiveness | | N | | | | | | | | |
| 27 | | Chlorine (free chlorine, hypochlorous acid, hypochlorite salts)<br>CAS #: 7782-50-5 | N | When Not Registered for a Use | | • Residuals remain in water after treatment<br>• Requires frequent applications<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | Y | | | | | | | | |
| 28 | | Chlorine Dioxide<br>CAS #: 10049-04-4 | N | When Not Registered for a Use | | • Effectiveness dependent upon dose and exposure | | Y | | | | | | | | |
| 29 | | Chlorothalonil<br>CAS #: 1897-45-6 | N | When Not Registered for a Use | | • Registered under FIFRA as a fungicide<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 30 | | Dibromonitrilopropionamide (DBNPA)<br>CAS #: 10222-01-2 | N | When Not Registered for a Use | | • Pulp and paper water treatment systems<br>• Disinfection of industrial water systems<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 31 | | Dichlofluanid<br>CAS #: 1085-98-9 | N | Experimental | | • Antifouling agent<br>• Effectiveness dependent upon dose and exposure | A | N | | | | | | | | |
| 32 | | N-(3-Chloroallyl) Hexamethylenetetrmine chloroallyl chloride<br>(Dowicil® 75) | N | When Not Registered for a Use | | • Not persistent and degrades rapidly under acidic conditions<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 33 | | Glutaraldehyde<br>CAS #: 111-30-8 | N | When Not Registered for a Use | | • Slight to moderate efficiency in presence of organic matter<br>• Some residuals remain in water after treatment<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 34 | **Biocides for Industrial Use § (continued)**<br><br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br><br>The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Hydrogen Peroxide<br>CAS #: 7722-84-1<br>CAS #: 79-21-0 | N | When Not Registered for a Use | | • Disinfection of drinking water, cooling systems and surfaces<br>• Presence of organic matter limits effectiveness<br>• Moderately corrosive<br>• Some residuals remain in water after treatment<br>• Effective on algal spores | | Y | | | | | | | | |
| 35 | | Iodine<br>CAS #: 7553-56-2 | N | When Not Registered for a Use | | • Disinfection of drinking water, cooling systems and surfaces<br>• Requires a controlled application and reacts quickly<br>• Corrosive<br>• Presence of organic matter limits effectiveness<br>• Residuals remain in water after treatment<br>• Requires frequent applications<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 36 | | 2-methylthio-4-tertbutylamino-6-cyclo-propylamino-striazine (Irgarol®) CAS #: 28159-98-0 | N | When Not Registered for a Use | | • Antifouling agent<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 37 | | Fatty Amines<br>(Mexel® 432) | N | Experimental | | • Rapid degradation in the environment<br>• Scale dispersant & corrosion inhibitor<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |

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# Reed Sweetgrass

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| 38 | | Peracetic Acid (Peraclean®)<br>CAS #: 79-21-0<br>CAS #: 7722-84-1 | | N | When Not Registered for a Use | | • No known toxic residual; more potent than hydrogen peroxide<br>• Rapidly active at low concentrations against a wide range of microorganisms<br>• Corrosive<br>• Highly efficient in presence of organic matter<br>• Wastewater treatment | | Y | | | | | | | | |
| 39 | | Phenol<br>CAS #: 108-95-2 | | N | When Not Registered for a Use | | • Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 40 | **Biocides for Industrial Use § (continued)** | Polyhexamethylene Biguanide (PHMB) CAS #: 32289-58-0 | | N | When Not Registered for a Use | | • Disinfection of industrial water systems<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 41 | Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br><br>The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Potassium Permanganate<br>CAS #: 7722-64-7 | | N | Experimental | | • Organic matter limits effectiveness & moderately corrosive<br>• Some residuals remain in water after treatment<br>• Effectiveness dependent upon dose and exposure | A | Y | | | | | | | | |
| 42 | | Vitamin K<br>(SeaKleen®)<br>CAS #: 11032-49-8 | | N | Experimental | | • Ballast water treatment<br>• Toxic to a broad spectrum of marine and freshwater organisms (fish larvae and eggs, planktonic crustaceans, bivalve larvae, Vibrio bacteria, and dinoflagellates)<br>• Effectiveness dependent upon dose and exposure | A | N | | | | | | | | |
| 43 | | Silver (Ionic or Salts)<br>Ions CAS #: 15046-91-0 | | N | Experimental | | • Disinfection of industrial water systems<br>• Limited applications of metal ions or salts<br>• Not generally used due to human side effect risk<br>• Effectiveness dependent upon dose and exposure | A | N | | | | | | | | |
| 44 | | Sodium Chlorite<br>CAS #: 7758-19-2 | | N | When Not Registered for a Use | | • Disinfection of drinking water, cooling systems and surfaces<br>• Presence of organic matter limits effectiveness<br>• Residuals remain in water after treatment<br>• Requires frequent applications and corrosive<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | Y | | | | | | | | |
| 45 | | Sodium Hydroxide [B, GS]<br>CAS #: 1310-73-2 | | N | When Not Registered for a Use | | • Under consideration for use in ballast water treatment<br>• <1% survival of test organisms including algae, annelids, crustaceans and fish with 48-hr exposure to pH adjustments of 11.5 to 12.5 using NaOH (TenEyek, M. 2009. Great Ships Initiative Bench-Scale Test Findings, Technical Report – Public, Sodium Hydroxide (NaOH). GSI/BS/5.) | | Y | | | | | | | | |
| 46 | | Triclosan<br>CAS #: 3380-34-5 | | N | When Not Registered for a Use | | • Stable and incompatible with strong oxidizing agents<br>• Wastewater treatment<br>• Effectiveness dependent upon dose and exposure | | N | | | | | | | | |
| 47 | | Zineb (Thiocarbamate)<br>CAS #: 12122-67-7 | | N | Experimental | | • Antifouling agent & disinfection of industrial water systems<br>• Effectiveness dependent upon dose and exposure | A | N | | | | | | | | |
| 48 | **Biological Controls** § | Introduced Predatory Fish Species | | N | Available | X | • Includes both carnivorous and herbivorous fish species<br>• Best used in waters with no outflows<br>• Predatory fish are non-selective feeders and may eat native species<br>• Predatorsare size selective feeders and may not eat eggs or larger organisms | | NA | N | Not effective on seeds | N | Not effective on floating root or rhizome fragments | N | Herbivorous fish not effective on emergent plant species | | |

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| 49 | | Introduced Predatory Insect Species | | N | Experimental | X | • United States Department of Agriculture (USDA) has not approved of any insects for use as biological controls of plants identified as ANS of Concern – CAWS<br>• Predators may be selective feeders (may not eat seeds) | T | NA | N | | N | | N | | | |
| 50 | | *Pseudomonas fluorescens* CL 145A | | N | Registered | | • Active ingredient (Pseudomonas fluorescens CL 145A) approved by the United States Environmental Protection Agency (USEPA) in July 2011(Reg. No. 84059-4)<br>• Formulation of commercial product as Zequanox™ is pending review by USEPA as of October 2010; Section 3 registration expected in March 2012<br>• Ongoing research to assess impacts to non-target mollusks | | NA | | | | | | | | |
| 51 | | Targeted Disease Agents | | N | Experimental | | • Under consideration for carp species | T | NA | | | | | | | | |
| 52 | **Controlled Harvest and Overfishing** | Controlled Harvest and Overfishing | | N | Available | | • Requires sorting and returning of native fish species<br>• Requires continual capture over a long period of time, or intensive harvest during critical periods of concentration and reproduction (e.g., migration and spawning season)<br>• Once harvesters, processors, and communities become economically dependent on harvesting nuisance fish, pressure to manage a sustainable population of these fish may conflict with the original purpose of removing them from the environment<br>• Typically for organisms larger than eggs and larvae. | | NA | | | | | | | | |
| 53 | **Deleterious Gene Spread** | Daughterless Gene | | Y | Experimental | | • Researched as a Control for silver carp (*H. molitrix* ), bighead carp (*H. nobilis* ), black carp (*Mylopharyngodon piceus* ), and sea lamprey (*Petromyzon marinus* )<br>• Researched as a Control for common carp<br>• Manipulation of genes can manifest unforeseen and significant undesirable side effects and would require extensive research before being accepted as a Control | T | NA | | | | | | | | |
| 54 | | Trojan Y Chromosome | | Y | Experimental | | • The Food and Drug Administration regulates genetically engineered animals | T | NA | | | | | | | | |
| 55 | **Dredging and Diver Dredging** | Dredging and Diver Dredging | | N | Available | X | • Requires careful disposal or reuse of dredged material to prevent the transfer of ANS to a new location<br>• May remove other ANS of Concern – CAWS and non-target organisms that reside in sediment | | NA | N | Will not remove seeds from water | N | Will not affect floating root/rhizome fragments | N | Not effective on emergent plant species | | |
| 56 | **Electron Beam Irradiation** | Electron Beam Irradiation | | N | Available | | • Used in irradiation of food, environmental waste, medical sterilization, and water treatment<br>• Requires a closed system and not appropriate for open water application<br>• May require pretreatment to remove suspended solids<br>• Used in irradiation of food, environmental waste, medical sterilization, and water treatment | | NA | | | | | | | | |

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| 57 | **Hydrologic Separation** | Physical Barriers | N | Available | X | • Modifies flow within waterway, including stormwater and combined sewer overflow discharge, and conveyance and commercial water dischargers and withdrawal of water<br>• Must be designed to handle storm flows. | | NA | Y | | Y | | Y | | Y | Y |
| 58 | **Irrigation Water Chemicals** § | Acrolein<br>CAS #: 107-02-8 | N | Available, Registered, Restricted Use Product* | X | • For control of submersed and floating weeds and algae only in irrigation canal systems in western states, provided the appropriate state registrations are also in place<br>• Toxic to fish and other aquatic organisms at labeled use rates<br>• Effectiveness dependent upon dose and exposure<br>• Minimum exposure requirement is 1 to 3 hours | | NA | N | Not effective on seeds | Y | | N | Not effective on emergent plant species | Y | Y |
| 59 | | Xylene<br>CAS #: 1330-20-7 | N | Registered | X | • For use only in irrigation and drainage canals designated by the Bureau of Reclamation and cooperating water user organizations<br>• For use in Programs of the Bureau of Reclamation and Cooperating Water User Organizations within the following states, provided that the appropriate state registrations are also in place: AZ, CA, CO, ID, KS, MT, NE, NM, NV, ND, OK, OR, SD, TX, UT, WA, and WY<br>• For control of submerged weeds in irrigation and drainage canals<br>• Toxic to fish and other aquatic organisms at labeled use rates<br>• Effectiveness dependent upon dose and exposure<br>• Minimum exposure requirement is 1 to 3 hours | | NA | N | Not effective on seeds | Y | | N | Not effective on emergent plant species | Y | Y |
| 60 | **Lethal Temperature** | Pressurized Hot Water/Steam Treatment | N | Available | X | • Hot water has been used to kill zebra and quagga mussels at municipal and industrial facilities, and high pressure hot water is used to clean ANS off of recreational boats<br>• Treated area (i.e. boat hull) must be above the surface. | | NA | N | Not effective on seeds | N | Not effective on root or rhizome fragments | N | Not effective on emergent plant species | | |
| 61 | | Hot Water Thermal Barrier | N | Available | X | • Difficult to manage in open water system, must be completely mixed throughout the water column<br>• During cold weather conditions, warm water temperatures may attract fish | | [illegible] | [illegible] | Not effective on [illegible] | [illegible] | Not effective on root or rhizome [illegible] | [illegible] | Not effective on emergent plant [illegible] | Y | Y |
| 62 | | Freezing | N | Available | X | [illegible] air temperatures<br>• Cluster mussels are more tolerant of reduced air temperatures than individual organisms<br>• Can be applied to static water. | | NA | N | Not effective on seeds | Y | | N | Perennial plants re-grow from roots/rhizomes in soil that can survive freezing | Y | Y |

Removed During Nov 2012 ANS Controls Screening Charette

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| 63 | | Carbon Dioxide ($CO_2$) Pellet (dry ice) Blasting | | N | Available | X | • Method used extensively to remove organics from aircrafts producing no deterioration of surfaces<br>• CO2 pellets convert to a gas at ambient temperatures, leaving no residue.<br>• Treated area (i.e. boat hull) must be above the surface. | | NA | N | Not effective on seeds | N | Not effective on floating root or rhizome fragments | N | Not effective on emergent plant species | | |
| 64 | | Desiccation | | N | Available | X | • Desiccation can only be achieved in areas where water levels can be controlled<br>• Exposure to air quickly leads to death for active water-breathing organism—mollusks and plants are more tolerant and require longer drying period | | NA | N | Not effective on seeds | N | Not effective on floating root or rhizome fragments | N | Not effective on emergent plant species | Y | Y |
| 65 | **Light Attenuating Dyes** § | Light Attenuating Dyes | | N | Registered | X | • Not effective for suppressing growth of floating aquatic plants or emergent shoreline vegetation identified as ANS of Concern – CAWS<br>• Not effective on floating algal mats<br>• May suppress the growth of non-target plants and algae<br>• Only for use in contained waterbodies with little or no outflow<br>• Do not apply to waters used for human consumption | | NA | N | Not effective on seeds | N | Not effective on floating root or rhizome fragments | N | Light-attenuating dyes are applied to water thus not effective on emergent plant species | | |
| 66 | **Manual Harvest** | Manual Harvest | | Y | Available | X | • Labor-intensive<br>• Selectively dependent upon training and skill of staff | | NA | N | Seeds are too small (1.5-2 mm) for manual harvesting | N | Not effective on root or rhizome fragments | Y | | Y | Y |
| 67 | **Mechanical Control Methods** | Mechanical Harvesting | | N | Available | X | • May disturb non-target organisms in equipment path | | NA | N | Not effective on seeds | N | Not effective on root or rhizome fragments | N | Not effective on emergent plant species | | |
| 68 | | Shredding | | N | Available | X | | | NA | N | Not effective on seeds | N | Not effective on root or rhizome fragments | N | Not effective on emergent plant species | | |
| 69 | | Mowing | | N | Available | X | | | NA | N | Not effective on seeds | N | Not effective on root or rhizome fragments | Y | | Y | Y |
| 70 | | Chaining | | N | Available | X | | | NA | N | Not effective on seeds | N | Not effective on root or rhizome fragments | N | Not effective on emergent plant species | | |
| 71 | | Roto-tilling | | N | Available | X | | | NA | N | Not effective on seeds | N | Not effective on root or rhizome fragments | Y | | Y | Y |
| 72 | | Rotovating | | N | Available | X | • Used for submersed vegetation rooted in the substrate<br>• May have applications on emergent plants<br>• May disturb non-target organisms in equipment path | | NA | N | Not effective on seeds | N | Not effective on root or rhizome fragments | Y | | | |

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| 73 | **Molluscicides** § | Quaternary and Polyquaternary Ammonium Compounds; Aromatic Hydrocarbons; Endothall as the Mono (N,N-imethylalkylamine) Salt (TD2335 Industrial Biocide-Molluscicide) | | N | Registered | | • Used for recirculating and once-through cooling water systems<br>• For control of established populations of freshwater and saltwater mollusks in closed systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | |
| 74 | | Metals and their salts (Copper Sulfate and Chelated Copper Formulations) | | N | Registered | | • Can be used to control mollusks in open water systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | |
| 75 | | Niclosamide CAS #: 1420-04-8 | | N | Available, Registered, Restricted Use Product* | | • First developed as a lampricide<br>• Used for control of snails in aquaculture ponds<br>• Toxic to fish and aquatic invertebrates at recommended use rates for control of snails in aquaculture ponds | | NA | | | | | | | | |
| 76 | **Pheromones** | Repellant and Attractant Pheromones | | Y | Experimental | | • Under investigation as an attractant and/or deterrent for silver carp (*H. molitrix* ), bighead carp (*H. nobilis* ), black carp (*M. piceus* ), and sea lamprey (*P. marinus* ) | T | NA | | | | | | | | |
| 77 | **Piscicides** § | Antimycin A CAS #: 1397-94-0 | | N | Available, Registered, Restricted Use Product* | | • Effectiveness can vary with the surfactant used.<br>• Requires approximately 8 to 32 hours to kill cyprinid species such as bighead carp (H. nobilis) and silver carp (H. molitrix)<br>• Restricted use pesticide due to aquatic toxicity and need for highly specialized applicator training | | NA | | | | | | | | |
| 78 | | Niclosamide CAS #: 1420-04-8 | | N | Available, Registered, Restricted Use Product* | | • First developed as a lampricide<br>• Toxic to aquatic invertebrates; non-target organisms may be killed at rates recommended for sea lamprey control<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by United States Department of Interior, United States Fish & Wildlife Service (USFWS), state fish and game, Fisheries and Oceans Canada, and Provincial Certified Applicators trained in sea lamprey control<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 79 | | Rotenone (Both Standard Application and Via Oral Delivery Platforms) CAS #: 83-79-4 | | N | Available, Registered, Restricted Use Product* | | • Kills bighead (*H. nobilis* ) carp and silver carp (*H. molitrix* ) within approximately 4 hours<br>• May be toxic to other aquatic organisms<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 80 | | TFM (3-Trifluoromethyl-4-nitrophenol) CAS #: 88-30-2 | | N | Available, Registered, Restricted Use Product* | | • Designed only to control sea lamprey (*P. marinus* )<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by certified applicators of USFWS, Fisheries and Oceans Canada, and provincial and state fish and game employees<br>• Non-target organisms may be killed at labeled use rates<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | |
| 81 | **Screens** | | Fences | N | Available | X | | | NA | N | Seeds are too small (1.5-2 mm) | N | Root, rhizome fragments too small | N | Not effective on rooted, emergent plants | | |

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| 82 | | Non-Mechanical Screens | Bar Screens | N | Available | X | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent movement of non-target organisms, depending on their size | | NA | N | Seeds are too small (1.5-2 mm) | N | Root, rhizome fragments too small | N | Not effective on rooted, emergent plants | | |
| 83 | | | Trash Racks | N | Available | X | | | NA | N | Seeds are too small (1.5-2 mm) | N | Root, rhizome fragments too small | N | Not effective on rooted, emergent plants | | |
| 84 | | | Curtains | N | Available | X | | | NA | N | Seeds are too small (1.5-2 mm) | N | Root, rhizome fragments too small | N | Not effective on rooted, emergent plants | | |
| 85 | | Mechanical Screens | Chain Bar Screens | N | Available | X | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent the movement of non-target organisms, depending on their size | | NA | N | Seeds are too small (1.5-2 mm) | N | Root, rhizome fragments too small | N | Not effective on rooted, emergent plants | | |
| 86 | | | Reciprocating Rake Bar Screens | N | Available | X | | | NA | N | Seeds are too small (1.5-2 mm) | N | Root, rhizome fragments too small | N | Not effective on rooted, emergent plants | | |
| 87 | | | Catenary Bar Screens | N | Available | X | | | NA | N | Seeds are too small (1.5-2 mm) | N | Root, rhizome fragments too small | N | Not effective on rooted, emergent plants | | |
| 88 | | | Continuous Belt Bar Screens | N | Available | X | | | NA | N | Seeds are too small (1.5-2 mm) | N | Root, rhizome fragments too small | N | Not effective on rooted, emergent plants | | |
| 89 | | | Rotating Drum Screens (Paddle Wheel Or Power) | N | Available | X | | | NA | N | Seeds are too small (1.5-2 mm) | N | Root, rhizome fragments too small | N | Not effective on rooted, emergent plants | | |
| 90 | | | Wedge-Wire Cylinders | N | Available | X | | | NA | N | Seeds are too small (1.5-2 mm) | N | Root, rhizome fragments too small | N | Not effective on rooted, emergent plants | | |
| 91 | | | Louvered Screens | N | Available | | | | NA | | | | | | | | |
| 92 | | | Mechanical Climber Screens | N | Available | X | | | NA | N | Seeds are too small (1.5-2 mm) | N | Root, rhizome fragments too small | N | Not effective on rooted, emergent plants | | |
| 93 | | Filters | | N | Available | X | • Generally used to treat small volumes of water<br>• Constrained by resistance through filter membrane and filter fouling<br>• Filters may prevent the movement of non-target organisms, depending on their size | | NA | Y | | Y | | N | Not effective on rooted, emergent plants | Y | Y |
| 94 | **Sensory Deterrent Systems** | Underwater Strobe lights | | N | Experimental | | • Used to prevent upstream movement of fish | A | NA | | | | | | | | |
| 95 | | Underwater Sound | | N | Experimental | | • May not prevent downstream movement of | A | NA | | | | | | | | |

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# Fish Hook Water Flea

| | A | B | C | D | E | I | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
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| 1 | | | | | | Tar | | | | | | | | | | | | | |
| 2 | Fact Sheet | ANS Control | | Selective for ANS of Concern – CAWS | Status [2] | crustacean | Comments<br>Refer to fact sheets for additional information on each Control | Level of R&D | Biocides for Industrial Use - Conventional, municipal drinking water or wastewater treatment technologies | Effective on Fishhook Water Flea (eggs) | Comments on eggs in water | Effective on Spiny Water Flea (adults) | Comments on Adult | Effective with Downstream Flow | Effective with Upstream Flow | Effective on Scud (Adhered to boat) | Comments on Adhered to Boat | Effective on Scud (Ballast Water) | Comments on Ballast Water |
| 3 | Accelerated Water Velocity | Accelerated Water Velocity | | N | Available | X | • Not effective in preventing downstream ANS movement<br>• Must have a length and speed of flow greater than the organism's leaping ability and swimming endurance | | NA | Y | | Y | | N | Y | | | | |
| 4 | Acoustic Fish Deterrents | Continuous Wave | | N | Experimental | | • Under development for control of fish<br>• May not be effective on all fish species | T | NA | | | | | | | | | | |
| 5 | | Pulsed Pressure Wave | | N | Experimental | | • Not lethal unless an organism is very close to sound source | A | NA | | | | | | | | | | |
| 6 | Algaecides § | Copper Sulfate and Chelated Copper Formulations (ethanolamines, ethylene diamines, triethanolamines, triethanolamine+ethylene diamine, and copper citrate/gluconate) | | N | Available, Registered | | • May be effective on diatoms (*S. binderanus* ) and grass kelp (*Enteromorpha flexuosa* )<br>• Chelated copper formulations may be effective on red macro-algae (Bangia atropupurea)<br>• Reduced efficacy in waters with high pH and water temperatures < 15 °C<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 7 | | Endothall (as the mono(N,N-dimethylalkylamine) salt)<br>CAS #: 66330-88-9 | | N | Available, Registered | | • May be effective on red macro-algae (*B. atropupurea* ) and diatoms (*S. binderanus* )<br>• Can be harmful to fish<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 8 | | Algaecides containing Sodium Carbonate Peroxyhydrate<br>CAS #: 15630-89-4 | | N | Available, Registered | | • May be effective on diatoms (*S. binderanus* ), and grass kelp (*E. flexuosa* )<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 9 | Alteration of Water Quality §<br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/10/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided. | Gases | Carbon Dioxide ($CO_2$) | N | Available, When Not Registered for a Use | X | • May repel fish at sub-lethal levels<br>• Lowers pH<br>• Creates irreversible cell damage and death<br>• Effectiveness dependent upon dose and exposure | | NA | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 10 | | Gases | Ozone | N | Available | X | • Rendered ineffective in the presence of organic matter<br>• Used commercially to decontaminate water<br>• Ozone oxidation is toxic to most small waterborne organisms<br>• Destroys the epithelium covering the gill lamella in fish<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | NA | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 11 | | Gases | Nitrogen | N | Available | X | • Adult fish are more tolerant than young fish<br>• Nitrogen supersaturation is a cause of gas bubble disease in fish<br>• Effectiveness dependent upon dose and exposure<br>• Not effective on eggs | | NA | N | Not effective on this species | N | Not effective on this species | | | | | | |
| 12 | | Solids | Alum | N | Available | | • Creates a solid precipitate from suspended solids within the water column which settles<br>• Alum is not classified as a pesticide, therefore does not require FIFRA registration<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | | | |
| 13 | | Solids | Sodium Thiosulfate<br>CAS #: 7772-98-7 | N | Experimental | X | • Deoxygenated compound<br>• Effectiveness dependent upon dose and exposure | T | NA | | | | | | | | | | |

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# Fish Hook Water Flea

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| 14 | **Aquatic Herbicides** § The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/13/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided | 2,4-D (both the amine and butoxy-ethyl ester formulations) CAS #: 94-75-7 | | N | Available, Registered | | • Tank mixing with other herbicides improves plant control • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 15 | | Diquat CAS #: 85-00-7 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 16 | | Fluridone CAS #: 59756-60-4 | | N | Available, Registered | | • Plants must be exposed to a lethal dose for a minimum of 45 days for optimal results • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 17 | | Glyphosate CAS #: 1071-83-6 | | N | Available, Registered | | • May be effective on reed sweetgrass (Glyceria maxima) • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 18 | | Imazapyr CAS #: 81334-34-1 | | N | Available, Registered | | • May be effective on reed sweetgrass (*G. maxima* ) • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 19 | | Triclopyr CAS #: 55335-06-3 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 20 | | | | | | | | | NA | | | | | | | | | | |
| 21 | **Benthic Barriers** | Textile or Plastic | | N | Available | | | | NA | | | | | | | | | | |
| 22 | | Silt | | N | Available | | • Created by applying excessive silt/sand to smother bottom-dwelling organism • Application to control aquatic nuisance species has not been widely studied | | NA | | | | | | | | | | |
| 27 | **Biocides for Industrial Use** § Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for | Chlorine (free chlorine, hypochlorous acid, hypochlorite salts) CAS #: 7782-50-5 | | N | When Not Registered for a Use | X | • Residuals remain in water after treatment • Requires frequent applications • Effectiveness dependent upon dose and exposure • Effective on algal spores | | Y | Y | | Y | | | | | | | |
| 28 | | Chlorine Dioxide CAS #: 10049-04-4 | | N | When Not Registered for a Use | | • Effectiveness dependent upon dose and exposure | | Y | | | | | | | | | | |
| 34 | **Biocides for Industrial Use** § **(continued)** Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004) The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical | Hydrogen Peroxide CAS #: 7722-84-1 CAS #: 79-21-0 | | N | When Not Registered for a Use | X | • Disinfection of drinking water, cooling systems and surfaces • Presence of organic matter limits effectiveness • Moderately corrosive • Some residuals remain in water after treatment • Effective on algal spores | | Y | Y | | Y | | | | | | | |
| 38 | | Peracetic Acid (Peraclean®) CAS #: 79-21-0 CAS #: 7722-84-1 | | N | When Not Registered for a Use | | • No known toxic residual; more potent than hydrogen peroxide • Rapidly active at low concentrations against a wide range of microorganisms • Corrosive • Highly efficient in presence of organic matter • Wastewater treatment | | Y | | | | | | | | | | |
| 41 | **Biocides for Industrial Use § (continued)** Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development | Potassium Permanganate CAS #: 7722-64-7 | | N | Experimental | X | • Organic matter limits effectiveness & moderately corrosive • Some residuals remain in water after treatment • Effectiveness dependent upon dose and exposure | A | Y | Y | | Y | | Y | Y | | | Y | |

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| | A | B | C | D | E | I | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
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| 44 | Center: Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br><br>The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. | Sodium Chlorite<br>CAS #: 7758-19-2 | | N | When Not Registered for a Use | X | • Disinfection of drinking water, cooling systems and surfaces<br>• Presence of organic matter limits effectiveness<br>• Residuals remain in water after treatment<br>• Requires frequent applications and corrosive<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | Y | Y | | Y | | | | | | | |
| 45 | | Sodium Hydroxide[B, GS]<br>CAS #: 1310-73-2 | | N | When Not Registered for a Use | X | • Under consideration for use in ballast water treatment<br>• <1% survival of test organisms including algae, annelids, crustaceans and fish with 48-hr exposure to pH adjustments of 11.5 to 12.5 using NaOH (TenEyek, M. 2009. Great Ships Initiative Bench-Scale Test Findings, Technical Report – Public, Sodium Hydroxide (NaOH). GSI/BS/5.) | | Y | Y | | Y | | | | | | | |
| 48 | **Biological Controls** § | Introduced Predatory Fish Species | | N | Available | | • Includes both carnivorous and herbivorous fish species<br>• Best used in waters with no outflows<br>• Predatory fish are non-selective feeders and may eat native species<br>• Predatorsare size selective feeders and may not eat eggs or larger organisms | | NA | | | | | | | | | | |
| 49 | | Introduced Predatory Insect Species | | N | Experimental | | • United States Department of Agriculture (USDA) has not approved of any insects for use as biological controls of plants identified as ANS of Concern – CAWS<br>• Predators may be selective feeders (may not eat seeds) | T | NA | | | | | | | | | | |
| 50 | | *Pseudomonas fluorescens* CL 145A | | N | Registered | | • Active ingredient (Pseudomonas fluorescens CL 145A) approved by the United States Environmental Protection Agency (USEPA) in July 2011(Reg. No. 84059-4)<br>• Formulation of commercial product as Zequanox™ is pending review by USEPA as of October 2010; Section 3 registration expected in March 2012<br>• Ongoing research to assess impacts to non-target mollusks | | NA | | | | | | | | | | |
| 51 | | Targeted Disease Agents | | N | Experimental | | • Under consideration for carp species | T | NA | | | | | | | | | | |
| 52 | **Controlled Harvest and Overfishing** | Controlled Harvest and Overfishing | | N | Available | | • Requires sorting and returning of native fish species<br>• Requires continual capture over a long period of time, or intensive harvest during critical periods of concentration and reproduction (e.g., migration and spawning season)<br>• Once harvesters, processors, and communities become economically dependent on harvesting nuisance fish, pressure to manage a sustainable population of these fish may conflict with the original purpose of removing them from the environment<br>• Typically for organisms larger than eggs and larvae. | | NA | | | | | | | | | | |
| 53 | **Deleterious Gene Spread** | Daughterless Gene | | Y | Experimental | | • Researched as a Control for silver carp (*H. molitrix*), bighead carp (*H. nobilis*), black carp (*Mylopharyngodon piceus*), and sea lamprey (*Petromyzon marinus*)<br>• Researched as a Control for common carp<br>• Manipulation of genes can manifest unforeseen and significant undesirable side effects and would require extensive research before being accepted as a Control | T | NA | | | | | | | | | | |
| 54 | | Trojan Y Chromosome | | Y | Experimental | | • The Food and Drug Administration regulates genetically engineered animals | T | NA | | | | | | | | | | |
| 55 | **Dredging and Diver Dredging** | Dredging and Diver Dredging | | N | Available | | • Requires careful disposal or reuse of dredged material to prevent the transfer of ANS to a new location<br>• May remove other ANS of Concern – CAWS and non-target organisms that reside in sediment | | NA | | | | | | | | | | |

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| 56 | **Electron Beam Irradiation** | Electron Beam Irradiation | | N | Available | X | • Used in irradiation of food, environmental waste, medical sterilization, and water treatment<br>• Requires a closed system and not appropriate for open water application<br>• May require pretreatment to remove suspended solids<br>• Used in irradiation of food, environmental waste, medical sterilization, and water treatment | | NA | Y | | Y | May not be effective for organisms near the bottom | Y | Y | | | | |
| 57 | **Hydrologic Separation** | Physical Barriers | | N | Available | X | • Modifies flow within waterway, including stormwater and combined sewer overflow discharge, and conveyance and commercial water dischargers and withdrawal of water<br>• Must be designed to handle storm flows | | NA | Y | | Y | | Y | Y | | | | |
| 58 | **Irrigation Water Chemicals** § | Acrolein<br>CAS #: 107-02-8 | | N | Available, Registered, Restricted Use Product* | | • For control of submersed and floating weeds and algae only in irrigation canal systems in western states, provided the appropriate state registrations are also in place<br>• Toxic to fish and other aquatic organisms at labeled use rates<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 59 | | Xylene<br>CAS #: 1330-20-7 | | N | Registered | | • For use only in irrigation and drainage canals designated by the Bureau of Reclamation and cooperating water user organizations<br>• For use in Programs of the Bureau of Reclamation and Cooperating Water User Organizations within the following states, provided that the appropriate state registrations are also in place: AZ, CA, CO, ID, KS, MT, NE, NM, NV, ND, OK, OR, SD, TX, UT, WA, and WY<br>• For control of submerged weeds in irrigation and drainage canals<br>• Toxic to fish and other aquatic organisms at labeled use rates<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 60 | **Lethal Temperature** | Pressurized Hot Water/Steam Treatment | | N | Available | X | • Hot water has been used to kill zebra and quagga mussels at municipal and industrial facilities, and high pressure hot water is used to clean ANS off of recreational boats<br>• Treated area (i.e. boat hull) must be above the surface | | NA | Y | | Y | | Y | Y | | | | |
| 61 | | Hot Water Thermal Barrier | | N | Available | X | • Difficult to manage in open water system, must be completely mixed throughout the water column | | | | | | | | | | | | |
| 62 | | Freezing | | N | Available | X | air temperatures<br>• Cluster mussels are more tolerant of reduced air temperatures than individual organisms<br>• Can be applied to static water. | | NA | N | Not effective on this species | N | Not effective on this species | | | | | | |
| 63 | | Carbon Dioxide ($CO_2$) Pellet (dry ice) Blasting | | N | Available | X | • Method used extensively to remove organics from aircrafts producing no deterioration of surfaces<br>• CO2 pellets convert to a gas at ambient temperatures, leaving no residue.<br>• Treated area (i.e. boat hull) must be above the surface | | NA | Y | Requires proper treatment of material | Y | Requires proper treatment of material | Y | Y | | | | |
| 64 | | Desiccation | | N | Available | X | • Desiccation can only be achieved in areas where water levels can be controlled<br>• Exposure to air quickly leads to death for active water-breathing organism—mollusks and plants are more tolerant and require longer drying period | | NA | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |

Removed During Nov 2012 ANS Controls Screening Charette

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| 65 | Light Attenuating Dyes § | Light Attenuating Dyes | | N | Registered | | • Not effective for suppressing growth of floating aquatic plants or emergent shoreline vegetation identified as ANS of Concern – CAWS<br>• Not effective on floating algal mats<br>• May suppress the growth of non-target plants and algae<br>• Only for use in contained waterbodies with little or no outflow<br>• Do not apply to waters used for human | | NA | | | | | | | | | | |
| 66 | Manual Harvest | Manual Harvest | | Y | Available | | • Labor-intensive<br>• Selectively dependent upon training and skill of staff | | NA | | | | | | | | | | |
| 67 | Mechanical Control Methods | Mechanical Harvesting | | N | Available | | • May disturb non-target organisms in equipment path | | NA | | | | | | | | | | |
| 68 | | Shredding | | N | Available | | | | NA | | | | | | | | | | |
| 69 | | Mowing | | N | Available | | | | NA | | | | | | | | | | |
| 70 | | Chaining | | N | Available | | | | NA | | | | | | | | | | |
| 71 | | Roto-tilling | | N | Available | | | | NA | | | | | | | | | | |
| 72 | | Rotovating | | N | Available | | • Used for submersed vegetation rooted in the substrate<br>• May have applications on emergent plants<br>• May disturb non-target organisms in equipment path | | NA | | | | | | | | | | |
| 73 | Molluscicides § | Quaternary and Polyquaternary Ammonium Compounds; Aromatic Hydrocarbons; Endothall as the Mono (N,N-imethylalkylamine) Salt (TD2335 Industrial Biocide-Molluscicide) | | N | Registered | | • Used for recirculating and once-through cooling water systems<br>• For control of established populations of freshwater and saltwater mollusks in closed systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | | | |
| 74 | | Metals and their salts (Copper Sulfate and Chelated Copper Formulations) | | N | Registered | | • Can be used to control mollusks in open water systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | | | |
| 75 | | Niclosamide CAS #: 1420-04-8 | | N | Available, Registered, Restricted Use Product* | | • First developed as a lampricide<br>• Used for control of snails in aquaculture ponds<br>• Toxic to fish and aquatic invertebrates at recommended use rates for control of snails in aquaculture ponds | | NA | | | | | | | | | | |
| 76 | Pheromones | Repellant and Attractant Pheromones | | Y | Experimental | | • Under investigation as an attractant and/or deterrent for silver carp (*H. molitrix*), bighead carp (*H. nobilis*), black carp (*M. piceus*), and sea lamprey (*P. marinus*) | T | NA | | | | | | | | | | |
| 77 | Piscicides § | Antimycin A CAS #: 1397-94-0 | | N | Available, Registered, Restricted Use Product* | | • Effectiveness can vary with the surfactant used.<br>• Requires approximately 8 to 32 hours to kill cyprinid species such as bighead carp (H. nobilis) and silver carp (H. molitrix)<br>• Restricted use pesticide due to aquatic toxicity and need for highly specialized applicator training | | NA | | | | | | | | | | |
| 78 | | Niclosamide CAS #: 1420-04-8 | | N | Available, Registered, Restricted Use Product* | | • First developed as a lampricide<br>• Toxic to aquatic invertebrates; non-target organisms may be killed at rates recommended for sea lamprey control<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by United States Department of Interior, United States Fish & Wildlife Service (USFWS), state fish and game, Fisheries and Oceans Canada, and Provincial Certified Applicators trained in sea lamprey control<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 79 | | Rotenone (Both Standard Application and Via Oral Delivery Platforms) CAS #: 83-79-4 | | N | Available, Registered, Restricted Use Product* | | • Kills bighead (*H. nobilis*) carp and silver carp (*H. molitrix*) within approximately 4 hours<br>• May be toxic to other aquatic organisms<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |

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# Fish Hook Water Flea

| | A | B | C | D | E | I | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80 | | TFM (3-Trifluoromethyl-4-nitrophenol) CAS #: 88-30-2 | | N | Available, Registered, Restricted Use Product* | | • Designed only to control sea lamprey (*P. marinus* ) • Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes • For use only by certified applicators of USFWS, Fisheries and Oceans Canada, and provincial and state fish and game employees • Non-target organisms may be killed at labeled use rates • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | | | |
| 81 | **Screens** | Non-Mechanical Screens | Fences | N | Available | | • May not prevent aquatic organism movement downstream • Effectiveness is dictated by the size of mesh or bar spacing • Screens may prevent movement of non-target | | NA | | | | | | | | | | |
| 82 | | | Bar Screens | N | Available | | | | NA | | | | | | | | | | |
| 83 | | | Trash Racks | N | Available | | | | NA | | | | | | | | | | |
| 84 | | | Curtains | N | Available | | | | NA | | | | | | | | | | |
| 85 | | Mechanical Screens | Chain Bar Screens | N | Available | | • May not prevent aquatic organism movement downstream • Effectiveness is dictated by the size of mesh or bar spacing • Screens may prevent the movement of non-target organisms, depending on their size | | NA | | | | | | | | | | |
| 86 | | | Reciprocating Rake Bar Screens | N | Available | | | | NA | | | | | | | | | | |
| 87 | | | Catenary Bar Screens | N | Available | | | | NA | | | | | | | | | | |
| 88 | | | Continuous Belt Bar Screens | N | Available | | | | NA | | | | | | | | | | |
| 89 | | | Rotating Drum Screens (Paddle Wheel Or Power) | N | Available | | | | NA | | | | | | | | | | |
| 90 | | | Wedge-Wire Cylinders | N | Available | | | | NA | | | | | | | | | | |
| 91 | | | Louvered Screens | N | Available | | | | NA | | | | | | | | | | |
| 92 | | | Mechanical Climber Screens | N | Available | | | | NA | | | | | | | | | | |
| 93 | | Filters | | N | Available | X | • Generally used to treat small volumes of water • Constrained by resistance through filter membrane and filter fouling • Filters may prevent the movement of non-target organisms, depending on their size | | NA | Y | | Y | For organisms suspended in the water column, may not be effective for organisms established on the bottom of channel | Y | Y | | | | |
| 94 | **Sensory Deterrent Systems** | Underwater Strobe lights | | N | Experimental | | • Used to prevent upstream movement of fish • May not prevent downstream movement of aquatic organisms | A | NA | | | | | | | | | | |
| 95 | | Underwater Sound | | N | Experimental | | | A | NA | | | | | | | | | | |
| 96 | | Acoustic Air Bubble Curtain | | N | Experimental | | | A | NA | | | | | | | | | | |
| 97 | | Electric Barrier | | N | Available | | • Must be configured to stop upstream and downstream movement of fish • May impact non-target aquatic organisms | A | NA | | | | | | | | | | |
| 98 | **Ultrasound** | Ultrasound | | N | Available | | • Used in small water bodies and water treatment plants • Ultrasound may be effective on diatoms (*S. binderanus* ) • Most effective on enclosed bodies of water • Additional research may be needed to investigate potential impacts on non-target organisms • Under investigation for use against aquatic vascular plants (non-algae) • Requires continuous application to maintain effectiveness | | NA | | | | | | | | | | |

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# Fish Hook Water Flea

| | A | B | C | D | E | I | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
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| 99 | **Ultraviolet Light** | | Ultraviolet (UV) Light | N | Available | X | • Used in fish hatcheries and water treatment facilities<br>• Used to treat contained flowing systems<br>• Best used after suspended solids, iron and manganese have been filtered from water<br>• May impact non-target aquatic organisms<br>• Under investigation for use against aquatic vascular plants (non-algae) | | NA | Y | | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 100 | **Vertical Drop Barrier** | | Vertical Drop Barrier | N | Available | X | • Does not prevent aquatic organism movement downstream<br>• May impact upstream movement of non-target organisms | | NA | Y | | Y | | N | Y | | | | |
| 101 | **Williams' Cage**<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | | Williams' Cage | Y | Experimental | | • May be effective on silver carp *(H. molitrix)* and sea lamprey *(P. marinus)*<br>• Does not prevent aquatic organism movement downstream | A | NA | | | | | | | | | | |

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# Bloody Red Shrimp

| | A | B | C | D | E | I | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | **Fact Sheet** | **ANS Control** | | Selective for ANS of Concern – CAWS | **Status [2]** | **crustacean** | **Comments Refer to fact sheets for additional information on each Control** | **Level of R&D** | **Biocides for Industrial Use - Conventional, municipal drinking water or wastewater treatment technologies** | **Effective on Bloody Red Shrimp (all life stages)** | **Comments** | **Effective with Downstream Flow** | **Effective with Upstream Flow** | **Effective on Scud (Adhered to boat)** | **Comments on Adhered to Boat** | **Effective on Scud (Ballast Water)** | **Comments on Ballast Water** |
| 3 | **Accelerated Water Velocity** | Accelerated Water Velocity | | N | Available | X | • Not effective in preventing downstream ANS movement<br>• Must have a length and speed of flow greater than the organism's leaping ability and swimming endurance | | NA | Y | | N | Y | | | | |
| 4 | **Acoustic Fish Deterrents** | Continuous Wave | | N | Experimental | | • Under development for control of fish<br>• May not be effective on all fish species | T | NA | | | | | | | | |
| 5 | | Pulsed Pressure Wave | | N | Experimental | | • Not lethal unless an organism is very close to sound source | A | NA | | | | | | | | |
| 6 | **Algaecides [§]** | Copper Sulfate and Chelated Copper Formulations (ethanolamines, ethylene diamines, triethanolamines, triethanolamine+ethylene diamine, and copper citrate/gluconate) | | N | Available, Registered | | • May be effective on diatoms (*S. binderanus* ) and grass kelp (*Enteromorpha flexuosa* )<br>• Chelated copper formulations may be effective on red macro-algae (Bangia atropupurea)<br>• Reduced efficacy in waters with high pH and water temperatures < 15 °C<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 7 | | Endothall (as the mono(N,N-dimethylalkylamine) salt) CAS #: 66330-88-9 | | N | Available, Registered | | • May be effective on red macro-algae (*B. atropupurea* ) and diatoms (*S. binderanus* )<br>• Can be harmful to fish<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 8 | | Algaecides containing Sodium Carbonate Peroxyhydrate CAS #: 15630-89-4 | | N | Available, Registered | | • May be effective on diatoms (*S. binderanus* ), and grass kelp (*E. flexuosa* )<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 9 | **Alteration of Water Quality [§]**<br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/10/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided. | Gases | Carbon Dioxide ($CO_2$) | N | Available, When Not Registered for a Use | X | • May repel fish at sub-lethal levels<br>• Lowers pH<br>• Creates irreversible cell damage and death<br>• Effectiveness dependent upon dose and exposure | | NA | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 10 | | | Ozone | N | Available | X | • Rendered ineffective in the presence of organic matter<br>• Used commercially to decontaminate water<br>• Ozone oxidation is toxic to most small waterborne organisms<br>• Destroys the epithelium covering the gill lamella in fish<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | NA | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |

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# Bloody Red Shrimp

| | A | B | C | D | E | I | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | | Nitrogen | N | Available | X | • Adult fish are more tolerant than young fish<br>• Nitrogen supersaturation is a cause of gas bubble disease in fish<br>• Effectiveness dependent upon dose and exposure<br>• Not effective on eggs | | NA | N | Not effective on this species | | | | | | |
| 12 | | Solids | Alum | N | Available | | • Creates a solid precipitate from suspended solids within the water column which settles<br>• Alum is not classified as a pesticide, therefore does not require FIFRA registration<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | |
| 13 | | | Sodium Thiosulfate<br>CAS #: 7772-98-7 | N | Experimental | X | • Deoxygenated compound<br>• Effectiveness dependent upon dose and exposure | T | NA | | | | | | | | |
| 14 | **Aquatic Herbicides** §<br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/13/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided | 2,4-D (both the amine and butoxy-ethyl ester formulations)<br>CAS #: 94-75-7 | | N | Available, Registered | | • Tank mixing with other herbicides improves plant control<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 15 | | Diquat<br>CAS #: 85-00-7 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 16 | | Fluridone<br>CAS #: 59756-60-4 | | N | Available, Registered | | • Plants must be exposed to a lethal dose for a minimum of 45 days for optimal results<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 17 | | Glyphosate<br>CAS #: 1071-83-6 | | N | Available, Registered | | • May be effective on reed sweetgrass (Glyceria maxima)<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 18 | | Imazapyr<br>CAS #: 81334-34-1 | | N | Available, Registered | | • May be effective on reed sweetgrass (*G. maxima* )<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 19 | | Triclopyr<br>CAS #: 55335-06-3 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 20 | | | | | | | | | NA | | | | | | | | |
| 21 | **Benthic Barriers** | Textile or Plastic | | N | Available | | | | NA | | | | | | | | |
| 22 | | Silt | | N | Available | | • Created by applying excessive silt/sand to smother bottom-dwelling organism<br>• Application to control aquatic nuisance species has not been widely studied | | NA | | | | | | | | |
| 27 | **Biocides for Industrial Use** §<br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for | Chlorine (free chlorine, hypochlorous acid, hypochlorite salts)<br>CAS #: 7782-50-5 | | N | When Not Registered for a Use | X | • Residuals remain in water after treatment<br>• Requires frequent applications<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | Y | Y | | Y | Y | Y | | Y | |
| 28 | | Chlorine Dioxide<br>CAS #: 10049-04-4 | | N | When Not Registered for a Use | | • Effectiveness dependent upon dose and exposure | | Y | | | | | | | | |
| 34 | **Biocides for Industrial Use** § **(continued)**<br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br>The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers | Hydrogen Peroxide<br>CAS #: 7722-84-1<br>CAS #: 79-21-0 | | N | When Not Registered for a Use | X | • Disinfection of drinking water, cooling systems and surfaces<br>• Presence of organic matter limits effectiveness<br>• Moderately corrosive<br>• Some residuals remain in water after treatment<br>• Effective on algal spores | | Y | Y | | Y | Y | Y | | Y | |
| 38 | | Peracetic Acid (Peraclean®)<br>CAS #: 79-21-0<br>CAS #: 7722-84-1 | | N | When Not Registered for a Use | | • No known toxic residual; more potent than hydrogen peroxide<br>• Rapidly active at low concentrations against a wide range of microorganisms<br>• Corrosive<br>• Highly efficient in presence of organic matter<br>• Wastewater treatment | | Y | | | | | | | | |

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# Bloody Red Shrimp

| | A | B | C | D | E | I | N | O | P | Q | R | S | T | U | V | W | X |
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| 41 | **Biocides for Industrial Use § (continued)**<br><br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for | Potassium Permanganate<br>CAS #: 7722-64-7 | | N | Experimental | X | • Organic matter limits effectiveness & moderately corrosive<br>• Some residuals remain in water after treatment<br>• Effectiveness dependent upon dose and exposure | A | Y | Y | | Y | Y | Y | | Y | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 44 | Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br><br>The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Sodium Chlorite<br>CAS #: 7758-19-2 | N | When Not Registered for a Use | X | • Disinfection of drinking water, cooling systems and surfaces<br>• Presence of organic matter limits effectiveness<br>• Residuals remain in water after treatment<br>• Requires frequent applications and corrosive<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | Y | Y | | Y | Y | Y | | Y | |
| 45 | | Sodium Hydroxide [B, GS]<br>CAS #: 1310-73-2 | N | When Not Registered for a Use | X | • Under consideration for use in ballast water treatment<br>• <1% survival of test organisms including algae, annelids, crustaceans and fish with 48-hr exposure to pH adjustments of 11.5 to 12.5 using NaOH (TenEyek, M. 2009. Great Ships Initiative Bench-Scale Test Findings, Technical Report – Public, Sodium Hydroxide (NaOH). GSI/BS/5.) | | Y | Y | | Y | Y | Y | | Y | |
| 48 | **Biological Controls** [§] | Introduced Predatory Fish Species | N | Available | | • Includes both carnivorous and herbivorous fish species<br>• Best used in waters with no outflows<br>• Predatory fish are non-selective feeders and may eat native species<br>• Predatorsare size selective feeders and may not eat eggs or larger organisms | | NA | | | | | | | | |
| 49 | | Introduced Predatory Insect Species | N | Experimental | | • United States Department of Agriculture (USDA) has not approved of any insects for use as biological controls of plants identified as ANS of Concern – CAWS<br>• Predators may be selective feeders (may not eat seeds) | T | NA | | | | | | | | |
| 50 | | *Pseudomonas fluorescens* CL 145A | N | Registered | | • Active ingredient (Pseudomonas fluorescens CL 145A) approved by the United States Environmental Protection Agency (USEPA) in July 2011(Reg. No. 84059-4)<br>• Formulation of commercial product as Zequanox™ is pending review by USEPA as of October 2010; Section 3 registration expected in March 2012<br>• Ongoing research to assess impacts to non-target mollusks | | NA | | | | | | | | |
| 51 | | Targeted Disease Agents | N | Experimental | | • Under consideration for carp species | T | NA | | | | | | | | |
| 52 | **Controlled Harvest and Overfishing** | Controlled Harvest and Overfishing | N | Available | | • Requires sorting and returning of native fish species<br>• Requires continual capture over a long period of time, or intensive harvest during critical periods of concentration and reproduction (e.g., migration and spawning season)<br>• Once harvesters, processors, and communities become economically dependent on harvesting nuisance fish, pressure to manage a sustainable population of these fish may conflict with the original purpose of removing them from the environment<br>• Typically for organisms larger than eggs and larvae. | | NA | | | | | | | | |
| 53 | **Deleterious Gene Spread** | Daughterless Gene | Y | Experimental | | • Researched as a Control for silver carp (*H. molitrix* ), bighead carp (*H. nobilis* ), black carp (*Mylopharyngodon piceus* ), and sea lamprey (*Petromyzon marinus* )<br>• Researched as a Control for common carp<br>• Manipulation of genes can manifest unforeseen and significant undesirable side effects and would require extensive research before being accepted as a Control | T | NA | | | | | | | | |

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| 54 | | Trojan Y Chromosome | | Y | Experimental | | • The Food and Drug Administration regulates genetically engineered animals | T | NA | | | | | | | | |
| 55 | **Dredging and Diver Dredging** | Dredging and Diver Dredging | | N | Available | | • Requires careful disposal or reuse of dredged material to prevent the transfer of ANS to a new location<br>• May remove other ANS of Concern – CAWS and non-target organisms that reside in sediment | | NA | | | | | | | | |
| 56 | **Electron Beam Irradiation** | Electron Beam Irradiation | | N | Available | X | • Used in irradiation of food, environmental waste, medical sterilization, and water treatment<br>• Requires a closed system and not appropriate for open water application<br>• May require pretreatment to remove suspended solids<br>• Used in irradiation of food, environmental waste, medical sterilization, and water treatment | | NA | Y | May not be effective for organisms near the bottom | Y | Y | | | | |
| 57 | **Hydrologic Separation** | Physical Barriers | | N | Available | X | • Modifies flow within waterway, including stormwater and combined sewer overflow discharge, and conveyance and commercial water dischargers and withdrawal of water<br>• Must be designed to handle storm flows. | | NA | Y | | Y | Y | | | | |
| 58 | **Irrigation Water Chemicals** [§] | Acrolein<br>CAS #: 107-02-8 | | N | Available, Registered, Restricted Use Product* | | • For control of submersed and floating weeds and algae only in irrigation canal systems in western states, provided the appropriate state registrations are also in place<br>• Toxic to fish and other aquatic organisms at labeled use rates<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 59 | | Xylene<br>CAS #: 1330-20-7 | | N | Registered | | • For use only in irrigation and drainage canals designated by the Bureau of Reclamation and cooperating water user organizations<br>• For use in Programs of the Bureau of Reclamation and Cooperating Water User Organizations within the following states, provided that the appropriate state registrations are also in place: AZ, CA, CO, ID, KS, MT, NE, NM, NV, ND, OK, OR, SD, TX, UT, WA, and WY<br>• For control of submerged weeds in irrigation and drainage canals<br>• Toxic to fish and other aquatic organisms at labeled use rates<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 60 | **Lethal Temperature** | Pressurized Hot Water/Steam Treatment | | N | Available | X | • Hot water has been used to kill zebra and quagga mussels at municipal and industrial facilities, and high pressure hot water is used to clean ANS off of recreational boats<br>• Treated area (i.e. boat hull) must be above the surface. | | NA | Y | | Y | Y | | | | |
| 61 | | Hot Water Thermal Barrier | | N | Available | X | • Difficult to manage in open water system, must be completely mixed throughout the water column | | | | | | | | | | |
| 62 | | Freezing | | N | Available | X | air temperatures<br>• Cluster mussels are more tolerant of reduced air temperatures than individual organisms<br>• Can be applied to static water. | | NA | N | Not effective on this species | | | | | | |

Removed During Nov 2012 ANS Controls Screening Charette

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 | | Carbon Dioxide ($CO_2$) Pellet (dry ice) Blasting | | N | Available | X | • Method used extensively to remove organics from aircrafts producing no deterioration of surfaces<br>• CO2 pellets convert to a gas at ambient temperatures, leaving no residue.<br>• Treated area (i.e. boat hull) must be above the surface | | NA | Y | Requires proper treatment of material | Y | Y | | | | |
| 64 | | Desiccation | | N | Available | X | • Desiccation can only be achieved in areas where water levels can be controlled<br>• Exposure to air quickly leads to death for active water-breathing organism—mollusks and plants are more tolerant and require longer drying period | | NA | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 65 | Light Attenuating Dyes § | Light Attenuating Dyes | | N | Registered | | • Not effective for suppressing growth of floating aquatic plants or emergent shoreline vegetation identified as ANS of Concern – CAWS<br>• Not effective on floating algal mats<br>• May suppress the growth of non-target plants and algae<br>• Only for use in contained waterbodies with little or no outflow<br>• Do not apply to waters used for human | | NA | | | | | | | | |
| 66 | Manual Harvest | Manual Harvest | | Y | Available | | • Labor-intensive<br>• Selectively dependent upon training and skill of staff | | NA | | | | | | | | |
| 67 | Mechanical Control Methods | Mechanical Harvesting | | N | Available | | • May disturb non-target organisms in equipment path | | NA | | | | | | | | |
| 68 | | Shredding | | N | Available | | | | NA | | | | | | | | |
| 69 | | Mowing | | N | Available | | | | NA | | | | | | | | |
| 70 | | Chaining | | N | Available | | | | NA | | | | | | | | |
| 71 | | Roto-tilling | | N | Available | | | | NA | | | | | | | | |
| 72 | | Rotovating | | N | Available | | • Used for submersed vegetation rooted in the substrate<br>• May have applications on emergent plants<br>• May disturb non-target organisms in equipment path | | NA | | | | | | | | |
| 73 | Molluscicides § | Quaternary and Polyquaternary Ammonium Compounds; Aromatic Hydrocarbons; Endothall as the Mono (N,N-imethylalkylamine) Salt (TD2335 Industrial Biocide-Molluscicide) | | N | Registered | | • Used for recirculating and once-through cooling water systems<br>• For control of established populations of freshwater and saltwater mollusks in closed systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | |
| 74 | | Metals and their salts (Copper Sulfate and Chelated Copper Formulations) | | N | Registered | | • Can be used to control mollusks in open water systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | |
| 75 | | Niclosamide CAS #: 1420-04-8 | | N | Available, Registered, Restricted Use Product* | | • First developed as a lampricide<br>• Used for control of snails in aquaculture ponds<br>• Toxic to fish and aquatic invertebrates at recommended use rates for control of snails in aquaculture ponds | | NA | | | | | | | | |
| 76 | Pheromones | Repellant and Attractant Pheromones | | Y | Experimental | | • Under investigation as an attractant and/or deterrent for silver carp (*H. molitrix* ), bighead carp (*H. nobilis* ), black carp (*M. piceus* ), and sea lamprey (*P. marinus* ) | T | NA | | | | | | | | |
| 77 | Piscicides § | Antimycin A CAS #: 1397-94-0 | | N | Available, Registered, Restricted Use Product* | | • Effectiveness can vary with the surfactant used.<br>• Requires approximately 8 to 32 hours to kill cyprinid species such as bighead carp (H. nobilis) and silver carp (H. molitrix)<br>• Restricted use pesticide due to aquatic toxicity and need for highly specialized applicator training | | NA | | | | | | | | |

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# Bloody Red Shrimp

| | A | B | C | D | E | I | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 78 | | Niclosamide<br>CAS #: 1420-04-8 | | N | Available, Registered, Restricted Use Product* | | • First developed as a lampricide<br>• Toxic to aquatic invertebrates; non-target organisms may be killed at rates recommended for sea lamprey control<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by United States Department of Interior, United States Fish & Wildlife Service (USFWS), state fish and game, Fisheries and Oceans Canada, and Provincial Certified Applicators trained in sea lamprey control<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 79 | | Rotenone (Both Standard Application and Via Oral Delivery Platforms)<br>CAS #: 83-79-4 | | N | Available, Registered, Restricted Use Product* | | • Kills bighead (*H. nobilis* ) carp and silver carp (*H. molitrix* ) within approximately 4 hours<br>• May be toxic to other aquatic organisms<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 80 | | TFM (3-Trifluoromethyl-4-nitrophenol)<br>CAS #: 88-30-2 | | N | Available, Registered, Restricted Use Product* | | • Designed only to control sea lamprey (*P. marinus* )<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by certified applicators of USFWS, Fisheries and Oceans Canada, and provincial and state fish and game employees<br>• Non-target organisms may be killed at labeled use rates<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 81 | **Screens** | Non-Mechanical Screens | Fences | N | Available | | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent movement of non-target | | NA | | | | | | | | |
| 82 | | | Bar Screens | N | Available | | | | NA | | | | | | | | |
| 83 | | | Trash Racks | N | Available | | | | NA | | | | | | | | |
| 84 | | | Curtains | N | Available | | | | NA | | | | | | | | |
| 85 | | Mechanical Screens | Chain Bar Screens | N | Available | | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent the movement of non-target organisms, depending on their size | | NA | | | | | | | | |
| 86 | | | Reciprocating Rake Bar Screens | N | Available | | | | NA | | | | | | | | |
| 87 | | | Catenary Bar Screens | N | Available | | | | NA | | | | | | | | |
| 88 | | | Continuous Belt Bar Screens | N | Available | | | | NA | | | | | | | | |
| 89 | | | Rotating Drum Screens (Paddle Wheel Or Power) | N | Available | | | | NA | | | | | | | | |
| 90 | | | Wedge-Wire Cylinders | N | Available | | | | NA | | | | | | | | |
| 91 | | | Louvered Screens | N | Available | | | | NA | | | | | | | | |
| 92 | | | Mechanical Climber Screens | N | Available | | | | NA | | | | | | | | |
| 93 | | Filters | | N | Available | X | • Generally used to treat small volumes of water<br>• Constrained by resistance through filter membrane and filter fouling<br>• Filters may prevent the movement of non-target organisms, depending on their size | | NA | Y | For organisms suspended in the water column, may not be effective for organisms established on the bottom of channel | Y | Y | | | | |
| 94 | **Sensory Deterrent Systems** | Underwater Strobe lights | | N | Experimental | | • Used to prevent upstream movement of fish | A | NA | | | | | | | | |

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# Bloody Red Shrimp

| | A | B/C | D | E | I | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 95 | | Underwater Sound | N | Experimental | | • May not prevent downstream movement of aquatic organisms | A | NA | | | | | | | | |
| 96 | | Acoustic Air Bubble Curtain | N | Experimental | | | A | NA | | | | | | | | |
| 97 | | Electric Barrier | N | Available | | • Must be configured to stop upstream and downstream movement of fish<br>• May impact non-target aquatic organisms | A | NA | | | | | | | | |
| 98 | **Ultrasound** | Ultrasound | N | Available | | • Used in small water bodies and water treatment plants<br>• Ultrasound may be effective on diatoms (*S. binderanus* )<br>• Most effective on enclosed bodies of water<br>• Additional research may be needed to investigate potential impacts on non-target organisms<br>• Under investigation for use against aquatic vascular plants (non-algae)<br>• Requires continuous application to maintain effectiveness | | NA | | | | | | | | |
| 99 | **Ultraviolet Light** | Ultraviolet (UV) Light | N | Available | X | • Used in fish hatcheries and water treatment facilities<br>• Used to treat contained flowing systems<br>• Best used after suspended solids, iron and manganese have been filtered from water<br>• May impact non-target aquatic organisms<br>• Under investigation for use against aquatic | | NA | Y | Future research is needed to determine if this species is susceptible to this technology | Y | Y | | | | |
| 100 | **Vertical Drop Barrier** | Vertical Drop Barrier | N | Available | X | • Does not prevent aquatic organism movement downstream<br>• May impact upstream movement of non-target organisms | | NA | Y | | N | Y | | | | |
| 101 | **Williams' Cage**<br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Williams' Cage | Y | Experimental | | • May be effective on silver carp *(H. molitrix)* and sea lamprey *(P. marinus)*<br>• Does not prevent aquatic organism movement downstream | A | NA | | | | | | | | |

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# Threespine Stickelback

| | A | B–C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | **Fact Sheet** | **ANS Control** | **Selective for ANS of Concern – CAWS** | **Status** [2] | **fish** | **Comments Refer to fact sheets for additional information on each Control** | **Level of R&D** | **Biocides for Industrial Use - Conventional, municipal drinking water or wastewater treatment technologies** | **Effective on Threespine Stickleback (eggs)** | **Comments on eggs** | **Effective on Threespine Stickleback (larvae)** | **Comments on larvae** | **Effective on Threespine Stickleback (adult)** | **Comments on adult** | **Effective with Downstream Flow** | **Effective with Upstream Flow** |
| 3 | **Accelerated Water Velocity** | Accelerated Water Velocity | N | Available | X | • Not effective in preventing downstream ANS movement<br>• Must have a length and speed of flow greater than the organism's leaping ability and swimming endurance | | NA | Y | | Y | | Y | | N | Y |
| 4 | **Acoustic Fish Deterrents** | Continuous Wave | N | Experimental | X | • Under development for control of fish<br>• May not be effective on all fish species | T | NA | N | Eggs do not react to external stimula and are incapable of directed movement | Y | | Y | | Y | Y |
| 5 | | Pulsed Pressure Wave | N | Experimental | X | • Not lethal unless an organism is very close to sound source | A | NA | N | Eggs not impacted by sound waves because they lack swim bladder | Y | | Y | | Y | Y |
| 6 | **Algaecides** [§] | Copper Sulfate and Chelated Copper Formulations (ethanolamines, ethylene diamines, triethanolamines, triethanolamine+ethylene diamine, and copper citrate/gluconate) | N | Available, Registered | | • May be effective on diatoms (*S. binderanus* ) and grass kelp (*Enteromorpha flexuosa* )<br>• Chelated copper formulations may be effective on red macro-algae (Bangia atropupurea)<br>• Reduced efficacy in waters with high pH and water temperatures < 15 °C<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 7 | | Endothall (as the mono(N,N-dimethylalkylamine) salt) CAS #: 66330-88-9 | N | Available, Registered | | • May be effective on red macro-algae (*B. atropupurea* ) and diatoms (*S. binderanus* )<br>• Can be harmful to fish<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | |
| 8 | | Algaecides containing Sodium Carbonate Peroxyhydrate CAS #: 15630-89-4 | N | Available, Registered | | • May be effective on diatoms (*S. binderanus* ), and grass kelp (*E. flexuosa* )<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | |
| 9 | **Alteration of Water Quality** [§]<br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/10/2011. The Chemical Abstracts | Carbon Dioxide ($CO_2$) | N | Available, When Not Registered for a Use | X | • May repel fish at sub-lethal levels<br>• Lowers pH<br>• Creates irreversible cell damage and death<br>• Effectiveness dependent upon dose and exposure | | NA | Y | | Y | | Y | | Y | Y |

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# Threespine Stickelback

| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 11/13/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided. | Gases | Ozone | N | Available | X | • Rendered ineffective in the presence of organic matter<br>• Used commercially to decontaminate water<br>• Ozone oxidation is toxic to most small waterborne organisms<br>• Destroys the epithelium covering the gill lamella in fish<br>• Effectiveness dependent upon dose and exposure | | NA | Y | | Y | | Y | | Y | Y |
| 11 | | | Nitrogen | N | Available | X | • Adult fish are more tolerant than young fish<br>• Nitrogen supersaturation is a cause of gas bubble disease in fish<br>• Effectiveness dependent upon dose and exposure<br>• Not effective on eggs | | NA | M | Uncertain of toxicity of nitrogen across egg membrane | Y | | Y | | Y | Y |
| 12 | | Solids | Alum | N | Available | | • Creates a solid precipitate from suspended solids within the water column which settles<br>• Alum is not classified as a pesticide, therefore does not require FIFRA registration | | NA | | | | | | | | |
| 13 | | | Sodium Thiosulfate<br>CAS #: 7772-98-7 | N | Experimental | X | • Deoxygenated compound<br>• Effectiveness dependent upon dose and | T | NA | Y | | Y | | Y | | Y | Y |
| 14 | **Aquatic Herbicides** §<br><br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/13/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided. | 2,4-D (both the amine and butoxy-ethyl ester formulations)<br>CAS #: 94-75-7 | | N | Available, Registered | | • Tank mixing with other herbicides improves plant control<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 15 | | Diquat<br>CAS #: 85-00-7 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 16 | | Fluridone<br>CAS #: 59756-60-4 | | N | Available, Registered | | • Plants must be exposed to a lethal dose for a minimum of 45 days for optimal results<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 17 | | Glyphosate<br>CAS #: 1071-83-6 | | N | Available, Registered | | • May be effective on reed sweetgrass (Glyceria maxima)<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 18 | | Imazapyr<br>CAS #: 81334-34-1 | | N | Available, Registered | | • May be effective on reed sweetgrass (*G. maxima* )<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | |
| 19 | | Triclopyr<br>CAS #: 55335-06-3 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 20 | | | | | | | | | NA | | | | | | | | |
| 21 | **Benthic Barriers** | Textile or Plastic | | N | Available | | | | NA | | | | | | | | |

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# Threespine Stickelback

| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | | Silt | | N | Available | X | • Created by applying excessive silt/sand to smother bottom-dwelling organism<br>• Application to control aquatic nuisance species has not been widely studied | | NA | Y | It lays eggs in a nest on the bottom (NatureServe 2010); therefore eggs and larvae are not expected to be transported by currents unless resuspended into the water column by a disturbance. | Y | | N | Adults would likely avoid areas of high turbidity | Y | Y |
| 27 | **Biocides for Industrial Use** § <br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of | Chlorine (free chlorine, hypochlorous acid, hypochlorite salts)<br>CAS #: 7782-50-5 | | N | When Not Registered for a Use | X | • Residuals remain in water after treatment<br>• Requires frequent applications<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | Y | Y | | Y | | Y | | Y | Y |

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# Threespine Stickelback

| | A | B/C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 28 | Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D- | Chlorine Dioxide<br>CAS #: 10049-04-4 | N | When Not Registered for a Use | X | • Effectiveness dependent upon dose and exposure | | Y | Y | | Y | | Y | | Y | Y |
| 34 | **Biocides for Industrial Use** § **(continued)**<br><br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br><br>The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been | Hydrogen Peroxide<br>CAS #: 7722-84-1<br>CAS #: 79-21-0 | N | When Not Registered for a Use | | • Disinfection of drinking water, cooling systems and surfaces<br>• Presence of organic matter limits effectiveness<br>• Moderately corrosive<br>• Some residuals remain in water after treatment<br>• Effective on algal spores | | Y | | | | | | | | |
| 38 | | Peracetic Acid (Peraclean®)<br>CAS #: 79-21-0<br>CAS #: 7722-84-1 | N | When Not Registered for a Use | X | • No known toxic residual; more potent than hydrogen peroxide<br>• Rapidly active at low concentrations against a wide range of microorganisms<br>• Corrosive<br>• Highly efficient in presence of organic matter<br>• Wastewater treatment | | Y | Y | | Y | | Y | | Y | Y |
| 41 | **Biocides for Industrial Use §** **(continued)**<br><br>Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br><br>The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Potassium Permanganate<br>CAS #: 7722-64-7 | N | Experimental | | • Organic matter limits effectiveness & moderately corrosive<br>• Some residuals remain in water after treatment<br>• Effectiveness dependent upon dose and | A | Y | | | | | | | | |
| 44 | | Sodium Chlorite<br>CAS #: 7758-19-2 | N | When Not Registered for a Use | X | • Disinfection of drinking water, cooling systems and surfaces<br>• Presence of organic matter limits effectiveness<br>• Residuals remain in water after treatment<br>• Requires frequent applications and corrosive<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | Y | Y | | Y | | Y | | Y | Y |
| 45 | | Sodium Hydroxide [B, GS]<br>CAS #: 1310-73-2 | N | When Not Registered for a Use | X | • Under consideration for use in ballast water treatment<br>• <1% survival of test organisms including algae, annelids, crustaceans and fish with 48-hr exposure to pH adjustments of 11.5 to 12.5 using NaOH (TenEyek, M. 2009. Great Ships Initiative Bench-Scale Test Findings, Technical Report – Public, Sodium Hydroxide (NaOH). GSI/BS/5.) | | Y | Y | | Y | | Y | | Y | Y |
| 48 | **Biological Controls** § | Introduced Predatory Fish Species | N | Available | X | • Includes both carnivorous and herbivorous fish species<br>• Best used in waters with no outflows<br>• Predatory fish are non-selective feeders and may eat native species<br>• Predatorsare size selective feeders and may not eat eggs or larger organisms | | NA | Y | | Y | | Y | | Y | Y |
| 49 | | Introduced Predatory Insect Species | N | Experimental | | • United States Department of Agriculture (USDA) has not approved of any insects for use as biological controls of plants identified as ANS of Concern – CAWS<br>• Predators may be selective feeders (may not eat seeds) | T | NA | | | | | | | | |

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# Threespine Stickelback

| | A | B / C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 | | *Pseudomonas fluorescens* CL 145A | N | Registered | | • Active ingredient (Pseudomonas fluorescens CL 145A) approved by the United States Environmental Protection Agency (USEPA) in July 2011(Reg. No. 84059-4)<br>• Formulation of commercial product as Zequanox™ is pending review by USEPA as of October 2010; Section 3 registration expected in March 2012<br>• Ongoing research to assess impacts to non-target mollusks | | NA | | | | | | | | |
| 51 | | Targeted Disease Agents | N | Experimental | X | • Under consideration for carp species | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |
| 52 | **Controlled Harvest and Overfishing** | Controlled Harvest and Overfishing | N | Available | X | • Requires sorting and returning of native fish species<br>• Requires continual capture over a long period of time, or intensive harvest during critical periods of concentration and reproduction (e.g., migration and spawning season)<br>• Once harvesters, processors, and communities become economically dependent on harvesting nuisance fish, pressure to manage a sustainable population of these fish may conflict with the original purpose of removing them from the | | NA | N | Eggs are too small to harvest | N | Larvae are too small to harvest | Y | | Y | Y |
| 53 | **Deleterious Gene Spread** | Daughterless Gene | Y | Experimental | X | • Researched as a Control for silver carp (*H. molitrix* ), bighead carp (*H. nobilis* ), black carp (*Mylopharyngodon piceus* ), and sea lamprey (*Petromyzon marinus* )<br>• Researched as a Control for common carp<br>• Manipulation of genes can manifest unforeseen and significant undesirable side effects and would require extensive research before being accepted as a Control | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |
| 54 | | Trojan Y Chromosome | Y | Experimental | X | • The Food and Drug Administration regulates genetically engineered animals | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |
| 55 | **Dredging and Diver Dredging** | Dredging and Diver Dredging | N | Available | | • Requires careful disposal or reuse of dredged material to prevent the transfer of ANS to a new location<br>• May remove other ANS of Concern – CAWS and non-target organisms that reside in sediment | | NA | | | | | | | | |

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# Threespine Stickelback

| | A | B / C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 56 | **Electron Beam Irradiation** | Electron Beam Irradiation | N | Available | | • Used in irradiation of food, environmental waste, medical sterilization, and water treatment<br>• Requires a closed system and not appropriate for open water application<br>• May require pretreatment to remove suspended solids<br>• Used in irradiation of food, environmental | | NA | | | | | | | | |
| 57 | **Hydrologic Separation** | Physical Barriers | N | Available | X | • Modifies flow within waterway, including stormwater and combined sewer overflow discharge, and conveyance and commercial water dischargers and withdrawal of water<br>• Must be designed to handle storm flows. | | NA | Y | | Y | | Y | | Y | Y |
| 58 | **Irrigation Water Chemicals** § | Acrolein<br>CAS #: 107-02-8 | N | Available, Registered, Restricted Use Product* | | • For control of submersed and floating weeds and algae only in irrigation canal systems in western states, provided the appropriate state registrations are also in place<br>• Toxic to fish and other aquatic organisms at labeled use rates | | NA | | | | | | | | |
| 59 | | Xylene<br>CAS #: 1330-20-7 | N | Registered | | • For use only in irrigation and drainage canals designated by the Bureau of Reclamation and cooperating water user organizations<br>• For use in Programs of the Bureau of Reclamation and Cooperating Water User Organizations within the following states, provided that the appropriate state registrations are also in place: AZ, CA, CO, ID, KS, MT, NE, NM, NV, ND, OK, OR, SD, TX, UT, WA, and WY<br>• For control of submerged weeds in irrigation and drainage canals<br>• Toxic to fish and other aquatic organisms at | | NA | | | | | | | | |
| 60 | **Lethal Temperature** | Pressurized Hot Water/Steam Treatment | N | Available | X | • Hot water has been used to kill zebra and quagga mussels at municipal and industrial facilities, and high pressure hot water is used to clean ANS off of recreational boats | | | | | | | | | | |
| 61 | | Hot Water Thermal Barrier | N | Available | X | be completely mixed throughout the water column<br>• During cold weather conditions, warm water temperatures may attract fish | | NA | Y | | Y | | Y | | Y | Y |
| 62 | | Freezing | N | Available | X | • Freezing is often combined with winter water level drawdowns to expose the ANS to freezing air temperatures<br>• Cluster mussels are more tolerant of reduced air temperatures than individual organisms<br>• Can be applied to static water. | | NA | Y | | Y | | Y | | Y | Y |

Removed During Nov 2012 ANS Controls Screening Charette

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# Threespine Stickelback

| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 | | Carbon Dioxide ($CO_2$) Pellet (dry ice) Blasting | | N | Available | X | • Method used extensively to remove organics from aircrafts producing no deterioration of surfaces<br>• CO2 pellets convert to a gas at ambient temperatures, leaving no residue.<br>• Treated area (i.e. boat hull) must be above the surface. | | NA | N | Eggs do not adhere to boat hulls | N | Larvae do not adhere to boat hulls | N | Fish do not adhere to boat hulls | | |
| 64 | | Desiccation | | N | Available | X | • Desiccation can only be achieved in areas where water levels can be controlled<br>• Exposure to air quickly leads to death for active water-breathing organism—mollusks and plants are more tolerant and require longer drying period | | NA | Y | | Y | | Y | | Y | Y |
| 65 | **Light Attenuating Dyes** § | Light Attenuating Dyes | | N | Registered | | • Not effective for suppressing growth of floating aquatic plants or emergent shoreline vegetation identified as ANS of Concern – CAWS<br>• Not effective on floating algal mats<br>• May suppress the growth of non-target plants and algae<br>• Only for use in contained waterbodies with little or no outflow<br>• Do not apply to waters used for human consumption | | NA | | | | | | | | |
| 66 | **Manual Harvest** | Manual Harvest | | Y | Available | | • Labor-intensive<br>• Selectively dependent upon training and skill of staff | | NA | | | | | | | | |
| 67 | **Mechanical Control Methods** | Mechanical Harvesting | | N | Available | | • May disturb non-target organisms in equipment path | | NA | | | | | | | | |
| 68 | | Shredding | | N | Available | | | | NA | | | | | | | | |
| 69 | | Mowing | | N | Available | | | | NA | | | | | | | | |
| 70 | | Chaining | | N | Available | | | | NA | | | | | | | | |
| 71 | | Roto-tilling | | N | Available | | | | NA | | | | | | | | |
| 72 | | Rotovating | | N | Available | | • Used for submersed vegetation rooted in the substrate<br>• May have applications on emergent plants<br>• May disturb non-target organisms in equipment path | | NA | | | | | | | | |
| 73 | **Molluscicides** § | Quaternary and Polyquaternary Ammonium Compounds; Aromatic Hydrocarbons; Endothall as the Mono (N,N-imethylalkylamine) Salt (TD2335 Industrial Biocide-Molluscicide) | | N | Registered | | • Used for recirculating and once-through cooling water systems<br>• For control of established populations of freshwater and saltwater mollusks in closed systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | |
| 74 | | Metals and their salts (Copper Sulfate and Chelated Copper Formulations) | | N | Registered | | • Can be used to control mollusks in open water systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | |
| 75 | | Niclosamide CAS #: 1420-04-8 | | N | Available, Registered, Restricted Use Product* | | • First developed as a lampricide<br>• Used for control of snails in aquaculture ponds<br>• Toxic to fish and aquatic invertebrates at recommended use rates for control of snails in aquaculture ponds | | NA | | | | | | | | |

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# Threespine Stickelback

| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 76 | **Pheromones** | Repellant and Attractant Pheromones | | Y | Experimental | X | • Under investigation as an attractant and/or deterrent for silver carp (*H. molitrix* ), bighead carp (*H. nobilis* ), black carp (*M. piceus* ), and sea lamprey (*P. marinus* ) | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |
| 77 | **Piscicides** § | Antimycin A<br>CAS #: 1397-94-0 | | N | Available, Registered, Restricted Use Product* | X | • Effectiveness can vary with the surfactant used.<br>• Requires approximately 8 to 32 hours to kill cyprinid species such as bighead carp (H. nobilis) and silver carp (H. molitrix)<br>• Restricted use pesticide due to aquatic toxicity and need for highly specialized applicator training | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |
| 78 | | Niclosamide<br>CAS #: 1420-04-8 | | N | Available, Registered, Restricted Use Product* | X | • First developed as a lampricide<br>• Toxic to aquatic invertebrates; non-target organisms may be killed at rates recommended for sea lamprey control<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by United States Department of Interior, United States Fish & Wildlife Service (USFWS), state fish and game, Fisheries and Oceans Canada, and Provincial Certified Applicators trained in sea lamprey control<br>• Effectiveness dependent upon dose and exposure | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |
| 79 | | Rotenone (Both Standard Application and Via Oral Delivery Platforms)<br>CAS #: 83-79-4 | | N | Available, Registered, Restricted Use Product* | X | • Kills bighead (*H. nobilis* ) carp and silver carp (*H. molitrix* ) within approximately 4 hours<br>• May be toxic to other aquatic organisms<br>• Effectiveness dependent upon dose and exposure | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |
| 80 | | TFM (3-Trifluoromethyl-4-nitrophenol)<br>CAS #: 88-30-2 | | N | Available, Registered, Restricted Use Product* | X | • Designed only to control sea lamprey (*P. marinus* )<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by certified applicators of USFWS, Fisheries and Oceans Canada, and provincial and state fish and game employees<br>• Non-target organisms may be killed at labeled use rates<br>• Effectiveness dependent upon dose and exposure | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |
| 81 | **Screens** | Non-Mechanical Screens | Fences | N | Available | X | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent movement of non-target organisms, depending on their size | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too large | | |
| 82 | | | Bar Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |
| 83 | | | Trash Racks | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |

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| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 84 | | | Curtains | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | extend to the bottom of channel | | |
| 85 | | Mechanical Screens | Chain Bar Screens | N | Available | X | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent the movement of non-target organisms, depending on their size | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |
| 86 | | | Reciprocating Rake Bar Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |
| 87 | | | Catenary Bar Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |
| 88 | | | Continuous Belt Bar Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too large | | |
| 89 | | | Rotating Drum Screens (Paddle Wheel Or Power) | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 90 | | | Wedge-Wire Cylinders | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 91 | | | Louvered Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |
| 92 | | | Mechanical Climber Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |
| 93 | | Filters | | N | Available | X | • Generally used to treat small volumes of water<br>• Constrained by resistance through filter membrane and filter fouling<br>• Filters may prevent the movement of non-target organisms, depending on their size | | NA | Y | | Y | | Y | | Y | Y |
| 94 | **Sensory Deterrent Systems** | Underwater Strobe lights | | N | Experimental | X | | A | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | M | Future research is needed to determine if this species is susceptible to this technology | Y | Y |

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| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 95 | | Underwater Sound | | N | Experimental | X | • Used to prevent upstream movement of fish<br>• May not prevent downstream movement of aquatic organisms | A | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | M | Future research is needed to determine if this species is susceptible to this technology | Y | Y |
| 96 | | Acoustic Air Bubble Curtain | | N | Experimental | X | | A | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | M | Future research is needed to determine if this species is susceptible to this technology | Y | Y |
| 97 | | Electric Barrier | | N | Available | X | • Must be configured to stop upstream and downstream movement of fish<br>• May impact non-target aquatic organisms | | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | Y | | N | Y |
| 98 | **Ultrasound** | Ultrasound | | N | Available | | • Used in small water bodies and water treatment plants<br>• Ultrasound may be effective on diatoms (*S. binderanus* )<br>• Most effective on enclosed bodies of water<br>• Additional research may be needed to investigate potential impacts on non-target organisms<br>• Under investigation for use against aquatic vascular plants (non-algae)<br>• Requires continuous application to maintain effectiveness | | NA | | | | | | | | |

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# Threespine Stickelback

| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 99 | **Ultraviolet Light** | Ultraviolet (UV) Light | | N | Available | | • Used in fish hatcheries and water treatment facilities<br>• Used to treat contained flowing systems<br>• Best used after suspended solids, iron and manganese have been filtered from water<br>• May impact non-target aquatic organisms<br>• Under investigation for use against aquatic vascular plants (non-algae) | | NA | | | | | | | | |
| 100 | **Vertical Drop Barrier** | Vertical Drop Barrier | | N | Available | X | • Does not prevent aquatic organism movement downstream<br>• May impact upstream movement of non-target organisms | | NA | Y | | Y | | Y | | N | Y |
| 101 | **Williams' Cage**<br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Williams' Cage | | Y | Experimental | X | • May be effective on silver carp *(H. molitrix)* and sea lamprey *(P. marinus)*<br>• Does not prevent aquatic organism movement downstream | A | NA | N | Eggs incapable of directed movement | N | Larvae have limited directed movement | N | Bar spacing typically too wide | | |

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# Ruffe

| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Fact Sheet | ANS Control | | Selective for ANS of Concern – CAWS | Status [2] | fish | Comments<br>Refer to fact sheets for additional information on each Control | Level of R&D | Biocides for Industrial Use - Conventional, municipal drinking water or wastewater treatment technologies | Effective on Ruffe (eggs) | Comments on eggs | Effective on Ruffe (larvae) | Comments on larvae | Effective on Ruffe (adult) | Comments on adult | Effective with Downstream Flow | Effective with Upstream Flow |
| 3 | **Accelerated Water Velocity** | Accelerated Water Velocity | | N | Available | X | • Not effective in preventing downstream ANS movement<br>• Must have a length and speed of flow greater than the organism's leaping ability and swimming endurance | | NA | Y | | Y | | Y | | N | Y |
| 4 | **Acoustic Fish Deterrents** | Continuous Wave | | N | Experimental | X | • Under development for control of fish<br>• May not be effective on all fish species | T | NA | N | Eggs do not react to external stimula and are incapable of directed movement | Y | | Y | | Y | Y |
| 5 | | Pulsed Pressure Wave | | N | Experimental | X | • Not lethal unless an organism is very close to sound source | A | NA | N | Eggs not impacted by sound waves because they lack swim bladder | Y | | Y | | Y | Y |
| 6 | **Algaecides** § | Copper Sulfate and Chelated Copper Formulations (ethanolamines, ethylene diamines, triethanolamines, triethanolamine+ethylene diamine, and copper citrate/gluconate) | | N | Available, Registered | | • May be effective on diatoms (*S. binderanus* ) and grass kelp (*Enteromorpha flexuosa* )<br>• Chelated copper formulations may be effective on red macro-algae (Bangia atropupurea)<br>• Reduced efficacy in waters with high pH and water temperatures < 15 °C<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 7 | | Endothall (as the mono(N,N-dimethylalkylamine) salt)<br>CAS #: 66330-88-9 | | N | Available, Registered | | • May be effective on red macro-algae (*B. atropupurea* ) and diatoms (*S. binderanus* )<br>• Can be harmful to fish<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | |
| 8 | | Algaecides containing Sodium Carbonate Peroxyhydrate<br>CAS #: 15630-89-4 | | N | Available, Registered | | • May be effective on diatoms (*S. binderanus* ), and grass kelp (*E. flexuosa* )<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | |
| 9 | **Alteration of Water Quality** §<br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/10/2011. The Chemical Abstracts | | Carbon Dioxide ($CO_2$) | N | Available, When Not Registered for a Use | X | • May repel fish at sub-lethal levels<br>• Lowers pH<br>• Creates irreversible cell damage and death<br>• Effectiveness dependent upon dose and exposure | | NA | Y | | Y | | Y | | Y | Y |

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# Ruffe

| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | Service (CAS) numbers were used to enter the query and for convenience have been provided. | Gases | Ozone | N | Available | X | • Rendered ineffective in the presence of organic matter<br>• Used commercially to decontaminate water<br>• Ozone oxidation is toxic to most small waterborne organisms<br>• Destroys the epithelium covering the gill lamella in fish<br>• Effectiveness dependent upon dose and exposure | | NA | Y | | Y | | Y | | Y | Y |
| 11 | | | Nitrogen | N | Available | X | • Adult fish are more tolerant than young fish<br>• Nitrogen supersaturation is a cause of gas bubble disease in fish<br>• Effectiveness dependent upon dose and exposure<br>• Not effective on eggs | | NA | M | Uncertain of toxicity of nitrogen across egg membrane | Y | | Y | | Y | Y |
| 12 | | Solids | Alum | N | Available | | • Creates a solid precipitate from suspended solids within the water column which settles<br>• Alum is not classified as a pesticide, therefore does not require FIFRA registration | | NA | | | | | | | | |
| 13 | | | Sodium Thiosulfate<br>CAS #: 7772-98-7 | N | Experimental | X | • Deoxygenated compound<br>• Effectiveness dependent upon dose and exposure | T | NA | Y | | Y | | Y | | Y | Y |
| 14 | **Aquatic Herbicides** §<br><br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/13/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided. | 2,4-D (both the amine and butoxy-ethyl ester formulations)<br>CAS #: 94-75-7 | | N | Available, Registered | | • Tank mixing with other herbicides improves plant control<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 15 | | Diquat<br>CAS #: 85-00-7 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 16 | | Fluridone<br>CAS #: 59756-60-4 | | N | Available, Registered | | • Plants must be exposed to a lethal dose for a minimum of 45 days for optimal results<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 17 | | Glyphosate<br>CAS #: 1071-83-6 | | N | Available, Registered | | • May be effective on reed sweetgrass (Glyceria maxima)<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 18 | | Imazapyr<br>CAS #: 81334-34-1 | | N | Available, Registered | | • May be effective on reed sweetgrass (*G. maxima* )<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | |
| 19 | | Triclopyr<br>CAS #: 55335-06-3 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 20 | | | | | | | | | NA | | | | | | | | |
| 21 | **Benthic Barriers** | Textile or Plastic | | N | Available | | | | NA | | | | | | | | |
| 22 | | Silt | | N | Available | X | • Created by applying excessive silt/sand to smother bottom-dwelling organism<br>• Application to control aquatic nuisance species has not been widely studied | | NA | Y | The eggs and larvae of the species are benthic, not free-floating (Ogle 1998), so the transport of eggs by currents is unlikely. | Y | | N | Adults would likely avoid areas of high turbidity | Y | Y |

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| 27 | **Biocides for Industrial Use** § <br><br> Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004) | Chlorine (free chlorine, hypochlorous acid, hypochlorite salts) CAS #: 7782-50-5 | N | When Not Registered for a Use | X | • Residuals remain in water after treatment <br>• Requires frequent applications <br>• Effectiveness dependent upon dose and exposure <br>• Effective on algal spores | | Y | Y | | Y | | Y | | Y | Y |
| 28 | | Chlorine Dioxide CAS #: 10049-04-4 | N | When Not Registered for a Use | X | • Effectiveness dependent upon dose and exposure | | Y | Y | | Y | | Y | | Y | Y |
| 34 | **Biocides for Industrial Use** § **(continued)** <br><br> Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004) <br><br> The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been | Hydrogen Peroxide CAS #: 7722-84-1 CAS #: 79-21-0 | N | When Not Registered for a Use | | • Disinfection of drinking water, cooling systems and surfaces <br>• Presence of organic matter limits effectiveness <br>• Moderately corrosive <br>• Some residuals remain in water after treatment <br>• Effective on algal spores | | Y | | | | | | | | |
| 38 | | Peracetic Acid (Peraclean®) CAS #: 79-21-0 CAS #: 7722-84-1 | N | When Not Registered for a Use | X | • No known toxic residual; more potent than hydrogen peroxide <br>• Rapidly active at low concentrations against a wide range of microorganisms <br>• Corrosive <br>• Highly efficient in presence of organic matter <br>• Wastewater treatment | | Y | Y | | Y | | Y | | Y | Y |
| 41 | **Biocides for Industrial Use § (continued)** <br><br> Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004) <br><br> The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided. <br><br> Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Potassium Permanganate CAS #: 7722-64-7 | N | Experimental | | • Organic matter limits effectiveness & moderately corrosive <br>• Some residuals remain in water after treatment <br>• Effectiveness dependent upon dose and | A | Y | | | | | | | | |
| 44 | | Sodium Chlorite CAS #: 7758-19-2 | N | When Not Registered for a Use | X | • Disinfection of drinking water, cooling systems and surfaces <br>• Presence of organic matter limits effectiveness <br>• Residuals remain in water after treatment <br>• Requires frequent applications and corrosive <br>• Effectiveness dependent upon dose and exposure <br>• Effective on algal spores | | Y | Y | | Y | | Y | | Y | Y |
| 45 | | Sodium Hydroxide [B, GS] CAS #: 1310-73-2 | N | When Not Registered for a Use | X | • Under consideration for use in ballast water treatment <br>• <1% survival of test organisms including algae, annelids, crustaceans and fish with 48-hr exposure to pH adjustments of 11.5 to 12.5 using NaOH (TenEyek, M. 2009. Great Ships Initiative Bench-Scale Test Findings, Technical Report – Public, Sodium Hydroxide (NaOH). GSI/BS/5.) | | Y | Y | | Y | | Y | | Y | Y |
| 48 | **Biological Controls** § | Introduced Predatory Fish Species | N | Available | X | • Includes both carnivorous and herbivorous fish species <br>• Best used in waters with no outflows <br>• Predatory fish are non-selective feeders and may eat native species <br>• Predatorsare size selective feeders and may not eat eggs or larger organisms | | NA | Y | | Y | | Y | | Y | Y |

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| 49 | | Introduced Predatory Insect Species | | N | Experimental | | • United States Department of Agriculture (USDA) has not approved of any insects for use as biological controls of plants identified as ANS of Concern – CAWS<br>• Predators may be selective feeders (may not eat seeds) | T | NA | | | | | | | | |
| 50 | | *Pseudomonas fluorescens* CL 145A | | N | Registered | | • Active ingredient (Pseudomonas fluorescens CL 145A) approved by the United States Environmental Protection Agency (USEPA) in July 2011(Reg. No. 84059-4)<br>• Formulation of commercial product as Zequanox™ is pending review by USEPA as of October 2010; Section 3 registration expected in March 2012<br>• Ongoing research to assess impacts to non-target mollusks | | NA | | | | | | | | |
| 51 | | Targeted Disease Agents | | N | Experimental | X | • Under consideration for carp species | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |
| 52 | **Controlled Harvest and Overfishing** | Controlled Harvest and Overfishing | | N | Available | X | • Requires sorting and returning of native fish species<br>• Requires continual capture over a long period of time, or intensive harvest during critical periods of concentration and reproduction (e.g., migration and spawning season)<br>• Once harvesters, processors, and communities become economically dependent on harvesting nuisance fish, pressure to manage a sustainable population of these fish may conflict with the original purpose of removing them from the | | NA | N | Eggs are too small to harvest | N | Larvae are too small to harvest | Y | | Y | Y |
| 53 | **Deleterious Gene Spread** | Daughterless Gene | | Y | Experimental | X | • Researched as a Control for silver carp (*H. molitrix* ), bighead carp (*H. nobilis* ), black carp (*Mylopharyngodon piceus* ), and sea lamprey (*Petromyzon marinus* )<br>• Researched as a Control for common carp<br>• Manipulation of genes can manifest unforeseen and significant undesirable side effects and would require extensive research before being accepted as a Control | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |
| 54 | | Trojan Y Chromosome | | Y | Experimental | X | • The Food and Drug Administration regulates genetically engineered animals | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |

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| 55 | **Dredging and Diver Dredging** | Dredging and Diver Dredging | N | Available | | • Requires careful disposal or reuse of dredged material to prevent the transfer of ANS to a new location<br>• May remove other ANS of Concern – CAWS and non-target organisms that reside in sediment | | NA | | | | | | | | |
| 56 | **Electron Beam Irradiation** | Electron Beam Irradiation | N | Available | | • Used in irradiation of food, environmental waste, medical sterilization, and water treatment<br>• Requires a closed system and not appropriate for open water application<br>• May require pretreatment to remove suspended solids<br>• Used in irradiation of food, environmental | | NA | | | | | | | | |
| 57 | **Hydrologic Separation** | Physical Barriers | N | Available | X | • Modifies flow within waterway, including stormwater and combined sewer overflow discharge, and conveyance and commercial water dischargers and withdrawal of water<br>• Must be designed to handle storm flows | | NA | Y | | Y | | Y | | Y | Y |
| 58 | **Irrigation Water Chemicals** § | Acrolein<br>CAS #: 107-02-8 | N | Available, Registered, Restricted Use Product* | | • For control of submersed and floating weeds and algae only in irrigation canal systems in western states, provided the appropriate state registrations are also in place<br>• Toxic to fish and other aquatic organisms at labeled use rates | | NA | | | | | | | | |
| 59 | | Xylene<br>CAS #: 1330-20-7 | N | Registered | | • For use only in irrigation and drainage canals designated by the Bureau of Reclamation and cooperating water user organizations<br>• For use in Programs of the Bureau of Reclamation and Cooperating Water User Organizations within the following states, provided that the appropriate state registrations are also in place: AZ, CA, CO, ID, KS, MT, NE, NM, NV, ND, OK, OR, SD, TX, UT, WA, and WY<br>• For control of submerged weeds in irrigation and drainage canals<br>• Toxic to fish and other aquatic organisms at | | NA | | | | | | | | |
| 60 | **Lethal Temperature** | Pressurized Hot Water/Steam Treatment | N | Available | X | • Hot water has been used to kill zebra and quagga mussels at municipal and industrial facilities, and high pressure hot water is used to clean ANS off of recreational boats | | | | | | | | | | |
| 61 | | Hot Water Thermal Barrier | N | Available | X | be completely mixed throughout the water column<br>• During cold weather conditions, warm water temperatures may attract fish | | NA | Y | | Y | | Y | | Y | Y |
| 62 | | Freezing | N | Available | X | • Freezing is often combined with winter water level drawdowns to expose the ANS to freezing air temperatures<br>• Cluster mussels are more tolerant of reduced air temperatures than individual organisms<br>• Can be applied to static water. | | NA | Y | | Y | | Y | | Y | Y |

Removed During Nov 2012 ANS Controls Screening Charette

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| 63 | | | Carbon Dioxide ($CO_2$) Pellet (dry ice) Blasting | N | Available | X | • Method used extensively to remove organics from aircrafts producing no deterioration of surfaces<br>• CO2 pellets convert to a gas at ambient temperatures, leaving no residue.<br>• Treated area (i.e. boat hull) must be above the surface. | | NA | N | Eggs do not adhere to boat hulls | N | Larvae do not adhere to boat hulls | N | Fish do not adhere to boat hulls | | |
| 64 | | | Desiccation | N | Available | X | • Desiccation can only be achieved in areas where water levels can be controlled<br>• Exposure to air quickly leads to death for active water-breathing organism—mollusks and plants are more tolerant and require longer drying period | | NA | Y | | Y | | Y | | Y | Y |
| 65 | **Light Attenuating Dyes** § | | Light Attenuating Dyes | N | Registered | | • Not effective for suppressing growth of floating aquatic plants or emergent shoreline vegetation identified as ANS of Concern – CAWS<br>• Not effective on floating algal mats<br>• May suppress the growth of non-target plants and algae<br>• Only for use in contained waterbodies with little or no outflow<br>• Do not apply to waters used for human consumption | | NA | | | | | | | | |
| 66 | **Manual Harvest** | | Manual Harvest | Y | Available | | • Labor-intensive<br>• Selectively dependent upon training and skill of staff | | NA | | | | | | | | |
| 67 | **Mechanical Control Methods** | | Mechanical Harvesting | N | Available | | • May disturb non-target organisms in equipment path | | NA | | | | | | | | |
| 68 | | | Shredding | N | Available | | | | NA | | | | | | | | |
| 69 | | | Mowing | N | Available | | | | NA | | | | | | | | |
| 70 | | | Chaining | N | Available | | | | NA | | | | | | | | |
| 71 | | | Roto-tilling | N | Available | | | | NA | | | | | | | | |
| 72 | | | Rotovating | N | Available | | • Used for submersed vegetation rooted in the substrate<br>• May have applications on emergent plants<br>• May disturb non-target organisms in equipment path | | NA | | | | | | | | |
| 73 | **Molluscicides** § | | Quaternary and Polyquaternary Ammonium Compounds; Aromatic Hydrocarbons; Endothall as the Mono (N,N-imethylalkylamine) Salt (TD2335 Industrial Biocide-Molluscicide) | N | Registered | | • Used for recirculating and once-through cooling water systems<br>• For control of established populations of freshwater and saltwater mollusks in closed systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | |
| 74 | | | Metals and their salts (Copper Sulfate and Chelated Copper Formulations) | N | Registered | | • Can be used to control mollusks in open water systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | |
| 75 | | | Niclosamide CAS #: 1420-04-8 | N | Available, Registered, Restricted Use Product* | | • First developed as a lampricide<br>• Used for control of snails in aquaculture ponds<br>• Toxic to fish and aquatic invertebrates at recommended use rates for control of snails in aquaculture ponds | | NA | | | | | | | | |

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| 76 | **Pheromones** | Repellant and Attractant Pheromones | | Y | Experimental | X | • Under investigation as an attractant and/or deterrent for silver carp (*H. molitrix* ), bighead carp (*H. nobilis* ), black carp (*M. piceus* ), and sea lamprey (*P. marinus* ) | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |
| 77 | **Piscicides** § | Antimycin A<br>CAS #: 1397-94-0 | | N | Available, Registered, Restricted Use Product* | X | • Effectiveness can vary with the surfactant used.<br>• Requires approximately 8 to 32 hours to kill cyprinid species such as bighead carp (H. nobilis) and silver carp (H. molitrix)<br>• Restricted use pesticide due to aquatic toxicity and need for highly specialized applicator training | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |
| 78 | | Niclosamide<br>CAS #: 1420-04-8 | | N | Available, Registered, Restricted Use Product* | X | • First developed as a lampricide<br>• Toxic to aquatic invertebrates; non-target organisms may be killed at rates recommended for sea lamprey control<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by United States Department of Interior, United States Fish & Wildlife Service (USFWS), state fish and game, Fisheries and Oceans Canada, and Provincial Certified Applicators trained in sea lamprey control<br>• Effectiveness dependent upon dose and exposure | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |
| 79 | | Rotenone (Both Standard Application and Via Oral Delivery Platforms)<br>CAS #: 83-79-4 | | N | Available, Registered, Restricted Use Product* | X | • Kills bighead (*H. nobilis* ) carp and silver carp (*H. molitrix* ) within approximately 4 hours<br>• May be toxic to other aquatic organisms<br>• Effectiveness dependent upon dose and exposure | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |
| 80 | | TFM (3-Trifluoromethyl-4-nitrophenol)<br>CAS #: 88-30-2 | | N | Available, Registered, Restricted Use Product* | X | • Designed only to control sea lamprey (*P. marinus* )<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by certified applicators of USFWS, Fisheries and Oceans Canada, and provincial and state fish and game employees<br>• Non-target organisms may be killed at labeled use rates<br>• Effectiveness dependent upon dose and exposure | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |
| 81 | **Screens** | Non-Mechanical Screens | Fences | N | Available | X | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent movement of non-target organisms, depending on their size | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too large | | |
| 82 | | | Bar Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |
| 83 | | | Trash Racks | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |

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| 84 | | | Curtains | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | not extend to the bottom of channel | | |
| 85 | | Mechanical Screens | Chain Bar Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |
| 86 | | | Reciprocating Rake Bar Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |
| 87 | | | Catenary Bar Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |
| 88 | | | Continuous Belt Bar Screens | N | Available | X | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent the movement of non-target organisms, depending on their size | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too large | | |
| 89 | | | Rotating Drum Screens (Paddle Wheel Or Power) | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 90 | | | Wedge-Wire Cylinders | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 91 | | | Louvered Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |
| 92 | | | Mechanical Climber Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |
| 93 | | Filters | | N | Available | X | • Generally used to treat small volumes of water<br>• Constrained by resistance through filter membrane and filter fouling<br>• Filters may prevent the movement of non-target organisms, depending on their size | | NA | Y | | Y | | Y | | Y | Y |
| 94 | **Sensory Deterrent Systems** | Underwater Strobe lights | | N | Experimental | X | | A | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | M | Future research is needed to determine if this species is susceptible to this technology | Y | Y |

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| 95 | | Underwater Sound | N | Experimental | X | • Used to prevent upstream movement of fish<br>• May not prevent downstream movement of aquatic organisms | A | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | M | Future research is needed to determine if this species is susceptible to this technology | Y | Y |
| 96 | | Acoustic Air Bubble Curtain | N | Experimental | X | | A | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | M | Future research is needed to determine if this species is susceptible to this technology | Y | Y |
| 97 | | Electric Barrier | N | Available | X | • Must be configured to stop upstream and downstream movement of fish<br>• May impact non-target aquatic organisms | | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | Y | | N | Y |
| 98 | **Ultrasound** | Ultrasound | N | Available | | • Used in small water bodies and water treatment plants<br>• Ultrasound may be effective on diatoms (*S. binderanus* )<br>• Most effective on enclosed bodies of water<br>• Additional research may be needed to investigate potential impacts on non-target organisms<br>• Under investigation for use against aquatic vascular plants (non-algae)<br>• Requires continuous application to maintain effectiveness | | NA | | | | | | | | |

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| 99 | **Ultraviolet Light** | | Ultraviolet (UV) Light | N | Available | | • Used in fish hatcheries and water treatment facilities<br>• Used to treat contained flowing systems<br>• Best used after suspended solids, iron and manganese have been filtered from water<br>• May impact non-target aquatic organisms<br>• Under investigation for use against aquatic | | NA | | | | | | | | |
| 100 | **Vertical Drop Barrier** | | Vertical Drop Barrier | N | Available | X | • Does not prevent aquatic organism movement downstream<br>• May impact upstream movement of non-target organisms | | NA | Y | | Y | | Y | | N | Y |
| 101 | **Williams' Cage**<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | | Williams' Cage | Y | Experimental | X | • May be effective on silver carp *(H. molitrix)* and sea lamprey *(P. marinus)*<br>• Does not prevent aquatic organism movement downstream | A | NA | N | Eggs incapable of directed movement | N | Larvae have limited directed movement | N | Bar spacing typically too wide | | |

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# Tubenose Goby

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| 2 | **Fact Sheet** | **ANS Control** | | Selective for ANS of Concern – CAWS | **Status** 2 | **fish** | **Comments**<br>**Refer to fact sheets for additional information on each Control** | **Level of R&D** | **Biocides for Industrial Use - Conventional, municipal drinking water or wastewater treatment technologies** | **Effective on Tubenose Goby (eggs)** | **Comments on eggs** | **Effective on Tubenose Goby (larvae)** | **Comments on larvae** | **Effective on Tubenose Goby (adult)** | **Comments on adult** | **Effective with Downstream Flow** | **Effective with Upstream Flow** |
| 3 | **Accelerated Water Velocity** | Accelerated Water Velocity | | N | Available | X | • Not effective in preventing downstream ANS movement<br>• Must have a length and speed of flow greater than the organism's leaping ability and swimming endurance | | NA | Y | | Y | | Y | | N | Y |
| 4 | **Acoustic Fish Deterrents** | Continuous Wave | | N | Experimental | X | • Under development for control of fish<br>• May not be effective on all fish species | T | NA | N | Eggs do not react to external stimula and are incapable of directed movement | Y | | Y | | Y | Y |
| 5 | | Pulsed Pressure Wave | | N | Experimental | X | • Not lethal unless an organism is very close to sound source | A | NA | N | Eggs not impacted by sound waves because they lack swim bladder | Y | | Y | | Y | Y |
| 6 | **Algaecides** § | Copper Sulfate and Chelated Copper Formulations (ethanolamines, ethylene diamines, triethanolamines, triethanolamine+ethylene diamine, and copper citrate/gluconate) | | N | Available, Registered | | • May be effective on diatoms (*S. binderanus* ) and grass kelp (*Enteromorpha flexuosa* )<br>• Chelated copper formulations may be effective on red macro-algae (Bangia atropupurea)<br>• Reduced efficacy in waters with high pH and water temperatures < 15 °C<br>• Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 7 | | Endothall (as the mono(N,N-dimethylalkylamine) salt)<br>CAS #: 66330-88-9 | | N | Available, Registered | | • May be effective on red macro-algae (*B. atropupurea* ) and diatoms (*S. binderanus* )<br>• Can be harmful to fish<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | |
| 8 | | Algaecides containing Sodium Carbonate Peroxyhydrate<br>CAS #: 15630-89-4 | | N | Available, Registered | | • May be effective on diatoms (*S. binderanus* ), and grass kelp (*E. flexuosa* )<br>• Effectiveness dependent upon dose and | | NA | | | | | | | | |
| 9 | **Alteration of Water Quality** §<br>The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on | | Carbon Dioxide ($CO_2$) | N | Available, When Not Registered for a Use | X | • May repel fish at sub-lethal levels<br>• Lowers pH<br>• Creates irreversible cell damage and death<br>• Effectiveness dependent upon dose and exposure | | NA | Y | | Y | | Y | | Y | Y |

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| 10 | 11/10/2011: The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided. | Gases | Ozone | N | Available | X | • Rendered ineffective in the presence of organic matter<br>• Used commercially to decontaminate water<br>• Ozone oxidation is toxic to most small waterborne organisms<br>• Destroys the epithelium covering the gill lamella in fish<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | NA | Y | | Y | | Y | | Y | Y |
| 11 | | | Nitrogen | N | Available | X | • Adult fish are more tolerant than young fish<br>• Nitrogen supersaturation is a cause of gas bubble disease in fish<br>• Effectiveness dependent upon dose and exposure<br>• Not effective on eggs | | NA | M | Uncertain of toxicity of nitrogen across egg membrane | Y | | Y | | Y | Y |
| 12 | | Solids | Alum | N | Available | | • Creates a solid precipitate from suspended solids within the water column which settles<br>• Alum is not classified as a pesticide, therefore does not require FIFRA registration | | NA | | | | | | | | |
| 13 | | | Sodium Thiosulfate CAS #: 7772-98-7 | N | Experimental | X | • Deoxygenated compound<br>• Effectiveness dependent upon dose and | T | NA | Y | | Y | | Y | | Y | Y |

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| 14 | **Aquatic Herbicides** § The status of these chemicals is in part based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 11/13/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided | 2,4-D (both the amine and butoxy-ethyl ester formulations) CAS #: 94-75-7 | | N | Available, Registered | | • Tank mixing with other herbicides improves plant control • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 15 | | Diquat CAS #: 85-00-7 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 16 | | Fluridone CAS #: 59756-60-4 | | N | Available, Registered | | • Plants must be exposed to a lethal dose for a minimum of 45 days for optimal results • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 17 | | Glyphosate CAS #: 1071-83-6 | | N | Available, Registered | | • May be effective on reed sweetgrass (Glyceria maxima) • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 18 | | Imazapyr CAS #: 81334-34-1 | | N | Available, Registered | | • May be effective on reed sweetgrass (*G. maxima* ) • Effectiveness dependent upon dose and | | NA | | | | | | | | |
| 19 | | Triclopyr CAS #: 55335-06-3 | | N | Available, Registered | | • Effectiveness dependent upon dose and exposure | | NA | | | | | | | | |
| 20 | | | | | | | | | NA | | | | | | | | |
| 21 | **Benthic Barriers** | Textile or Plastic | | N | Available | | | | NA | | | | | | | | |
| 22 | | Silt | | N | Available | X | • Created by applying excessive silt/sand to smother bottom-dwelling organism • Application to control aquatic nuisance species has not been widely studied | | NA | Y | Tubenose goby spawn on the underside of fixed objects like rocks | Y | | N | Adults would likely avoid areas of high turbidity | Y | Y |
| 27 | **Biocides for Industrial Use** § Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004) | Chlorine (free chlorine, hypochlorous acid, hypochlorite salts) CAS #: 7782-50-5 | | N | When Not Registered for a Use | X | • Residuals remain in water after treatment • Requires frequent applications • Effectiveness dependent upon dose and exposure • Effective on algal spores | | Y | Y | | Y | | Y | | Y | Y |
| 28 | | Chlorine Dioxide CAS #: 10049-04-4 | | N | When Not Registered for a Use | X | • Effectiveness dependent upon dose and exposure | | Y | Y | | Y | | Y | | Y | Y |
| 34 | **Biocides for Industrial Use** § **(continued)** Unless noted by B,GS, information was obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004) The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been | Hydrogen Peroxide CAS #: 7722-84-1 CAS #: 79-21-0 | | N | When Not Registered for a Use | | • Disinfection of drinking water, cooling systems and surfaces • Presence of organic matter limits effectiveness • Moderately corrosive • Some residuals remain in water after treatment • Effective on algal spores | | Y | | | | | | | | |
| 38 | | Peracetic Acid (Peraclean®) CAS #: 79-21-0 CAS #: 7722-84-1 | | N | When Not Registered for a Use | X | • No known toxic residual; more potent than hydrogen peroxide • Rapidly active at low concentrations against a wide range of microorganisms • Corrosive • Highly efficient in presence of organic matter • Wastewater treatment | | Y | Y | | Y | | Y | | Y | Y |
| 41 | **Biocides for Industrial Use §** **(continued)** Unless noted by B,GS, information was | Potassium Permanganate CAS #: 7722-64-7 | | N | Experimental | | • Organic matter limits effectiveness & moderately corrosive • Some residuals remain in water after treatment • Effectiveness dependent upon dose and | A | Y | | | | | | | | |

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| 44 | obtained from (U.S. Coast Guard Research and Development Center. Evaluation of Biocides for Potential Treatment of Ballast Water: Final Report. (Report No. CG-D-01-05) Washington, DC, 2004)<br><br>The status of these chemicals is based on results of a Pesticide Product Information System (PPIS) index query at http://ppis.ceris.purdue.edu/ run on 9/28/2011. The Chemical Abstracts Service (CAS) numbers were used to enter the query and for convenience have been provided.<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Sodium Chlorite<br>CAS #: 7758-19-2 | N | When Not Registered for a Use | X | • Disinfection of drinking water, cooling systems and surfaces<br>• Presence of organic matter limits effectiveness<br>• Residuals remain in water after treatment<br>• Requires frequent applications and corrosive<br>• Effectiveness dependent upon dose and exposure<br>• Effective on algal spores | | Y | Y | | Y | | Y | | Y | Y |
| 45 | | Sodium Hydroxide [B, GS]<br>CAS #: 1310-73-2 | N | When Not Registered for a Use | X | • Under consideration for use in ballast water treatment<br>• <1% survival of test organisms including algae, annelids, crustaceans and fish with 48-hr exposure to pH adjustments of 11.5 to 12.5 using NaOH (TenEyek, M. 2009. Great Ships Initiative Bench-Scale Test Findings, Technical Report – Public, Sodium Hydroxide (NaOH). GSI/BS/5.) | | Y | Y | | Y | | Y | | Y | Y |
| 48 | **Biological Controls** [§] | Introduced Predatory Fish Species | N | Available | X | • Includes both carnivorous and herbivorous fish species<br>• Best used in waters with no outflows<br>• Predatory fish are non-selective feeders and may eat native species<br>• Predatorsare size selective feeders and may not eat eggs or larger organisms | | NA | Y | | Y | | Y | | Y | Y |
| 49 | | Introduced Predatory Insect Species | N | Experimental | | • United States Department of Agriculture (USDA) has not approved of any insects for use as biological controls of plants identified as ANS of Concern – CAWS<br>• Predators may be selective feeders (may not eat seeds) | T | NA | | | | | | | | |
| 50 | | *Pseudomonas fluorescens* CL 145A | N | Registered | | • Active ingredient (Pseudomonas fluorescens CL 145A) approved by the United States Environmental Protection Agency (USEPA) in July 2011(Reg. No. 84059-4)<br>• Formulation of commercial product as Zequanox™ is pending review by USEPA as of October 2010; Section 3 registration expected in March 2012<br>• Ongoing research to assess impacts to non-target mollusks | | NA | | | | | | | | |
| 51 | | Targeted Disease Agents | N | Experimental | X | • Under consideration for carp species | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |

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| 52 | **Controlled Harvest and Overfishing** | Controlled Harvest and Overfishing | N | Available | X | • Requires sorting and returning of native fish species<br>• Requires continual capture over a long period of time, or intensive harvest during critical periods of concentration and reproduction (e.g., migration and spawning season)<br>• Once harvesters, processors, and communities become economically dependent on harvesting nuisance fish, pressure to manage a sustainable population of these fish may conflict with the original purpose of removing them from the | | NA | N | Eggs are too small to harvest | N | Larvae are too small to harvest | Y | | Y | Y |
| 53 | **Deleterious Gene Spread** | Daughterless Gene | Y | Experimental | X | • Researched as a Control for silver carp (*H. molitrix* ), bighead carp (*H. nobilis* ), black carp (*Mylopharyngodon piceus* ), and sea lamprey (*Petromyzon marinus* )<br>• Researched as a Control for common carp<br>• Manipulation of genes can manifest unforeseen and significant undesirable side effects and would require extensive research before being accepted | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |
| 54 | | Trojan Y Chromosome | Y | Experimental | X | • The Food and Drug Administration regulates genetically engineered animals | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |
| 55 | **Dredging and Diver Dredging** | Dredging and Diver Dredging | N | Available | | • Requires careful disposal or reuse of dredged material to prevent the transfer of ANS to a new location<br>• May remove other ANS of Concern – CAWS and non-target organisms that reside in sediment | | NA | | | | | | | | |
| 56 | **Electron Beam Irradiation** | Electron Beam Irradiation | N | Available | | • Used in irradiation of food, environmental waste, medical sterilization, and water treatment<br>• Requires a closed system and not appropriate for open water application<br>• May require pretreatment to remove suspended solids<br>• Used in irradiation of food, environmental | | NA | | | | | | | | |
| 57 | **Hydrologic Separation** | Physical Barriers | N | Available | X | • Modifies flow within waterway, including stormwater and combined sewer overflow discharge, and conveyance and commercial water dischargers and withdrawal of water<br>• Must be designed to handle storm flows | | NA | Y | | Y | | Y | | Y | Y |
| 58 | **Irrigation Water Chemicals** § | Acrolein<br>CAS #: 107-02-8 | N | Available, Registered, Restricted Use Product* | | • For control of submersed and floating weeds and algae only in irrigation canal systems in western states, provided the appropriate state registrations are also in place<br>• Toxic to fish and other aquatic organisms at labeled use rates | | NA | | | | | | | | |

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| 59 | | Xylene CAS #: 1330-20-7 | | N | Registered | | • For use only in irrigation and drainage canals designated by the Bureau of Reclamation and cooperating water user organizations • For use in Programs of the Bureau of Reclamation and Cooperating Water User Organizations within the following states, provided that the appropriate state registrations are also in place: AZ, CA, CO, ID, KS, MT, NE, NM, NV, ND, OK, OR, SD, TX, UT, WA, and WY • For control of submerged weeds in irrigation and drainage canals • Toxic to fish and other aquatic organisms at | | NA | | | | | | | | |
| 60 | **Lethal Temperature** | Pressurized Hot Water/Steam Treatment | | N | Available | X | • Hot water has been used to kill zebra and quagga mussels at municipal and industrial facilities, and high pressure hot water is used to clean ANS off of recreational boats • Treated area (i.e. boat hull) must be above the | | | | Eggs do not | | Larvae do not | | Fish do not | | |
| 61 | | Hot Water Thermal Barrier | | N | Available | X | column • During cold weather conditions, warm water temperatures may attract fish | | NA | Y | | Y | | Y | | Y | Y |
| 62 | | Freezing | | N | Available | X | • Freezing is often combined with winter water level drawdowns to expose the ANS to freezing air temperatures • Cluster mussels are more tolerant of reduced air temperatures than individual organisms • Can be applied to static water. | | NA | Y | | Y | | Y | | Y | Y |
| 63 | | Carbon Dioxide ($CO_2$) Pellet (dry ice) Blasting | | N | Available | X | • Method used extensively to remove organics from aircrafts producing no deterioration of surfaces • CO2 pellets convert to a gas at ambient temperatures, leaving no residue. • Treated area (i.e. boat hull) must be above the surface. | | NA | N | Eggs do not adhere to boat hulls | N | Larvae do not adhere to boat hulls | N | Fish do not adhere to boat hulls | | |
| 64 | | Desiccation | | N | Available | X | • Desiccation can only be achieved in areas where water levels can be controlled • Exposure to air quickly leads to death for active water-breathing organism—mollusks and plants are more tolerant and require longer drying period | | NA | Y | | Y | | Y | | Y | Y |

Removed During Nov 2012 ANS Controls Screening Charette

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| 65 | **Light Attenuating Dyes** § | | Light Attenuating Dyes | N | Registered | | • Not effective for suppressing growth of floating aquatic plants or emergent shoreline vegetation identified as ANS of Concern – CAWS<br>• Not effective on floating algal mats<br>• May suppress the growth of non-target plants and algae<br>• Only for use in contained waterbodies with little or no outflow<br>• Do not apply to waters used for human consumption | | NA | | | | | | | | |
| 66 | **Manual Harvest** | | Manual Harvest | Y | Available | | • Labor-intensive<br>• Selectively dependent upon training and skill of staff | | NA | | | | | | | | |
| 67 | **Mechanical Control Methods** | | Mechanical Harvesting | N | Available | | • May disturb non-target organisms in equipment path | | NA | | | | | | | | |
| 68 | | | Shredding | N | Available | | | | NA | | | | | | | | |
| 69 | | | Mowing | N | Available | | | | NA | | | | | | | | |
| 70 | | | Chaining | N | Available | | | | NA | | | | | | | | |
| 71 | | | Roto-tilling | N | Available | | | | NA | | | | | | | | |
| 72 | | | Rotovating | N | Available | | • Used for submersed vegetation rooted in the substrate<br>• May have applications on emergent plants<br>• May disturb non-target organisms in equipment path | | NA | | | | | | | | |
| 73 | **Molluscicides** § | | Quaternary and Polyquaternary Ammonium Compounds; Aromatic Hydrocarbons; Endothall as the Mono (N,N-imethylalkylamine) Salt (TD2335 Industrial Biocide-Molluscicide) | N | Registered | | • Used for recirculating and once-through cooling water systems<br>• For control of established populations of freshwater and saltwater mollusks in closed systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | |
| 74 | | | Metals and their salts (Copper Sulfate and Chelated Copper Formulations) | N | Registered | | • Can be used to control mollusks in open water systems<br>• Is non-selective at use rates to control mollusks | | NA | | | | | | | | |
| 75 | | | Niclosamide<br>CAS #: 1420-04-8 | N | Available, Registered, Restricted Use Product* | | • First developed as a lampricide<br>• Used for control of snails in aquaculture ponds<br>• Toxic to fish and aquatic invertebrates at recommended use rates for control of snails in aquaculture ponds | | NA | | | | | | | | |
| 76 | **Pheromones** | | Repellant and Attractant Pheromones | Y | Experimental | X | • Under investigation as an attractant and/or deterrent for silver carp (*H. molitrix*), bighead carp (*H. nobilis*), black carp (*M. piceus*), and sea lamprey (*P. marinus*) | T | NA | N | Not being developed for this species | N | Not being developed for this species | N | Not being developed for this species | | |
| 77 | **Piscicides** § | | Antimycin A<br>CAS #: 1397-94-0 | N | Available, Registered, Restricted Use Product* | X | • Effectiveness can vary with the surfactant used.<br>• Requires approximately 8 to 32 hours to kill cyprinid species such as bighead carp (H. nobilis) and silver carp (H. molitrix)<br>• Restricted use pesticide due to aquatic toxicity and need for highly specialized applicator training | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |

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Experimental - A novel option or technology, or a chemical that is not a U.S. Environmental Protection Agency (USEPA)-registered pesticide under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).
Registered - A chemical that is a USEPA-registered pesticide under FIFRA for the fact sheet use in compliance with the USEPA-approved product label.
When Not Registered for a Use - A product can only be used for the control of ANS, if the product is labeled for ANS Control. Under FIFRA section 2(ee), where an ANS is not listed on the pesticide label, the product may still be used to control those species so long as the site, where the pesticide is to be used, is on the label. If the use site is not listed on the pesticide label, the proposed new use must be submitted to the USEPA for a "new use assessment" which may require the USEPA to conduct human health and ecological risk assessments.

# Tubenose Goby

| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 78 | | Niclosamide<br>CAS #: 1420-04-8 | | N | Available, Registered, Restricted Use Product* | X | • First developed as a lampricide<br>• Toxic to aquatic invertebrates; non-target organisms may be killed at rates recommended for sea lamprey control<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by United States Department of Interior, United States Fish & Wildlife Service (USFWS), state fish and game, Fisheries and Oceans Canada, and Provincial Certified Applicators trained in sea lamprey control<br>• Effectiveness dependent upon dose and exposure | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |
| 79 | | Rotenone (Both Standard Application and Via Oral Delivery Platforms)<br>CAS #: 83-79-4 | | N | Available, Registered, Restricted Use Product* | X | • Kills bighead (*H. nobilis* ) carp and silver carp (*H. molitrix* ) within approximately 4 hours<br>• May be toxic to other aquatic organisms<br>• Effectiveness dependent upon dose and exposure | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |
| 80 | | TFM (3-Trifluoromethyl-4-nitrophenol)<br>CAS #: 88-30-2 | | N | Available, Registered, Restricted Use Product* | X | • Designed only to control sea lamprey (*P. marinus* )<br>• Limited geographically to the Great Lakes Basin, the Lake Champlain system and the Finger Lakes<br>• For use only by certified applicators of USFWS, Fisheries and Oceans Canada, and provincial and state fish and game employees<br>• Non-target organisms may be killed at labeled use rates<br>• Effectiveness dependent upon dose and exposure | | NA | M | Bioassays needed to determine toxicity to eggs | Y | | Y | | Y | Y |
| 81 | **Screens** | Non-Mechanical Screens | Fences | N | Available | X | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent movement of non-target organisms, depending on their size | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too large | | |
| 82 | | | Bar Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |
| 83 | | | Trash Racks | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |
| 84 | | | Curtains | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Curtains do not extend to the bottom of channel | | |
| 85 | | ...ns | Chain Bar Screens | N | Available | X | • May not prevent aquatic organism movement | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |
| 86 | | | Reciprocating Rake Bar Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |
| 87 | | | Catenary Bar Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |

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# Tubenose Goby

| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 88 | | Mechanical Scree | Continuous Belt Bar Screens | N | Available | X | • May not prevent aquatic organism movement downstream<br>• Effectiveness is dictated by the size of mesh or bar spacing<br>• Screens may prevent the movement of non-target organisms, depending on their size | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too large | | |
| 89 | | | Rotating Drum Screens (Paddle Wheel Or Power) | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 90 | | | Wedge-Wire Cylinders | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | Y | | N | Y |
| 91 | | | Louvered Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |
| 92 | | | Mechanical Climber Screens | N | Available | X | | | NA | N | Eggs are too small | N | Larvae are too small | N | Bar spacing typically too wide | | |
| 93 | | Filters | | N | Available | X | • Generally used to treat small volumes of water<br>• Constrained by resistance through filter membrane and filter fouling<br>• Filters may prevent the movement of non-target organisms, depending on their size | | NA | Y | | Y | | Y | | Y | Y |
| 94 | Sensory Deterrent Systems | Underwater Strobe lights | | N | Experimental | X | • Used to prevent upstream movement of fish<br>• May not prevent downstream movement of aquatic organisms | A | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | M | Future research is needed to determine if this species is susceptible to this technology | Y | Y |
| 95 | | Underwater Sound | | N | Experimental | X | | A | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | M | Future research is needed to determine if this species is susceptible to this technology | Y | Y |

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# Tubenose Goby

| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 96 | | Acoustic Air Bubble Curtain | | N | Experimental | X | | A | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | M | Future research is needed to determine if this species is susceptible to this technology | Y | Y |
| 97 | | Electric Barrier | | N | Available | X | • Must be configured to stop upstream and downstream movement of fish<br>• May impact non-target aquatic organisms | | NA | N | Eggs do not react to external stimuli | N | Larvae do not posses the motor skills to avoid external stimuli | Y | | N | Y |
| 98 | **Ultrasound** | Ultrasound | | N | Available | | • Used in small water bodies and water treatment plants<br>• Ultrasound may be effective on diatoms (*S. binderanus* )<br>• Most effective on enclosed bodies of water<br>• Additional research may be needed to investigate potential impacts on non-target organisms<br>• Under investigation for use against aquatic vascular plants (non-algae)<br>• Requires continuous application to maintain effectiveness | | NA | | | | | | | | |
| 99 | **Ultraviolet Light** | Ultraviolet (UV) Light | | N | Available | | • Used in fish hatcheries and water treatment facilities<br>• Used to treat contained flowing systems<br>• Best used after suspended solids, iron and manganese have been filtered from water<br>• May impact non-target aquatic organisms<br>• Under investigation for use against aquatic vascular plants (non-algae) | | NA | | | | | | | | |
| 100 | **Vertical Drop Barrier** | Vertical Drop Barrier | | N | Available | X | • Does not prevent aquatic organism movement downstream<br>• May impact upstream movement of non-target organisms | | NA | Y | | Y | | Y | | N | Y |

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# Tubenose Goby

| | A | B | C | D | E | J | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | **Williams' Cage**<br><br>Manufacturers and products mentioned are examples only. Nothing contained herein constitutes an endorsement of a non-Federal entity, event, product, service, or enterprise by the U.S. Army Corps of Engineers or its employees. | Williams' Cage | | Y | Experimental | X | • May be effective on silver carp *(H. molitrix)* and sea lamprey *(P. marinus)*<br>• Does not prevent aquatic organism movement downstream | A | NA | N | Eggs incapable of directed movement | N | Larvae have limited directed movement | N | Bar spacing typically too wide | | |

2 Status
Available - An option or technology that has been implemented in the field.
Experimental - A novel option or technology, or a chemical that is not a U.S. Environmental Protection Agency (USEPA)-registered pesticide under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).
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# ATTACHMENT D

# RESIDUAL RISK FINAL


# Interbasin Transfer of Selected Aquatic Nuisance Species via Non-Aquatic Transfer Methods

Final Report

January 2014

US Army Corps of Engineers®

*Product of the GLMRIS Team*

The Great Lakes and Mississippi River Interbasin Study (GLMRIS) Team consists of a regional, collaborative effort led by the U.S. Army Corps of Engineers (Corps), including various District and Division offices, as well as Corps Centers of Expertise and Research Laboratories. Products of the GLMRIS Team are also made possible in collaboration with various federal, state, local, and non-governmental stakeholders.


# Interbasin Transfer of Selected Aquatic Nuisance Species via Non-Aquatic Transfer Methods

Final Report
January 2014

Prepared by

William Vinikour
Environmental Science Division
Argonne National Laboratory

for

The GLMRIS Risk Assessment Team
U.S. Army Corps of Engineers
Chicago District

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**CONTENTS (CONT.)**



## TABLES

# INTERBASIN TRANSFER OF SELECTED AQUATIC NUISANCE SPECIES VIA NON-AQUATIC TRANSFER MECHANISMS

## 1 INTRODUCTION

In support of the Great Lakes and Mississippi River Interbasin Study (GLMRIS) Program, Grippo et al. (2013) conducted a qualitative risk assessment to evaluate the potential risks of aquatic nuisance species (ANS) for undergoing successful interbasin transfer through the Chicago Aquatic Waterways System (CAWS) and causing unacceptable environmental, economic, and socio/political consequences. The risk assessment focused on aquatic-based mechanisms through which ANS could arrive at and transfer through the CAWS: active movement (swimming or crawling), passive drift via currents, and vessel-mediated movement. The risk assessment evaluated potential establishment over four time steps encompassing a 50-year time period:

| | | |
|---|---|---|
| Time 0 ($T_0$) | = | potential for establishment in the immediate future based on the current distribution of the ANS; |
| Time 10 ($T_{10}$) | = | potential for establishment within 10 years from present time; |
| Time 25 ($T_{25}$) | = | potential for establishment within 25 years from present time; and |
| Time 50 ($T_{50}$) | = | potential for establishment within 50 years from now. |

The use of these time steps captures changes in the distribution of ANS species that may occur during a time step and thus affects the likelihood of establishment.

The risk assessment conducted by Grippo et al. (2013) identified 13 ANS that could pose medium to high risks of adverse impacts within the next 50 years should they undergo successful interbasin transfer between the Great Lakes and Mississippi River basins by aquatic pathways. The aquatic pathways are the primary mechanisms for the interbasin spread of the ANS.

This report presents the result of a subsequent evaluation to identify and assess potential mechanisms of interbasin transfer for the 13 medium- and high-risk ANS that focuses on mechanisms for interbasin transfer that could potentially take place separate from the CAWS and involve non-aquatic pathway routes not under U.S. Army Corps of Engineers (USACE) GLMRIS study authority.[1] The ability for ANS to transfer through non-aquatic pathways may occur, but is not the primary methods expected to result in interbasin transfers. The GLMRIS Natural Resources Team White Paper (Veraldi et al. 2011) identifies several of the non-aquatic pathways. This present study also considers non-aquatic transfer mechanisms for species other than those evaluated in the risk assessment (Grippo et al. 2013), but that are ecologically and taxonomically similar to those species evaluated in the risk assessment. Some non-aquatic transfer mechanisms for those species may thus apply to the ANS evaluated in this report.

[1] This report does not address the viral hemorrhagic septicemia virus (VHSV) in detail. Nevertheless, any interbasin transfer mechanism identified for the other 12 ANS could also transfer the VHSV.

# 2 METHODS

## 2.1 SPECIES EVALUATED

Table 2.1 lists the 13 medium- and high-risk ANS, the basins they currently inhabit, their risk levels, and the time period to attain the indicated risk level via interbasin transfer through the CAWS. These ANS include three algal species, one species of rooted vegetation, three crustacean species, and five species of fish. Of these 13 species, ten are currently in the Great Lakes Basin, and three are in the Mississippi River Basin.

**Table 2.1 Aquatic Nuisance Species Posing Medium or High Risks Due to Potential Interbasin Transfer through the Chicago Area Waterway System.**

| Taxonomic Category | Common Name | Scientific Name | Basin Currently Inhabited[a] | Risk Level | Time Period to Attain Risk Level[b] |
|---|---|---|---|---|---|
| | | | | | |
| Virus | Viral hemorrhagic septicemia virus | *Novirhabdovirus* spp. | GL | High | $T_0$ |
| | | | | | |
| Algae | Grass kelp | *Enteromorpha flexuosa* | GL | Medium | $T_{10}$ |
| | Red algae | *Bangia atropurpurea* | GL | Medium | $T_0$ |
| | Diatom | *Stephanodiscus binderanus* | GL | Medium | $T_0$ |
| | | | | | |
| Rooted Plants | Reed sweetgrass | *Glyceria maxima* | GL | Medium | $T_{50}$ |
| | | | | | |
| Crustaceans | Fishhook waterflea | *Cercopagis pengoi* | GL | High | $T_{25}$ |
| | Bloody red shrimp | *Hemimysis anomala* | GL | High | $T_0$ |
| | Scud | *Apocorophium lacustre* | MR | Medium | $T_0$ |
| | | | | | |
| Fish | Ruffe | *Gymnocephalus cernuus* | GL | Medium | $T_{50}$ |
| | Tubenose goby | *Proterorhinus semilunaris* | GL | Medium | $T_{10}$ |
| | Threespine stickleback | *Gasterosteus aculeatus* | GL | Medium | $T_0$ |
| | Bighead carp | *Hypophthalmichthys nobilis* | MR | Medium | $T_{25}$ |
| | Silver carp | *Hypophthalmichthys molitrix* | MR | Medium | $T_{25}$ |

a GL = Great Lakes; MR = Mississippi River.

b T0 = potential for imminent establishment; T10 = potential for establishment 10 years from present time; T25 = potential for establishment 25 years from present time; T50 = potential for establishment 50 years from present time.

Source: Grippo et al. (2013).

## 2.2 DATA SOURCES

Literature and Websites were searched to determine potential mechanisms for transfer of the medium- and high-risk ANS other than by vessel attachment, passive drift, or active swimming.

These sources are cited, as appropriate, throughout this report. Information was obtained for both ANS in general and for specific information on the medium- and high-risk ANS.

# 3 RESULTS

## 3.1 OVERVIEW OF THE MECHANISMS FOR INTERBASIN TRANSFER OF AQUATIC NUISANCE SPECIES

The mechanisms responsible for the establishment and spread of ANS vary spatially, temporally, and by taxon. The transfer of an ANS from its first location of establishment to other locations may include a wider range of mechanisms than was responsible for the species initial establishment (see Stokes et al. 2004). In addition, some species may spread by more than one mechanism e.g., intentional establishment for aquaculture followed by accidental establishment into a new environment (Stokes et al. 2004).

The National Invasive Species Council and Aquatic Nuisance Species Task Force (NISC and ANS Task Force 2006) identified three categories of mechanisms by which ANS may be established and spread: (1) transportation-related mechanisms, (2) living industry-related mechanisms, and (3) miscellaneous mechanisms. For these categories, mechanisms for establishment and spread include, but are not limited to, the following:

- *Transportation-related mechanisms*—ballast water and hull fouling, aircraft, recreational boats and other craft, vehicles, stowaways in holds, transportation/relocation of dredge spoils, movement or transport of topsoil and fill, hikers, hunters, anglers, divers, travelers (including their luggage), pets and plants, natural packing materials (e.g., wood, other plant materials), and internet and mail order;
- *Living industry-related mechanisms*—aquaculture and horticulture escapes, hitchhikers with intended food animal or plant, use of live bait, release or escape from aquariums or water gardens, science and laboratory escapes, live fish food releases, seafood packing and disposal, unauthorized fish transfers or stocking, and transport of animal carcasses or products made from them; and
- *Miscellaneous mechanisms*—opening of canals and other waterways, transport on or within other plants and animals, disposal of solid waste or wastewater, past government programs, land or water alterations (e.g., land disturbance and water level changes), natural spread of established populations, and water transport and using water for dust control.

These mechanisms have been documented for a number of invasive species (DFO 2013; Georgia Invasive Species Task Force 2013; NISC and ANS Task Force 2006; OMNR 2009, 2012; Pennsylvania Sea Grant, 2013a; USEPA 2012).

Human-mediated dispersal may transport individuals at greater distances, or in much higher numbers, than could disperse naturally from a source area. Humans may also be instrumental in the secondary spread of ANS following initial establishment (Muirhead and MacIsaac 2005; Jacobs and MacIsaac 2009). Ballast water is one of the dominant mechanisms leading to the establishment of ANS. Invasion risk from hull fouling may be comparable to or exceed that of ballast water discharge. For example, over 100 species may occur on the hull of a single ship (Drake and Lodge 2007). While ballast water is an important mechanism for the establishment of ANS, other non-aquatic transfer mechanisms could negate management efforts aimed at controlling ballast releases (Cohen et al. 2007). For example, Ludwig and Leitch (1996) estimated the probability of a single angler on a single day in the Hudson Bay Basin releasing live bait from the Mississippi River Basin to be 1.2/100. Considering an estimated 19 million angler days per year, the number of bait bucket transfers would be extremely large.

In addition, commercial activities involving live fish bait, horticulture and water-garden plants, biological supplies, pets, and live food are principal mechanisms that can lead to the establishment of ANS (Keller and Lodge 2007). In the southern basin of Lake Michigan, five retail trades that sell live aquatic organisms are live bait, live food, biological supplies, nursery (including water-garden) plants, and pets (including aquarium biota). Kerr et al. (2005) concluded that the highest potentials for future establishment and spread of ANS are associated with ballast water, live food industry, and the ornamental pond/aquarium trade.

## 3.2 POTENTIAL NON-AQUATIC TRANSFER MECHANISMS EVALUATED

Table 3.1 presents the potential non-aquatic mechanisms for interbasin transfer of ANS evaluated in this report.

### 3.2.1 Recreation

Non-aquatic transfer mechanisms related to recreation can include bait bucket and livewell releases; discharge of bilge water; and transport on angler or hunter clothing, equipment, or vehicles (Table 3.1).

The greatest concern regarding the use of live bait is anglers who empty their bait buckets into the water where they are fishing. Many anglers continue to do this even when they know the potential risks of such actions (Kerr et al. 2005). An angler survey in Maryland revealed that 64% of freshwater anglers use live bait and that the release of live bait was quite common (e.g., 65% and 68% of anglers using fishes and crayfishes released their unused bait, respectively). Kulwicki et al. (2003) reported that 36% of the anglers who used live bait in northern Wisconsin and the Upper Peninsula of Michigan released live bait. Thus, any non-native, potentially invasive species imported into the state via the bait industry are likely to be released by anglers (Kilian et al. 2012). Improper baitfish disposal is the source of establishment of at least 14 species in Ontario (see Kerr et al. 2005). Courtenay and Taylor (1984) stated that the potential expansion of 60 native fish species in the contiguous United States was possibly due to bait releases. Because more than 40% of anglers release live bait into angling waters, the probability of establishment of nonnative species (or introduction of native species outside their native range) is high (Litvak and Mandrak 1993). Bait bucket releases are a primary cause of invasive crayfish establishments. One reason for this is that some 97% of bait shop managers cannot identify the species they sell (DiStefano et al. 2009).

**Table 3.1 Potential Non-Aquatic Mechanisms for Interbasin Transfer of Aquatic Nuisance Species**

| Transfer Mechanism | Description | References |
|---|---|---|
| | | |
| Recreation | Bait bucket and livewell releases; discharge of bilge water; transport on angler and hunter clothing and boots; transport on equipment such as fishing poles, nets, traps, and decoys; all-terrain vehicles or off-road travel | Buck et al. (2010); Courtenay and Taylor (1984); DiStefano et al. (2009); Donahue (2011); DPIPWE (2002); Drake (2005); Duggan et al. (2003); Estepp (2012); Fuller (2013); Hill and Pegg (2008); IDNR (2005); Jacobs and MacIsaac (2007); Keller and Lodge (2007); Kerfoot et al. (2011); Kerr (2012); Kerr et al. (2005); Kilian et al. (2012); Kocovsky et al. (2011); Kolar et al. (2005); Kulwicki et al. (2003); Litvak and Mandrak (1993); Ludwig and Leitch (1996); Makarewicz et al. (2001); MDNR (2007, 2013); NPS (2013); Pennsylvania Sea Grant (2013a,b); Stokes et al. (2004); USEPA (2012); Wiltshire (2009); Winfield et al. (1996) |
| Private aquaria and water gardens | Intentional or accidental release or escape following purchase from pet shops, garden centers, or from mail or internet sources | Champion and Clayton (2000); Chang et al. (2009); Cohen et al. (2007); Donahue (2011); Duggan (2010); Duggan et al. (2003); Ericson (2005); Kay and Hoyle (2001); Keller and Lodge (2007); Kerr et al. (2005); Maki and Galatowitsch (2004); Osborn (2013a,b); Padilla and Williams (2004); Pennsylvania Sea Grant (2012, 2013a); Pyšek and Richardson (2010); Rixon et al. (2005); Severinghaus and Chi (1999); Stokes et al. (2004); Strecker et al. (2011); USEPA (2012); USFWS (2002); Wabnitz et al. (2003); WDNR (2013) |
| Aquaculture and horticulture | Intentional or accidental releases or escapes (including accidental release or escape of prohibited species) from commercial operations | Arthington and McKenzie (1997); Donahue et al. (2011); Irons et al. (2009); Keller and Lodge (2007); Maki and Galatowitsch (2004); MDNR (2007); Patel et al. (2010); Rasmussen (2002); Stokes et al. (2004); USEPA (2012) |
| Accidental or unregulated stocking | Stocking (including past intentional practices) for recreational use, providing forage species, and biocontrol; unregulated private stocking for recreational use followed by subsequent escape; accidental inclusion of an unplanned species (hitchhiker) along with intended species | Buck et al. (2010); Cudmore et al. (2012); Donahue (2011); Elvira and Almodóvar 2001; Kerr et al. (2005); MDNR (2007); Nico and Fuller (2013); OMNR (2009); Panov et al. (2004); Stokes et al. (2004); USEPA (2012) |

**Table 3.1 (Cont.)**

| Transfer Mechanism | Description | References |
|---|---|---|
| | | |
| Live food fish market | Discarding of unused live organisms by either vendors or purchasers | Donahue (2011); Duggan et al. (2003); Higbee and Glassner-Shwayder (2004); Keller and Lodge (2007); Kerr et al. (2005); Kolar et al. (2005); Michigan Sea Grant (2010); MDNR (2007); Rasmussen (2002); Rixon et al. (2005); USEPA (2012) |
| Educator/researcher releases | Disposal into wild when no longer needed in classroom or laboratory; accidental spread by field researchers (e.g., contaminated nets or other sampling equipment) | Chan (2012); Donahue (2011); Makarewicz et al. (2001); MDNR (2007); Stokes et al. (2004); USEPA (2012) |
| Cultural/religious practices, animal rights activism, and bioterrorism | Release during religious practices or animal rights protests; purposeful release to cause ecological, economic, or psychological damage | Higbee and Glassner-Shwayder (2004); Kolar et al. (2005); Pratt (2004); Roberge (2011); Severinghaus and Chi (1999) |
| Industrial and agricultural use | Accidental release or escape of organisms used as feed crops or for bioremediation | Champion and Clayton (2000); Sivasamy et al. (2012); WDNR (2013) |
| Dredge spoils/topsoil/fill transport and use | Accidental spread of species contained in dredge spoils, topsoil, or fill | Shearer (2008) |
| Transport by animals | External and/or internal transport by insects, amphibians, birds (especially waterfowl and shorebirds), mammals (including hunting dogs and livestock), and other biota | Champion and Clayton (2000); DPIPWE (2002); Estepp (2012); Frisch et al. (2007); Green and Figuerola (2005); Green et al. (2005); Lin and Blum (1977); Ludwig and Leitch (1996); Makarewicz et al. (2001); Meisenburg and Fox (2002); Myers et al. (2004); Panov et al. (2004); Peterson Environmental Consulting (2002); Proctor (1964); Proctor et al. (1967); Sánchez et al. (2007); USFS (2006); Williams et al. (2008) |
| Weather | Transport by wind and tornadoes. | Champion and Clayton (2000); Kerr et al. (2005) Ludwig and Leitch (1996); NPS (2013); Peterson Environmental Consulting (2002); Proctor (1964); USGS (2012) |

The gear used to harvest wild bait can also serve as a mechanism for the spread of invasive species since biota may adhere and accumulate on nets and traps. In addition, non-target species and plant fragments collected with baitfish can be transported to other water bodies. As a secondary concern, baitfish can also serve as a mechanism in the spread of parasites and pathogens (Kerr 2012).

Felt-soled waders used by some anglers may provide an attachment surface for ANS such as the algae *Didymosphenia geminate* and subsequent transfer to another water body. Even without the felt soles, there are other places on waders and other fishing gear that can trap and thus transport

ANS (Wiltshire 2009). Even waterfowl decoys and hunting dogs could potentially be mechanisms responsible for the spread of ANS (Estepp 2012).

### 3.2.2 Private Aquaria and Water Gardens

Non-aquatic transfer mechanisms related to private aquaria and water gardens include the intentional or accidental release or escape of ANS from pet shops, garden centers, and personal aquaria and water gardens (Table 3.1). One problem with the commerce in live aquatic organisms is the common misidentification of the species (Keller and Lodge 2007). In part, this is because many wetland and aquatic plant nurseries and dealerships have minimal knowledge of the plants they sell. Thus, similar-appearing species are often misidentified and accidentally (or intentionally) misrepresented as other, non-nuisance species. In addition, nuisance species may occur in small numbers attached to or on wetland and aquatic plants sold from nurseries and dealerships (Kay and Hoyle 2001).

The aquarium trade is an important and rapidly growing mechanism for the establishment of ANS in the United States, including the Great Lakes Basin (Chang et al. 2009; Rixon et al. 2005). The transfer of ANS from aquaria to nature may occur as a result of the dumping of unwanted organisms, escape from tanks and breeding farms (e.g., during storms), and via drainage of water containing organisms from tanks (Severinghaus and Chi 1999). A third of the world's worst aquatic invasive species are aquarium or ornamental species (Padilla and Williams 2004). Aquarium species are often large and usually traded as adults, affording them a greater probability of surviving to reproduce should they escape into the wild. In addition, aquarium animals and plants tend to be relatively healthy, because weaker individuals are mostly eliminated during collection and transportation (Wabnitz et al. 2003). Fortunately, most aquarium releases are tropical species that cannot survive the year-round temperatures in the Great Lakes Basin, and some species are too uncommon to be released in numbers sufficient to establish a viable population in the (Osborn 2013b). Nevertheless, the aquarium trade as a non-aquatic mechanism of transfer will increase in the future due to population growth (resulting in more owners of aquaria) and an increasing array of available aquarium species (Duggan et al. 2003).

The aquarium trade is a commonly recognized means for the establishment of non-indigenous plants, but few regulations exist that control the industry. For example, thousands of non-indigenous plant propagules are released into the St. Lawrence Seaway each year alone from the aquarium plant trade in Montreal (Cohen et al. 2007). The commercial trade in ornamental plants is another major mechanism for the release and dissemination of invasive non-indigenous plants with the most serious plant invaders resulting from garden escapes (Pyšek and Richardson 2010). The unintentional establishment of aquatic plants from aquaria and water gardens is a relatively common event (Kerr et al. 2005). For example, at least a dozen species of exotic plants and animals established in the Great Lakes Basin are a result of aquarium releases. The aquarium trade also accounts for over a third of the non-indigenous mollusc species established in North America (see Kerr et al. 2005).

The sale and transport of prohibited aquatic plants likely presents the greatest risk associated with the aquatic plant trade. Other important factors include misidentification leading to the unintentional sale of invasive plants and the incidental inclusion of invasive species during translocation of native species. The unintentional transport of prohibited species via aquatic plant sales occurs in about 8% of orders (Maki and Galatowitsch 2004). The intentional transport of prohibited species can be accomplished by concealing seeds or propagules of aquatic plants within items of clothing or in baggage (Champion and Clayton 2000). Hitchhikers (e.g., snails) found among plants, especially floating small-leaved plants marketed for outdoor ponds, sold at nurseries is another source of invasive species (Osborn 2013b).

Mail, internet, and overnight shipping companies facilitate the spread of invasive species. Mail order and e-commerce exacerbates the unregulated sale of plants for aquarium and ornamental pools. Most noxious weeds, including highly invasive plants, are offered for sale by sites both internationally and throughout the United States (Kay and Hoyle 2001). One of the more recent mechanisms for the spread of invasive aquatic plants is the Internet, where seeds and plants can be purchased from locations worldwide (USFWS 2002). The transfer of species via internet sales is a very difficult mechanism to control (Ericson 2005).

### 3.2.3 Aquaculture and Horticulture

As described in Table 3.1, the non-aquatic transfer mechanisms related to aquaculture and horticulture include intentional or accidental release or escape from commercial operations. This includes past accidental releases or escapes of prohibited species. In addition to the transfer or escape of a species into a new environment, there is also the risk for the transmission of disease (see Kerr et al. 2005). In some cases, long-distance transfer of target aquatic organisms for stocking (e.g., fish) or planting (commercial plants) can be coupled with the unintentional establishment of other organisms (Maki and Galatowitsch 2004; Panov et al. 2004). Irrespective of the type of system or management strategies employed, escapes of cultivated species into the wild are virtually impossible to prevent (Arthington and McKenzie 1997). For example, the aquaculture industry is responsible for the establishment of at least 96 fish species in North America

### 3.2.4 Accidental or Unregulated Stocking

As described in Table 3.1, the non-aquatic transfer mechanisms related to accidental or unregulated stocking include stocking for recreational use, forage, and biocontrol. This can include the accidental inclusion of an unplanned species (hitchhiker) along with the stocking of an intended species. In the past, some invasive species were established intentionally for habitat restoration activities, fish stocking, and biological control of pests (OMNR 2009). Authorized fish stocking projects are as a leading mechanism in the spread of fishes in North America. Over 200 non-indigenous fish species have been stocked in North America (see Kerr et al. 2005).

### 3.2.5 Live Food Fish Market

The non-aquatic transfer mechanisms related to the live food fish market includes the discarding of live organisms by either the vendor or purchaser (Table 3.1). Live food fish include any fish, or other aquatic organism, which is imported, or transferred live, for distribution and sale for human consumption (Kerr et al. 2005). The live fish market represents a potential source of future invaders in the Great Lakes (Rixon et al. 2005). The trade in live organisms may also include species that hitchhike on or in the species of primary interest, including pathogens and parasites (Keller and Lodge 2007). Even species of marine algae may be become established in inland brackish habitats from kitchen workers discarding seafood packaging and shells (Taft 1946).

### 3.2.6 Educator/Researcher Releases

The non-aquatic transfer mechanisms related to educator/researcher releases includes the release into the wild of live organisms no longer needed in a classroom or laboratory, and accidental spread by field researchers (e.g., through contaminated nets or other field equipment) (Table 3.1). For example, a survey of teachers from the United States and Canada found that one out of four educators who used live animals as part of their science curriculum release the organisms into the wild after they were done using them in the classroom (Chan 2013).

### 3.2.7 Cultural/Religious Practices, Animal Rights Activism, and Bioterrorism

The non-aquatic transfer mechanisms related to release of organisms during religious practices, animal rights protests, or acts of bioterrorism to cause ecological, economic or psychological damage (Table 3.1) are included within this category. An emerging issue of concern is the risk of ANS transfer posed by cultural and religious practices. Establishment of ANS by these mechanisms can undermine efforts to address the interbasin transfer of ANS (Higbee and Glassner-Shwayder 2004). While documentation of specific cases of ANS transfer was not identified, the potential exists for animal rights activists to release captive organisms into the wild. Bioterrorism could include the purposeful introduction of an invasive species to inflict ecological, economic, and psychological damage (Pratt 2004; Roberge 2011).

### 3.2.8 Industrial and Agricultural Use

The non-aquatic transfer mechanisms related to industrial and agricultural use includes the accidental release or escape of organisms used for crops or for bioremediation (Table 3.1). Industrial use of aquatic plants (e.g., treatment of wastewater) is a potential risk for the entry of new species (Champion and Clayton 2000).

### 3.2.9 Dredge Spoils, Topsoil and Fill Transport and Use

The non-aquatic transfer mechanisms in this category are related to the accidental spread of hitchhikers contained in dredge spoils, topsoil, or fill materials (Table 3.1). Dormant spores, seeds, cysts, eggs, and even larval and adult benthic invertebrates collected in sediments or soils at one location could survive short periods of desiccation and be successfully transferred to a new location.

### 3.2.10 Transport by Animals

The non-aquatic transfer mechanisms related to transport by animals includes the external and/or internal transport of an ANS by birds (especially waterfowl and shorebirds), mammals, and other biota (Table 3.1). Even beetles have been found to passively carry algae (see Peterson Environmental Consulting 2002). Birds in particular may have a major role in the expansion of native and exotic invertebrate species via both internal and external transport (Frisch et al. 2007; Green and Figuerola 2005; Green et al. 2005), and have been considered to be one of the principal means by which small aquatic organisms are carried from one isolated waterbody to another (Proctor 1964). Short-distance dispersal may occur in fish stomachs and terrestrial animals. However, longer distance dispersal may occur if coupled with human-mediated establishment of fish. Waterfowl are a more effective mechanism for dispersal of invertebrates (see Panov et al. 2004). Passage of crustacean eggs through waterfowl digestive tracts is an effective means for the dispersal of many freshwater species (Proctor 1964). Killdeer and similar shorebirds may be important agents in the transport of many kinds of aquatic organisms (e.g., algae and crustaceans) (Proctor et al. 1967). Viable cysts of parthenogenetic brine shrimp (*Artemia*) survive gut passage in some migratory wading birds which creates the potential for long-distance dispersal (Sánchez et al. 2007).

Animals also serve as dispersal mechanisms for many plant species, ferrying seeds either internally or externally (Meisenburg and Fox 2002). Transfer of aquatic plants via migratory birds has been documented in New Zealand (Champion and Clayton 2000). More than 70 native and exotic plant species from a full range of habitat types germinated from white-tailed deer feces collected in central New York. White-tailed deer have a high potential for effecting long-distance seed dispersal, which may help explain rapid rates of plant migration (Myers et al. 2004). In a study from southern Connecticut, 61% of deer pellet groups contained seeds that germinated. Of the 86 taxa that geminated, 40 species were not native to the United States. Because the maximum distance traveled by a doe in the study was almost 3.7 mi, white-tailed deer could serve as an important agent in the dispersal of seeds of exotic species (Williams et al. 2008). Overland dispersal of algae is not fully understood, but transport may occur via animals (Peterson Environmental Consulting 2002).

### 3.2.11 Weather

The non-aquatic transfer mechanisms related to weather include the transport of ANS by wind and tornadoes (Table 3.1). For example, natural methods for entry of aquatic plants in New Zealand include wind-blown seeds (Champion and Clayton 2000). Because few truly aquatic species can actively migrate among basins, several passive transport mechanisms have been identified such as wind dispersal (particularly desiccation-resistant life stages of protozoa, algae, plants, and many micro- and meioinvertebrates) and rare meteorological events (e.g., tornadoes) (Peterson Environmental Consulting 2002; Proctor 1964). Natural mechanisms for interbasin transfer of aquatic organisms may also include high water and extraordinary meteorological events (i.e., tornadoes, hurricanes, or earthquakes) (Ludwig and Leitch 1996).

## 3.3 OVERVIEW OF THE MECHANISMS OF SPREAD FOR THE ANS IDENTIFIED AS MEDIUM OR HIGH RISK FOR INTER-BASIN INVASION

Thirteen ANS pose medium or high risks from interbasin transfer between the Great Lakes and the Mississippi River basins (Table 2.1). The risk assessment report (Grippo et al. 2013) discussed the potential risk of interbasin transfer and establishment of these species through the CAWS by vessels, active swimming, or passive drift by the species. The potential for 12 of these ANS to undergo interbasin transfer via one or more of the non-aquatic transfer mechanisms identified in Table 3.1 are discussed below.[2]

### 3.3.1 Fishes

#### 3.3.1.1 Asian carp: silver carp *(Hypophthalmichthys molitrix)* and bighead carp (*H. nobilis)*[3]

Establishment of Asian carp in the United States first occurred in the 1970s from use in aquaculture production of food fishes and for biological control of plankton in aquaculture ponds, reservoirs, and sewage treatment lagoons (Grippo et al. 2013). Flood events allowed both the silver carp and bighead carp to escape confinement. They subsequently spread throughout much of the Mississippi River Basin. Transportation of fishes caught for live bait, livehaulers, live fish food industry, and by those practicing prayer animal releases have contributed to the spread throughout the Mississippi River Basin (Kolar et al. 2005).

More than 30 potential mechanisms have been suggested by which Asian carp may potentially enter the Great Lakes Basin (Higbee and Glassner-Shwayder 2004; Hill and Pegg 2008; Conover et al., 2007; Eaton 2010). Possible mechanisms for the establishment of Asian carp

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2 The viral hemorrhagic septicemia virus (VHSV) is not addressed in detail in this report. Nevertheless, any interbasin transfer mechanism identified for the other 12 ANS could also transfer VHSV.

3 Two other Asian carp, the grass carp (*Ctenopharyngodon idella*) and black carp (*Mylopharyngodon piceus*), are not identified as medium or high risk for interbasin transfers. The bighead and silver carp together are sometimes referred to as bigheaded carps.

include (1) spread of wild populations through interstate waters, (2) spread via release of wild-caught baitfish, (3) importation and release, (4) incidental inclusion in shipments of farm-raised fish, and (5) unauthorized releases by individuals (MDNR 2007). Asian carp have become established in the United States via authorized stocking by various agencies and unauthorized stocking by private individuals, as well as by unintentional escapes from university research facilities, federal and state agency facilities, fish hatcheries, ethnic live food fish markets, private aquaculture operations, and possibly, by illegal intentional releases (Buck et al. 2010; Donahue 2011; MDNR 2007). The fish culture industry abandoned the use of bighead carp as it was not effective in improving conditions in culture ponds. As a result, bighead carp may have escaped or been allowed to escape to the wild (Rasmussen 2002).

All non-aquatic transfer mechanisms listed in Table 3.2 (except industrial and agricultural use and the transport and use of dredge spoils, topsoil, and fill) are documented or potential means for the establishment or interbasin transfer of Asian carp.

Strategies for the management and control of Asian carp (Donahue 2011) highlight some of the mechanisms that account for the establishment and spread of Asian carp such as: (1) Asian carp intermixed with native baitfish; (2) unintentional transport, release or disposal of Asian carp by natural resource managers; (3) illegal importation; (4) incidental inclusion in international imports with other fishes; (5) unintentional escape, release or improper disposal from aquaculture facilities at poorly sited locations; (6) incidental inclusion in aquaculture shipments of other farm-raised species to non-aquaculture waters; (7) live transport of wild-caught Asian carp and subsequent potential release; (8) release, escape or improper disposal of domestic commercial shipments of live Asian carps; (9) accidental and deliberate unauthorized release by individuals; (10) release, escape or improper disposal by aquarium/hobby industry importers, wholesalers and retailers; (11) release, escape or improper disposal via educational facilities; and (12) transport and release by boaters, anglers, and bow fishers.

Boats that are not drained after use could potentially carry juvenile carp or eggs to a new water body (NPS 2013). Anglers sometimes catch juvenile Asian carp and use them as live bait not only because they look similar to native baitfishes such as gizzard shad (*Dorosoma cepedianum*) but also because anglers are not always concerned about the species they collect or use as bait (Kolar et al. 2005; MDNR 2013). Dumping of unused baitfish may contribute to the establishment and spread of these species (Buck et al. 2010). Although not shown in from the literature, there is a potential for release of Asian carp through animal rights activism (Kolar et al. 2005).

The live food fish industry could be a potential pathway for the establishment of Asian carp in the Great Lakes. Live food fish species are sold predominantly in the Asian-American market primarily in larger cities of the Great Lakes Basin such as Chicago and Toronto, as well as New York City (Higbee and Glassner-Shwayder 2004). Some large cities have promulgated local laws that require Asian carp sold by a retail grocer to be slaughtered upon sale (MDNR 2007) or have banned the sale of live fish (Osborn 2013a). Another threat to the Great Lakes is the smuggling of live Asian carp by trucks from the United States to Canada (Anderson 2012; Lynch 2012). The bighead carp reported from Lake Erie are likely from shipments of live fish from the United States to Canada or their release after purchase (Kerr et al. 2005; Michigan Sea Grant 2010).

Flooding can spread Asian carp if it connects water bodies that are not normally connected (NPS 2013). For instance, floods in the 1980s increased the number of Asian carp in the Mississippi River and enabled them to spread further northward in the Mississippi River system (Patel et al. 2010).

#### 3.3.1.2 Ruffe (Gymnocephalus cernuus)

The establishment of the ruffe in the Great Lakes likely occurred via ballast water discharges from transoceanic ships. Its spread within the Great Lakes has also been attributed to shipping transport (Fuller and Jacobs 2012). The distribution of ruffe in North America is currently limited to the Great Lakes probably because mechanisms for dispersal to inland waters are primarily anthropogenic, and considerable effort has been invested in management of ruffe (Drake 2005). Among the non-aquatic transfer mechanisms identified in Table 3.1, only bait release has been documented in the reviewed literature. However, a number of other potential non-aquatic transfer mechanisms, based on the reviewed literature, may be possible for the ruffe (Table 3.2). These include aquarium releases, accidental stocking, researcher releases, and transport by animals or weather events (e.g., flooding).

The potential spread of ruffe to inland waters may occur via transport in live wells and bilge water of recreational boats, and by bait bucket releases (Great Lakes Commission 2011). The expansion of ruffe in the United Kingdom has been attributed to the probable use of ruffe as bait (Winfield et al. 1996). The chance of establishment of ruffe in inland lakes (e.g., due to their use as bait and their reproductive ability) is considered high, even if only a few individuals are released (Drake 2005).

#### 3.3.1.3 Tubenose goby (Proterorhinus semilunaris)

The establishment of the tubenose goby in the Great Lakes likely occurred via ballast water discharges from transoceanic cargo ships (Fuller et al. 2012; Mills et al. 1991; Rasmussen 2002). Their presence around the Bass Islands in Lake Erie and their discontinuous range in western Lake Erie suggest that bait bucket releases may be one possible mechanism for the spread of the species (Kocovsky et al. 2011). Bait release is the only literature documentation obtained that addressed potential establishment or interbasin transfer for the tubenose goby among the non-aquatic transfer mechanisms identified in Table 3.1. However, a number of other potential non-aquatic transfer mechanisms, based on the reviewed literature, may be possible for the tubenose goby (Table 3.2). These include aquarium releases, accidental stocking, researcher releases, and transport by animals or weather events (e.g., flooding).

#### 3.3.1.4 Threespine stickleback (*Gasterosteus aculeatus*)

The spread of the threespine stickleback in the Great Lakes occurred through bait releases or by active swimming through the artificial Nipissing Canal (see Fuller 2013). Bait release is the only documented mechanism identified in the reviewed literature among the non-aquatic transfer mechanisms identified in Table 3.1. However, a number of other potential non-aquatic transfer mechanisms, based on the reviewed literature, may be possible for the threespine stickleback (Table 3.2). These include aquarium releases, accidental stocking, researcher releases, and transport by animals or weather events (e.g., flooding).

### 3.3.2 Crustaceans

#### 3.3.2.1 Scud (Apocorophium lacustre)

The scud was transported to the Mississippi River Basin from the Atlantic coast on boat hulls or in ballast water (Grigorovich et al. 2008; Johnson et al. 2007). None of the non-aquatic transfer mechanisms identified in Table 3.1 have been documented in the literature reviewed for the scud. However, a number of potential non-aquatic transfer mechanisms may be possible for the scud (Table 3.3). These include recreation, aquarium releases, accidental stocking, researcher releases, dredge and fill transport and use, and transport by animals or weather events (e.g., flooding).

**Table 3.2 Potential Mechanisms for Non-Aquatic Interbasin Transfer of the Aquatic Nuisance High- and Medium-Risk Fish Species[a]**

| Transfer Mechanism[b] | Silver Carp (*Hypophthalmichthys molitrix*) | Bighead Carp (*Hypophthalmichthys nobilis*) | Ruffe (*Gymnocephalus cernuus*) | Tubenose Goby (*Proterorhinus semilunaris*) | Threespine Stickleback (*Gasterosteus aculeatus*) |
|---|---|---|---|---|---|
| | | | | | |
| Recreation | | | | | |
| Private aquaria and water gardens | | | | | |
| Aquaculture and horticulture | | | | | |
| Accidental or unregulated stocking | | | | | |
| Educator/researcher releases | | | | | |
| Live food fish market | | | | | |
| Cultural/religious practices, animal rights activism, and ecoterrorism | | | | | |
| Industrial and agricultural use | | | | | |
| Dredge spoils/topsoil/fill transport and use | | | | | |
| Transport by animals | | | | | |
| Weather | | | | | |

[a] White cells are not determined to be potential non-aquatic transfer mechanisms, light gray cells are potential non-aquatic transfer mechanisms based on the reviewed literature, and dark gray cells are non-aquatic transfer mechanisms documented in the reviewed literature for the target or similar species.

[b] See Table 3.1 for a description of the transfer mechanisms.

### 3.3.2.2 Bloody red shrimp (*Hemimysis anomala*)

Establishment of the bloody red shrimp in the Great Lakes likely occurred via ballast water releases from transoceanic cargo vessels (Kipp et al. 2013). The reviewed literature identified recreation and private aquaria releases as potential mechanisms of establishment or interbasin transfer for the bloody red shrimp. Several other non-aquatic transfer mechanisms, based on the reviewed literature, are also considered possible for the bloody red shrimp (Table 3.3). These include accidental stocking, researcher releases, dredge and fill transport and use, and transport by animals or weather events (e.g., flooding). Once established in the Great Lakes, subsequent spread to interbasin areas has occurred through bait bucket transfers, as well as hitchhiking in live wells, bilges, boat motors, trailers, hulls, and other equipment used in the water. While there are no records of the bloody red shrimp used as food for aquarium fish, it could be a possible transfer mechanism (Pennsylvania Sea Grant 2012). Because the bloody red shrimp inhabits areas near structures such as docks, activities around docks that pick up and move water (such as transportation of live bait) likely represent a higher risk of secondary non-aquatic transport of the species (DFO 2010).

**Table 3.3 Potential Mechanisms for Non-Aquatic Interbasin Transfer of the Aquatic Nuisance High- and Medium-Risk Planktonic and Benthic Crustacean Species[a]**

| **Transfer Mechanism[b]** | **Zooplankton** | | **Crustacean** |
|---|---|---|---|
| | **Bloody Red Shrimp (*Hemimysis anomala*)** | **Fishhook Waterflea (*Cercopagis pengoi*)** | **Scud (*Apocorophium lacustre*)** |
| | | | |
| Recreation | | | |
| Private aquaria and water gardens | | | |
| Aquaculture and horticulture | | | |
| Accidental or unregulated stocking | | | |
| Educator/researcher releases | | | |
| Live food fish market | | | |
| Cultural/religious practices, animal rights activism; and ecoterrorism | | | |
| Industrial and agricultural use | | | |
| Dredge spoils/topsoil/fill transport and use | | | |
| Transport by animals | | | |
| Weather | | | |

[a] White cells are not determined to be potential non-aquatic transfer mechanisms, light gray cells are potential non-aquatic transfer mechanisms based on the reviewed literature, and dark gray cells are non-aquatic transfer mechanisms based documented in the reviewed literature for the target or similar species.

[b] See Table 3.1 for a description of the transfer mechanisms.

#### 3.3.2.3 Fishhook waterflea (*Cercopagis pengoi*)

The establishment of the fishhook waterflea to the Great Lakes occurred from their presence in ballast water or from their attachment on boat hulls (Benson et al. 2011). The reviewed literature identifies recreation, educator/research releases, and transport by animals as potential mechanisms of establishment or interbasin transfers for the fishhook waterflea. Several other potential non-aquatic transfer mechanisms, based on the reviewed literature, may also be possible for the fishhook waterflea (Table 3.3). These include aquarium releases, accidental stocking, dredge and fill transport and use, and transport by weather events (e.g., flooding).

Generally, species that have biphasic life modes, such as waterfleas that have an active and dormant phase, may be capable of exploiting many different dispersal mechanisms and consequently may be represented frequently among established ANS. These species may also pose the greatest concern since a number of unrelated mechanisms may contribute to their dispersal (Holeck et al. 2004). One possible mechanism for their spread to inland lakes is via fouling of and subsequent transfer on sport fishing lines. This includes diapausing eggs that can remain viable for weeks or more (Jacobs and MacIsaac 2007). They can also be transferred as hitchhikers in bilge water and livewells (IDNR 2005). Drake (2004) argued that establishment of *Bythotrephes* (a genus of waterfleas similar to the fishhook waterflea that also has diapausing eggs that hatch into parthenogenetic females) could succeed in a new waterbody with a high probability (~1.0) with the release of as few as about 10 parthenogenetic females, or with a lower probability (~0.45) with the release of as few as only one parthenogenetic female.

Local dispersal mechanisms for the fishhook waterflea also include transport by waterfowl (Makarewicz et al 2001). The thick-shelled diapausing eggs of *Bythotrephes longimanus* (spiny waterflea) can pass through fish guts in viable conditions; thus the species can be spread in fecal pellets, including those deposited in livewells and bait buckets (Kerfoot et al. 2011). Because resting eggs may survive in lake sediments for decades or more, actions such as physical storm-driven disturbance, bioturbation of sediments by invertebrates and fishes, or some human activities may bring even very old resting eggs to the surface of sediments and expose them to environmental hatching cues (see Panov et al. 2004).

### 3.3.3 Algae

#### 3.3.3.1 Red alga (*Bangia atropurpurea*)

The establishment of the red alga in the Great Lakes occurred from their presence in ballast water or from their attachment on boat hulls (Kipp 2011; Lin and Blum 1977). Transport by animals was the only transfer mechanism among those in Table 3.1 that was identified for *Bangia atropurpurea* in the reviewed literature. However, a number of other potential non-aquatic transfer mechanisms, based on the reviewed literature, may be possible for the *Bangia atropurpurea* (Table 3.4). These include recreation, aquarium releases, accidental stocking, researcher releases, dredge and fill transport and use, and transport by weather events (e.g., flooding). Transport by currents, aquatic animals, and ship hulls appear to have been the important dispersal mechanisms responsible for the rapid invasion of Lake Michigan by *Bangia atropurpurea* (Lin and Blum 1977).

#### 3.3.3.2 Diatom (Stephanodiscus binderanus)

The establishment of the diatom *Stephanodiscus binderanus* in the Great Lakes occurred from ballast water discharge (Kipp 2011). However, paleolimnological data from Lake Simcoe, Ontario, give unequivocal evidence that *Stephanodiscus binderanus* has been present in the Great Lakes region since at least the late 17th century, which may refute the assumption that the diatom is a nonindigenous species to North America (Hawryshyn et al. 2012). No literature documentation was obtained that addressed potential establishment or interbasin transfer of *Stephanodiscus binderanus* by the non-aquatic transfer mechanisms identified in Table 3.1. However, a number of non-aquatic transfer mechanisms may be possible for *Stephanodiscus binderanus* (Table 3.4). These include recreation, aquarium releases, accidental stocking, researcher releases, dredge and fill transport and use, and transport by animals or weather events (e.g., flooding).

#### 3.3.3.3 Grass kelp (*Enteromorpha flexuosa*)

Grass kelp was probably first established in the Great Lakes by ballast water or hull fouling (Grippo et al. 2013). Industrial use is the only transfer mechanism documented in the reviewed literature. Potentially, grass kelp could be used in industrial settings for wastewater treatment in dye manufacturing, tannery, textile, and cosmetic industries (Sivasamy et al. 2012). Several other interbasin non-aquatic transfer mechanisms, based on the reviewed literature, may also be possible for grass kelp (Table 3.4). These include recreation, aquarium releases, accidental stocking, researcher releases, dredge and fill transport and use, and transport by animals or weather events (e.g., flooding).

### 3.3.4 Rooted Aquatic/Semi-Aquatic Plants: Reed Sweetgrass (*Glyceria maxima*)

Reed sweetgrass became established in some areas of the Great Lakes Basin through its use as a forage species or as an ornamental species; transportation with packing material; or transportation by waterfowl (Howard 2012; Mills et al. 1991). The reviewed literature identified accidental releases from water gardens and horticulture operations, agricultural use, and dredges spoils, as well as transport by animals, as potential mechanisms for establishment of reed sweetgrass into new areas (Table 3.4). Several other potential non-aquatic transfer mechanisms may also be possible for the reed sweetgrass (Table 3.4). These include recreation, accidental stocking, and transport by weather events (e.g., flooding).

Reed sweetgrass was imported to New Zealand primarily as a coarse grass that would provide feed for cattle in wet areas (Champion and Clayton 2000). It has also been sold as an ornamental plant (WDNR 2013). Seeds of reed sweetgrass spread on water, in mud on machinery and vehicles, on footwear, and on wildlife. Wind is not considered a primary route for seed spread.

Most seeds can germinate immediately, but some may remain dormant for several years (DPIPWE 2002). The removal of tree species and exclusion of livestock from riparian zones may facilitate the growth and ultimate spread of reed sweetgrass (Loo et al. 2009). Foraging by muskrats and beavers may uproot plants or cut rhizomes to disperse and reestablish along stream courses (USFS 2006). Fowl mannagrass (*Glyceria striata*), a native species that occupies similar habitats as reed sweetgrass, have been observed to germinate from white-tailed deer feces. White-tailed deer may provide a means of upstream spread and overland dispersal to new watersheds (Myers et al. 2004). Thus, it reed sweetgrass could spread in a similar manner.

**Table 3.4 Potential Mechanisms for Non-Aquatic Interbasin Transfer of the Aquatic Nuisance High- and Medium-Risk Algae and Rooted/Semi-Aquatic Vegetation Species**[a]

| **Transfer Mechanism**[b] | **Algae** | | | **Rooted/Semi-Aquatic Vegetation** |
|---|---|---|---|---|
| | **Red Alga (*Bangia atropurpurea*)** | **Diatom (*Stephanodiscus binderanus*)** | **Grass Kelp (*Enteromorpha flexuosa*)** | **Reed Sweetgrass (*Glyceria maxima*)** |
| | | | | |
| Recreation | | | | |
| Private aquaria and water gardens | | | | |
| Aquaculture and horticulture | | | | |
| Accidental or unregulated stocking | | | | |
| Educator/researcher releases | | | | |
| Live food fish market | | | | |
| Cultural/religious practices, animal rights activism, and ecoterrorism | | | | |
| Industrial and agricultural use | | | | |
| Dredge spoils/topsoil/fill transport and use | | | | |
| Transport by animals | | | | |
| Weather | | | | |

[a] White cells are not determined to be potential non-aquatic transfer mechanisms, light gray cells are potential non-aquatic transfer mechanisms based on the reviewed literature, and dark gray cells are potential non-aquatic transfer mechanisms based on the reviewed literature that is supported by the literature for the specific species.

[b] See Table 3.1 for a description of the transfer mechanisms.

# 4 CONCLUSION

No matter what actions are enacted to address interbasin transfer of the 13 medium- and high-risk ANS via the aquatic transfer mechanisms considered in the risk assessment report (Grippo et al. 2013), there remains the risk for the species to be transferred by one or more of the non-aquatic transfer mechanisms identified in Table 3.1. Recreational use, particularly in the vicinity of the CAWS, may be of more concern for interbasin transfer than the other non-aquatic transfer mechanisms due to a combination of (1) the number of individuals that participate in hunting, fishing, boating, and other water sports in the vicinity of the interface between the Mississippi River and Great Lakes basins; and (2) the number of transfer mechanisms associated with recreation (e.g., equipment, clothing, vehicles). Interbasin transfer is also possible from private aquaria and water gardens, accidental and unregulated stocking, and the live food fish market. Transport by animals or adverse weather events such as floods are also foreseeable. The remaining five transfer mechanism categories listed in Table 3.1 are less likely, but still potential, means of interbasin transfers not directly linked to the CAWS.

There are more non-aquatic transfer mechanisms identified for some of the medium- and high-risk ANS than for others (Tables 3.2 through 3.4). However, the information is too uncertain to conduct a risk assessment for non-aquatic pathways as was done by Grippo et al. (2013) for the aquatic pathways. Nevertheless, the documented non-aquatic transfer mechanisms identified in Tables 3.2 through 3.4 indicate that the two species of Asian carp and, to a lesser extent, the fishhook water flea and reed sweetgrass are the most likely of the 12 ANS evaluated in detail in this report to be transferred by mechanisms not directly linked to the CAWS. The remaining eight species evaluated in this report are less likely, but still potentially transferred, by mechanisms not directly linked to the CAWS. The viral hemorrhagic septicemia virus can potentially be transferred by any of the non-aquatic mechanisms listed in Table 3.1. Its potential to be transferred by means not directly linked to the CAWS is potentially as high as or higher than that for the other 12 ANS.

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# ATTACHMENT E

# EFFECT OF MID SYSTEM SEPARATION ON LOW FLOWS IN DOWNSTREAM WATERWAY

# Effect of Mid-System Separation on Low Flows in Downstream Waterway

## 13 June 2013

A meeting was held between the Corps and IDNR on Thursday, June 13 regarding GLMRIS vs. Diversion. Arlan mentioned that several power plants had operation issues and the navigation industry was also affected during the drought, 2012. This note summarizes how the Mid-system separation alternative will affect the discharge in the waterway.

7Q10, the 7-day 10-year low flows, is a common discharge statistics used in the water resources management and water quality regulation which may represent the minimum flow in the river that needs to be maintained or the water quality standards will apply. Often permitted water users are not allowed to withdraw waters from the river once the discharge falls below 7Q10. 7Q10 in the waterway in NE Illinois is mainly consisted of effluent from the wastewater treatment plants, commercial and industrial discharges and groundwater infiltration. Since the low flow normally occurs in the winter months in NE Illinois watersheds, 7Q discharge usually occurs in the winter month as well. Therefore, direct diversion through the lakefront controlling works can safely be assume to be negligible without losing much accuracy in making estimates for the 7Q10 . In addition groundwater infiltration into the waterway was also found to be very small in the Chicago area waterway. Therefore, the effect of the mid-system separation on the low flow in the downstream waterway can simply be viewed as a result of stopping some wastewater treatment plant and commercial and industrial discharges on the lake side of the barriers to continue flowing to the downstream waterway.

The 7Q10 in the NE Illinois streams was most recently analyzed by the Illinois State Water Survey in 2003 [1]. It was estimated that the 7Q10 on the CSSC above the Cal-Sag Junction was about 1,050 cfs, whereas the 7Q10 in the Cal-Sag Channel was about 259 cfs. These numbers check reasonably well with the recent reported effluents from MWRD's WRPs during the dry weather. The 7Q10 value generally increases along the course of the river when flows are added to the river by plant discharge or tributary inflows which in turn are mainly wastewater treatment plant discharges. However, it may also decrease as a result of non-return withdrawals. With the mid-system hydro-separation, 311 (Northside WRP and other minor inflows) plus 259 (Calumet WRP and other minor inflows)=570 cfs will flow to Lake Michigan if the effluents from these facilities will not be rerouted to the river side of the barriers. In the GLMRIS study the 7Q10 downstream from the Cal-Sag Junction with the mid-system separation will be computed by subtracting 570 cfs from the estimated values under the existing condition.

| Location | 7Q10 (cfs) -- Existing | 7Q10 (cfs) – Mid-system Separation |
|---|---|---|
| CSSC above Cal-Sag Junction | 1,050 | 739 |
| Cal-Sag Channel | 259 | 0 |
| CSSC near Lemont | 1,315 | 745 |
| CSSC at Lockport | 1,317 | 747 |
| Des Plaines River below CSSC confluence | 1,471 | 901 |
| Des Plaines River at Brandon Road Dam | 1,493 | 923 |
| Illinois River at Dresden | 2,100 | 1,530 |
| Illinois River at Morris | 2,115 | 1,545 |
| Illinois River at Marselles | 1,990 | 1,420 |
| Illinois River at Ottawa | 1,985 | 1,415 |

Reference


1. Illinois State Water Survey, 7-Day 10-Year Low Flow Maps, http://www.isws.illinois.edu/docs/maps/lowflow/background.asp

# ATTACHMENT F

# WATER QUALITY MEASURES AND NON-FEDERAL SPONSOR RESPONSIBILITIES

Per USACE Engineering Regulation 1110-2-8154, Water Quality and Environmental Management at Corps Civil Works Projects, the Corps manages its projects in accordance with all applicable Federal and state environmental laws, criteria, and standards. In accordance with the cost sharing provisions of the Water Resources Development Act of 1996, the non-federal share of the cost of water quality features generally shall be 100 percent. Before there can be a Federal interest to cost share a water quality improvement feature, the State must be in compliance with water quality standards for the current use of the water to be affected.

Under USACE Engineering Regulation 1165-2-501, Civil Works Ecosystem, Civil Works restoration and protection projects may involve cost effective solutions involving measures to improve water quality parameters as important components of ecosystem structure and function. However, the Corps will not propose, for Civil Works implementation, restoration projects or activities that would principally result in treating or otherwise abating pollution problems caused by other parties where they have, or are likely to have, a legal responsibility for remediation or other compliance responsibility. Therefore, any water quality mitigation measures designed to achieve State water quality standards for current water uses will be constructed and operated at 100% non-federal expense, unless otherwise prescribed by law. Upon achieving state water quality standards for current water uses, the USACE may cost share improvements to water quality if deemed cost effective and important to ecosystem structure and function.

If an ANS Control alternative would result in adverse impacts to water quality, where State water quality standards for current water uses are being achieved, then the USACE will explore potential mitigation measures to ensure the construction and operation of the ANS Control alternative is compliant with applicable State water quality requirements. If a non-federal sponsor is identified, the non-federal sponsor would most likely be responsible for ensuring compliance with State water quality standards during OMRR&R activities.

# ATTACHMENT G

# COMMERCIAL NAVIGATION MITIGATION DISCUSSION

## Commercial Navigation Mitigation Discussion

Two suitable options exist to mitigate for potential impact to CAWS commercial navigation users. One option is a transloading facility where the commodity remains on the waterway by having either the barge itself or the commodity within the barge being transferred across the barrier. Another option is a multimodal facility which is location where commercial navigation users could transfer their goods from the waterway to other modes of transportation such as truck or rail. A multimodal facility is similar to an intermodal facility, but an intermodal facility usually refers to a facility that transfers containers from one transportation mode to another mode, while multimodal refers to a facility that moves bulk commodities from one transportation mode to another.

The discussion on mitigating impacts to commercial navigation revolves around several key points:

1. **A transloading facility where a vessel is lifted over a barrier presents several challenges.** Vessel lifts are one type of transloading facility. Lifts can be designed to move a vessel over the barrier without water in the caisson, a dry lift, or with water in the caisson, a wet lift.

   A dry lift could be used to move smaller recreational vessels, but is unsuitable for commercial cargo vessels because they require the force of water pushing against the outside of the barge to maintain their shape and stability. Any dry lift would also require the exterior of vessels to be washed. Due to the thoroughness required in washing all wetted areas ANS transport via hull fouling or temporary vessel attachment would remain a concern.
   A wet lift could be used to transfer commercial cargo vessels, but the largest lift in operation handles one barge per operation, so a CAWS three barge tow would take much more time relative to lock operation. In addition ANS transfer due to attachment on hulls or the exchange of water between basins still exists with the wet lift, so the effectiveness of the physical barrier of preventing ANS transfer is negatively impacted.

2. **Transloading the commodity around a barrier or transferring the commodity to another transportation mode at a multimodal facility as a mitigation measure would increase the cost of transporting materials.**
   Any transloading facility where a commodity is lifted over a barrier or a multi-modal facility where a commodity is transferred to or from a barge onto rail or truck imposes an additional cost of handling the material on the shipper. The margins of profit for shipping these commodities via waterway is slim, so the increase in cost caused by increasing the number of times a commodity is handled could potentially make the business unprofitable.

3. **CAWS operators are unlikely to use a transloading or multi-modal facility.**
   The GLMRIS Navigation and Economics PDT contracted with the University of Tennessee, Center for Transportation Research to conduct a shipper response survey. This survey was given to commercial navigation operators that utilize the various waterways within CAWS and asked how shippers would likely operate their businesses under potential future CAWS operational scenarios. Specifically, respondents were asked how they would operate their businesses if lockage times through the CAWS locks were increased, how would they operate their businesses if the locks were permanently closed (essentially a hydrologic separation scenario), and if they would transfer around a temporary closure or permanent barrier by unloading from barge to truck or rail and then reloading to barge once past the point of disruption on the CAWS. In regards to permanent lock closures, the majority of the

responders indicated that they would either: (1) choose a different method of moving their respective commodities (e.g., truck or rail), (2) relocate their business, or (3) go out of business. When asked about the transloading option almost all docks and shippers (representing over 90% of the docks in the CAWS and 93% of all tonnage) responded that they would not undertake this option.

4. **Any multimodal facility would likely require a large amount of area.**
   Any multimodal facility built in the Chicago region would need the capability to handle both bulk and liquid commodities. For general and bulk commodities, the multimodal facility would likely need a crane for handling general cargo, a crane for handling bulk commodities, loading / unloading rail or truck facilities, bulk material covered storage area, docking barges, and other equipment. According to The University of Tennessee, Center for Transportation Research (UT-CTR), any multimodal facility handling liquids would require a separate pipeline for each impacted liquid commodity to avoid mixing of liquids. The UT-CTR roughly estimates that 100 to 500 acres would be required for a multi-modal facility in the Chicago Area depending on the location of the barrier.

   It should be noted that USACE has identified a currently operating multi-modal facility owned by CenterPoint Properties in Joliet, Illinois. This facility provides an opportunity for commercial navigation mitigation under this GLMRIS alternative. The CenterPoint Properties facility could be used to offset the impact to those commercial navigation entities affected by ANS controls that choose to remain in business in the Chicago land area.

5. **Several obstacles exist for Chicago to become a Container on Barge (COB) hub.**
   One obstacle would be in establishing the connections between rail and water. While Chicago can be considered a rail hub in the sense that many Class I lines converge in the Chicago area, these lines do not necessarily intersect one with the other, and few have terminals on the river – none with container transfer capability. Another hurdle is the current advantages of rail and truck in moving containers. The multi-agency, joint U.S. and Canada *Great Lakes St. Lawrence Seaway Study*, Fall 2007, found that the relatively greater speed, frequency of service, and expansive reach of rail and truck put COB at a disadvantage. Countering these disadvantages would require implementing a strong transportation policy encouraging COB, along with public and private financial partnerships.

6. **For the GLMRIS Report Commercial Navigation Mitigation was not considered further.**
   Several obstacles to implementing commercial navigation mitigation were identified: increased transportation cost, diminished effectiveness of ANS control measures, and shipper response. Given these obstacles and the rough cost estimates for establishing transloading or multimodal facilities, the GLMRIS Report does not consider commercial navigation mitigation for alternatives.

7. **If a hydrologic separation alternative is selected, further study is required.**
   Only a preliminary analysis of the requirements for a transloading or multimodal facility was performed. If a hydrological separation alternative is selected, then further study would be needed to determine whether additional cost-effective commercial navigation mitigation would be appropriate.

# ATTACHMENT H

# GLMRIS LOCK DATA REPORT

ERDC/CHL

Coastal and Hydraulics Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

# GLMRIS Lock - Reducing Risk of Aquatic Nuisance Species Transfer through Locks, Chicago Area Waterway System, IL, Data Report

Richard L. Stockstill and Richard B. Styles

September 2013

## Contents



## Figures



## Tables

# Introduction

Previous investigations have been conducted to determine how a navigation lock may be used as a conduit to facilitate passage of substances such as ice and debris. Ice and debris studies (e.g. Tuthill et al. 2004, and Mausshardt and Singleton 1995) have focused on passing materials which tend to float on the water surface. Numerous studies are documented in the literature regarding how a lock may serve as a barrier to salt water intrusion. Salt water intrusion studies (e.g. Parchure et al. 2000, Abraham et al. 1973, Bastian 1971, Wood 1970, and Boggess 1970) have focused on preventing salt water from entering the lock chamber. The salt water problem focuses on the density differences of the fresh and salt water bodies which are to remain separated. The current study differs from previous research in that the objective is to prevent passage of aquatic nuisance species (ANS) which, for the purposes of the current study, are assumed to be neutrally buoyant particles. The exchange of upstream and downstream waters for the Chicago Area Waterway System (CAWS) is complicated by the fact that the mixing of water from these bodies is to be limited even though natural mixing processes occur during normal locking operations. The simple act of opening the lock gates generates turbulent mixing of the fluids on either side of the gate. Also, vessels entering and exiting the chamber generate mixing as return currents and propeller wash mix large quantities of water. These mixing processes make it difficult to maintain the ANS concentration at near zero levels.

# Chicago Area Waterway System (CAWS) Projects

Three projects considered herein as “barriers” to ANS are the Chicago Lock, O’Brien Lock and Dam, and the Brandon Road Lock and Dam, located on the waterways under consideration. The Brandon Road Lock and Dam is just downstream of the Lockport Lock and Dam which is shown in Figure 1 with the locations of Chicago and O’Brien Locks. The ANS are assumed to exist on the upstream side of the Chicago and O’Brien

Locks and on the downstream side of the Brandon Road Lock. The objective is to prevent ANS from entering the CAWS from Lake Michigan via either the Chicago or O'Brien Lock or from the Lower Des Plaines River via the Brandon Road Lock. Since the presence of ANS on the upstream or downstream side of a lock directly affects any plan to prevent passage of the ANS, the Chicago and O'Brien Locks are treated as one situation and the Brandon Road Lock as another. The hydraulics of the Chicago and O'Brien Locks are fairly simple, whereas the higher-lift Brandon Road Lock has a significantly more complicated filling and emptying system.

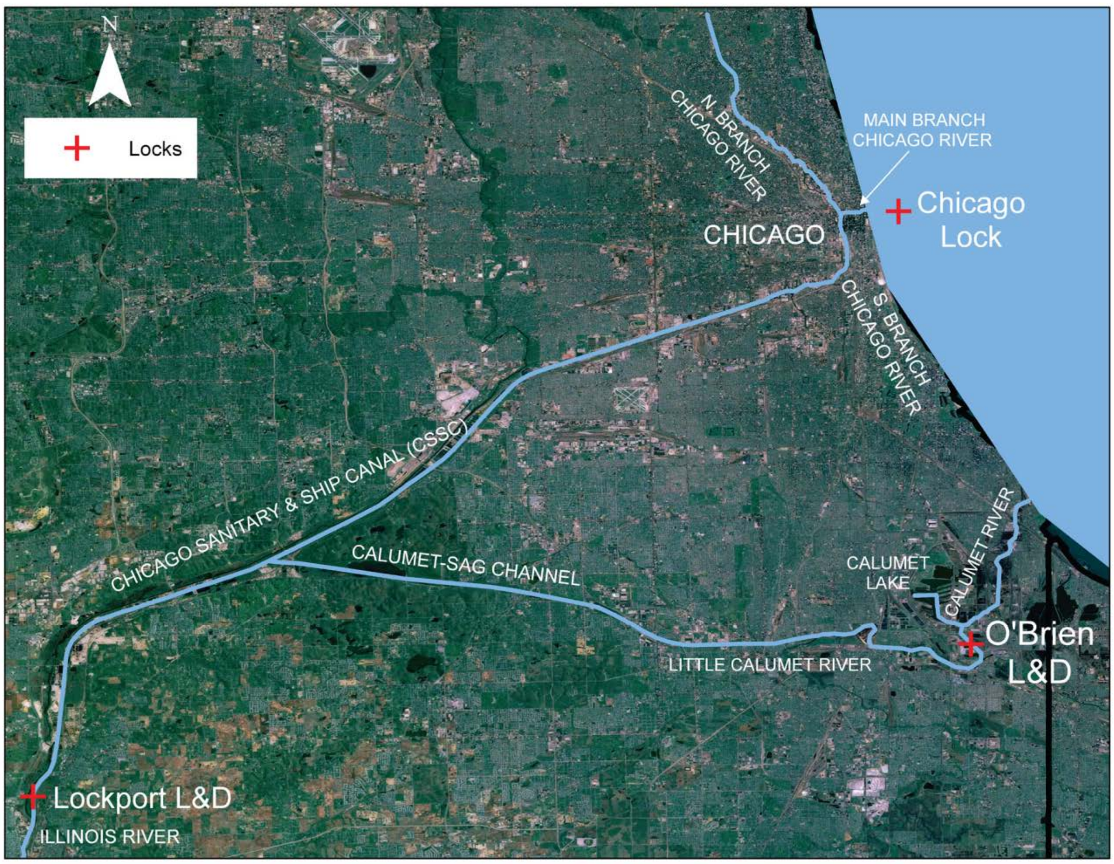


Figure 1. Chicago Area Waterway System, locations of lock projects.

### ANS Upstream of Project

The two locks considered in this study that have ANS in the upper pool are very low lift locks with end filling system designs. The US Army Corps of Engineers (USACE) standards define very low lift locks as those having lifts less than 10 ft (Headquarters, US Army Corps of Engineers 2006). USACE locks with end filling and emptying systems are generally of the sector-gate design (Headquarters, US Army Corps of Engineers 1995). A plan view sketch of an end filling lock system with sector gates is provided in Figure 2. Sector gates rotate about a vertical axis and can be designed to withstand head from either side so they are ideal for pool combinations that may result in reverse head.

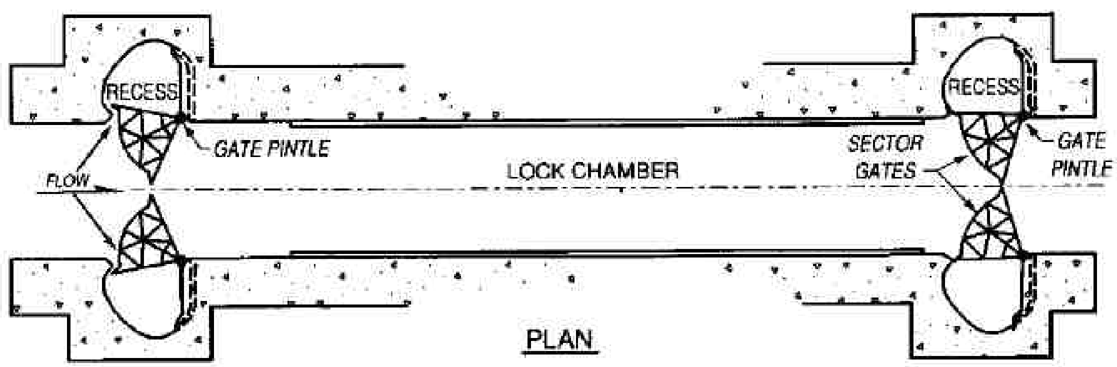


Figure 2. End filling and emptying system (sector gate design).

Under the gravity-fed lock system that exists today, there are four possible cases involving clean water and water that has ANS, as to how a vessel interacts with a lock as it navigates through the chamber. The currents generated as a tow enters a lock chamber are illustrated in Figure 3. The particular flow directions shown in Figure 3 are the result of an upbound tow entering the chamber. As the vessel enters the chamber, the displacement forces the same volume of water out of the chamber. The resulting flow is referred to as return currents. A barge tow leaving the lock draws water into the chamber to replace the vessels displacement volume in which case, the tow and current directions are opposite those depicted in Figure 3. Vessel speed and squat, and thus the return currents, are influenced by the depth over the sill and chamber floor (Maynord 2000).

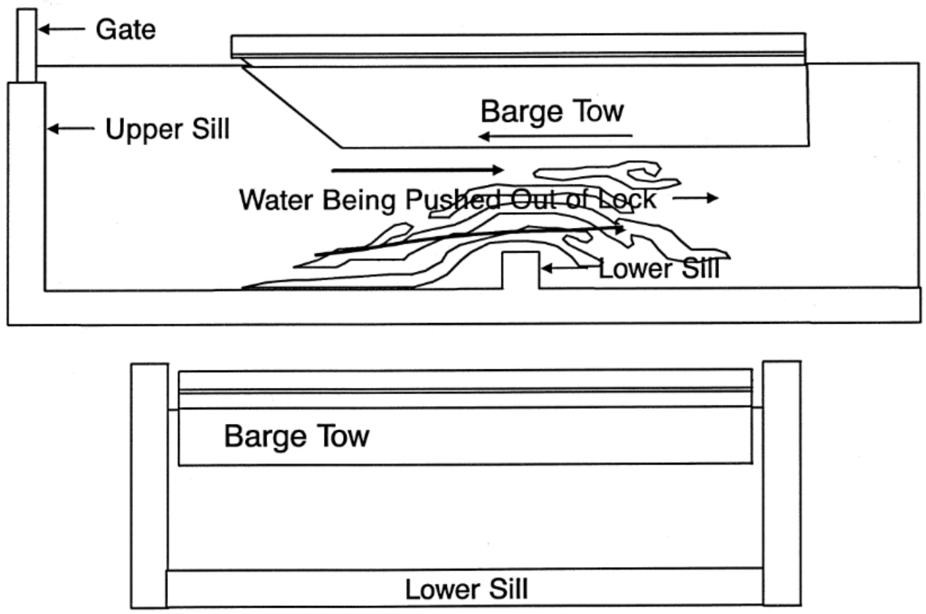


Figure 3. Currents generated as a barge tow enters a lock chamber, upbound tow.

The possible cases are:

Case 1: Vessel exits lock filled with clean water and enters ANS contaminated water in Lake Michigan (LM).

Case 2: Vessel exits lock filled with ANS contaminated water and enters the Chicago Area Waterway System (CAWS) buffer zone.

Case 3: Vessel enters lock from ANS contaminated water in LM and enters initially clean water in the lock chamber.

Case 4: Vessel enters lock from the CAWS buffer zone into a chamber that has ANS contaminated.

For the case where the vessel is exiting the lock into ANS contaminated water, a first approximation of mixing is to assume that the volume of chamber water displaced by the tow will be replaced by the ANS contaminated water as the vessel exits the chamber. Similarly, in the case where the vessel is exiting the lock into ANS contaminated water, a rough approximation is to assume that the volume of water initially displaced by the tow will be replaced by ANS contaminated water as it sails out of the chamber.

## Chicago Lock

Pool and floor elevations at the Chicago Lock are provided in Table 1. Details such as dimensions, operation times, flow depths, and water volumes of the Chicago Lock are given in Table 2.

Table 1. Chicago Lock, elevation information.

| Pool Elevations (ft CCD) | |
|---|---|
| Lake Michigan Normal | 0.8 |
| Lake Michigan Minimum | -2.5 |
| Lake Michigan Maximum | 3.5 |
| Chicago River Normal | -2 |
| Chicago River Minimum | -3 |
| Chicago River Maximum | 4.3 |
| Chamber Floor | -24.94 |

Table 2. Chicago Lock, lock particulars.

| Lock Information | |
|---|---|
| Lock Filling and Emptying System | End Filling |
| Width | 80 ft |
| Length | 600 ft |
| Cycle Time | 15 min |
| Depth when Filled | 25.74 ft |
| Volume of “Filled” Lock | 1,235,520 $ft^3$ |
| Depth when Empty | 22.94 ft |
| Volume of “Empty” Lock | 1,101,120 $ft^3$ |
| Normal Lift | 2.8 ft |
| Normal Lift Volume | 134,400 $ft^3$ |

## O’Brien Lock

Elevation information for the O’Brien Lock is shown in Table 3. Design, geometric, and operation information is provided in Table 4.

Table 3. O'Brien Lock, elevation information.

| Pool Elevations (ft CCD) | |
|---|---|
| Lake Michigan Normal | 0.8 |
| Lake Michigan Minimum | -2.5 |
| Lake Michigan Maximum | 3.5 |
| Calumet River Normal | -2 |
| Calumet River Minimum | -3 |
| Calumet River Maximum | 3.7 |
| Chamber Floor | -18.5 |

Table 4. O'Brien Lock, lock particulars.

| Lock Information | |
|---|---|
| Lock Filling and Emptying System | End Filling: Sector gate w/ Loop Culverts |
| Width | 110 ft |
| Length | 1000 ft |
| Cycle Time | 15 min |
| Depth when Filled | 19.3 ft |
| Volume of "Filled" Lock | 12,123,000 ft$^3$ |
| Depth when Empty | 16.5 ft |
| Volume of "Empty" Lock | 1,815,000 ft$^3$ |
| Normal Lift | 2.8 ft |
| Normal Lift Volume | 308,000 ft$^3$ |

## *ANS Downstream of Project*

### Brandon Road Lock

The Brandon Road Lock is classified as a low lift lock (Headquarters, US Army Corps of Engineers 2006). Low lift locks are defined as those having lift between 10 and 30 (or 40) ft. The Brandon Road Lock, as the majority of locks operated by the USACE, are of the sidewall port design filling and emptying system. A schematic of a sidewall port filling and emptying system is provided in Figure 4.

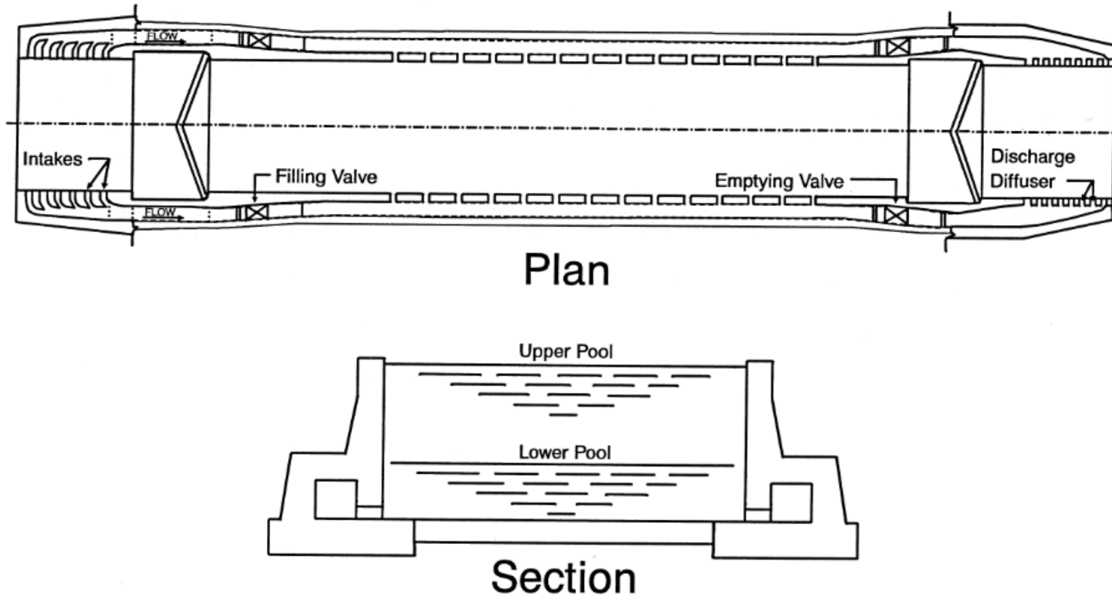


Figure 4. Sidewall port filling and emptying system.

Vessels passing through the Brandon Road Lock will experience one of the four cases as it interacts with the lock Chamber:

Case 1: Vessel exits lock filled with clean water and enters ANS contaminated water in the Lower Des Plains River (LDPR).

Case 2: Vessel exits lock filled with ANS contaminated water and enters the Chicago Area Waterway System (CAWS) buffer zone.

Case 3: Vessel enters lock from ANS contaminated water in the LDPR and enters initially clean water in the lock chamber.

Case 4: Vessel enters lock from the CAWS buffer zone and enters initially clean water in the lock chamber.

Simple volume exchange calculations can provide estimates of the results of mixing attributed to a vessel entering or leaving a lock chamber. For the case in which a tow exits the lock into ANS contaminated water, a first approximation is to assume the volume of water displaced by the tow in the lock will be replaced by ANS-contaminated water as it the barge leaves the chamber. These calculations are based on geometrical parameters of the lock chamber and the design vessel such as those listed in Tables 5 and 6.

**Table 5. Brandon Road Lock, elevation information.**

| **Pool Elevations (ft NGVD)** | |
|---|---|
| Upper Pool Normal | 538.5 |
| Upper Pool Minimum | 537.2 |
| Upper Pool Maximum | 540.5 |
| Lower Pool Normal (no flow) | 504.5 |
| Lower Pool Minimum | 501.1 |
| Lower Pool Maximum | 513.5 |
| Chamber Floor | 489.7 |

**Table 6. Brandon Road Lock, lock particulars.**

| **Lock Information** | |
|---|---|
| Lock Filling and Emptying System | Sidewall Port |
| Width | 110 ft |
| Length | 600 ft |
| Filling Time | 19 min |
| Emptying Time | 15 min |
| Depth when Filled | 48.8 ft |
| Volume of “Filled” Lock | 3,220,800 $ft^3$ |
| Depth when Empty | 14.8 ft |
| Volume of “Empty” Lock | 976,800 $ft^3$ |
| Normal Lift | 34 ft |
| Normal Lift Volume | 2,244,000 $ft^3$ |

## Lock Flushing

A first-order approximation of the flushing process can be described as introducing clean water at one end of the empty chamber (chamber water-surface at lower pool elevation) via pumping. Water is pumped into one end of the chamber and pumped out of the other end while assuming a plug flow exchange. A schematic of the pumping system setup is provided in Figure 5.

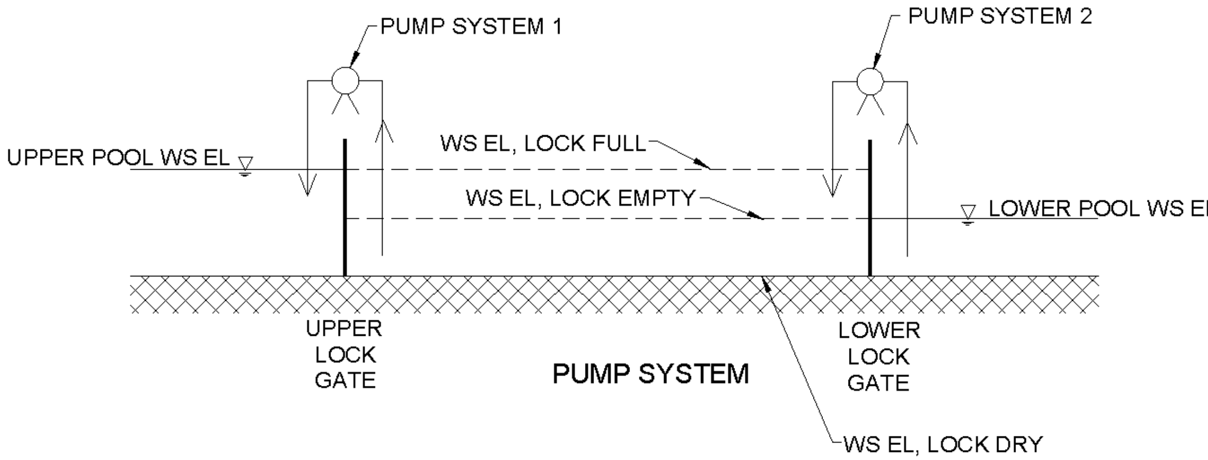


Figure 5. Lock exchange using pumping systems.

If the volume of water in the chamber is to remain constant, then continuity (conservation of mass) requires that the flow rate into the chamber, $Q_{in}$, equals the rate of flow being pumped out of the chamber, $Q_{out}$. Defining this discharge as, $Q$

$$Q_{in} = Q_{out} = Q \tag{1}$$

Navigation locks are designed and operated to ensure safety for vessel operators and project personnel. Safety is viewed in terms of lock chamber performance. Chamber performance is evaluated based on surface currents and turbulence such that conditions cannot be hazardous to small craft and on hawser forces, the mooring line forces required to hold a vessel in place. USACE lock design criteria (Headquarters, US Army Corps of Engineers 2006) limits hawser forces to 5 tons. The hawser force can be estimated as the product of the vessel weight and the water-surface slope, *s*.

$$F = W\ s \qquad (2)$$

Here $F$ = hawser force, $W$ = vessel weight = $(b\,d\,l)\gamma$, where $b$ = vessel beam width, $d$ = vessel draft, $l$ = vessel length, and $\gamma$ = unit weight of water.

If the inertia is neglected, then the longitudinal flow is uniform from one end of the chamber to the other. Uniform flow conditions can be described using the Manning equation.

$$Q = \frac{C_m}{n} A\, R^{2/3}\ s^{1/2} \qquad (3)$$

where $Q$ = discharge, $C_m$ = constant (1.0 SI units and 1.486 US Customary units), $n$ = Manning coefficient, $A$ = flow area = $BD$, and $R$ = hydraulic radius = $\frac{BD}{(2D+B)}$ (flow area divided by wetted perimeter). The variables describing the lock chamber and design vessel are illustrated in Figure 6.

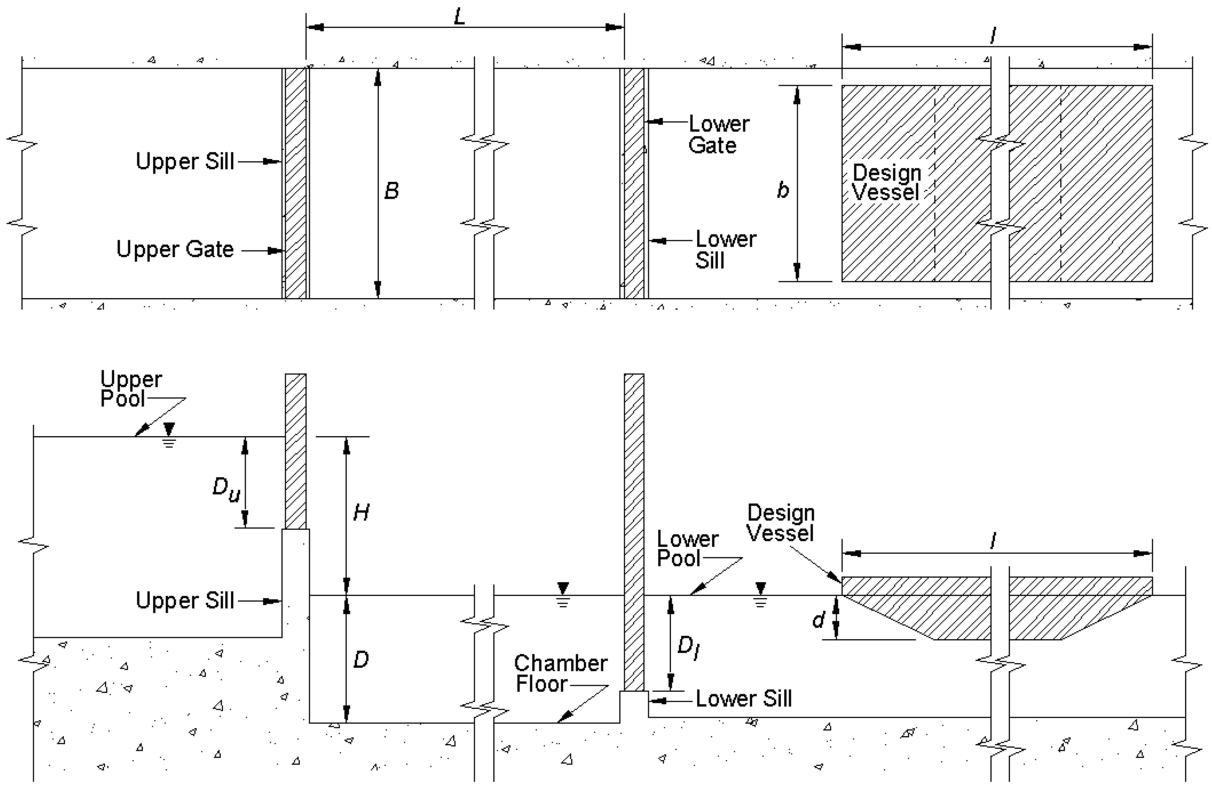


Figure 6. Definition sketch of variables.

From (2)

$$s = \frac{F}{W} = \frac{F}{(bdl)\gamma} \tag{4}$$

From (3)

$$Q = \frac{C_m}{n} BD \left[ \frac{BD}{(2D+B)} \right]^{2/3} \left[ \frac{F}{(bdl)\gamma} \right]^{1/2} \tag{5}$$

Constants and coefficients are $C_m$ = 1.486, $n$ = 0.02, $\gamma = 62.4$ lb/ft$^3$, and the maximum allowable hawser force is $F_{\max}$ = 10,000 lbs.

The dimensions of a particular lock project's chamber are the depth, *D*, width, *B*, and length, *L* (see Figure 6). Generally, these variables are site specific. The design vessel dimensions are the beam width, *b*, the length, *l*, and draft, *d*.

The maximum flow rate that can be safely pumped through the chamber is limited by the maximum allowable hawser force:

$$Q_{\max} = \frac{C_m}{n} BD \left[ \frac{BD}{(2D+B)} \right]^{2/3} \left[ \frac{F_{\max}}{(bdl)\gamma} \right]^{1/2} \quad (6)$$

Substituting the known constants and coefficients provides a relation for the maximum allowable discharge that is dependent on the vessel size and lock chamber cross-sectional dimensions

$$Q_{\max} = \frac{1.486}{0.02} BD \left[ \frac{BD}{(2D+B)} \right]^{2/3} \left[ \frac{10{,}000}{(bdl)62.4} \right]^{1/2} \quad (7)$$

Here, the length terms *B*, *D*, *b*, *d*, and *l* must be in units of ft.

It then follows that the time required to pump water into and out of the chamber is the volumetric flow rate times the volume to be exchanged. The fastest time is limited by the maximum allowable discharge:

$$T_{\min} = Q_{\max}(BDL) \quad (8)$$

Table 7. Lock flushing times, chamber at lower pool elevation.

| Project | Chamber of Volume to be Exchanged, $ft^3$ | Maximum Flushing Discharge, cfs | Minimum Flushing Time, min |
|---|---|---|---|
| Chicago Lock* | 1,101,120 | 19,800 | 0.9 |
| O'Brien Lock | 1,815,000 | 21,400 | 1.4 |
| Brandon Road Lock | 976,800 | 10,500 | 1.6 |

*The salt barge was used as the design vessel for the Chicago Lock calculations.

## Ideas for Alternatives to Conventional Lock Designs

Various alternatives to conventional lock designs have been used to reduce water usage. These thrift locks, as they are often called, are used in areas where water shortages require the use of water-saving basins in addition to the lock chamber. Water-saving basins are usually designed to reuse about 50 percent of water volume required to fill the chamber. Water-saving basins such as these are being incorporated in the Panama Canal 3rd Lane project, currently under construction.

When adjacent land is not available designs such as lock lifts have been constructed. Ship lifts in the form of vertical lifts or inclined planes are used in Europe, North America, and Asia. Examples of lifts are the Strepy-Thieu boat lift in Belgium and the Peterborough Lift Lock in Canada. Also, a lift is being constructed to accompany the canal locks of the Three Gorges Dam in China. The Ronquières Inclined Plane in Belgium is an example of an inclined plane on a canal.

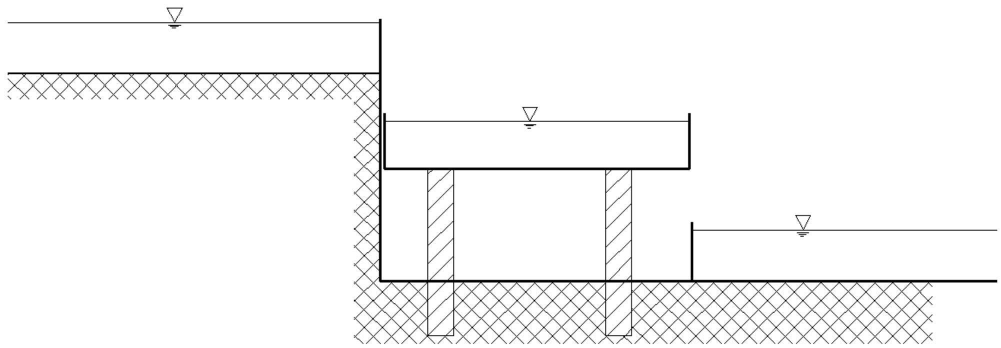


Figure 7. Schematic of lock vertical lift.

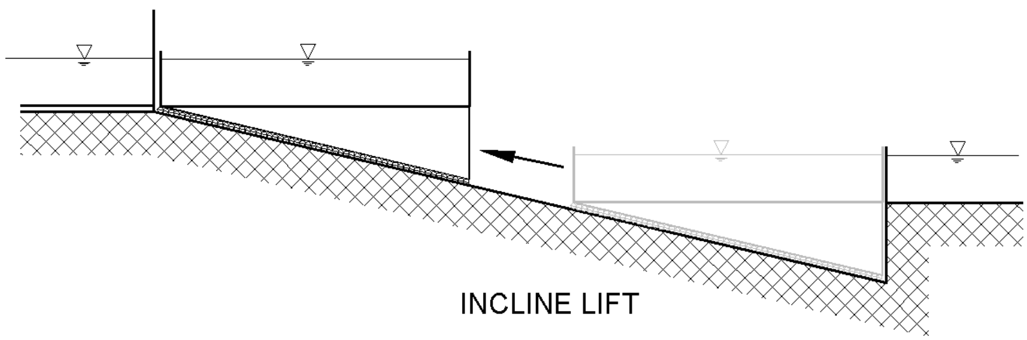


Figure 8. Schematic of lock incline lift.

Another way to save water and yet still primarily rely on gravity for filling and emptying is constructing an additional lock chamber adjacent to the existing lock chamber. Water could be exchanged between these 2 chambers by a combination of gravity flow followed by pumping. Schemes such as this are used as water saving measures. An example sketch is given in Figure 9.

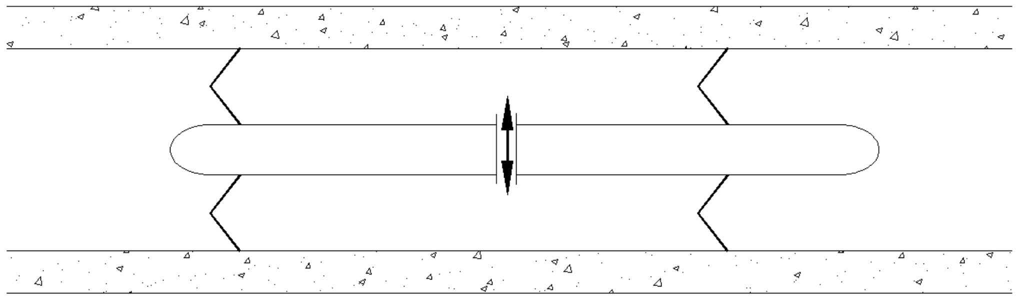


Figure 9. Dual lock chambers for water exchange and saving.

# Further Research

## *Quantify Exchange Volumes using Physical Model*

A physical model could be constructed at US Army Engineer Research and Development Center (ERDC) with which a suite of filling and emptying tests could be conducted to determine flushing rates for the lock chamber in the context of maintaining separation of ANS water between the CAWS and surrounding water bodies. Several scenarios exist within this framework. Existing lock models at ERDC could serve as generic substitutes for the prototype or a new scaled physical model(s) could be constructed with the design specs from the prototype(s). In either case, flushing would be measured with and without tows to directly determine residence time within the lock chamber and the culverts. This would unequivocally establish the lock operation procedures required to completely replace the water within the lock. Questions such as "How much water is exchanged during a single emptying cycle?" and "How many cycles are required to completely replace the volume within the lock?" and "If not gravity driven, then what are the pumping requirements to empty or flush a lock such that ANS remains isolated from the buffer zone?" could be answered. In addition to emptying and filling without vessels, experiments using remote-controlled tow with different barge configurations could determine the effects of vessel lockage on exchange.  Vessel blockage during the locking process can either increase (exiting) or decrease (entering) the volume within the lock.  Localized mixing along the hull as well as propeller wash can further complicate the exchange mechanism, so the case with tows is significantly more complex and critical to understanding the role of navigation in lock flushing.  Vessel effects such as "What is the role of vessels during the locking process in enhancing/hindering the exchange flow?" and "How does vessel-induced turbulence and prop wash modify residence time?" and "What role does vessel blockage play in modifying the exchange flow rate?" could be quantified. Experiments would explore the consequences of upbound and downbound tows with different barge configurations based upon vessel traffic information for the CAWS.

Rhodamine dye could be used to track the water mass within the lock chamber to quantify turbulent diffusion coefficients and flushing rates.  Rhodamine dye has been used extensively in the marine environment as a water mass tracer and accurate methodologies to measure the mixing rates and dispersion are well developed. Rhodamine fluorescence can be easily measured using inexpensive fluorometers, thus providing residence time and flushing efficiency within the lock chamber and culvert. Confetti can be used to measure surface water exchange and flow visualization techniques, such as high speed digital photography, provide direct measurements of particle velocity and rotation to evaluate water mass exchange dynamics.

## *Validate and Refine Mixing Processes using Computational Model*

A physical model would provide data on flushing requirements for the scenarios listed above.  This data would provide information needed to validate a three-dimensional (3-D) Navier-Stokes (nonhydrostatic) numerical flow model of a lock.  The computational model would then be used as a predictive tool to explore other filling and emptying scenarios in the context of volume exchange rates.  The ERDC's 3-D Navier-Stokes module of the Adaptive Hydraulics (ADH) code or a similar commercial code such as Fluent could be used to model the complicated turbulent exchange processes as flow passes into and out of a lock.

The study would:

- Determine lock operation procedures needed to fully replace the water mass within a lock
- Establish partial flushing optimization confidence limits for the 50%, 75%, 95% and 99% residence time for lock filling and emptying
- Determine the role of vessel blockage in modulating residence time and develop optimal vessel operational and maneuvering procedures
- Explore ways to mitigate vessel effects (e.g. turbulence, eddies, and propeller wash) in modulating water exchange between the canal and the lock chamber

Table 8. Time requirements to conduct physical and numerical model experiments.

| Task | 3 mo | 6 mo | 9 mo | 12 mo | 15 mo |
|---|---|---|---|---|---|
| Model Construction | X | | | | |
| Navigation Tests | X | X | | | |
| Data Analysis | | X | X | | |
| Numerical Model Validation | | X | X | | |
| Numerical Model Test/Analysis | | | X | X | |
| Prepare Reports | | | | X | X |
| Study Complete | | | | | X |

Table 9. Cost estimates for modeling efforts.

| Budget Item* | Cost |
|---|---|
| Model Construction | $300,000 |
| Model Testing | $450,000 |
| Numerical Model Validation | $150,000 |
| Model Testing | $200,000 |
| | |
| Total | $1,100,000 |

*Note: construction and testing costs could be reduced if an existing lock model is modified with sector gates as opposed to building a new model of the prototype (i.e., Chicago, Brandon Road, or O'Brien Locks)

Construction costs include a 1:25-scale lock model of one of the CAWS locks (to be determined in consultation with project sponsors based upon their priorities and needs). Experiments would include running multiple lock filling and emptying scenarios with and without tows to measure flushing times and to determine optimal lock operations. Several methods would be used to quantify volume exchange time including dye tracers and confetti combined with digital camera systems to determine flow trajectories, mixing rates and turbulence. Testing will specifically focus on addressing the items listed in the objectives. A final report would be prepared detailing the study's findings including recommendations for lock and vessel operations in the context of maintaining separation of water masses using the lock as a barrier device.

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# ATTACHMENT I

# HYDROLOGIC SEPARATION 0.2 PERCENT ACE AND BYPASS CONSIDERATIONS

## Hydrologic Separation – 0.2% Annual Chance Exceedance and Bypass Considerations

The GLMRIS Team developed a series of synthetic events to model the effects of potential hydrologic separation locations on the CAWS. The goal of GLMRIS is to develop a range of options and technologies to protect the Great Lakes and Mississippi River aquatic ecosystems from Aquatic Nuisance Species (ANS) that could transfer via aquatic pathways connecting the Great Lakes and Mississippi River basins. While it would have been possible to evaluate extreme storms, such as the Probable Maximum Flood, those evaluations are typically tied to consideration of the impacts on human life and safety that could result from such an event. Absent consideration of life-safety, and focusing on the study goals and objectives, the team utilized the 0.2% annual chance exceedance storm event (aka 500-year event) as the design event, thus effectively reducing the likelihood of a transfer to the 0.2% in any given year.

When selecting preliminary separation sites thought had to be given to how the flow of water may bypass the physical barrier at that site. Are there any tributaries that could reconnect the system at another location? Could the flow back-up behind and then spread around the barrier due to low ground? Could the flow spill over the bank of one part of the system and into another? These were just a few of the questions that needed to be answered in the preliminary site analysis. Sites on localized high ground were preferable, as well as meeting other considerations. For additional detail, refer to Appendix E - Hydrologic & Hydraulic Analyses.

# ATTACHMENT J

# HYDROLOGIC SEPARATION SITE SCREENING

PRELIMINARY SCREENING OF POTNETIAL PHYSICAL SEPARATION ALTERNATIVES

I. Bypass Connections and Screening Plan
II. Preliminary Screening Results
III. Observations and Engineer's Notes

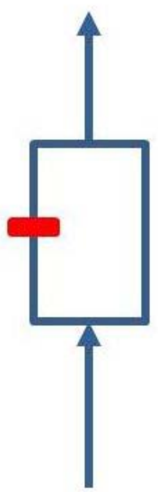
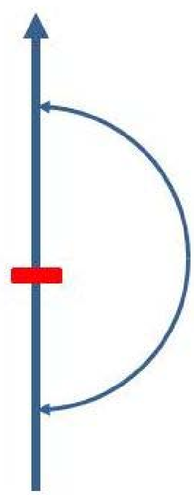
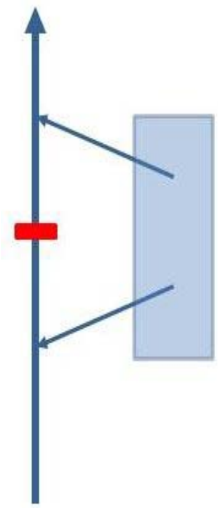
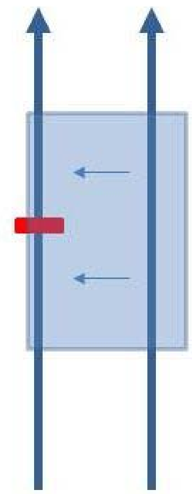
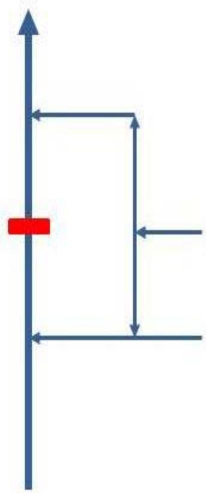
BYPASS CONNECTIONS

The physical barrier can be constructed on the waterway as high as it needs to be to block flows through the river channel or floodplain. However, flow can bypass the barrier and a path can be formed under certain circumstances that make the barrier ineffective. Various probable scenarios of bypass paths are discussed below:

1. Divided Channels: CAWS is divided into multiple channels at certain location. If a physical barrier is placed on one channel, the other channel will form a bypass connection. The North Branch of Chicago River near Goose Island is an example. This is the most obvious type of bypass, and it can hardly be missed by visual inspection of the hydrographic maps
2. Bypass Tributary: A tributary system connects to the CAWS at two points. If a physical barrier is placed on the CAWS somewhere between these two points, a permanent bypass connection will be formed. East Stoney Creek/West Stoney Creek and Midlothian Creek/Midlothian diversion culvert are two examples.
3. Connecting Watersheds: Two tributaries connect to the CAWS at two points. During large storm events the upstream watershed may be connected by the overbank flood waters. If a physical barrier is placed between the outlets of these two tributaries, a temporal connection will be formed. Natalie Creek/Midlothian Creek is an example. The remedy to this situation is to divert floodwaters in the upstream watersheds to separate the otherwise connected floodplains under the flood conditions.
4. Spillover: A separate stream runs in parallel with the CAWS. During large storm events the stream flow can go overbank and spill over to the CAWS. The Des Plaines River/CSSC is an example.
5. Flanking: Floodwater can move around the physical barrier if the elevation of tie-in high ground is not available or not high enough. The area near the Bubbly Creek and the South Branch of Chicago River is an example.
6. Sewer Connection: Hundreds of sewer outfalls discharge storm water or combined-sewer to the CAWS during wet periods. Most outfalls will be partially or fully submerged during the flood. If the flap gates are inadvertently left open, a by-pass path can be formed through the grid-like sewer network.
7. Groundwater Connection: Rock fiche can seep moderate amount of water. It may become a bypass path for certain ANS species of small sizes.
8. Water Purification Plant: It is assumed that water supply processing will screen or kill any life-form of the ANS.
9. Waste Water Treatment Plant: It is assumed that sewer treatment process will kill any life-form of the ANS.

In the site screening process, the focus is on connection types 1 through 5.

Schematic of Bypass Connections

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Divided Channels | Bypass Tributary | Connecting Watersheds | Spillover | Flanking |
|  |  |  |  |  |
| |  | | | |
| Permanent | Permanent | Temporal | Temporal | Temporal |

SCREENING PLAN

Except for the scenario where the physical barrier will be placed downstream from the Calumet-Sag Junction, multiple barriers are required on the Chicago waterway to separate watersheds to reduce the risk of ANS transfer. The combination of different locations of these barriers on the waterway can produce a large number of different hydraulic conditions. Unfortunately, the divide-and-conquer strategy may not work perfectly here as the river stages on one reach of the waterways can affect the conditions on other reaches. Therefore, all the barriers associated with a specific separation scenario must be included in the hydraulic model to quantify how the water levels under the modified river conditions would differ from the so-called baseline conditions. In the GLMRIS study there are two baseline conditions to be considered: existing and future conditions. These conditions do not reflect potential changes in land use or land cover because 1) most areas in Chicago and Calumet watersheds are fully developed, and 2) stormwater management measures to mitigate the impact on the existing hydrology are required by regulatory agencies for the newly developed areas. These conditions differ, instead, in the aspect of presence of two large flood control reservoirs, i.e., Thornton and McCook. The existing condition includes TARP tunnels, which was fully completed in 2006 and has provided a total storage of 2.3 BG. The future condition includes Thornton and McCook reservoirs, which would be completed by 2015 and 2029, respectively, and provide a total storage about 15 BG in addition to the existing tunnels.

It would be too laborious and technically unnecessary to screen various separation alternatives using a full set of rainstorms (eight frequencies and four durations) for modeling the baseline conditions. It is prudent that the 500-year and 24-hour rainstorm will be chosen for screening initial alternatives, and additional rainstorms will only be modeled for a small set (e.g., no more than three) of final alternatives at a later time. Table 1 shows the river stations for the potential physical separation locations on the waterway.

| Separation ID | River Reach | Actual River Station | Remarks |
|---|---|---|---|
| 1 | North Shore Channel | 340.795/1008 | Wilmette Pumping Station. |
| 1A | North Shore Channel | 336.542/1112.5 | North of Northside WRP outfall (RS 1113). |
| 2 | North Branch Chicago River | 333.05 | South of NSC confluence (RS 333.11). Upper NBCR flow and Northside WRP effluent go to lake. |
| 3 | Chicago River | 327.12/1033 | West lock gates at CRCW. |
| 3A | Chicago River | 325.656/1134.5 | Near Wolf Point |
| 4 | CSSC | 316.01 | East of Stickney WRP outfall (RS 315.81) |
| 4A | SBCR | 322.74 | East of Bubbly Creek confluence (a location that is difficult to contain, but flood stage |

| | | | |
|---|---|---|---|
| | | | may not be significant; RS 321.5) |
| 5 | CSSC | 302.33 | Near the USGS streamgage in Lemont for diversion accounting. |
| 6 | Calumet-Sag Channel | 319.25 | West of Little Calumet River confluence (RS 319.6). Little Calumet river water goes to lake. |
| 7 | Calumet River | 326.26/1183 | O'Brien Lock and dam. |
| 8 | Little Calumet River North | 321.00 | At ACME bend near the Calumet WRP outfall RS 320.92/321.28). Calumet WRP effluent goes to Lockport. |
| 9 | Little Calumet River South | ?? | Near the Hart Ditch control structure included in the LCR tributary model. |
| 10 | Grand Calumet River | 4.21 | Near the Hammond WWTP outfall, east of Columbia Avenue. |
| 10A | Grand Calumet River | 0.815 | Near east end of Storage Areas CR6 and CR7-1. |

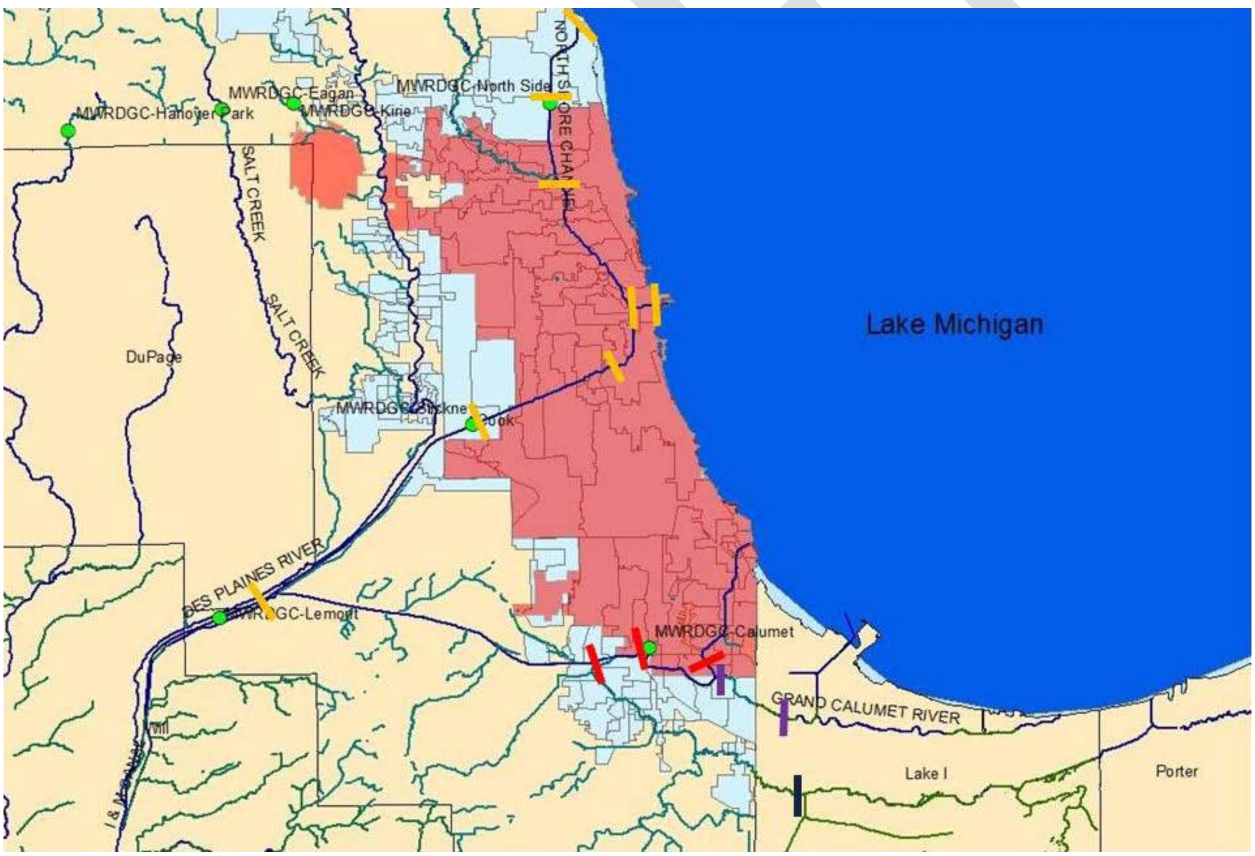


Table 2 shows the scenarios that the waterway would be modified with physical separations (i.e., barriers) to prevent the transfer of ANS between the Great Lakes and Mississippi River watersheds.

| Scenario | Barrier 1 | Barrier 2 | Barrier 3 | Barrier 4 | Barrier 5 |
|---|---|---|---|---|---|
| A1 (Lakefront Closure) | 1 | 3 | 7 | 9 | 10 |
| B1 (Lakefront Closure; Levee up around O'Brien Dam) | 1 | 3 | 7 | 9 | 10 |
| C1 (Lakefront Closure; Levee up and GCR Blocked at CR6 and CR7-1) | 1 | 3 | 7 | 9 | 10A |
| D1 (C1 but Wolf Point on Chicago River) | 1 | 3A | 7 | 9 | 10A |
| A2 (NBCR near NSC Conf.) | 2* | 3 | 7 | 9 | 10 |
| B2 (NSC near Northside WRP) | 1A | 3 | 7 | 9 | 10 |
| A3 (CSSC near Stickney) | 4 | 7 | 9 | 10 | |
| B3 (SBCR near Bubbly Creek conf.) | 4A | 7 | 9 | 10 | |
| C3 (Chicago Lock removed) | 4 | 7 | 9 | 10 | |
| D3 (Chicago Lock opens at 580) | 4 | 7 | 9 | 10 | |
| A4 (LCR near Calumet WRP) | 1A | 3 | 8 | 9 | |
| A5 (LCR near LCR conf.) | 1A | 3 | 6 | | |
| A6 | 2 | 3 | 8 | 9 | |
| A7 | 2 | 3 | 6 | | |
| A8 | 4 | 8 | 9 | | |
| A9 | 4 | 6 | | | |
| A10 | 5 | | | | |

*Based on modeling results for Scenario A2, barrier location 2 was dropped from further consideration, and scenarios A6 and A7 were not modeled.

Since implementation of any physical separations would likely occur after McCook reservoir is on-line to alleviate flooding issues in the Chicago river basin, the screening runs of the hydraulic model may focus on the future condition plus one additional high lake level condition (e.g., +3.8 ft CCD). Besides the CUP reservoirs are committed projects and their construction is moving forward, any physical separation without significant mitigation measures of flood water diversion would not likely be acceptable to flood regulatory agencies or the commonwealth of society.

It is difficult to cut off the bypass flood water if a barrier is placed in the South Branch of Chicago River near the Bubbly Creek confluence. This is because the surrounding areas are densely populated with residential and industrial structures. However, Scenario B3 was still included in the preliminary site screening just in case the induced river stage increase near this location might be limited as it is near the flow divide while canal backflow operation occurs during severe flood events.

Table 3 summarizes the scenarios of physical separation; the names of these scenarios were used as the plan IDs in the unsteady HEC-RAS (CAWS) modeling.

## Table 3 – 500-year/24-hour rain event and 580 ft NAVD88 lake level (Future Condition)

| Scenario | No. Barriers | NSC | NBCR | Ch. River | SBCR | CSSC | Cal-Sag | LCR-S | LCR-N | Cal. River | GCR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 5 | WPS | | CRCW | | | | Hart Ditch Confluence | | O'Brien | Columbia Ave. |
| B1 | 5 | WPS | | CRCW | | | | Hart Ditch Confluence | | O'Brien (Modified 1) | Columbia Ave. |
| C1 | 5 | WPS | | CRCW | | | | Hart Ditch Confluence | | O'Brien (Modified 2) | East of CR6 and CR7-1 |
| D1 | 5 | WPS | | Wolf Point | | | | Hart Ditch Confluence | | O'Brien (Modified 2) | East of CR6 and CR7-1 |
| A2 | 5 | | NSC Confluence | CRCW | | | | Hart Ditch Confluence | | O'Brien | Columbia Ave. |
| B2 | 5 | Northside WRP | | CRCW | | | | Hart Ditch Confluence | | O'Brien | Columbia Ave. |
| A3 | 4 | | | (Lock gates open all the time) | | Stickney WRP | | Hart Ditch Confluence | | O'Brien | Columbia Ave. |
| B3 | 4 | | | (Lock gates open all the time) | Bubbly Creek Confluence | | | Hart Ditch Confluence | | O'Brien | Columbia Ave. |
| C3 | 4 | | | (Chicago Lock gates removed) | | Stickney WRP | | Hart Ditch Confluence | | O'Brien | Columbia Ave. |
| D3 | 4 | | | (Lock gates open at 580) | | Stickney WRP | | Hart Ditch Confluence | | O'Brien | Columbia Ave. |
| A4 | 4 | Northside WRP | | CRCW | | | | Hart Ditch Confluence | Calumet WRP | | |
| A5 | 3 | Northside WRP | | CRCW | | | LCR Confluence | | | | |
| A8 | 3 | | | | | Stickney WRP | | Hart Ditch Confluence | Calumet WRP | | |
| A9 | 2 | | | | | Stickney WRP | LRC Confluence | | | | |
| A10 | 1 | | | | | Lemont gaging station | | | | | |

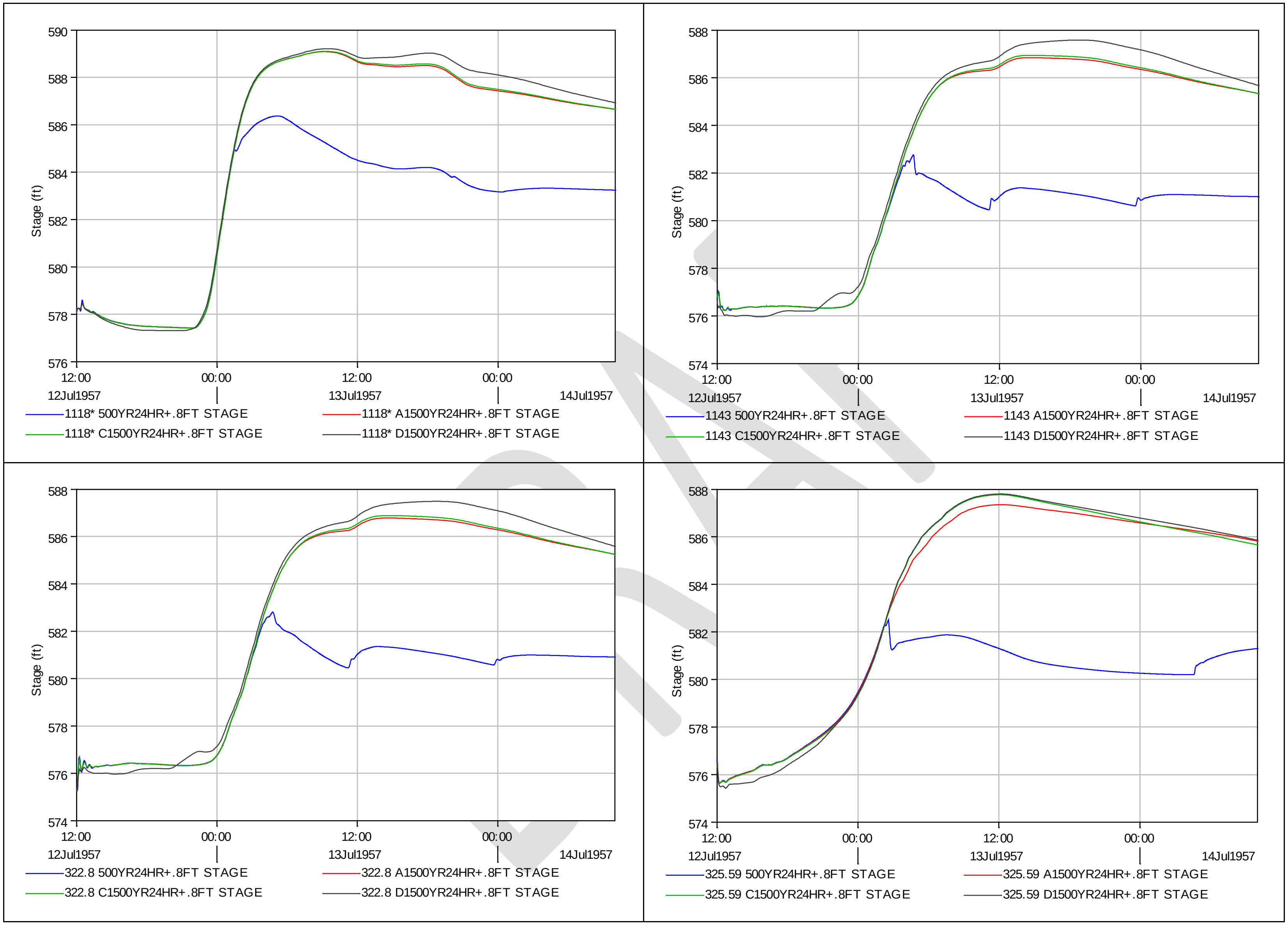
PRELIMINARY SCREENING RESULTS

Future Condition with CUP Reservoirs

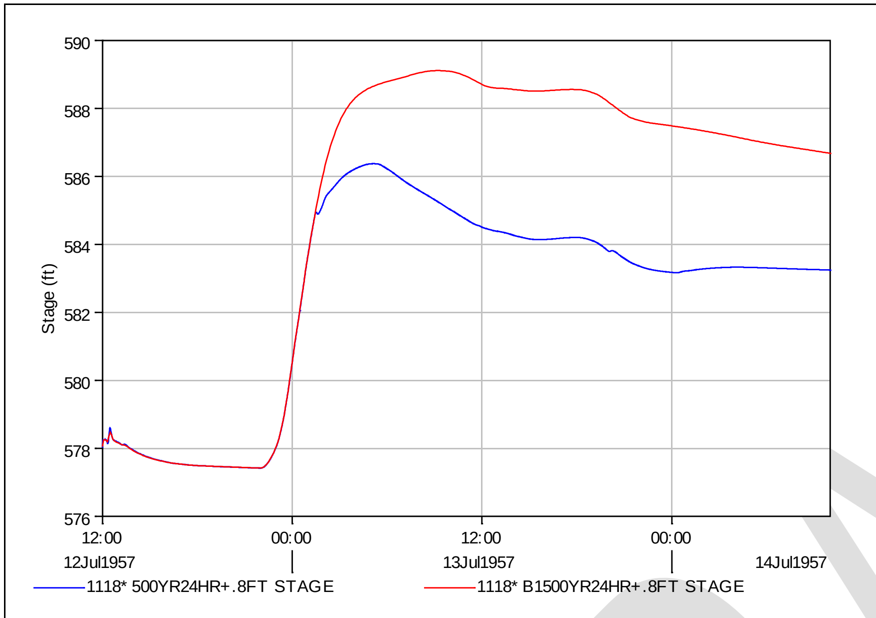
500-year/24-hour Rain Event

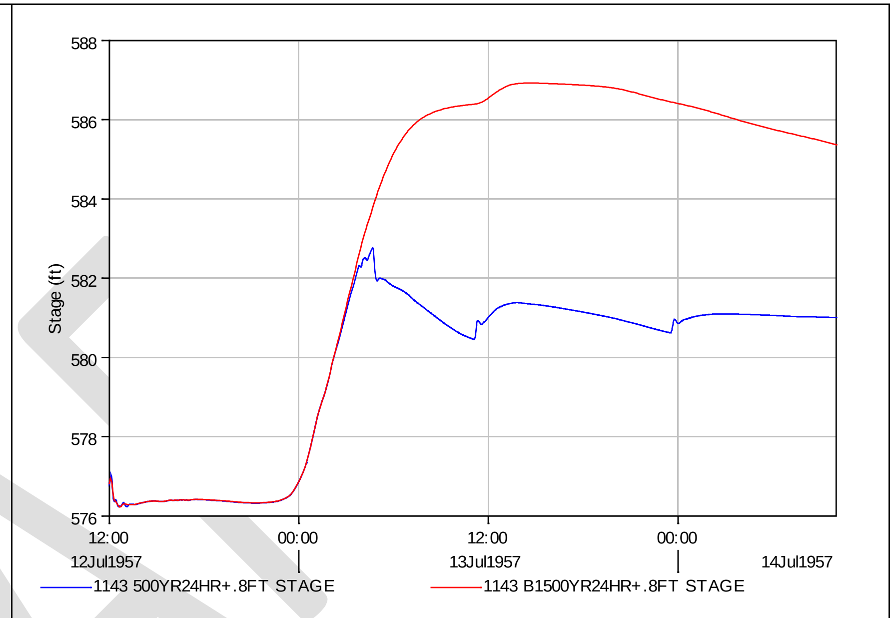
Lake Michigan Level: 580 ft & 583 ft NAVD88

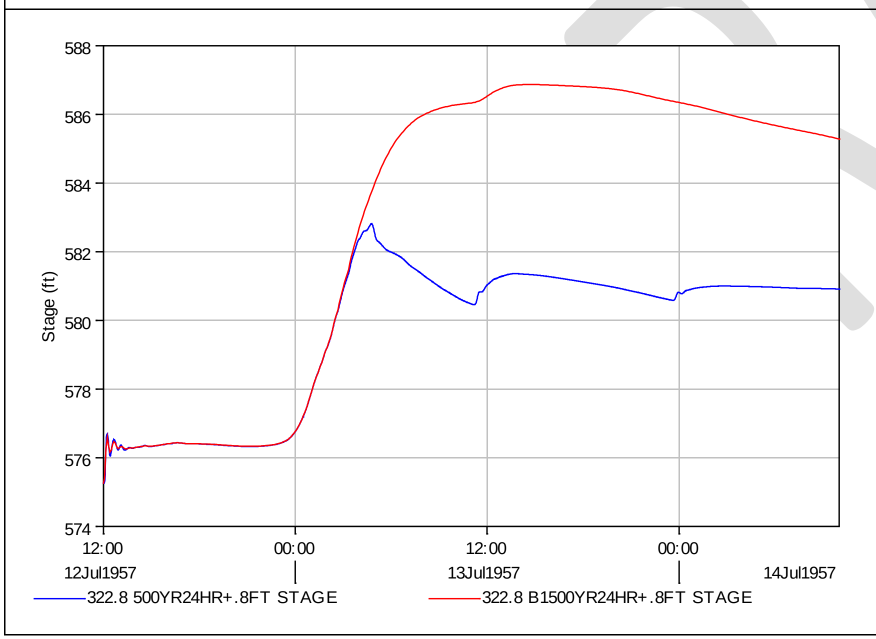
SCENARIO A1 – 5 Barriers Including Physical Separation at Lakefront Controlling Works

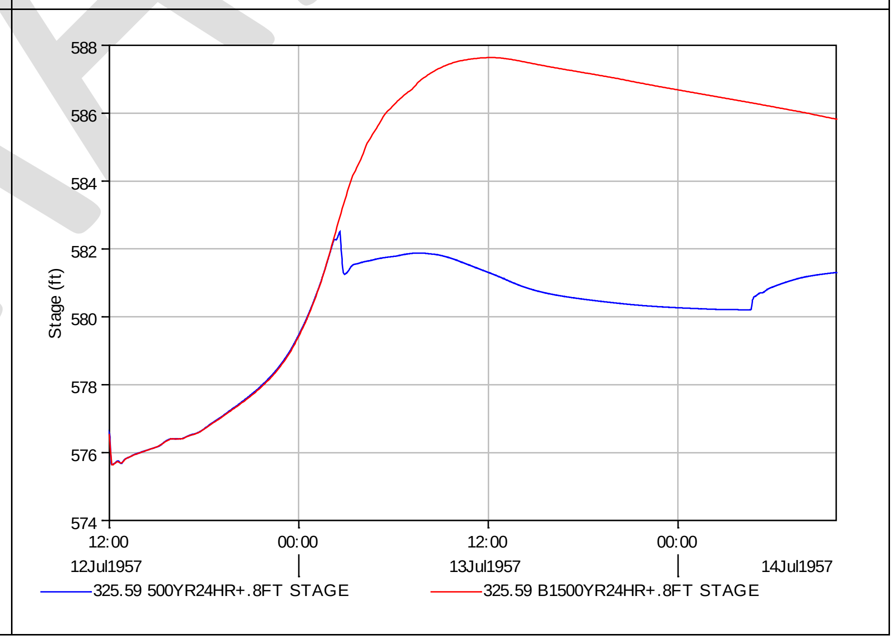


SCENARIO B1 – 5 Barriers Including Physical Separation at Lakefront Controlling Works (O'Brien Bypass Blocked)

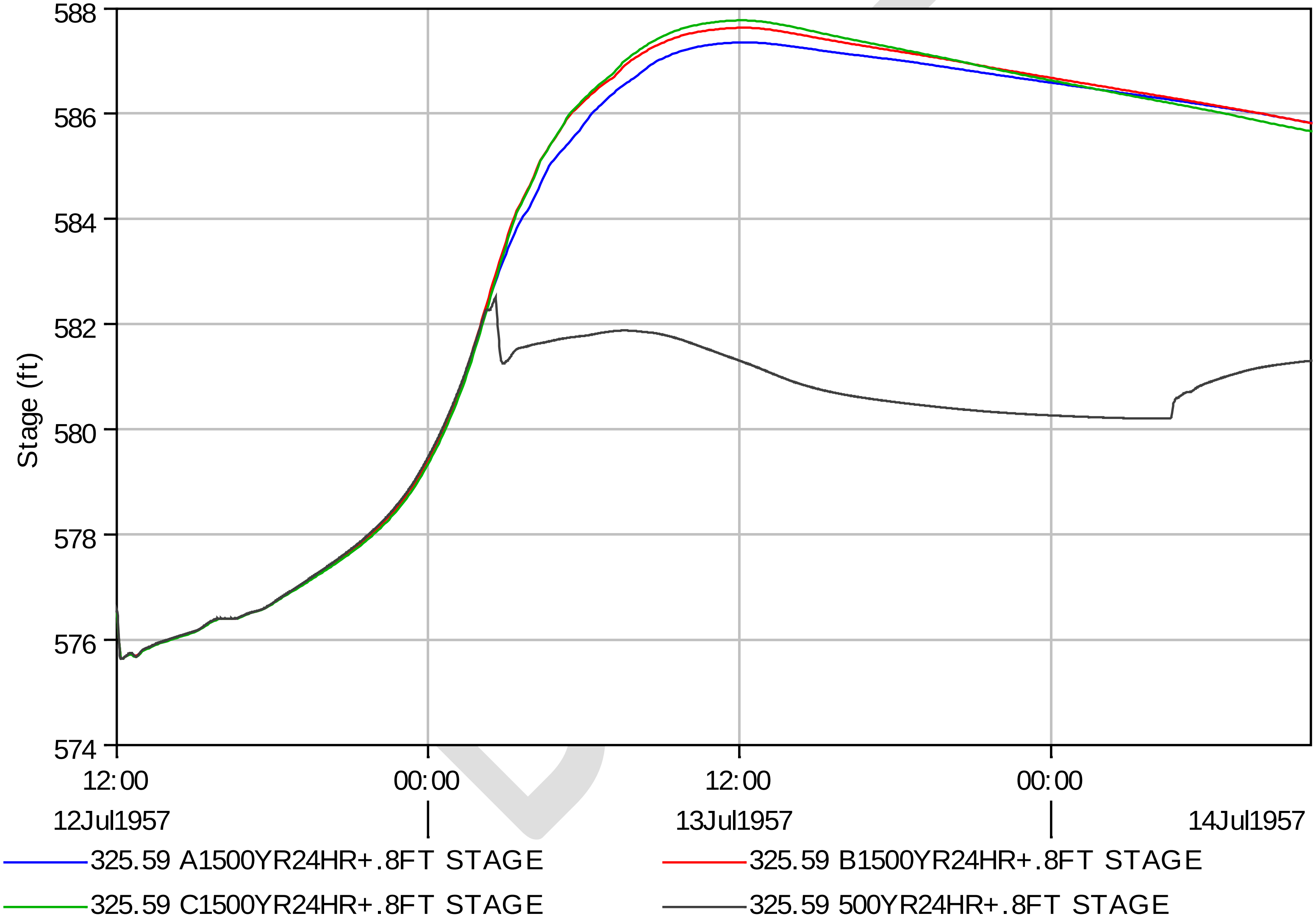


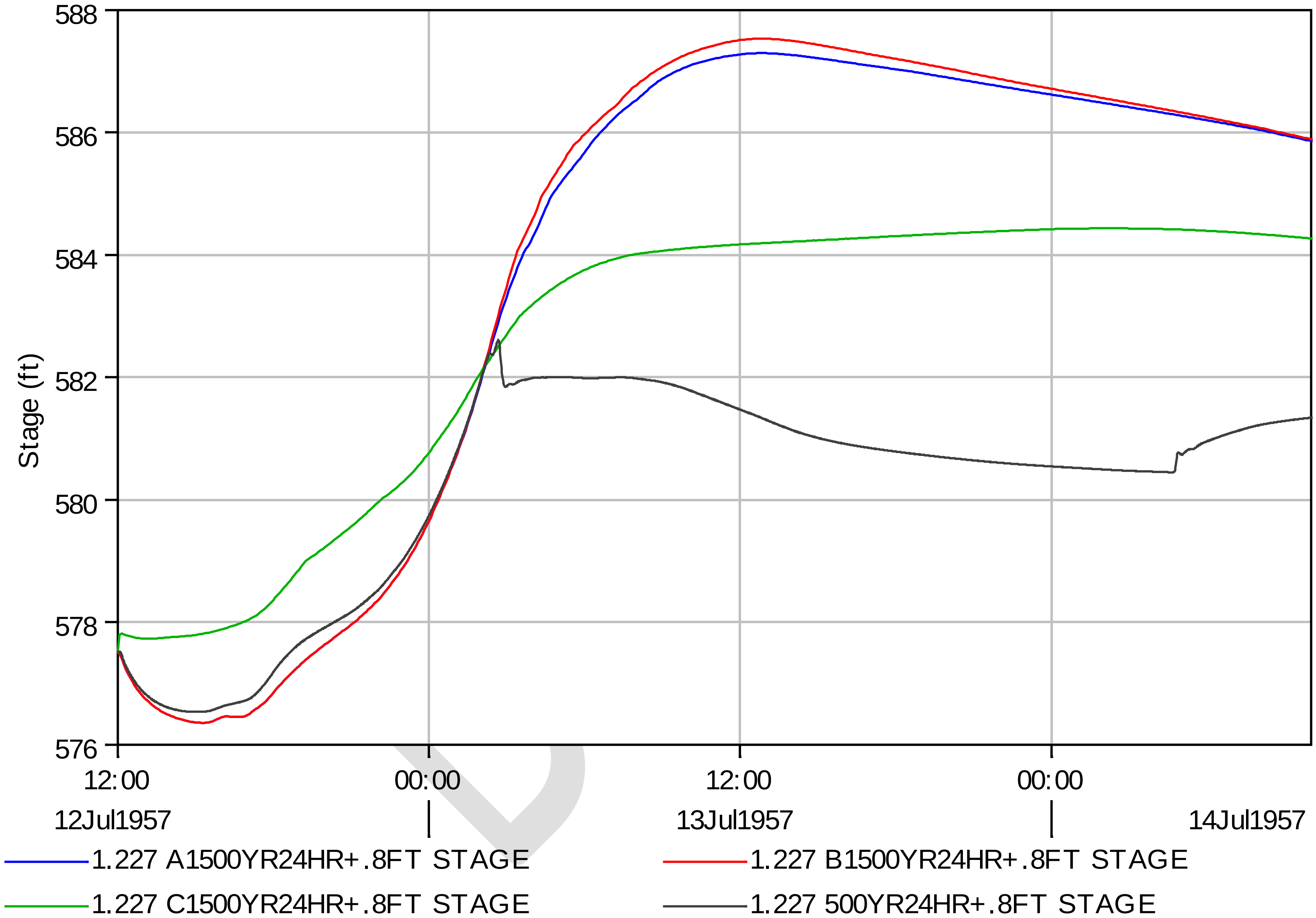



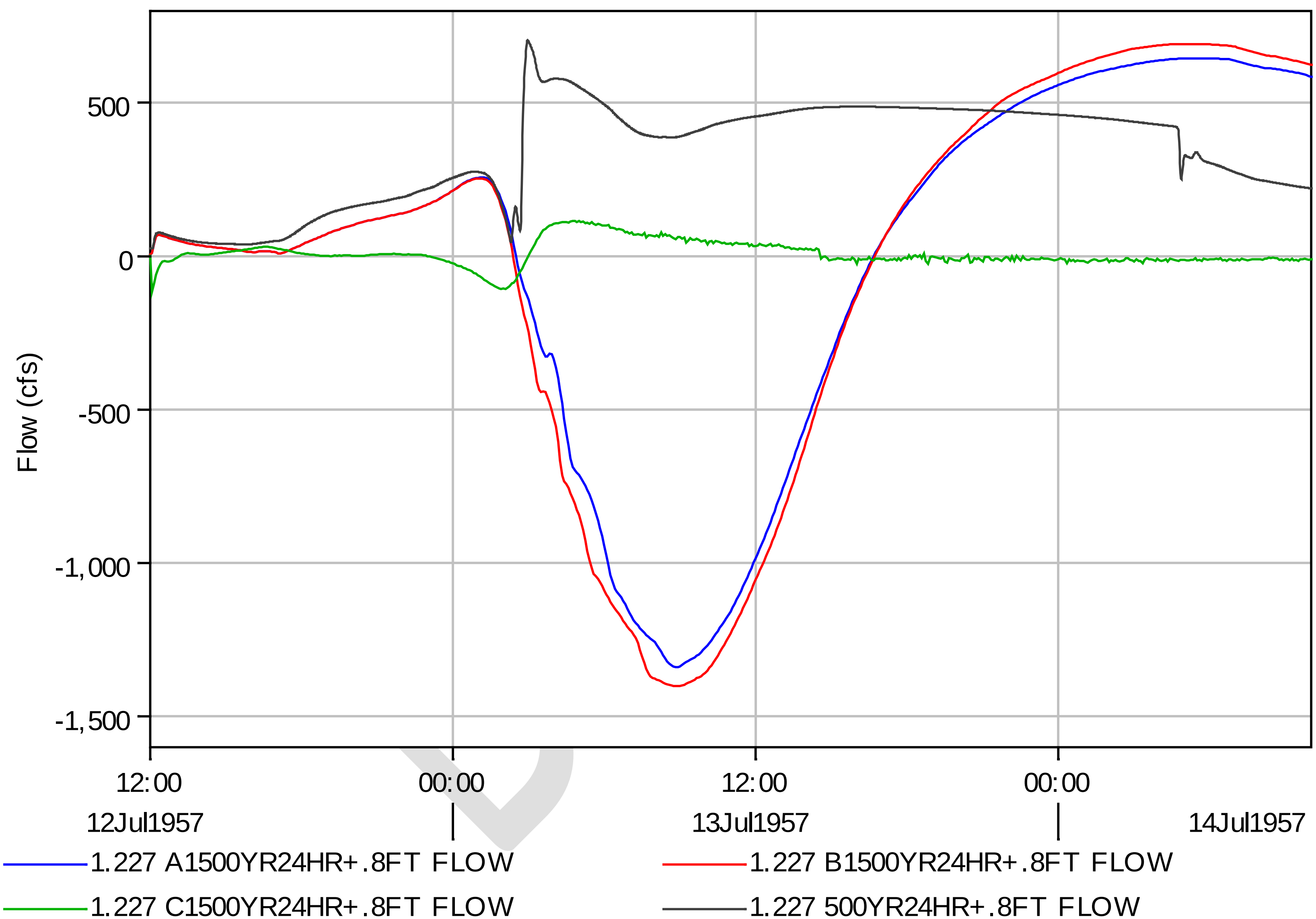
Scenarios Baseline, A1, B1 and C1 (LCR at RS 325.59)



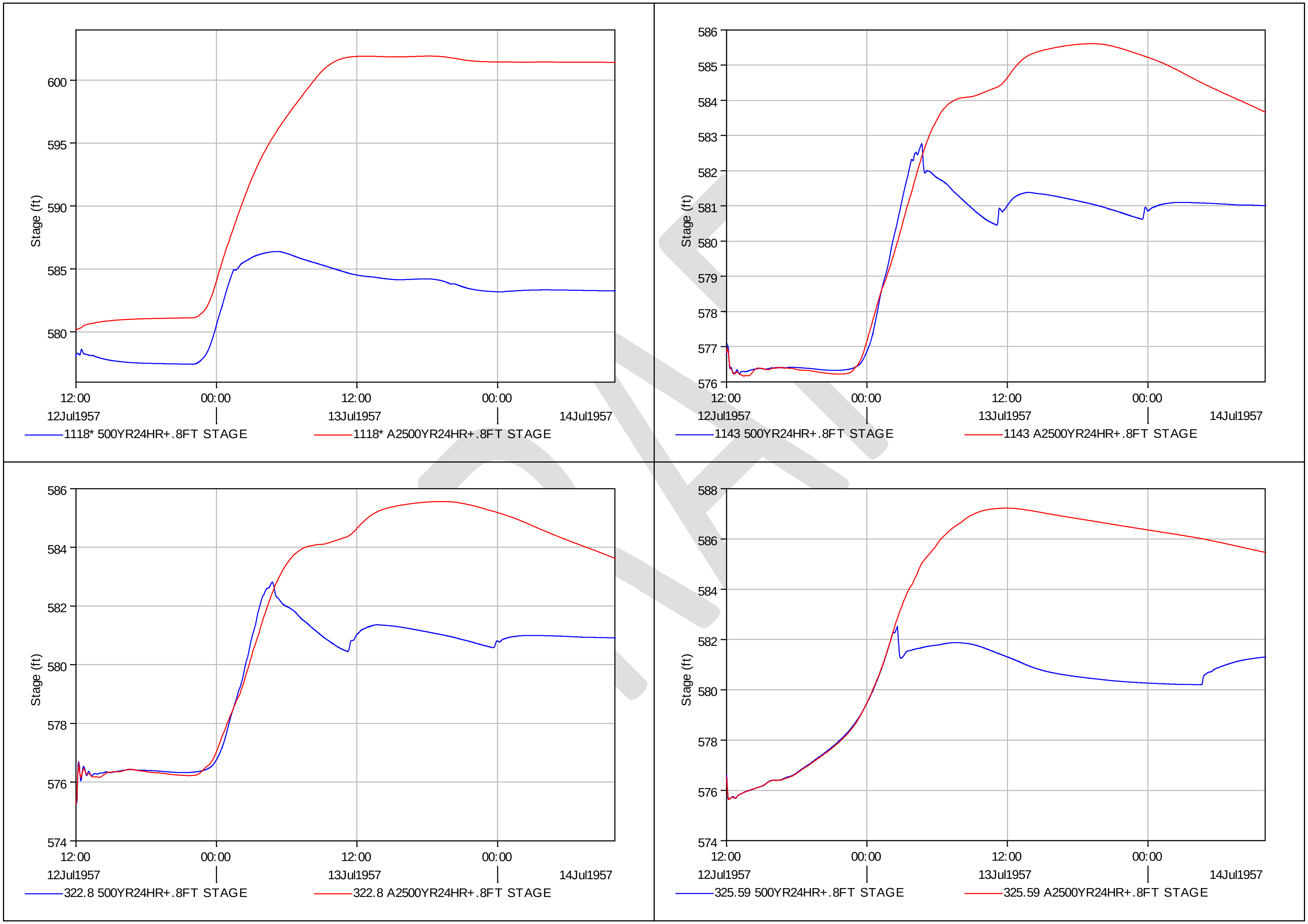
Scenarios Baseline, A1, B1 and C1 (GCR at RS 1.227)



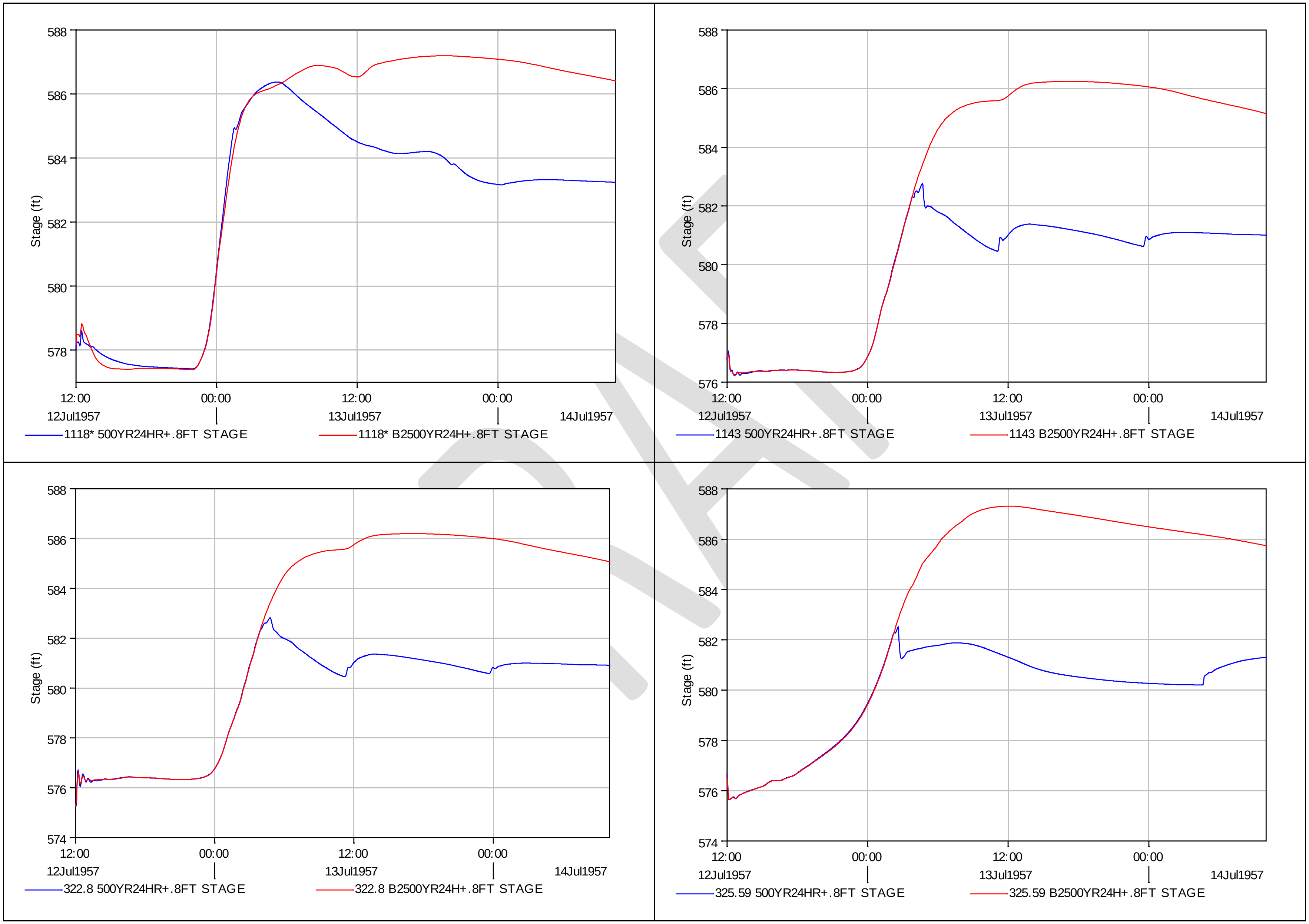
Scenarios Baseline, A1, B1 and C1 (GCR at RS 1.227)



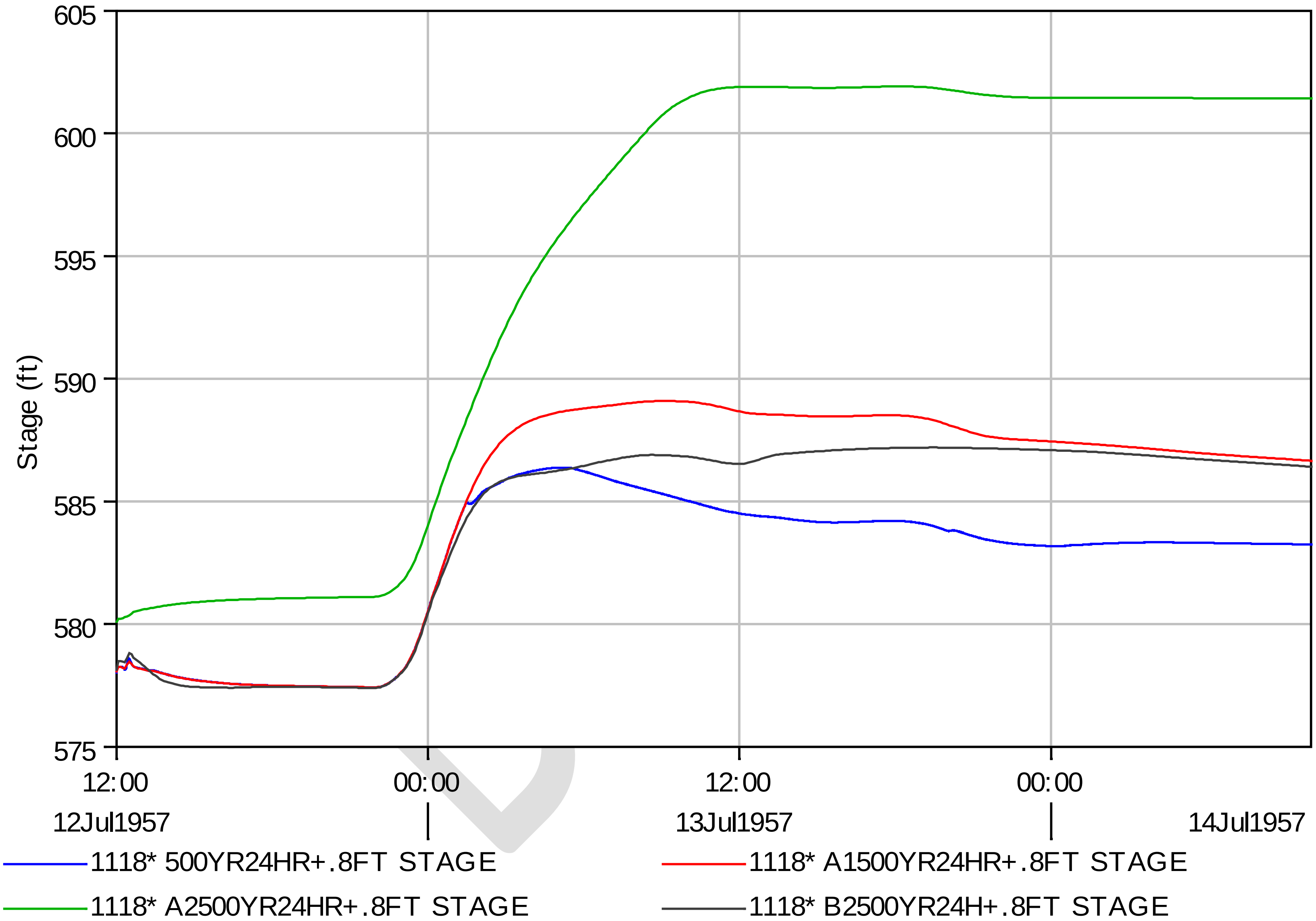
SCENARIO A2 – 5 Barriers Including a Physical Separation on the NBCR South of NSC Confluence



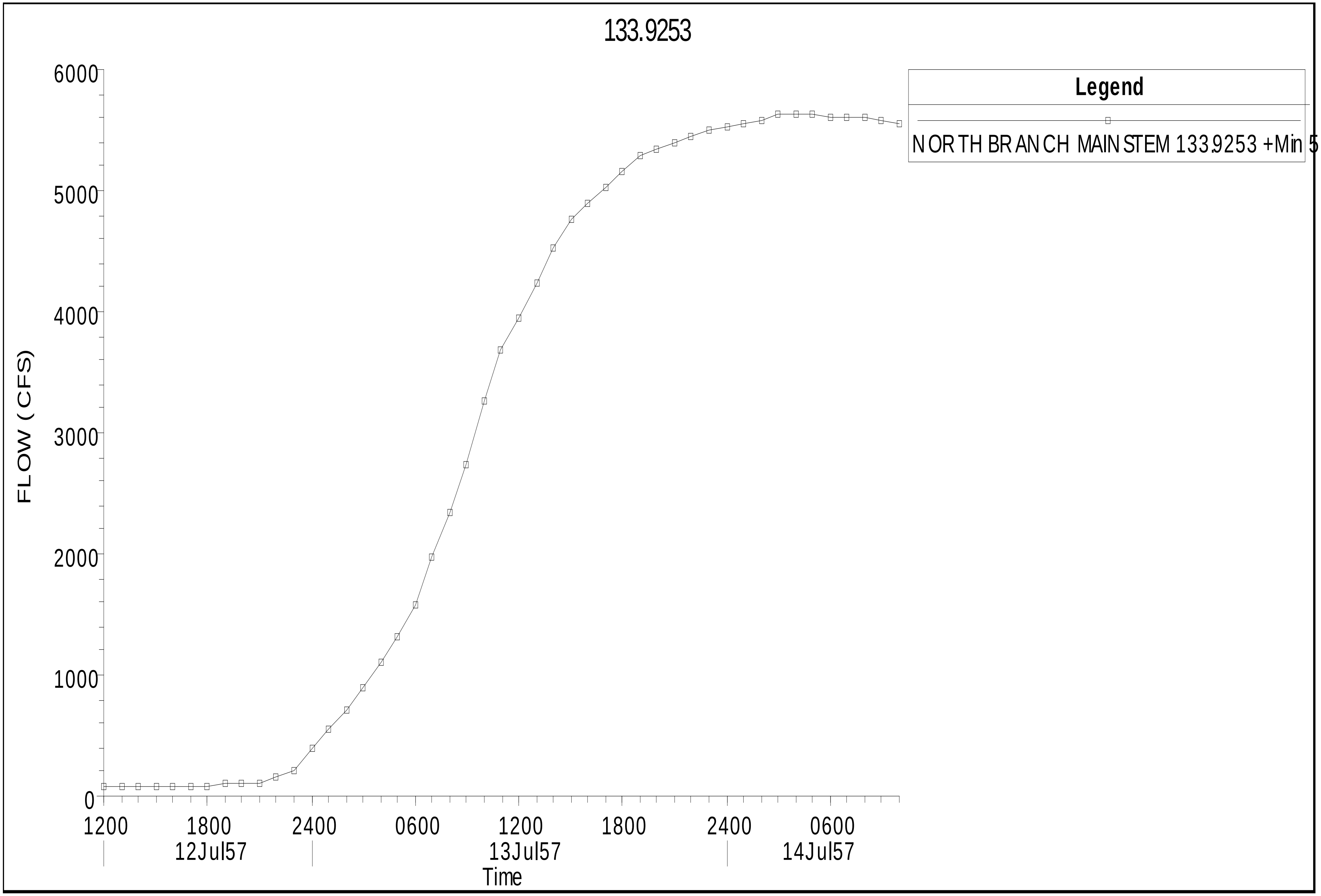
SCENARIO B2 – 5 Barriers Including a Physical Separation on the NSC North of Northside WRP Outfall



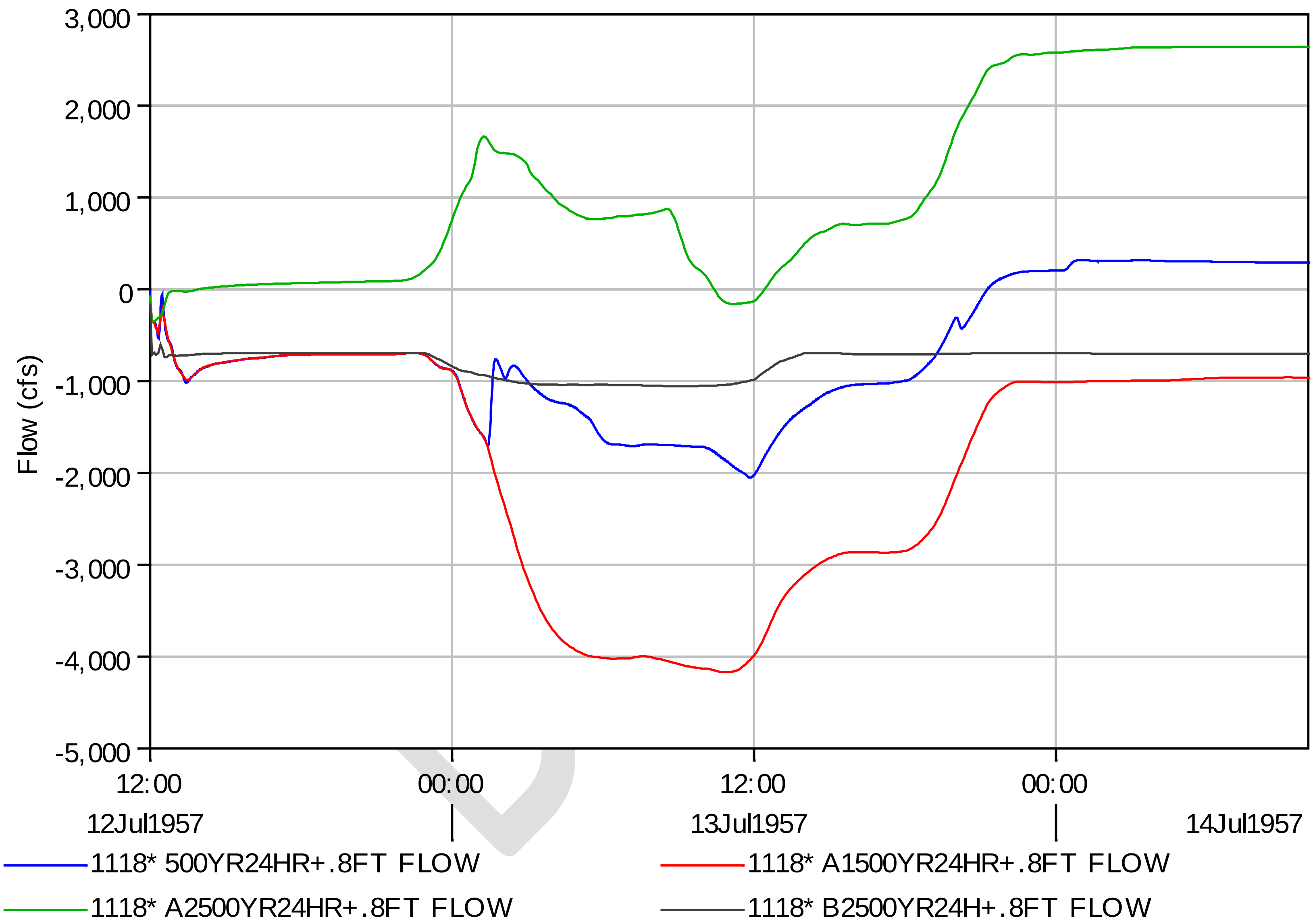
Comparison of Stages on NSC for Scenarios Baseline, A1, A2 and B2



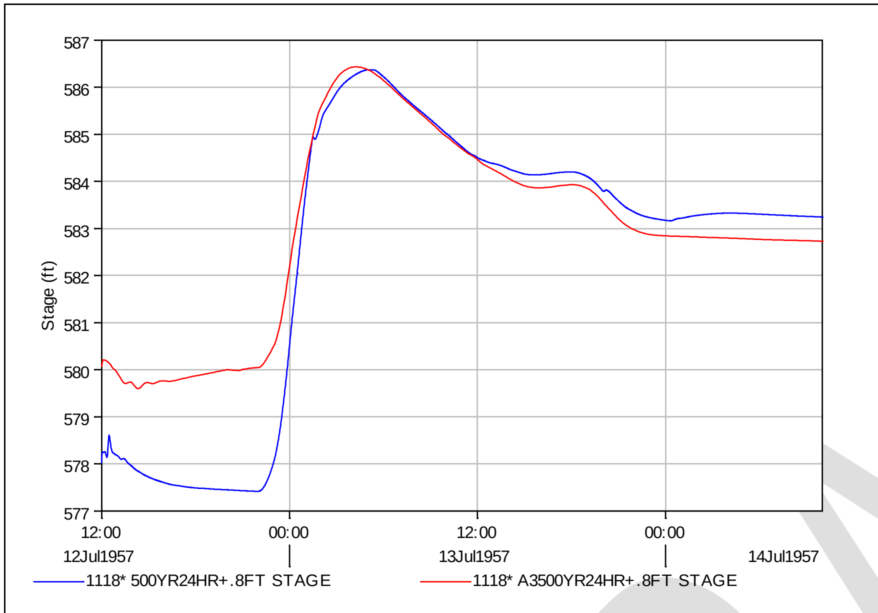
500YR/24HR Inflow Hydrograph from NBCR near Albany Avenue

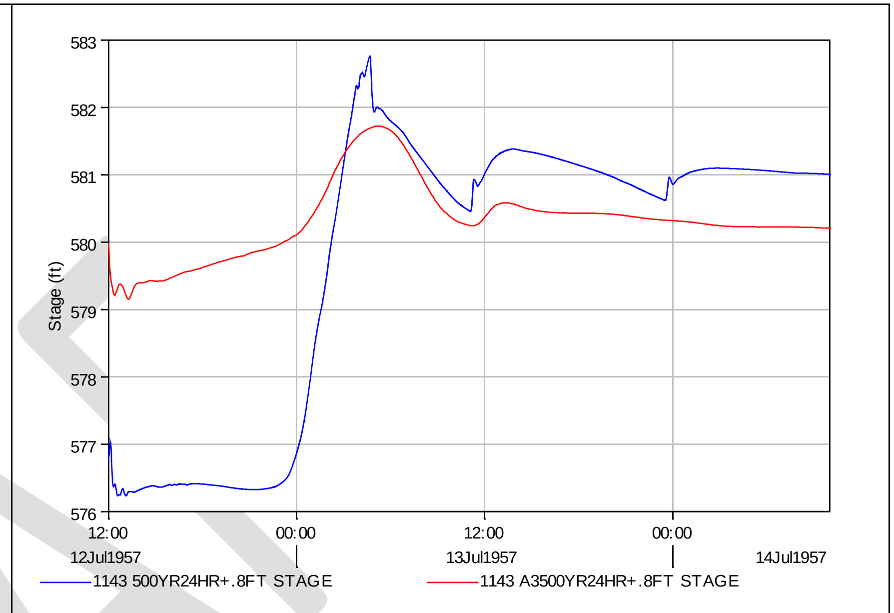


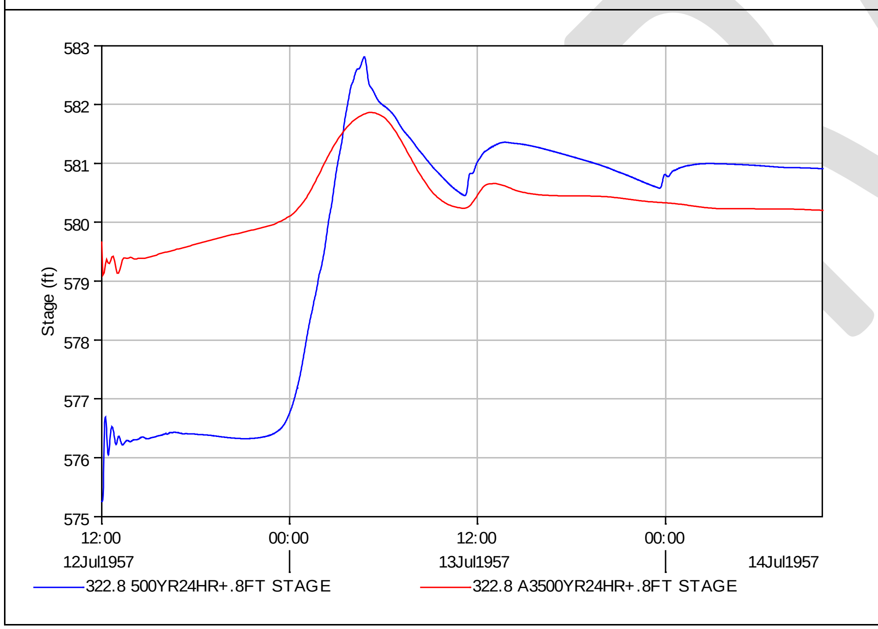
Comparison of Flows on NSC for Scenarios Baseline, A1, A2 and B2

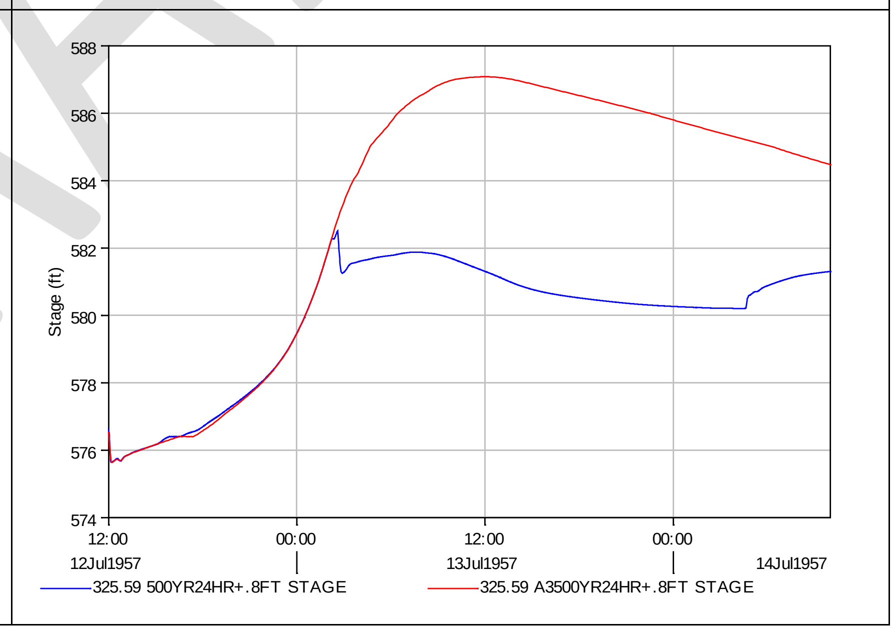


SCENARIO A3 – 4 Barriers Including a Physical Separation on the CSSC East of Stickney WRP Outfall

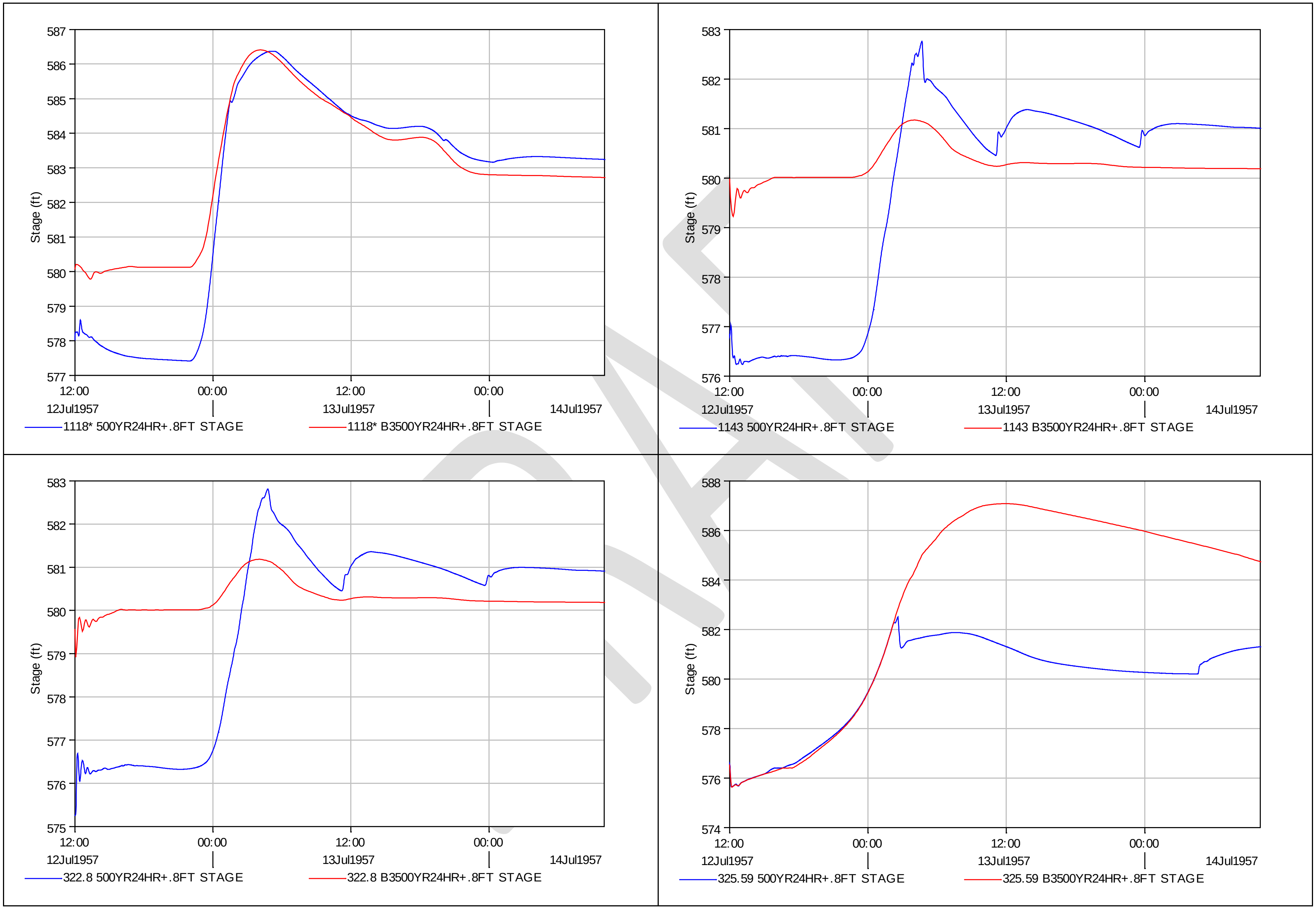


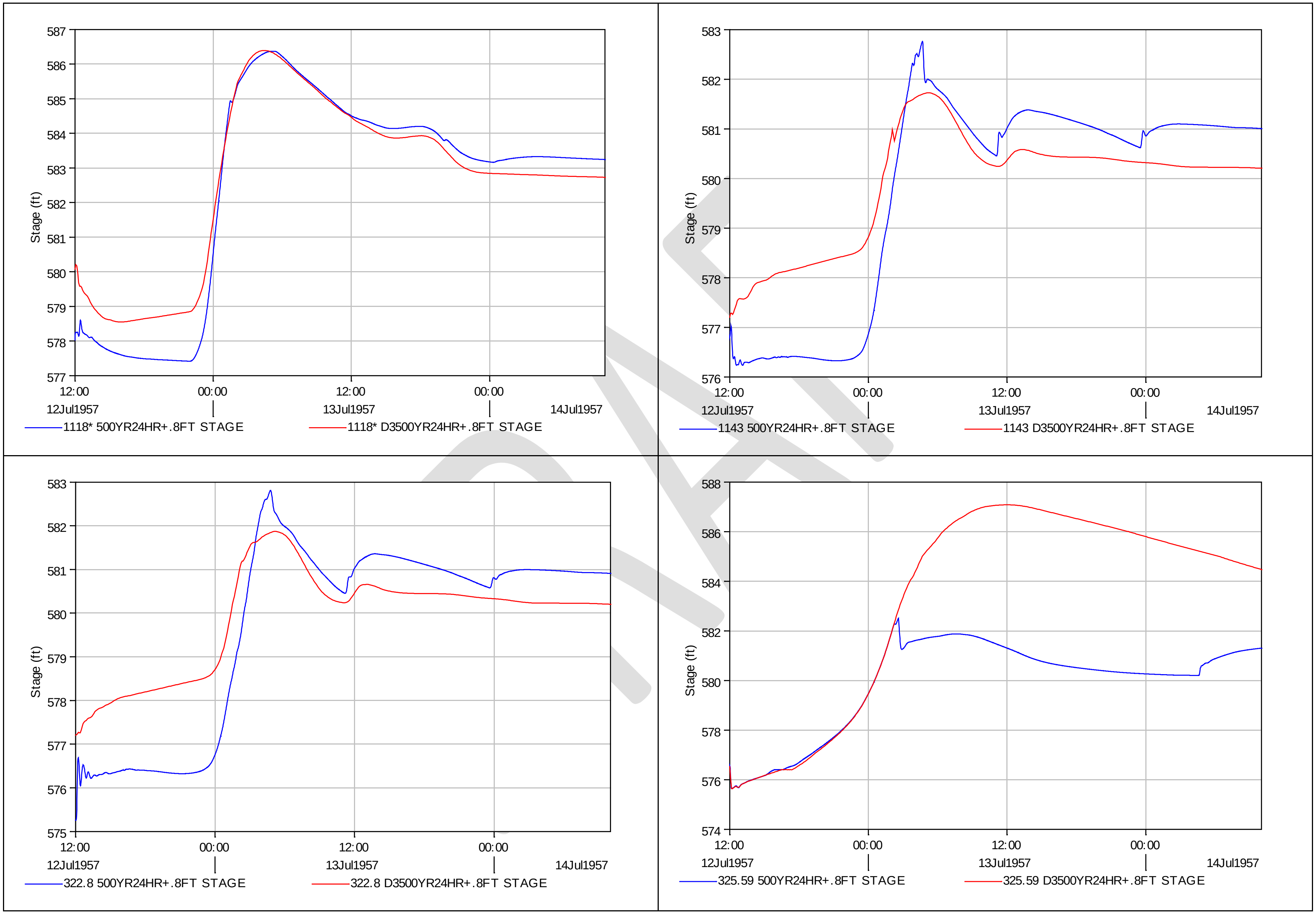



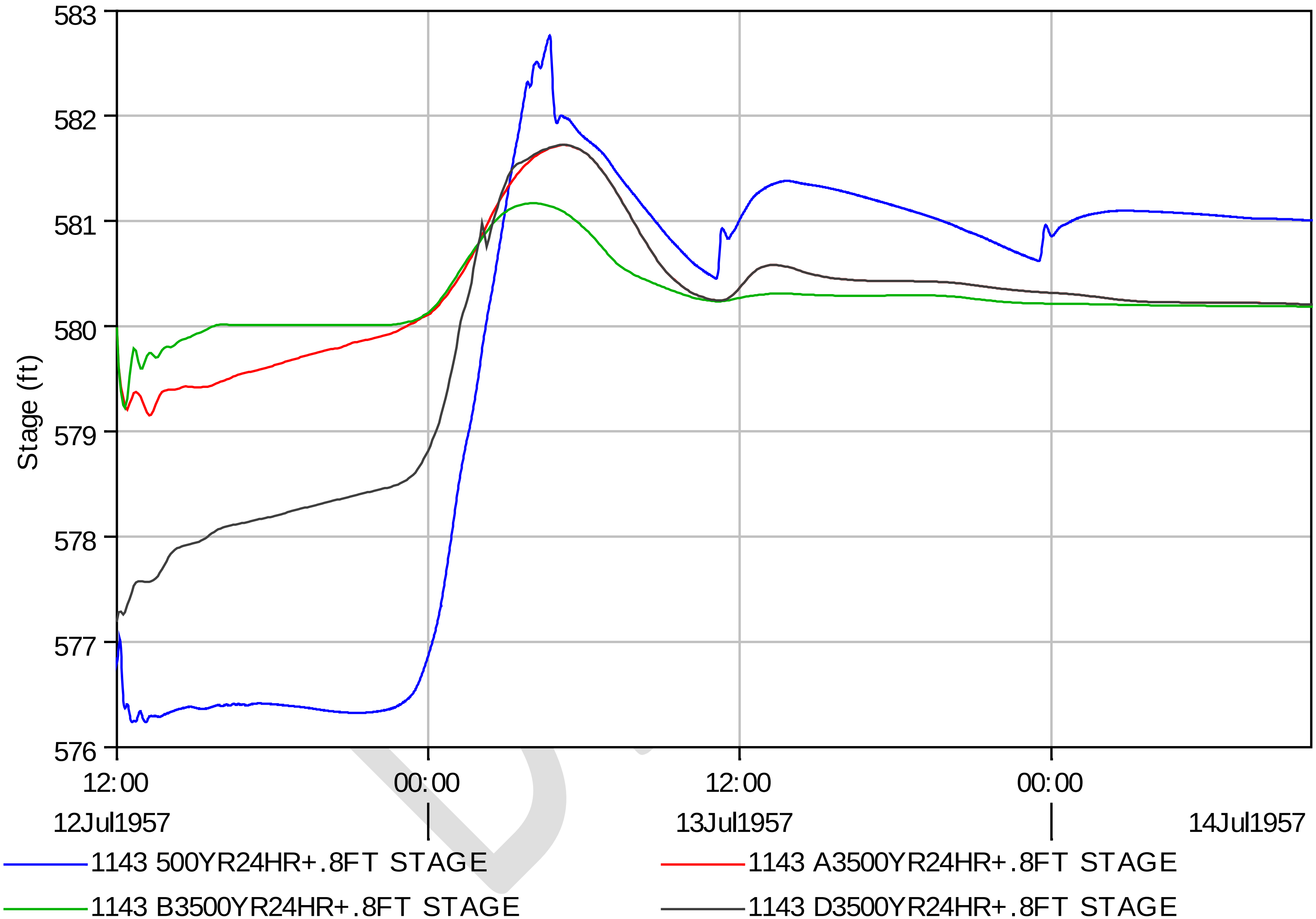
SCENARIO B3 – 4 Barriers Including a Physical Separation on the SBCR East of Bubbly Creek Confluence



SCENARIO D3 – 4 Barriers Including a Physical Separation on the Stickney WRP Outfall and CRCW Retained but Only Opened at 580

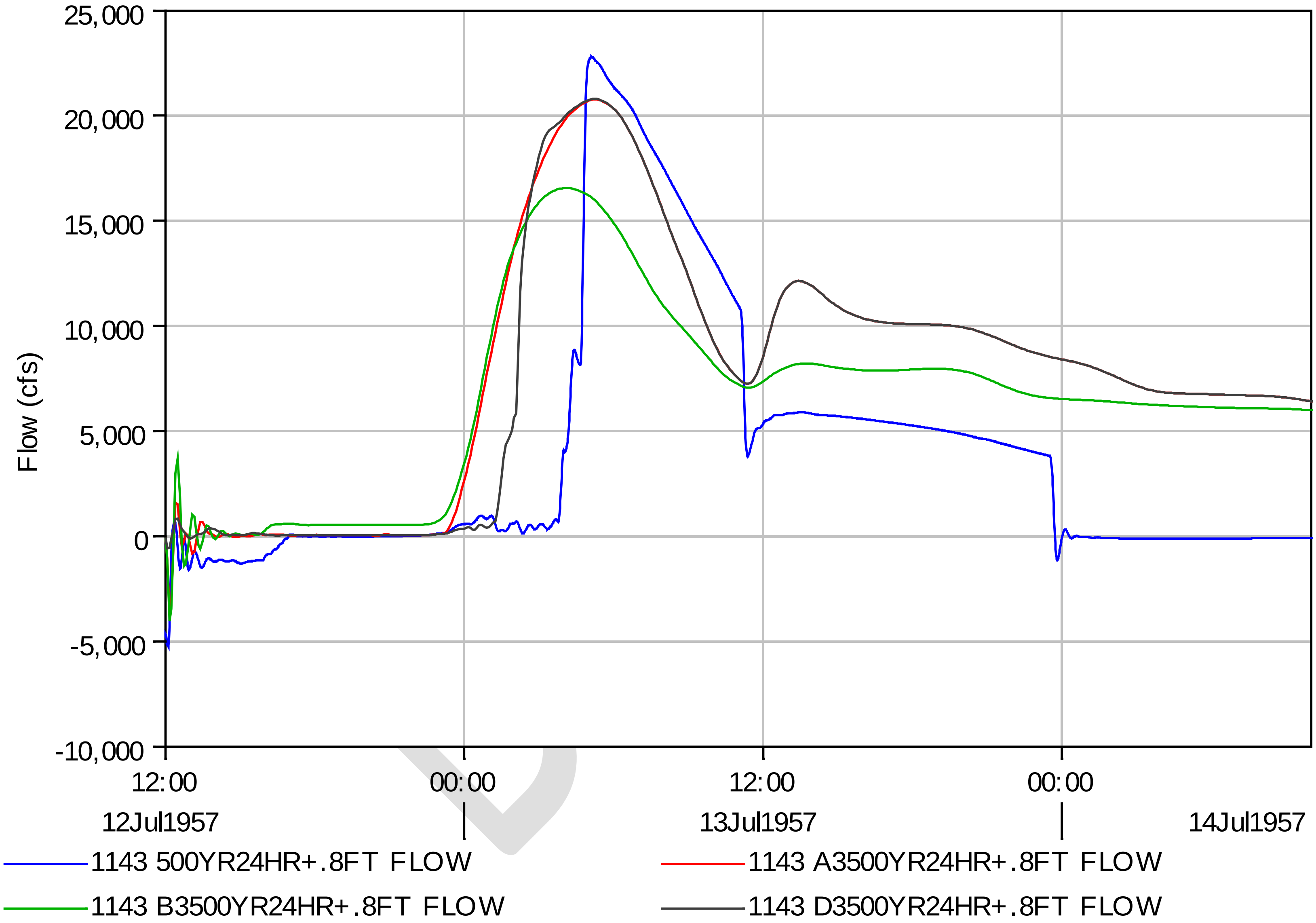



Comparison of Stages on Chicago River near Wolf Point for Scenarios Baseline, A3, B3 and D3 (Effect of Initial Channel Storage Negligible)

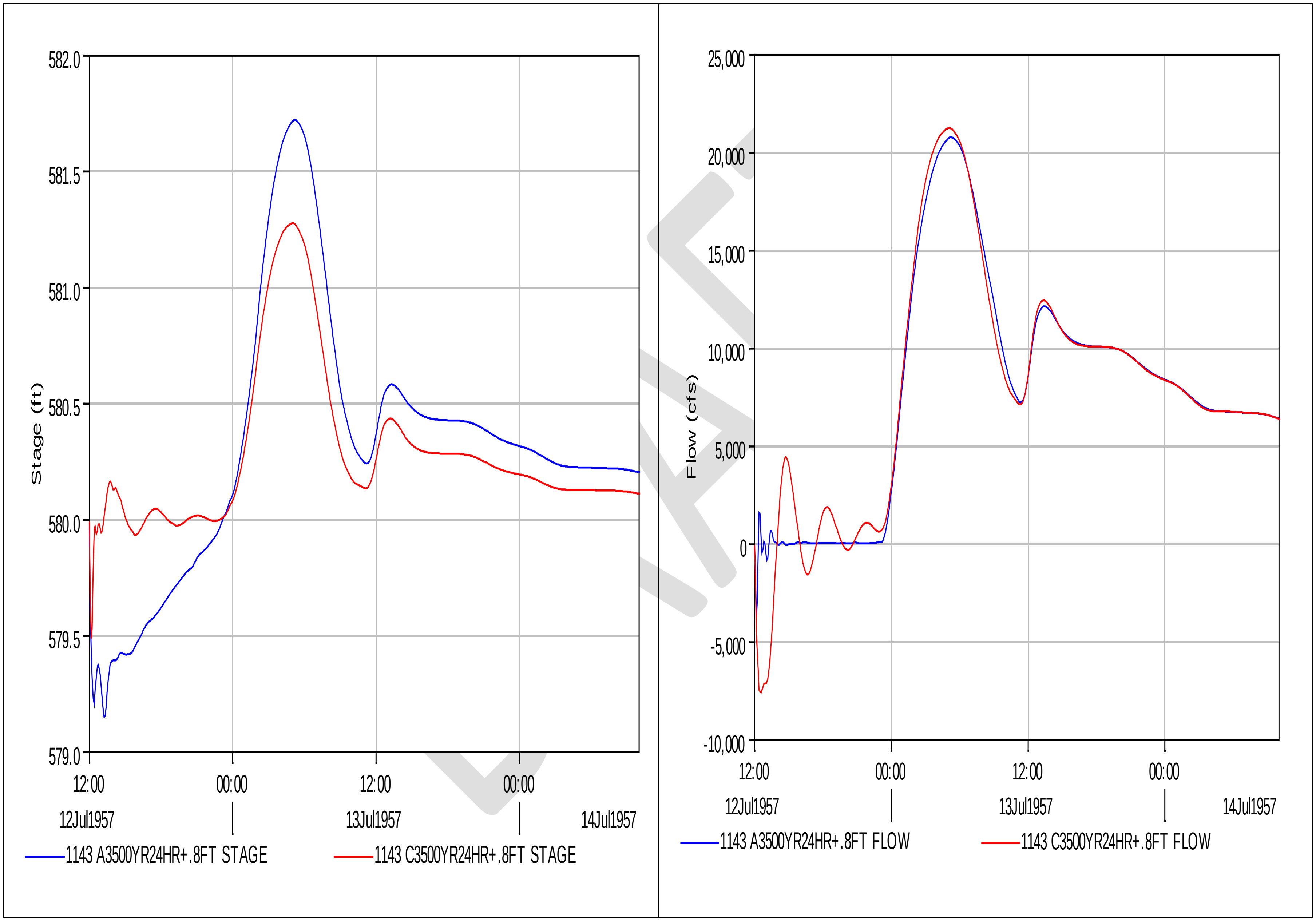


583
582
581
580
579
578
577
576
Stage (ft)
12:00
12Jul1957
00:00
12:00
13Jul1957
00:00
14Jul1957
1143 500YR24HR+.8FT STAGE
1143 A3500YR24HR+.8FT STAGE
1143 B3500YR24HR+.8FT STAGE
1143 D3500YR24HR+.8FT STAGE

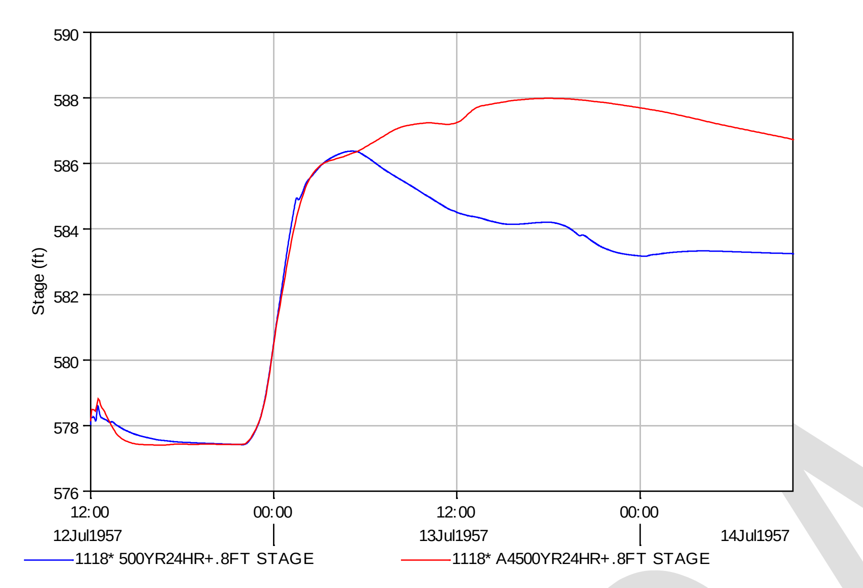
Comparison of Flows on Chicago River near Wolf Point for Scenarios Baseline, A3, B3 and D3

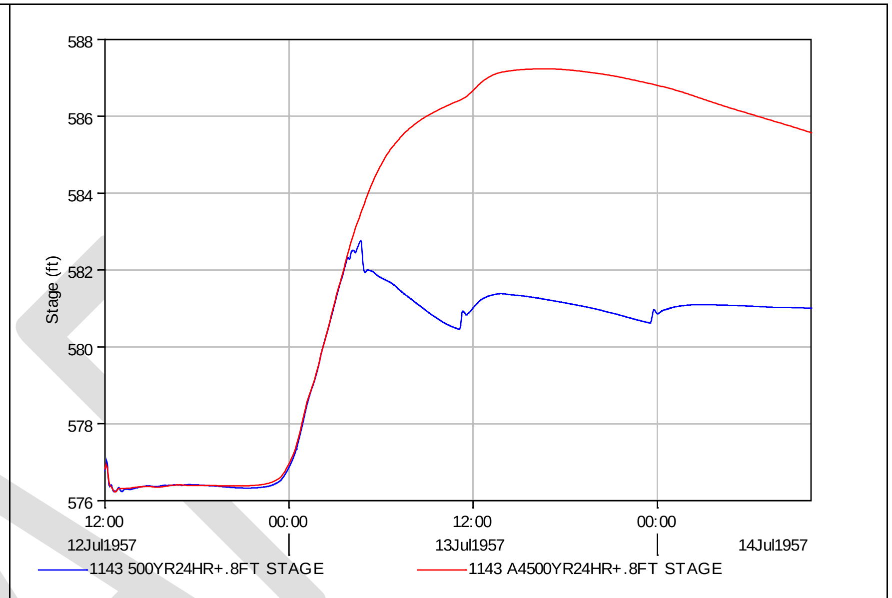


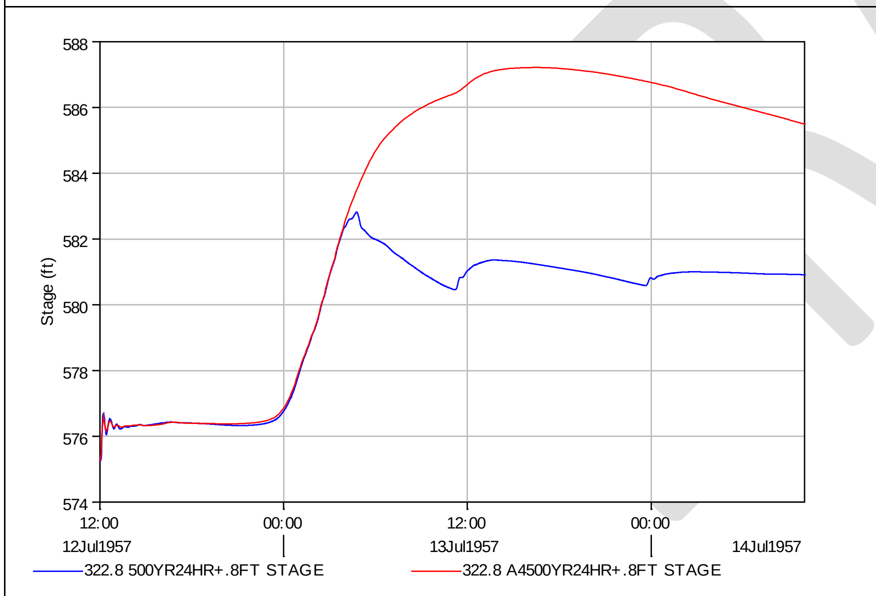
Comparison of Stage and Flow on Chicago River near Wolf Point for Scenarios A3 and C3 (Effect of Lock Removal – Gate vs. Channel Flows)

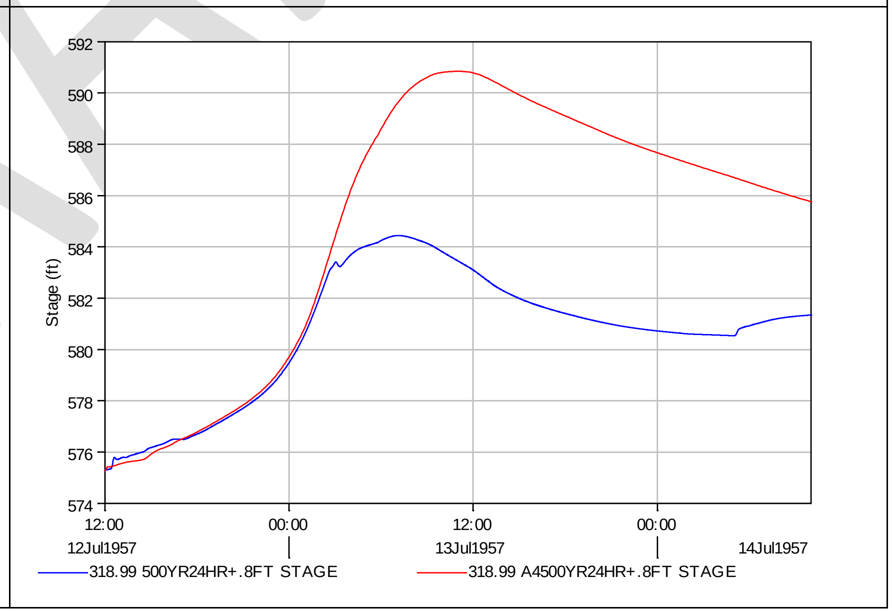


SCENARIO A4 – 4 Barriers Including Physical Separations on the NSC near Northside WRP and on the LCR near Calumet WRP

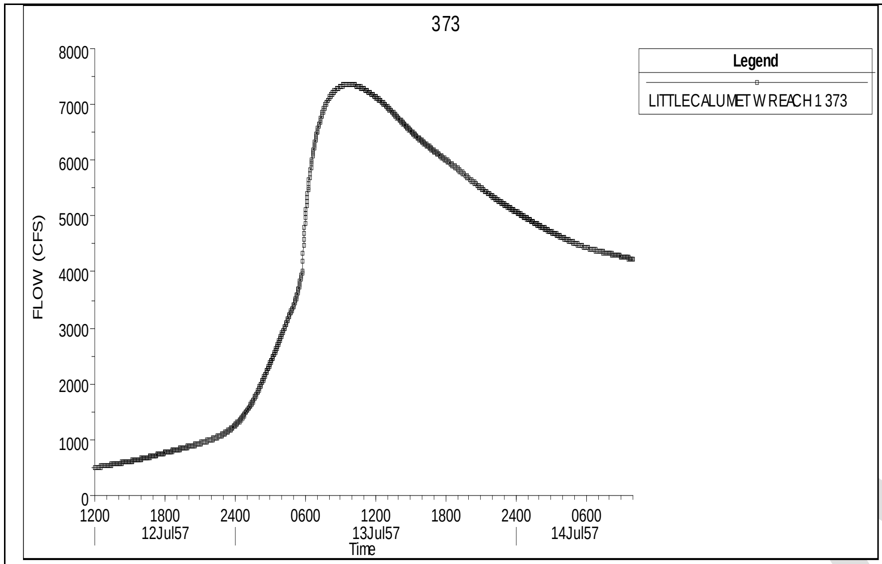


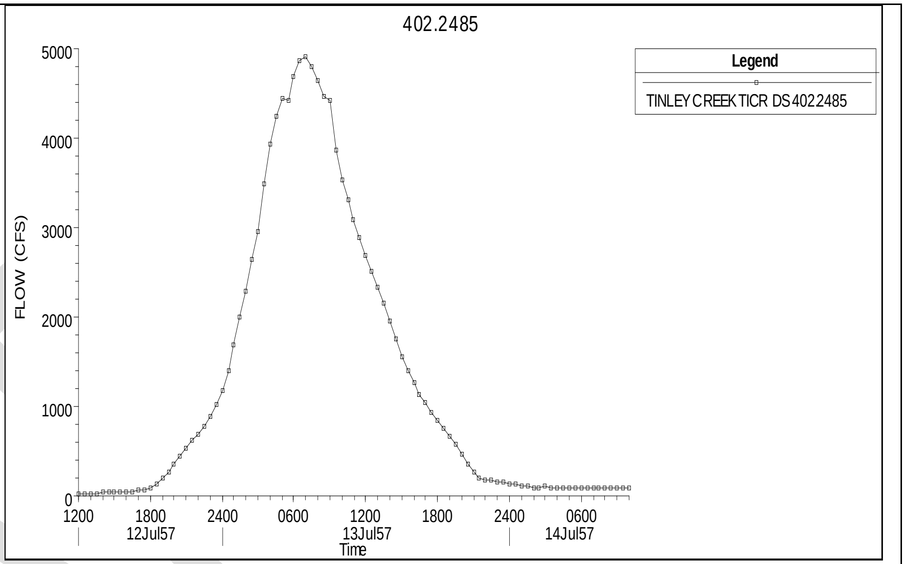



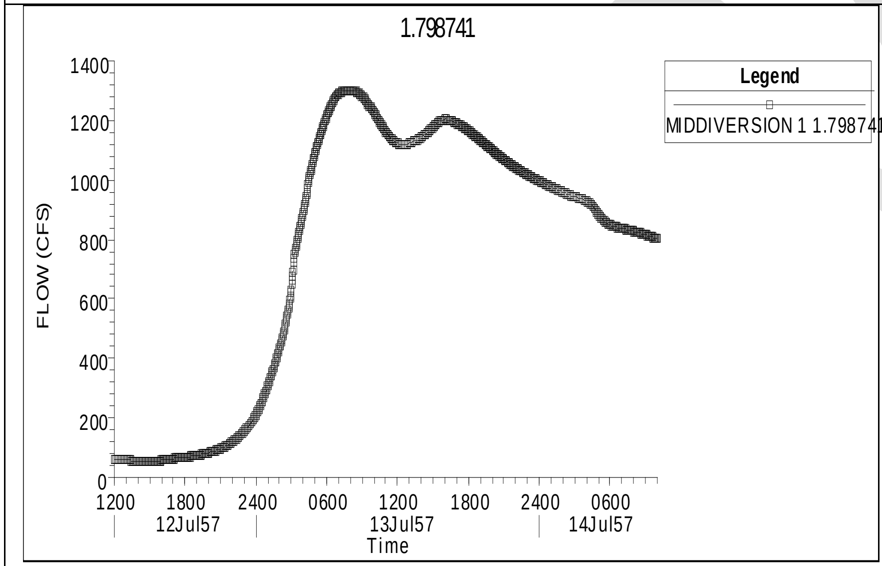
500YR/24HR Inflow Hydrographs from Tributaries in Calumet Basin



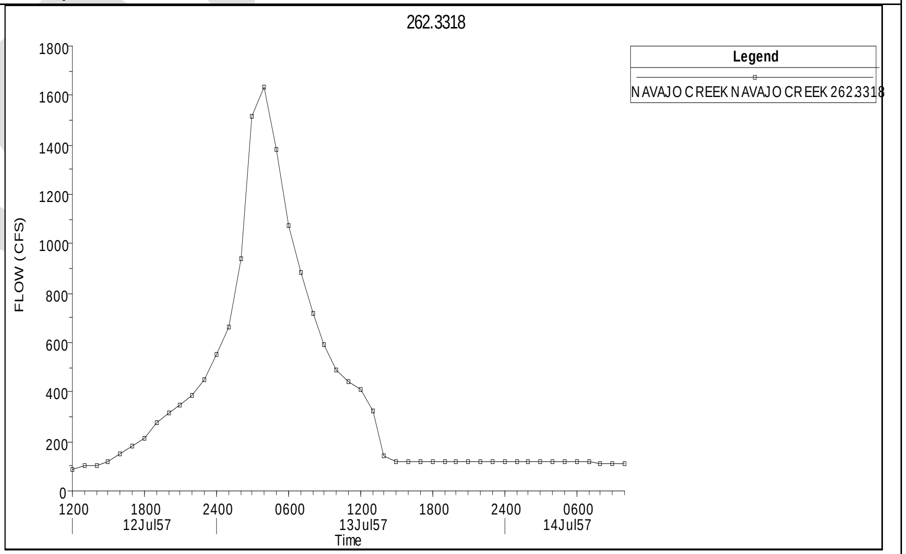

Little Calumet River at RS 319.6




Tinley Creek at RS 313.96

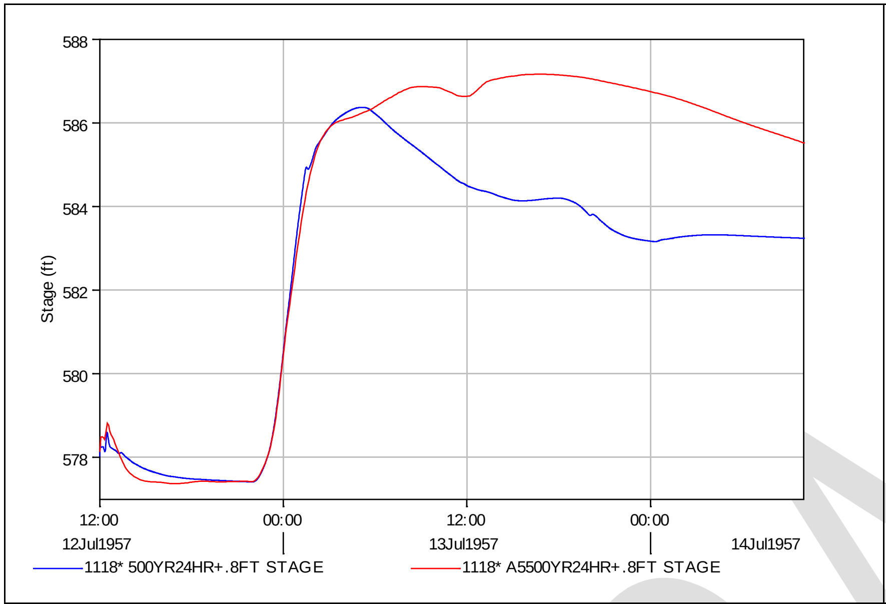


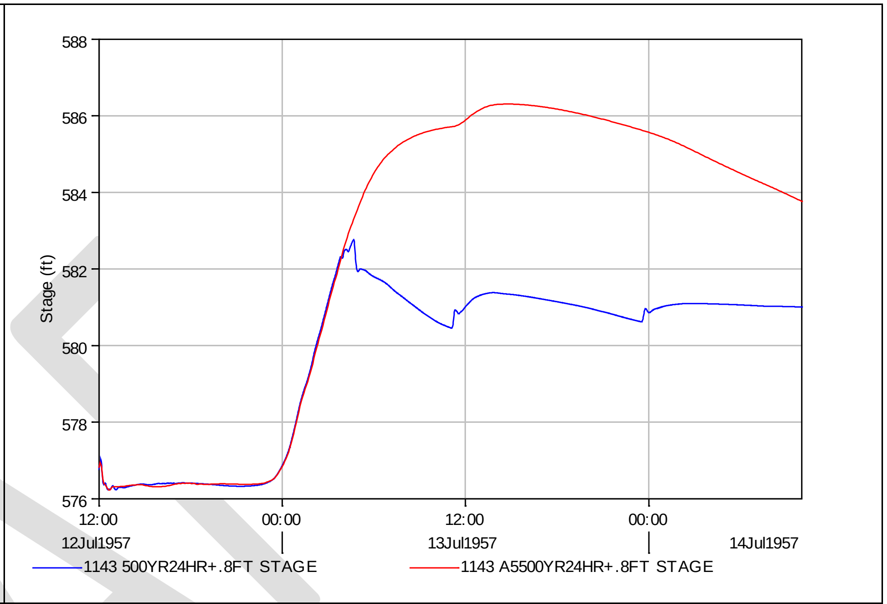

Midlothian Creek at RS 316.96

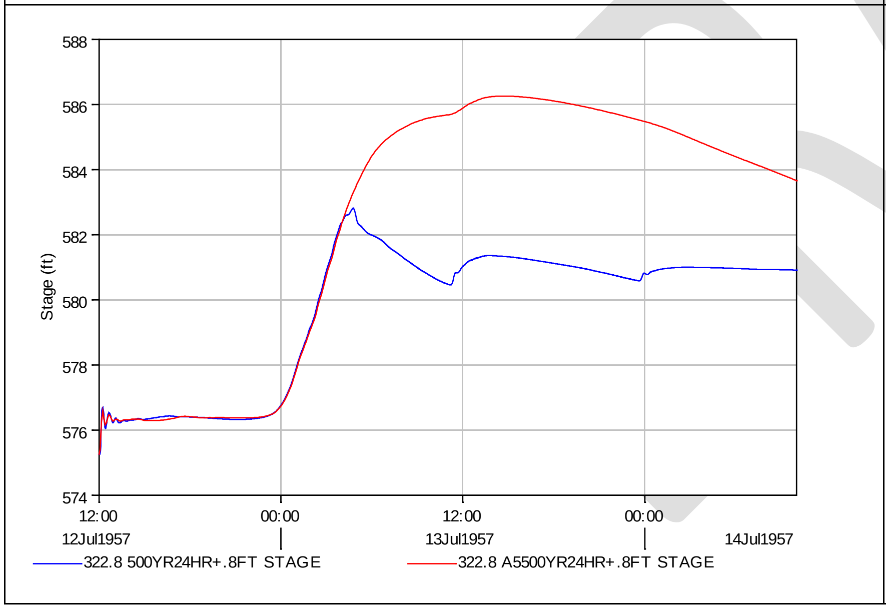


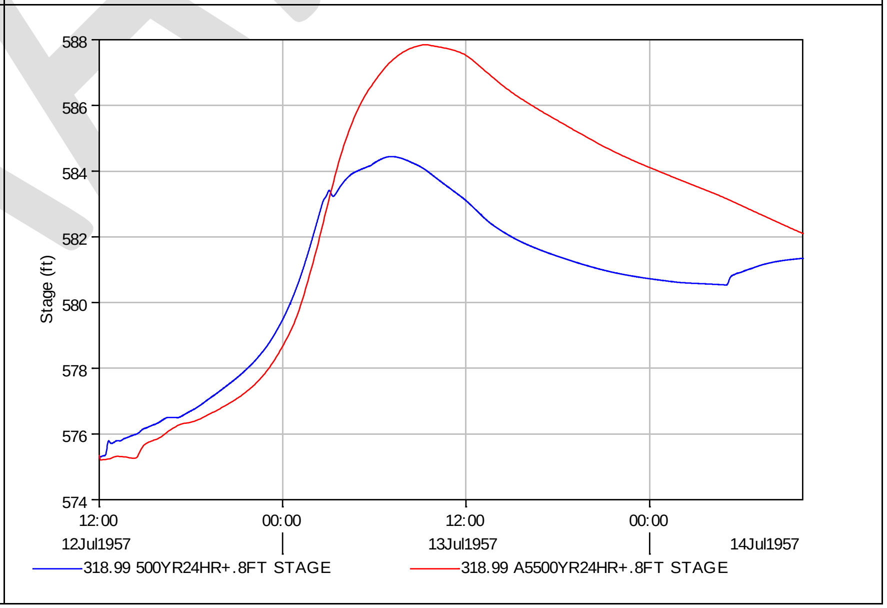

Navajo Creek at RS 312.31

SCENARIO A5 – 3 Barriers Including Physical Separations on the NSC near Northside WRP and on the Cal-Sag Channel near LCR Confluence

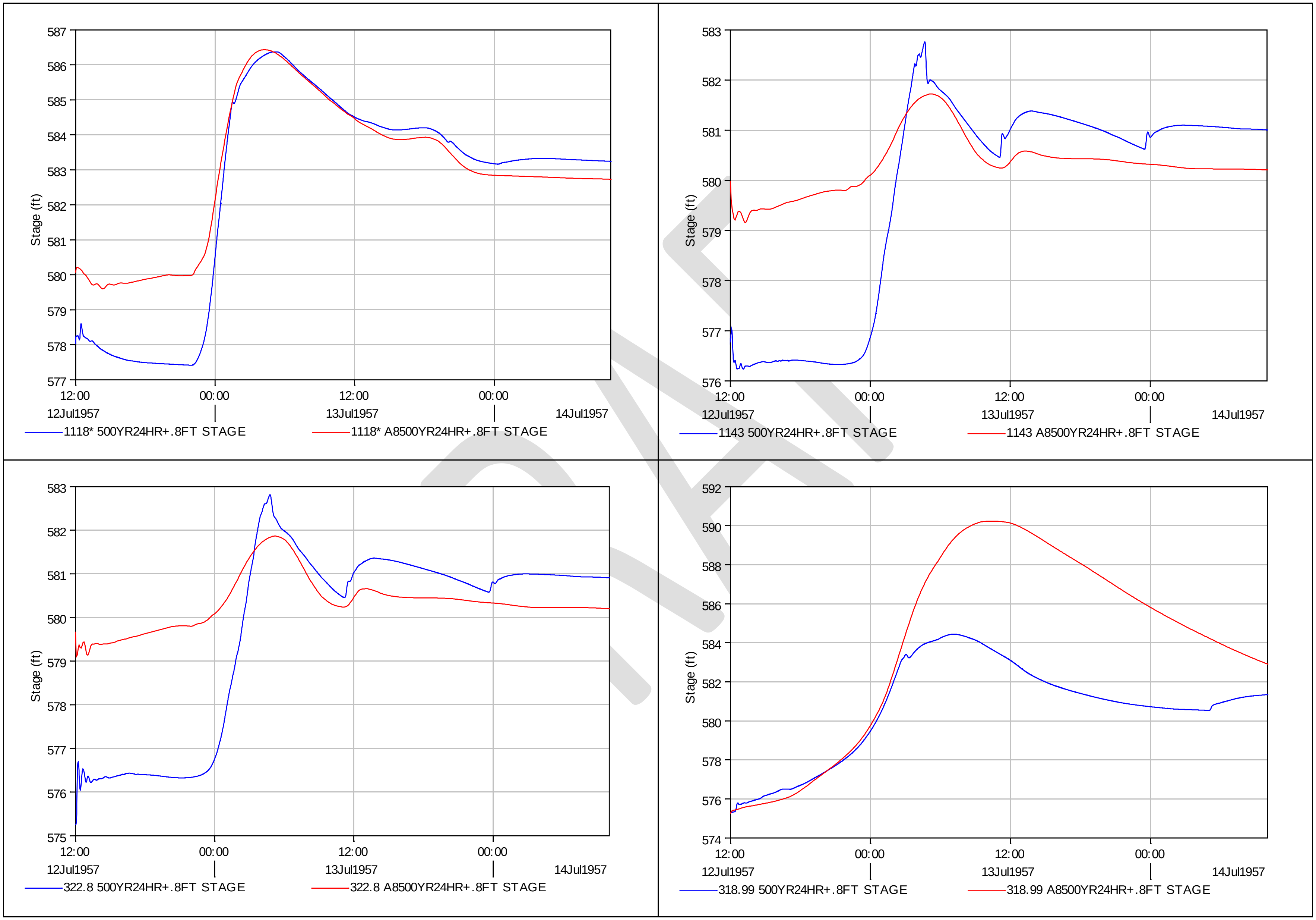


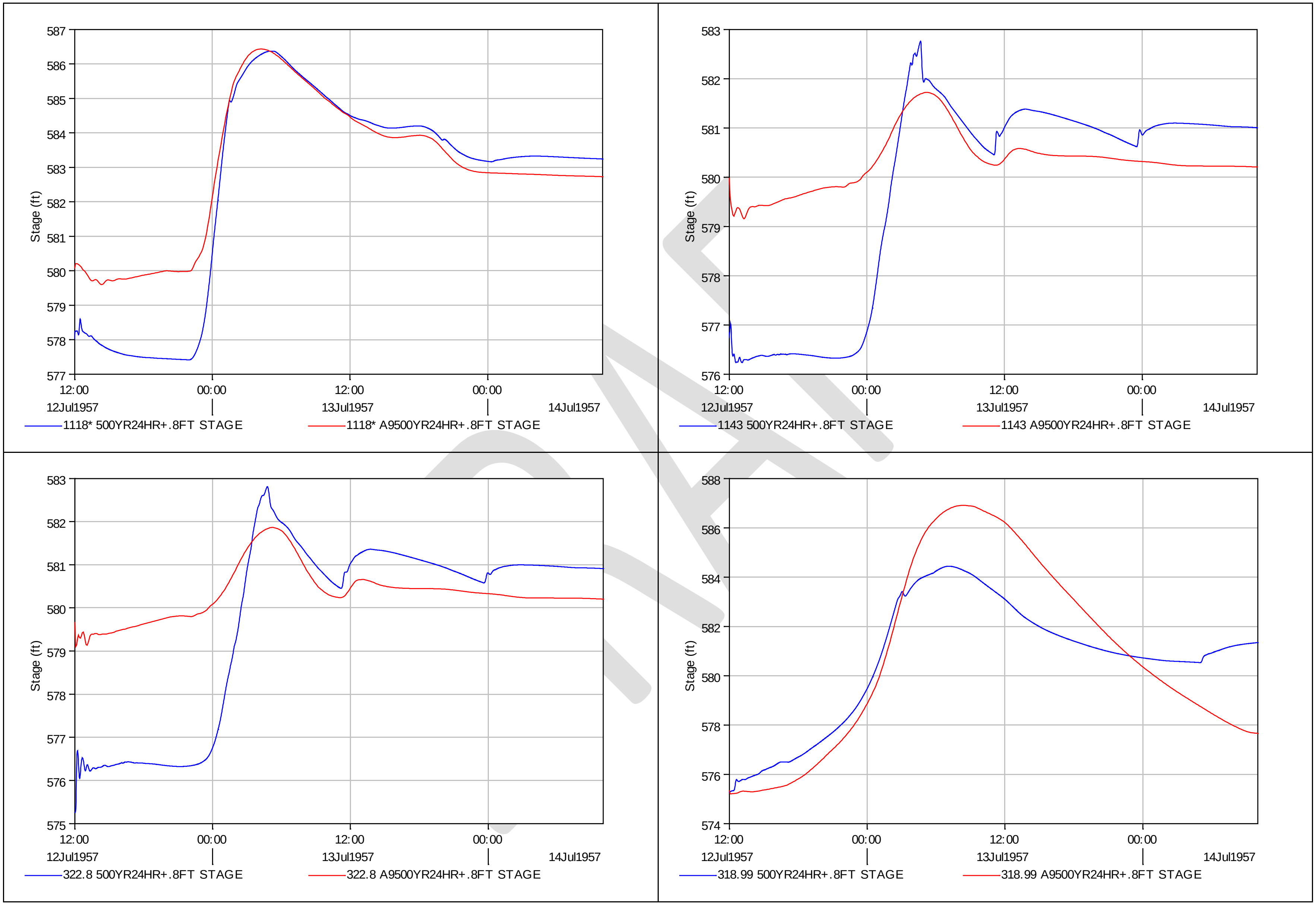



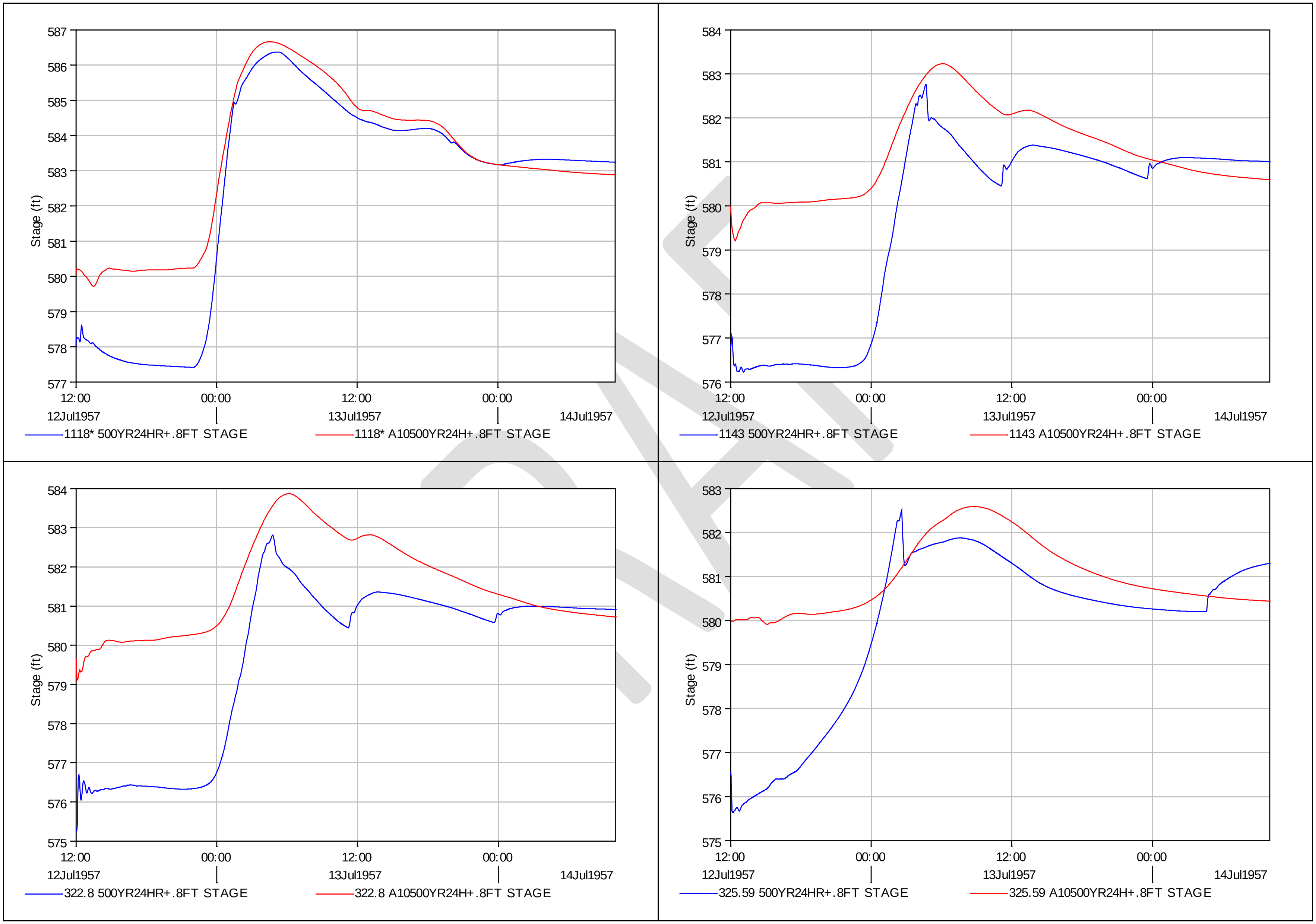
SCENARIO A8 – 3 Barriers Including Physical Separations on the CSSC near Stickney WRP and on the LCR near Calumet WRP



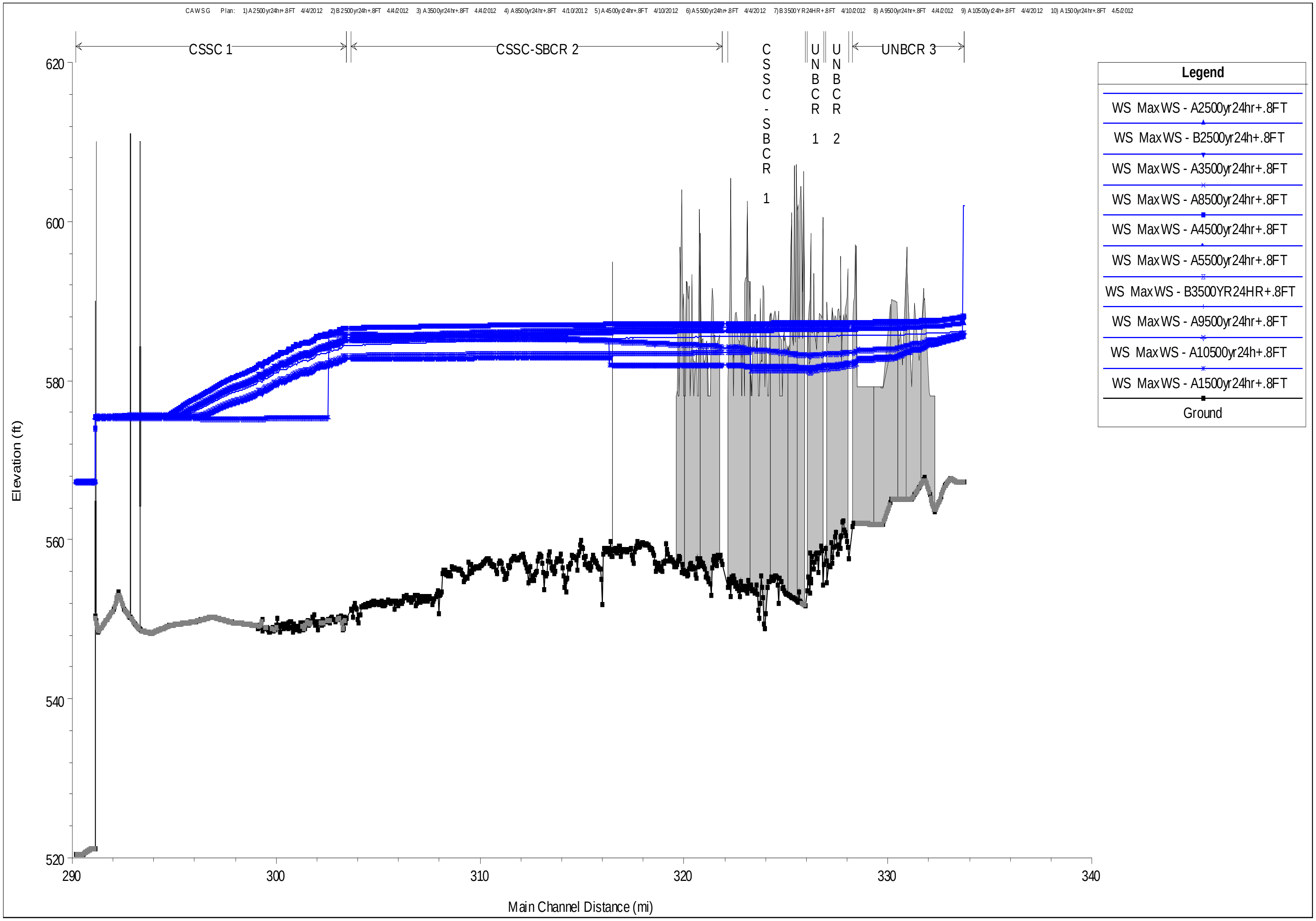
SCENARIO A9 – 2 Barriers Including Physical Separations on the CSSC near Stickney WRP and on the Cal-Sag Channel near LCR Confluence



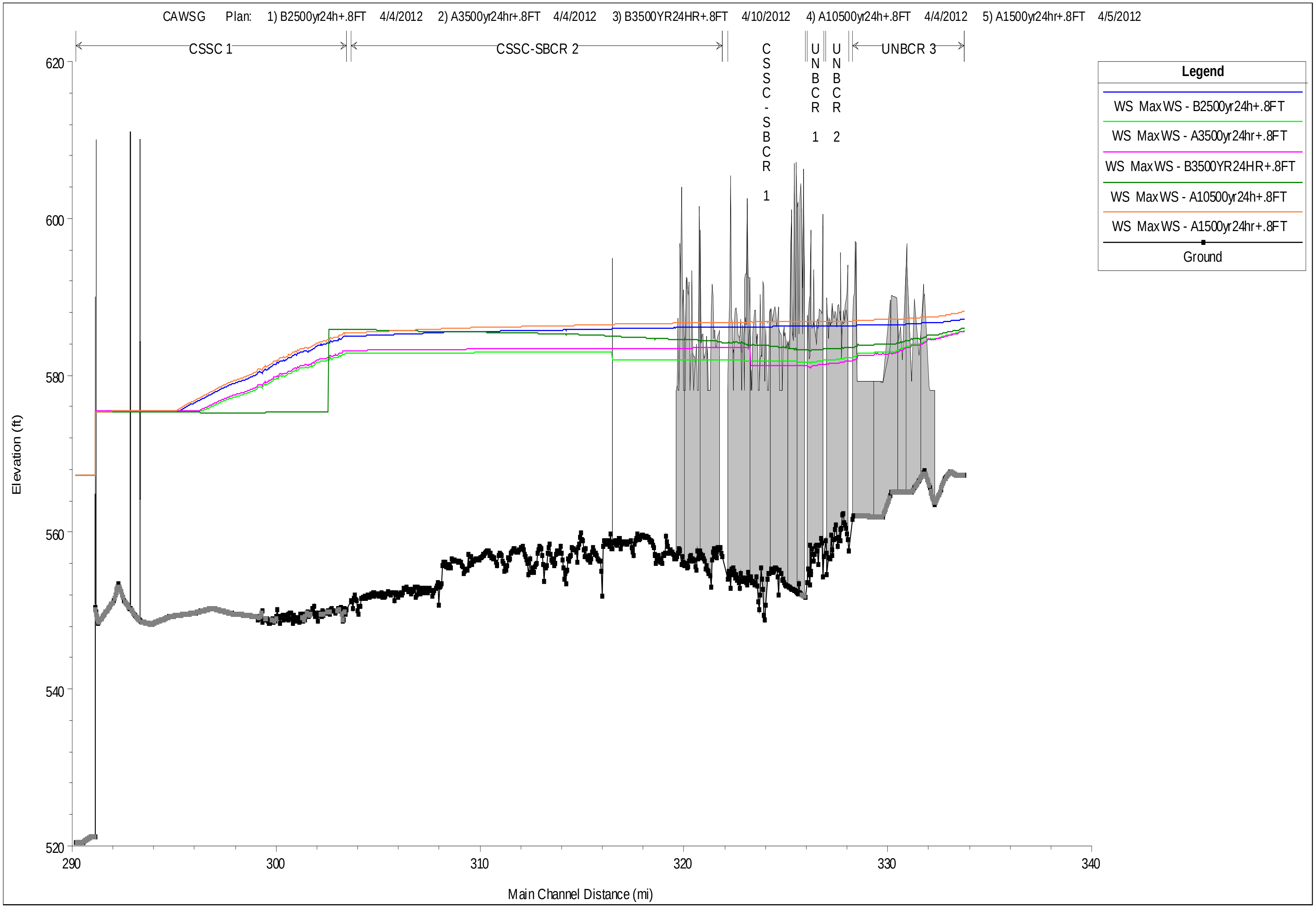
SCENARIO A10 – 1 Barrier on the CSSC near Lemont Gaging Station



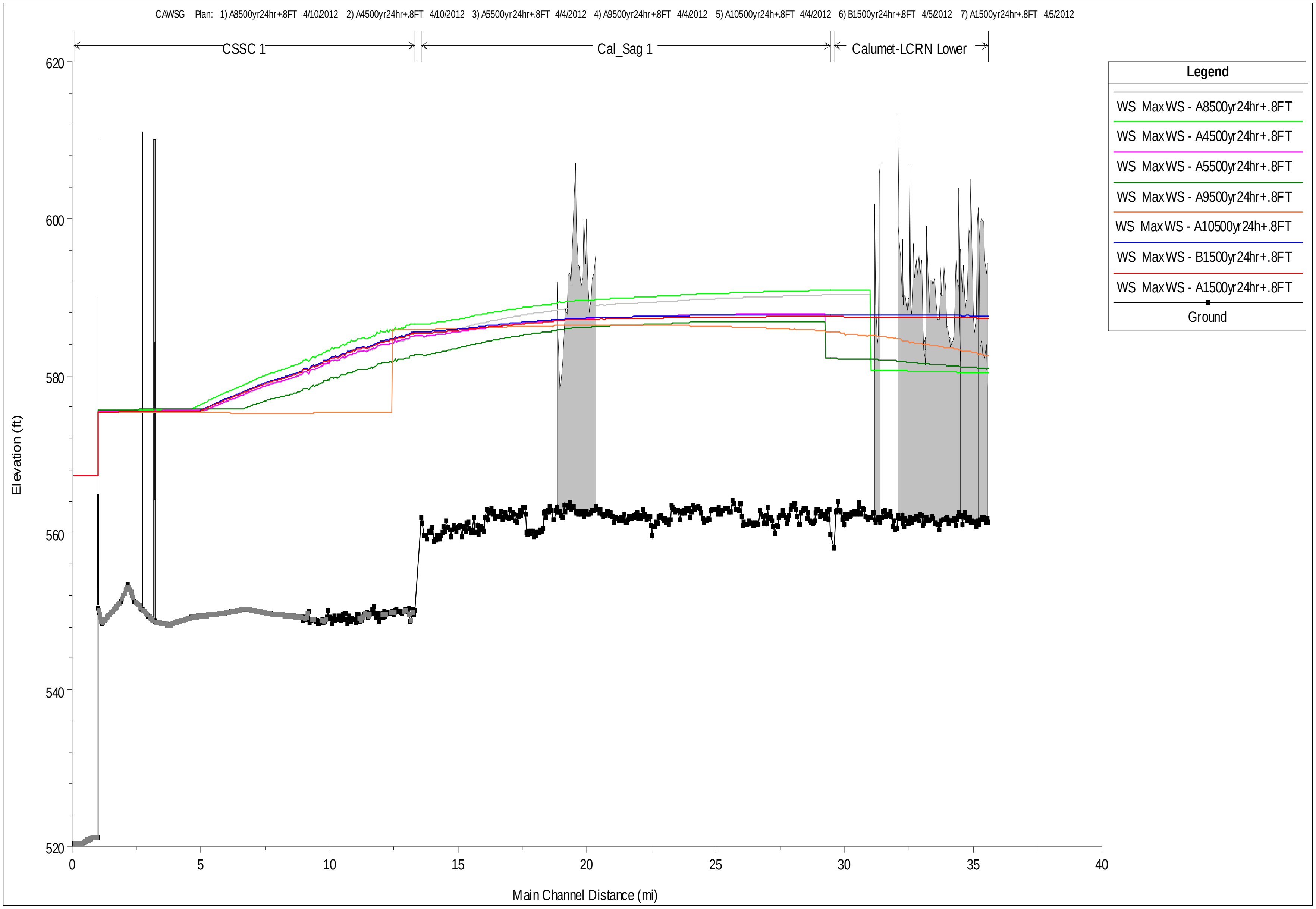
Maximum Water Surface Profile (Chicago River System) – All Major Scenarios



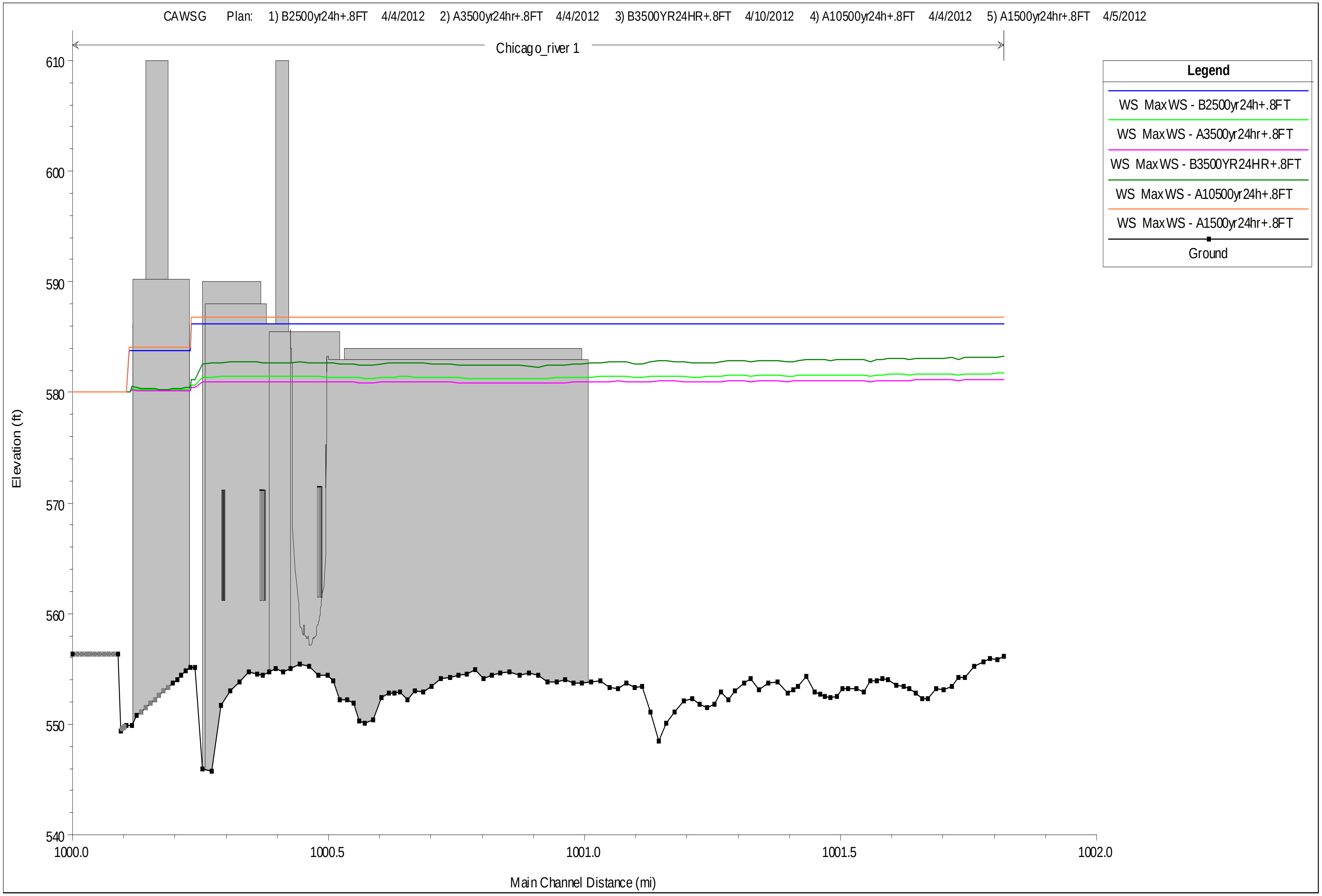
Maximum Water Surface Profile (Chicago River System) – A1, B2, A3, B3 and A10



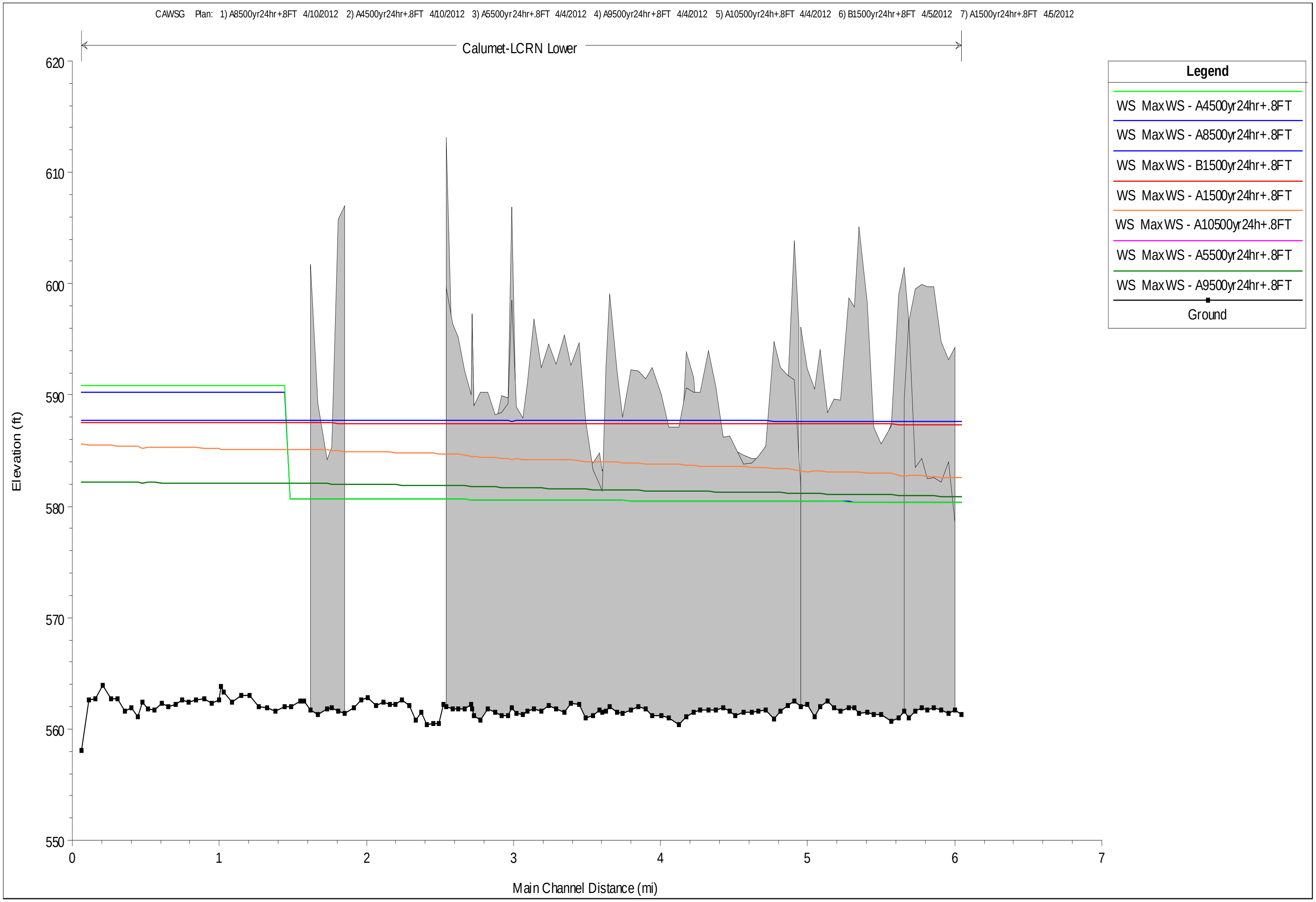
Maximum Water Surface Profile (Calumet River System) – A1, B1, A4, A5, A8, A9 and A10



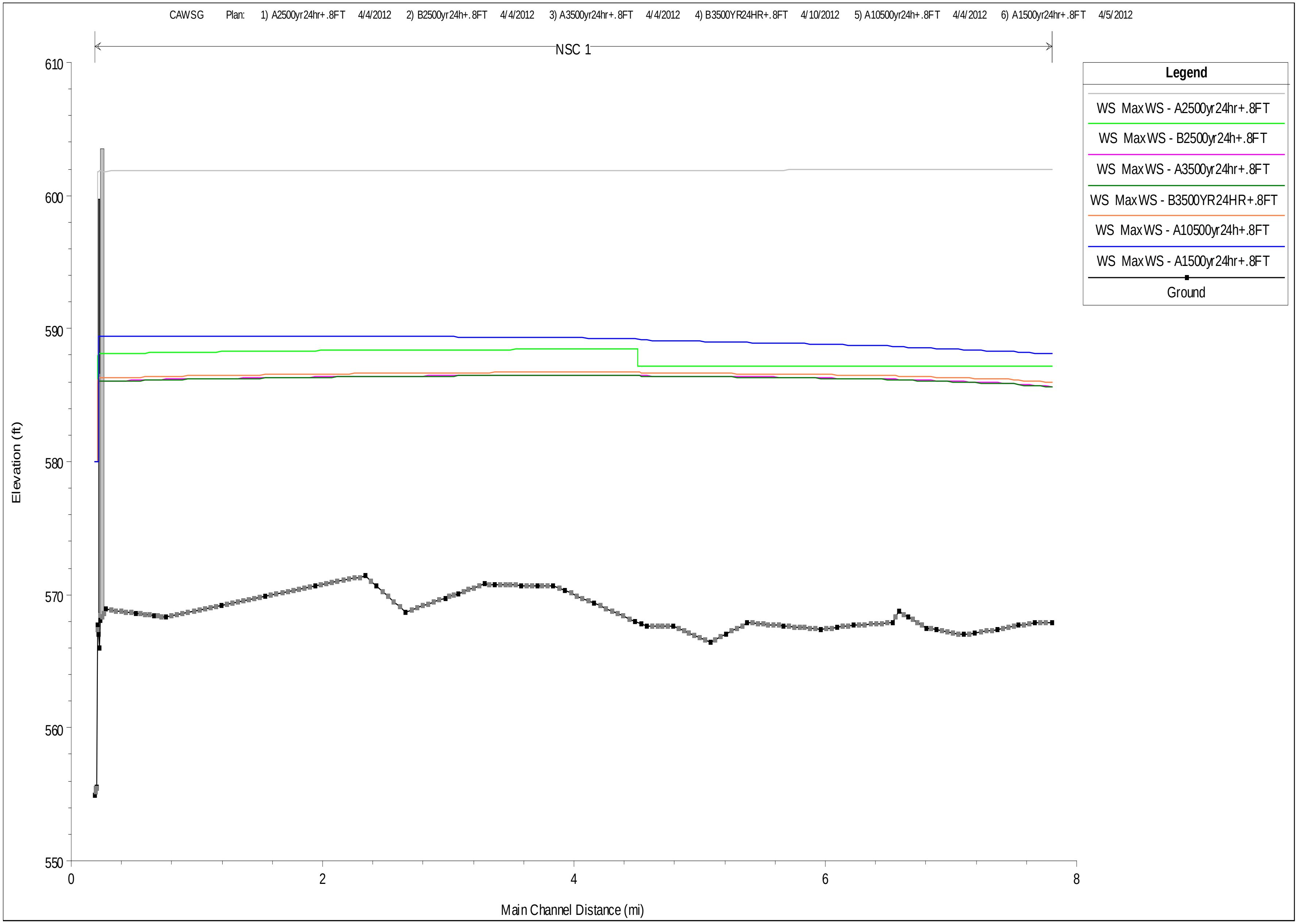
Maximum Water Surface Profile (Chicago River) – A1, B2, A3, B3 and A10



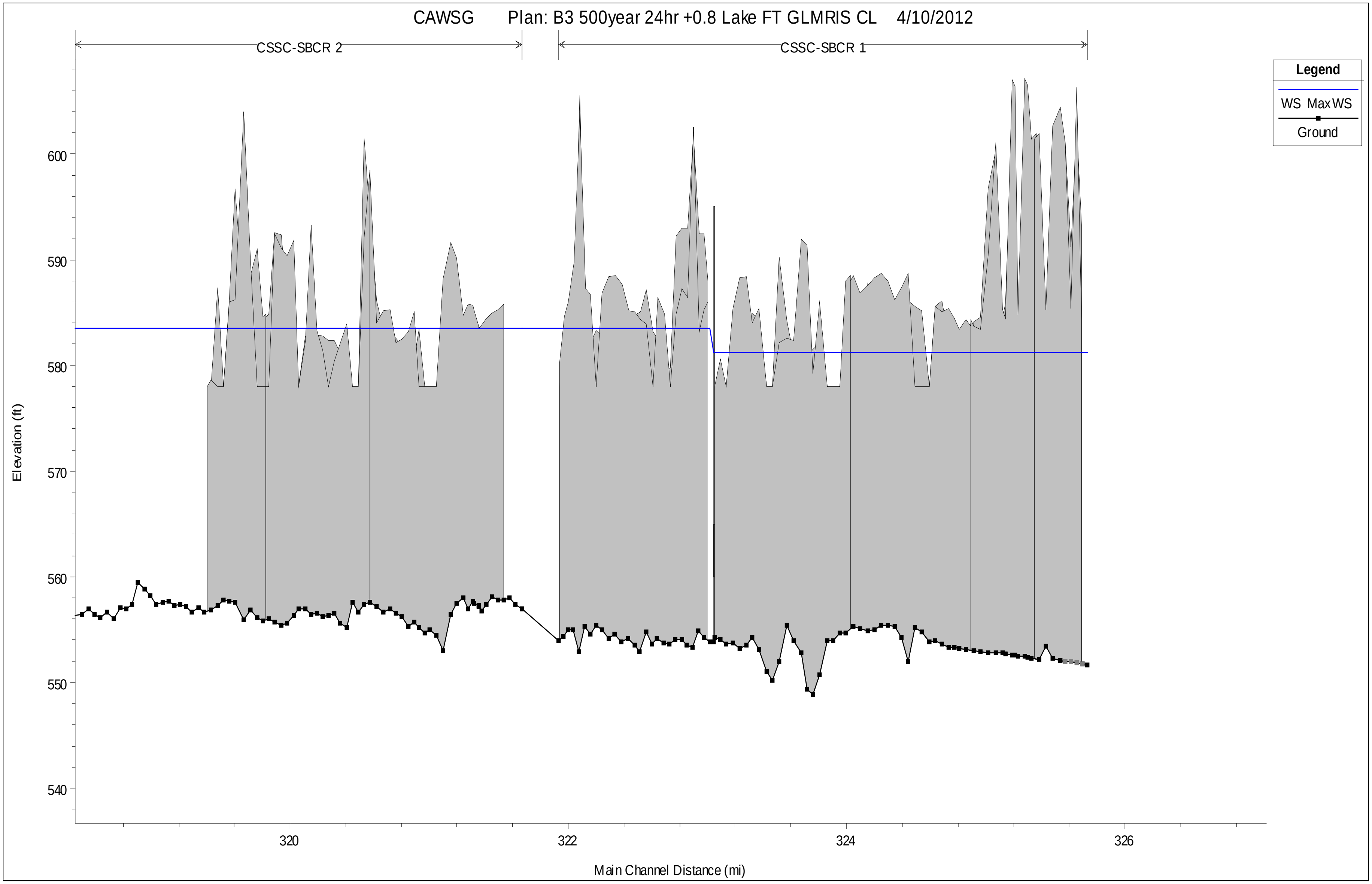
Maximum Water Surface Profile (Calumet River) – A1, B1, A4, A5, A8, A9 and A10



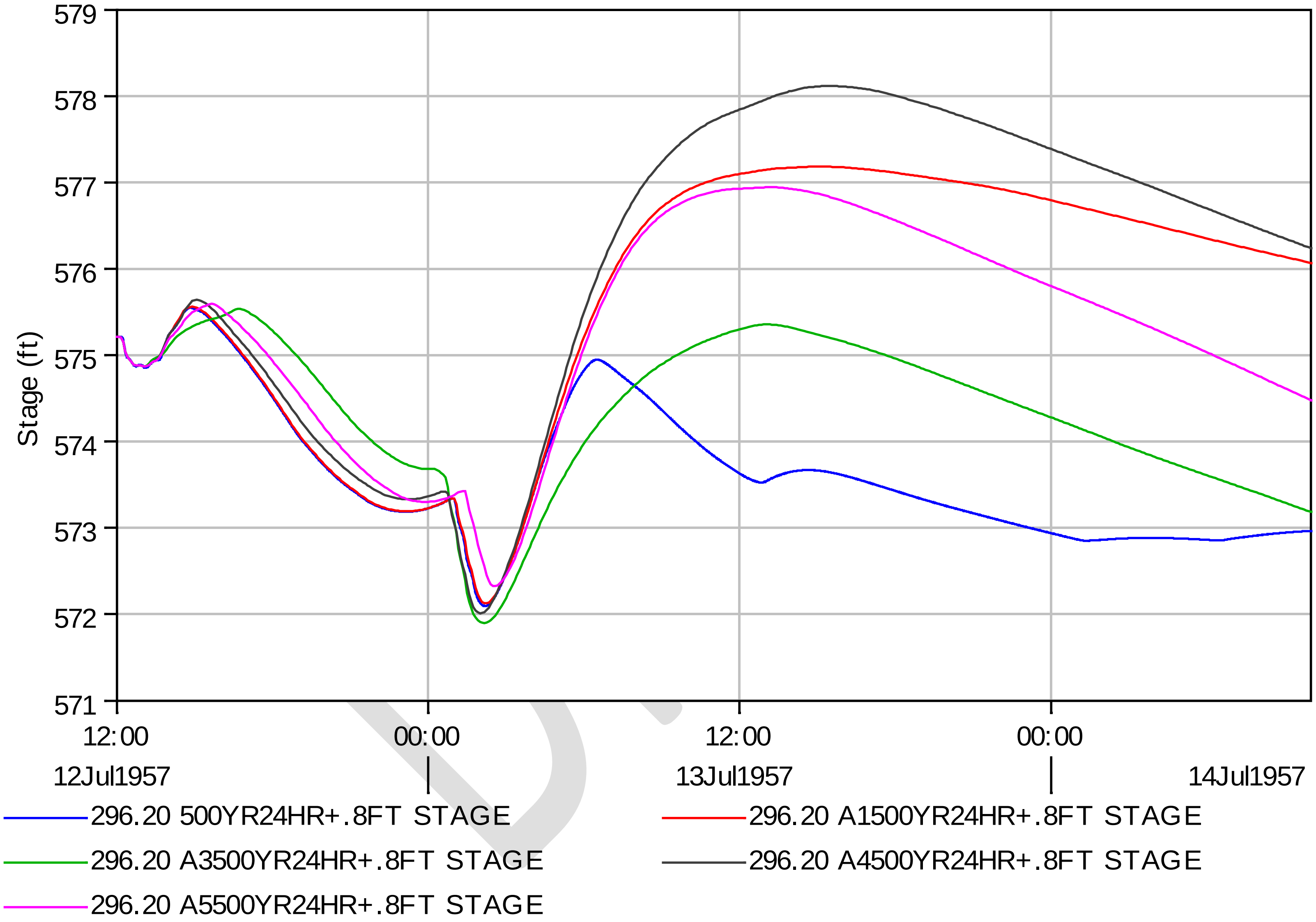
Maximum Water Surface Profile (North Shore Channel) – A1, A2, B2, A3, B3 and A10



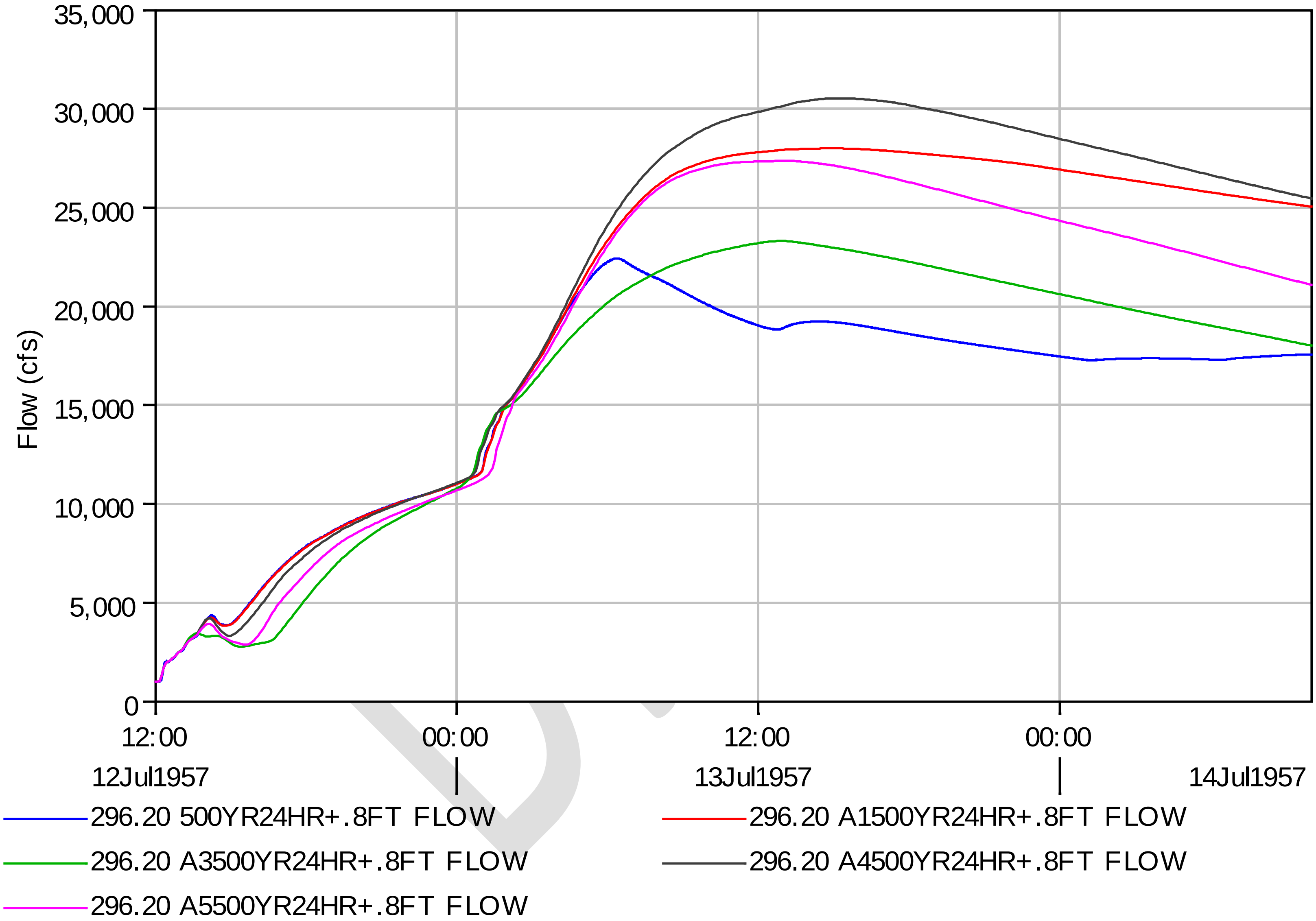
Maximum Water Surface Profile (SBCR-CSSC) – B3



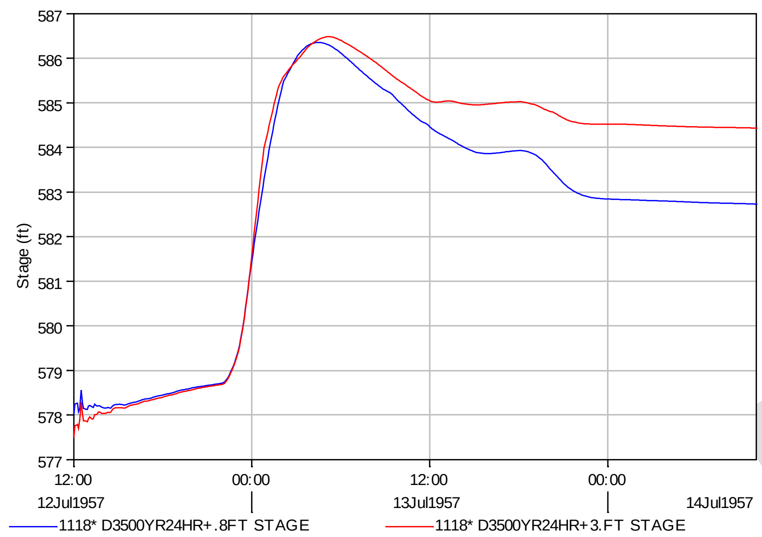
Stages on the CSSC near Lemont Gaging Station – Baseline, A1, A3, A4 and A5

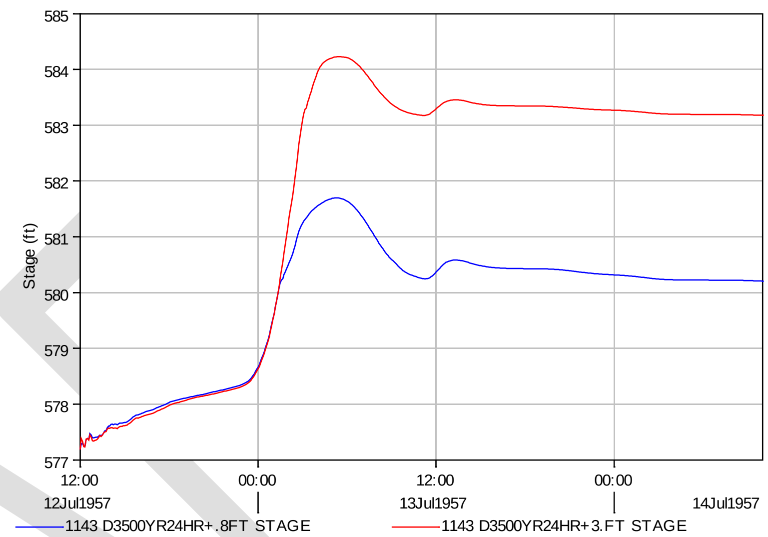


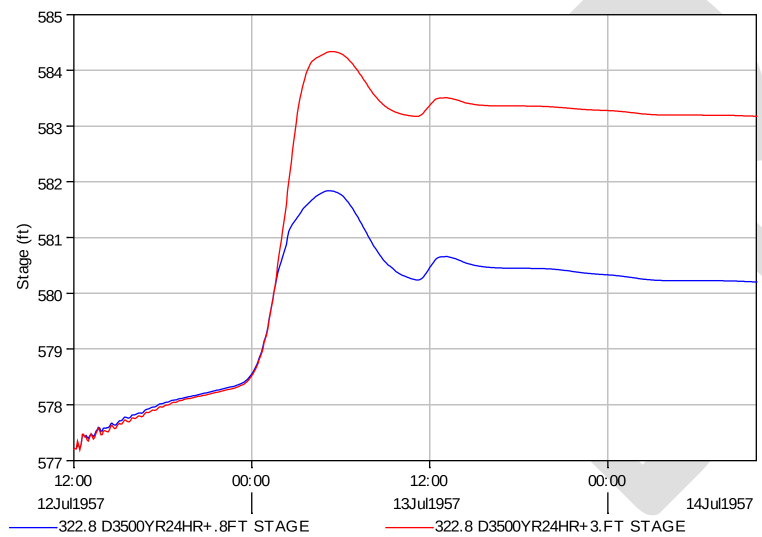
Flows on the CSSC near Lemont Gaging Station – Baseline, A1, A3, A4 and A5

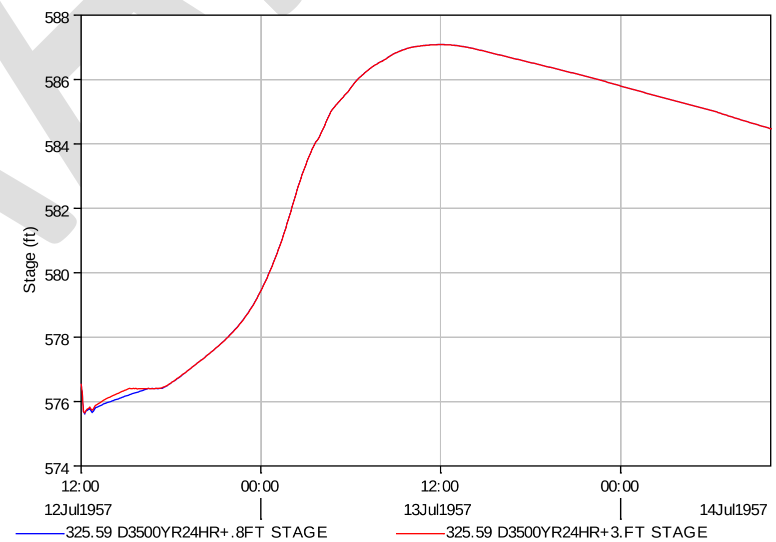


SCENARIO D3 – Lake Level 580 vs. 583

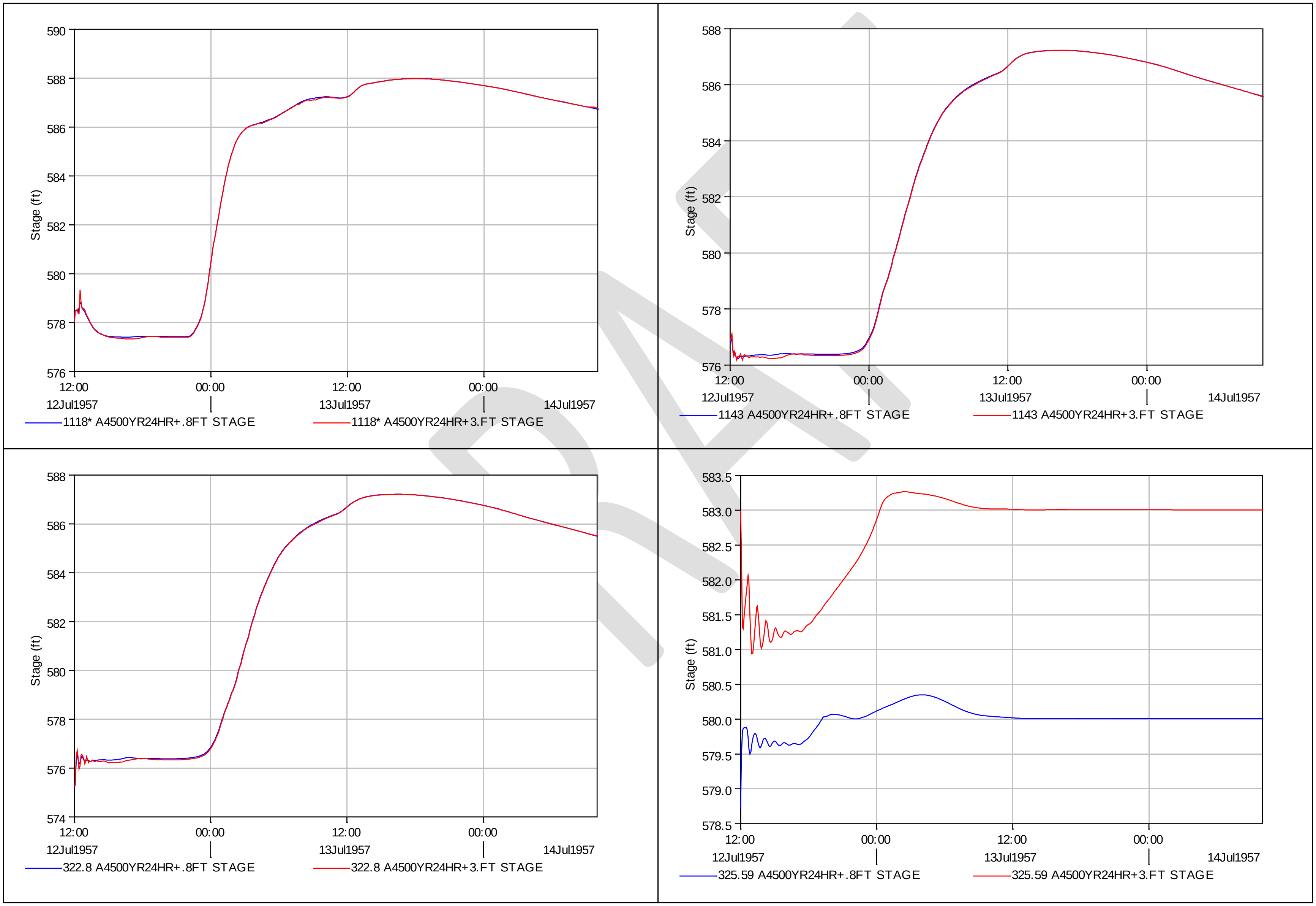


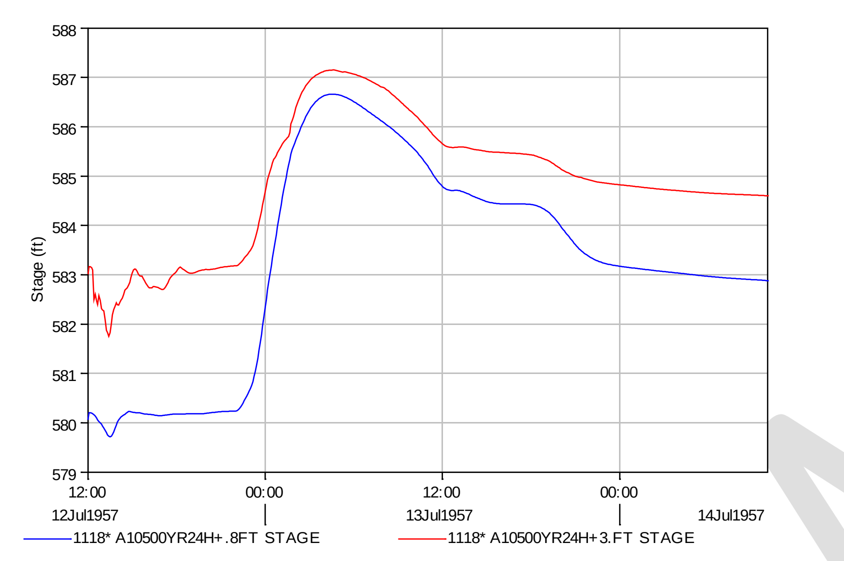



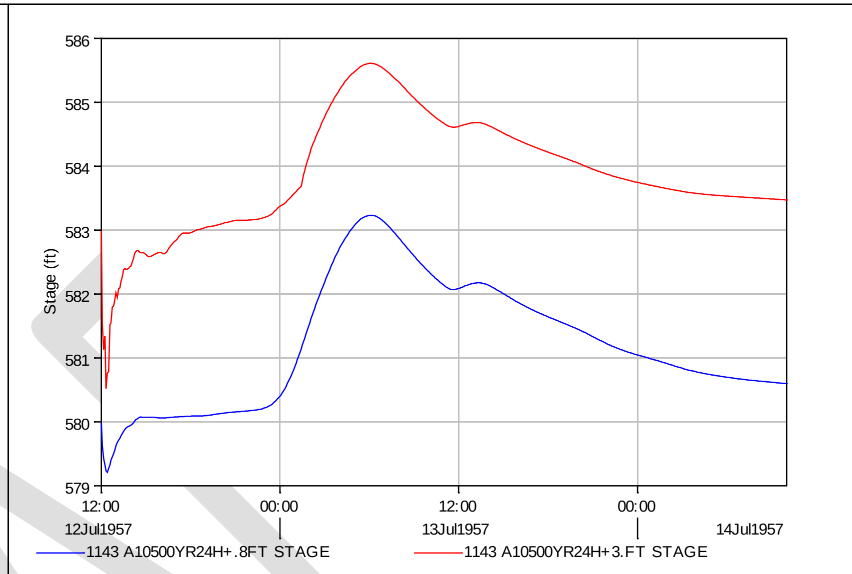



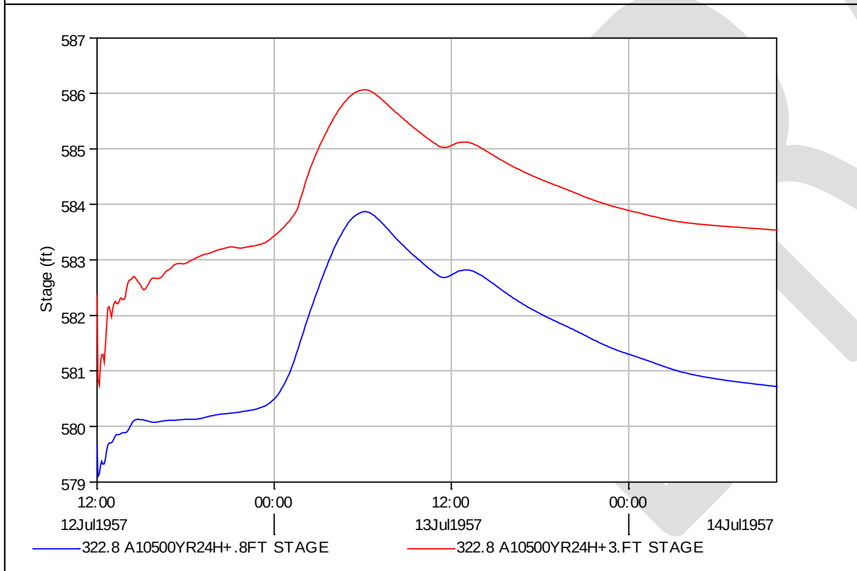
SCENARIO A4 – Lake Level 580 vs. 583

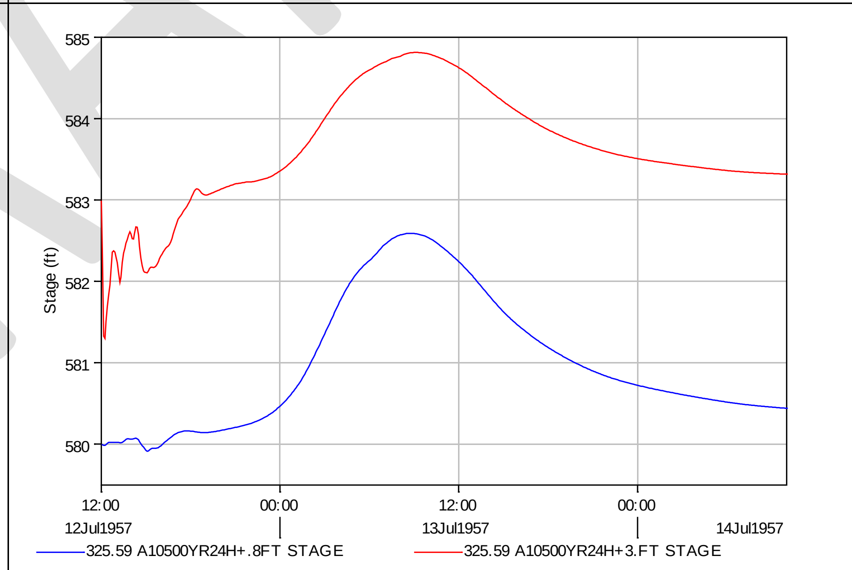


SCENARIO A10 – Lake Level 580 vs. 583



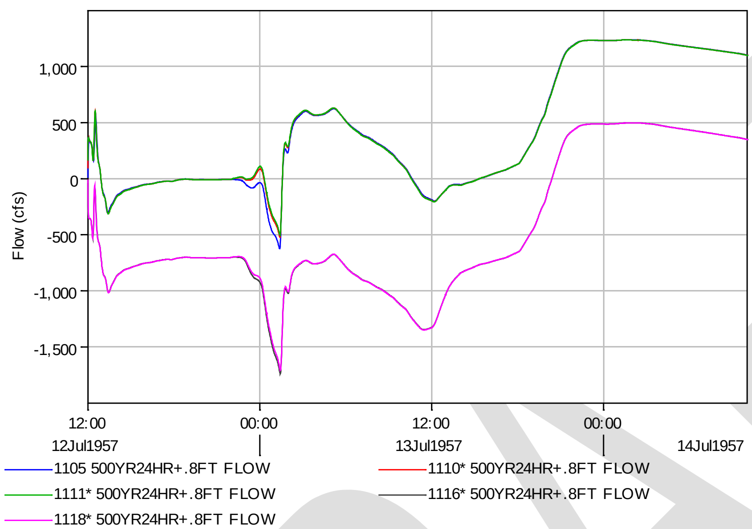



# OBSERVATIONS AND ENGINEER'S NOTES

Inflow from the Upper North Branch of Chicago River

Myth: Flood water would go north or south.

Preliminary Finding: With the 500yr/24hr storm event and inclusion of CUP reservoirs, the flow split in the northern part of the waterway system is located on the North Shore Channel during flow reversal. That is, the entire flow from the Upper North Branch of Chicago River upstream from Albany Avenue would flow towards south and exits the waterway system at CRCW.

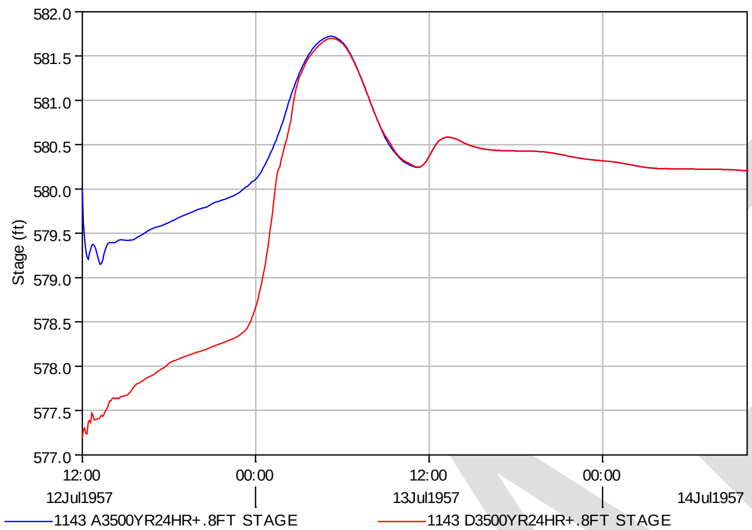



The split is at the outfall of the Northside WRP near RS 1113 (336.5). The above chart shows the discharge hydrographs at five distinct river stations: 1105 (336.866), 1110 (336.634), 1111 (336.588), 1116 (336.366) and 1118 (336.282). It clearly indicates that the flow pattern can be divided into two groups: the river stations north of the outfall (<1113) fall under the top curve, whereas the river stations south of the outfall (>1113) go with the bottom curve. The negative discharge points to south.

Floodwater Storage in Waterway

Myth: Flood water elevation would likely be lower if the initial pool level in the waterway is low.

Preliminary Finding: With the 500yr/24h storm event and inclusion of CUP reservoirs, the flood peaks on the waterway system appears to be not sensitive to the initial water surface elevation in the system.

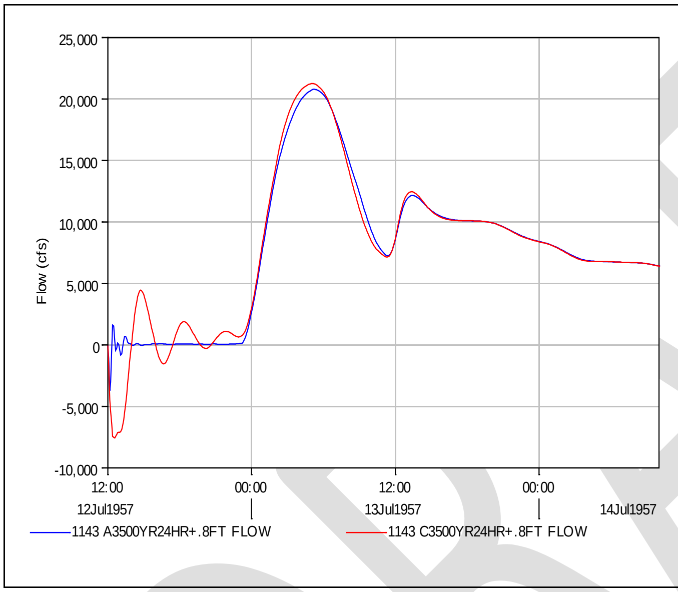


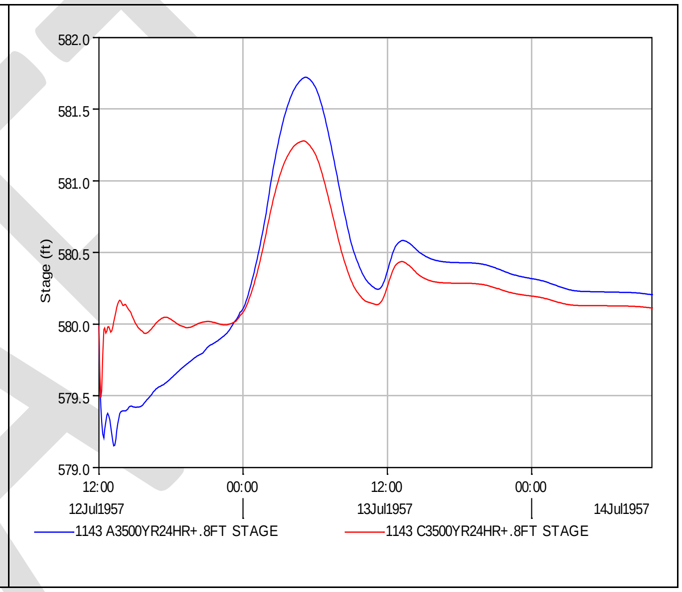

The above chart shows the simulated stages on the CSSC near Wolf Point (RS 1143/325.54) for Scenarios A3 versus D3. Both scenarios assumed a physical separation on the CSSC near the Stickney WRP outfall. However, the difference is that A3 assumed an initial stage of 580 ft CCD in the portion of waterway open to the lake, whereas D3 assumes an initial stage of 577.2 ft CCD and the retained lock would be opened at 580 ft CCD.

Discharge Computation through Lock Gates

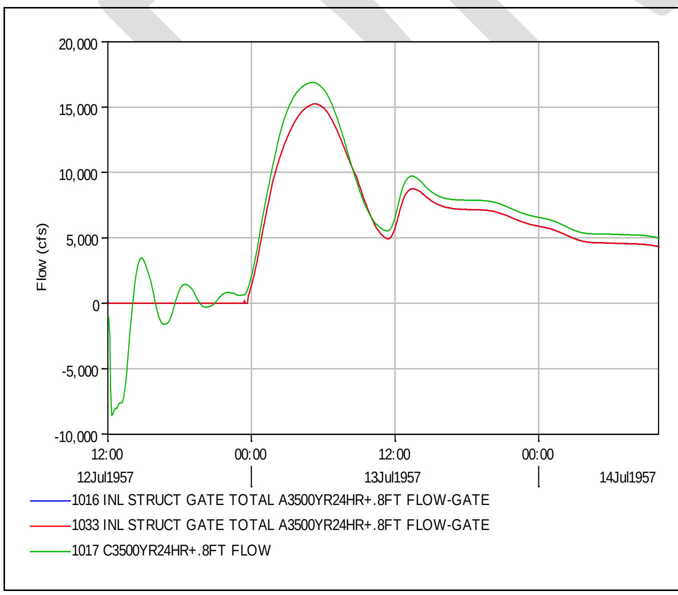
Myth: HEC-RAS has built-in discharge formula (or curves) for traditional hydraulic structures, i.e., weir, orifice, sluice gate, etc. The lock is not a typical hydraulic structure and it does not have a control point. Thus, the accuracy of computed flow through lock gates is doubtful.

Preliminary Finding: The computed discharge on the Chicago River near Wolf Point appears to be consistent by comparing the simulated results for treating the lock gate at CRCW as an overflow gate versus removing the lock gate completely and so that the lock channel behaves like an open channel directly connected to the approaching channel and turning basin. The water surface elevation, however, shows a difference about six inches. The reason for the head difference is yet to be determined.




The following chart shows the comparison of discharge within the lock chamber.



## Overbank Flooding

Myth: Under the existing baseline condition overbank flooding is a rare event.

Preliminary Finding: With the 500yr/24h storm event and inclusion of CUP reservoirs, the storage areas created to represent the low lying areas adjacent to the waterway show the flux of water and non-zero storage. It implies that localized overbank flooding does exist.

```
Profile Output Table - Storage Area
HEC-RAS  Plan: 500yr24hr+.8FT    Profile: Max WS

# Rivers           = 1
# Hydraulic Reaches = 1
# River Stations    = 72
# Plans            = 1
# Profiles         = 1
```

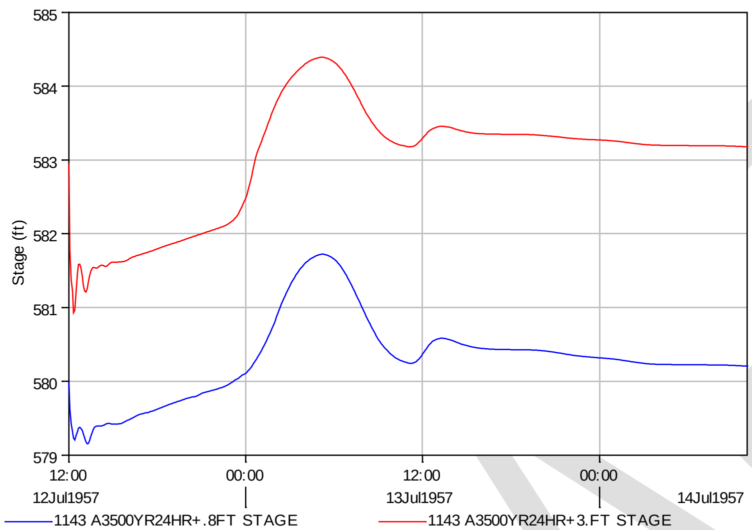
| Storage Area | Profile | W.S. Elev (ft) | SA Min El (ft) | Net Flux (cfs) | SA Area (acres) | SA Volume (acre-ft) |
|---|---|---|---|---|---|---|
| 101 | Max WS | 584.30 | 578.00 | 26.55 | 60.97 | 183.48 |
| 11 | Max WS | 580.70 | 560.00 | 5.18 | 2.73 | 56.52 |
| 12 | Max WS | 580.67 | 560.00 | 15.35 | 2.54 | 52.51 |
| 13 | Max WS | 580.48 | 560.00 | 295.94 | 2.67 | 54.68 |
| 14 | Max WS | 580.47 | 560.00 | 2.53 | 1.83 | 37.45 |
| 15 | Max WS | 580.45 | 560.00 | 84.77 | 2.71 | 55.42 |
| 18 | Max WS | 580.21 | 560.00 | -105.45 | 1.93 | 39.01 |
| 19 | Max WS | 580.10 | 560.00 | 52.20 | 3.60 | 72.35 |
| CR1 | Max WS | 581.05 | 548.35 | -22.55 | 621.62 | 18530.98 |
| CR10 | Max WS | 578.00 | 578.00 | 0.00 | 4.93 | 0.00 |
| CR100 | Max WS | 584.00 | 584.00 | 0.00 | 0.21 | 0.00 |
| CR101 | Max WS | 587.00 | 587.00 | 0.00 | 0.18 | 0.00 |
| CR102 | Max WS | 584.00 | 584.00 | 0.00 | 0.00 | 0.00 |
| CR11 | Max WS | 582.00 | 582.00 | 0.00 | 17.35 | 0.00 |
| CR12 | Max WS | 578.00 | 578.00 | 0.00 | 7.75 | 0.00 |
| CR13 | Max WS | 581.72 | 578.00 | 89.07 | 42.21 | 98.74 |
| CR14 | Max WS | 581.88 | 578.00 | 6.36 | 2.55 | 4.62 |
| CR15 | Max WS | 581.78 | 578.00 | 93.18 | 38.31 | 76.56 |
| CR16 | Max WS | 581.88 | 578.00 | 8.81 | 4.47 | 6.26 |
| CR17 | Max WS | 581.82 | 578.00 | 3.84 | 1.92 | 4.63 |
| CR18 | Max WS | 579.00 | 579.00 | 0.00 | 0.06 | 0.00 |
| CR19 | Max WS | 581.98 | 578.00 | 0.00 | 3.25 | 12.05 |
| CR2 | Max WS | 578.00 | 578.00 | 0.00 | 1.60 | 0.00 |
| CR20-1 | Max WS | 581.87 | 578.00 | 0.89 | 0.44 | 0.95 |
| CR21-1 | Max WS | 581.92 | 578.00 | 2.47 | 1.12 | 1.81 |
| CR21-2 | Max WS | 581.82 | 578.00 | 0.97 | 0.50 | 1.19 |
| CR22 | Max WS | 581.00 | 581.00 | 0.00 | 0.39 | 0.00 |
| CR3 | Max WS | 583.18 | 578.00 | 7.62 | 27.50 | 11.51 |
| CR4 | Max WS | 582.95 | 578.00 | 336.29 | 37.31 | 158.08 |
| CR5 | Max WS | 582.17 | 578.00 | 46.96 | 1.76 | 2.98 |
| CR6 | Max WS | 581.85 | 578.00 | 1322.44 | 104.11 | 207.51 |
| CR7-1 | Max WS | 578.00 | 578.00 | 0.00 | 0.99 | 0.00 |
| CR7-2 | Max WS | 578.00 | 578.00 | 0.00 | 0.01 | 0.00 |
| CR8 | Max WS | 578.00 | 578.00 | 0.00 | 0.16 | 0.00 |
| CR9 | Max WS | 580.89 | 578.00 | 0.53 | 6.24 | 13.59 |
| DowntownNorth | Max WS | 582.71 | 557.11 | 947.22 | 7.17 | 183.45 |
| DowntownSouth | Max WS | 584.79 | 585.00 | -3407.83 | 10.90 | -2.34 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Michigan | Max WS | 580.00 | 543.95 | 8649.84 | 1000000000000000.00 | 36049990000000000.00 |
| N18 | Max WS | 584.36 | 578.00 | 50.27 | 7.78 | 55.98 |
| N19 | Max WS | 583.89 | 578.00 | 5.48 | 5.29 | 36.13 |
| N2 | Max WS | 583.00 | 578.00 | 21.41 | 25.39 | 162.45 |
| N21 | Max WS | 584.35 | 578.00 | 2.22 | 8.15 | 59.36 |
| N22 | Max WS | 583.89 | 578.00 | 88.58 | 4.45 | 31.57 |
| N23 | Max WS | 583.50 | 578.00 | -52.03 | 12.35 | 82.88 |
| N24 | Max WS | 583.67 | 578.00 | 337.33 | 14.78 | 101.29 |
| N25 | Max WS | 583.50 | 578.00 | 268.61 | 12.21 | 81.24 |
| N26 | Max WS | 583.87 | 578.00 | 0.00 | 13.77 | 94.42 |
| N27 | Max WS | 582.27 | 578.00 | 77.38 | 18.81 | 91.39 |
| N28 | Max WS | 582.69 | 578.00 | 211.50 | 8.31 | 49.89 |
| N29 | Max WS | 583.35 | 578.00 | 0.00 | 11.41 | 48.95 |
| N3 | Max WS | 583.67 | 578.00 | 474.70 | 14.72 | 103.20 |
| N30 | Max WS | 582.79 | 578.00 | 13.34 | 6.17 | 37.70 |
| N31 | Max WS | 582.80 | 578.00 | 88.08 | 10.75 | 63.83 |
| N32 | Max WS | 582.80 | 578.00 | 309.13 | 14.23 | 81.36 |
| N33 | Max WS | 582.81 | 578.00 | 92.33 | 13.63 | 83.97 |
| N34 | Max WS | 582.81 | 578.00 | 107.99 | 13.86 | 80.73 |
| N35 | Max WS | 582.84 | 578.00 | 72.16 | 31.65 | 193.64 |
| N36 | Max WS | 582.88 | 578.00 | 18.19 | 22.03 | 128.80 |
| N37 | Max WS | 582.87 | 578.00 | 73.68 | 21.94 | 132.89 |
| N38 | Max WS | 582.85 | 578.00 | 108.85 | 11.70 | 71.65 |
| N39 | Max WS | 582.85 | 578.00 | 103.40 | 13.51 | 82.33 |
| N40 | Max WS | 582.85 | 578.00 | 44.17 | 10.91 | 67.24 |
| N41 | Max WS | 582.85 | 578.00 | 1.57 | 8.16 | 50.84 |
| N44 | Max WS | 583.94 | 578.00 | 0.00 | 10.93 | 77.79 |
| N45 | Max WS | 583.09 | 578.00 | 36.43 | 11.60 | 71.57 |
| N46 | Max WS | 585.91 | 578.00 | 0.00 | 12.46 | 107.32 |
| N47 | Max WS | 582.84 | 578.00 | 59.06 | 20.55 | 124.75 |
| N5 | Max WS | 565.00 | 565.00 | 0.00 | 0.50 | 0.00 |
| N6 | Max WS | 582.99 | 578.00 | -252.42 | 19.47 | 120.93 |
| N7 | Max WS | 583.00 | 578.00 | -39.33 | 11.97 | 75.55 |
| N8 | Max WS | 584.88 | 578.00 | 102.57 | 6.52 | 50.65 |
| N9 | Max WS | 584.88 | 578.00 | 140.88 | 6.35 | 49.61 |

Lake Level

Myth: Lake level may affect the water surface elevation in the waterway with segments of river open to Lake Michigan

Preliminary Finding: Modeling results confirmed this effect for the scenarios that certain reaches of the waterway are openly connected to Lake Michigan without any dam structures to regulate the stage.

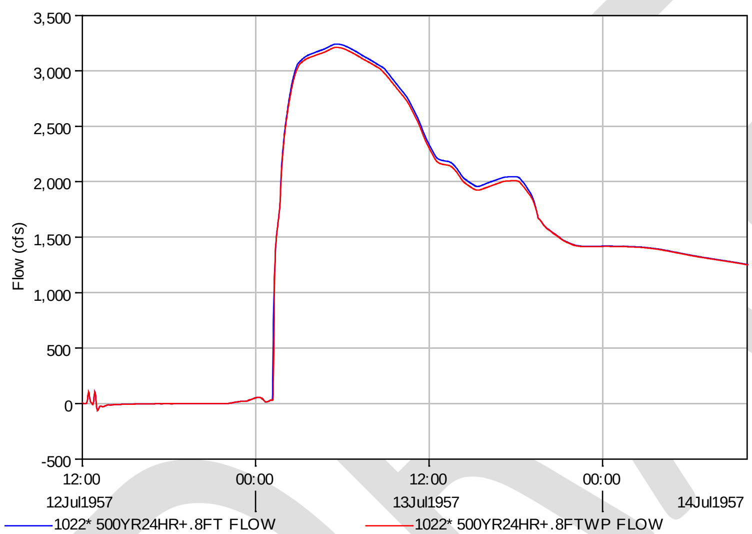



The peak stage on the Chicago River near Wolf Point is about 2.7-ft higher with the lake level at 583 ft CCD than that at 580 ft CCD.

Sluice Gate vs. Overflow Gate

Myth: The sluice gate at Wilmette Pumping Station is completely lifted off of water during the backflow operation. Neither the sluice gate nor the overflow gate appears to be a precise depiction of this hydraulic structure.

Preliminary Finding: With the 500yr/24h storm event and inclusion of CUP reservoirs, the simulated discharges in the NSC are nearly identical whether the gate is modeled as sluice gate or overflow gate. With the sluice gate, the gate is raised up from the bottom and allows flow through the opening at bottom. The flow eventually becomes weir flow after the lip of the gate goes above the water surface. On the other hand, the overflow gate is lowered from a high level down to the invert; the flow is always weir flow although the submergence effect may increase. Once the gate is fully open (after 18 minutes), the flow patterns for the above two types of gate representations are identical.

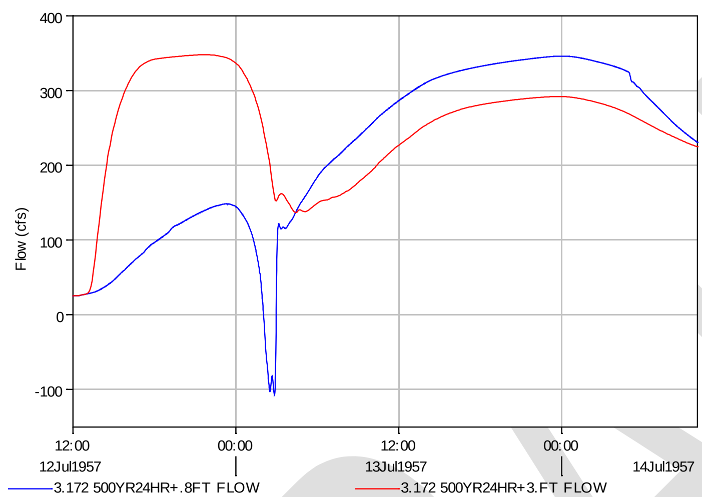



In theory, the sluice gate is a better representation than the overflow gate regardless the computed discharges show no major differences. Thus, the geometry of Wilmette Pumping Station will not be changed in future runs. In any rate, the discharge capacity (~15,000 cfs) for the gate at Wilmette Pumping Station appears to be much lower than that for the lock at CRCW (~3,250 cfs).

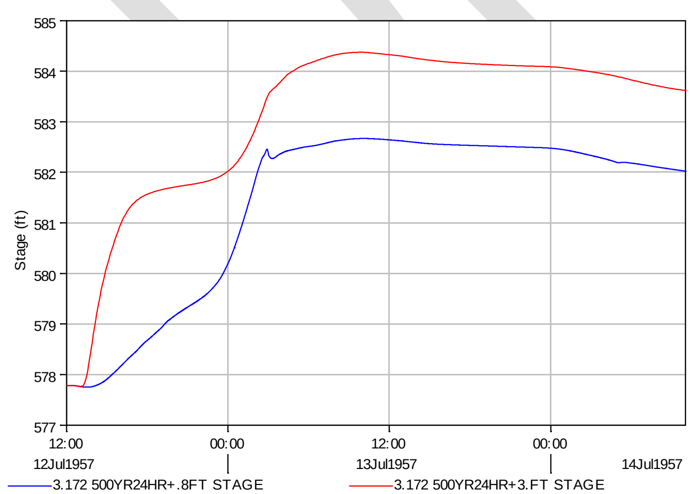
Complex Flow Conditions on Grand Calumet River

Myth: The water elevation and flow on the West Branch of Grand Calumet River will be controlled by O'Brien Lock to the west and the lake level. The flow divide on this river reach is located between the outfalls of Hammond and East Chicago SSTPs.

Preliminary Finding: The discharge gage on the Grand Calumet River at Hohman Avenue in Hammond has had more than 20 years of records. The largest peak discharges recorded at this gaging site were 701 cfs and 694 cfs for water years 1997 and 1992, respectively.




The discharge hydrographs in the above chart show that the maximum flow on the West Branch of Grand Calumet River for a 0.2% change flood is about 350 cfs, which is much lower than peak discharge records, and it is also lower than the coordinated 1% change flood discharge, 470 cfs, published by InDNR.




The effect of the lake level on the river stage is depicted in the chart above.

# ATTACHMENT K

# LAKEFRONT HYDROLOGIC SEPARATION FRM MITIGATION AND VARIATIONS

## Lakefront Hydrologic Separation FRM Mitigation and Variations

USACE has a very specific FRM mission. Any GLMRIS alternative that creates FRM impacts would require mitigation of those impacts. In this case, the PDT formulated the mitigation to FRM with the goal of having no stage increases on the CAWS. This means that under this alternative during storm events without mitigation the water level would rise above typical levels. The mitigation features for this alternative would then act in a way to maintain the normal water level in the CAWS during a storm. In this case, the storm the PDT designed for was the 0.2% chance storm event.

Since the flow of water in the CAWS backflows into Lake Michigan during the 0.2% chance storm event, the total volume of the water that would backflow would need to be captured to prevent an increase in stage levels on the CAWS. This backflow volume was determined from USACE's H&H model and is the basis of the reservoirs sizes in this alternative. The modeling resulted in a series of reservoirs that would be needed to accommodate the total volume of storm water and CSOs.

The first reservoir would be capable of holding 6.5 Billion Gallons (20,000 acre-feet) of water and is tentatively located in McCook (IL). This 6.5 Billion Gallon Reservoir would hold the storm water from the North Shore Channel, which would otherwise backflow through the Wilmette Pumping Station and the Chicago River, which would otherwise backflow through the Chicago Lock and Controlling Works.

The second reservoir would be capable of holding 9.1 Billion Gallons (28,000 acre-feet) of water and is tentatively located in Thornton (IL). This 9.1 Billion Gallon reservoir would hold the storm water from the Calumet and Grand Calumet Rivers, which would otherwise backflow through the TJ O'Brien Lock and out Indiana Harbor.

The third and final reservoir in this alternative would be capable of holding 4.4 Billion Gallons (13,500 acre-feet) of water and is tentatively located in Thornton (IL). This 4.4 Billion Gallon Reservoir would hold the storm water along the Little Calumet River. The Little Calumet reservoir is separate from the 9.1 Billion Gallon Reservoir holding the Calumet and Grand Calumet flood waters because the Little Calumet flood water will be collect on the LAKE SIDE of the physical barrier in Hammond (IL). Since the flood waters will be collected from two separate basins, they cannot be mixed together in the same reservoir because that would not meet the GLMRIS definition of Hydrologic Separation.

Initially the third reservoir was not a reservoir, but a rather it was a tunnel sized to convey the flood waters from the Little Calumet River directly to Lake Michigan. Under existing conditions flow on the Grand Calumet River and Little Calumet River flows towards the Mississippi River and Great Lakes basins. In earlier iterations, the PDT believed that a tunnel routing this water to Lake Michigan would be the preferred solution because it would mimic existing conditions. Upon consulting stakeholders it became apparent that this would lead to intolerable water quality degradation. Thus the PDT developed an alternative that would preserve lake water quality while still meeting the flood risk concerns. This led the PDT eventually to the solution to collect the storm water from the Hart Ditch and Little Calumet River junction and convey the storm water via tunnel to a reservoir near Thornton (IL).

Sizing the reservoirs was the first step in determining the mitigation for this alternative. The second step was determining how to get the flood waters from the CAWS to the reservoirs. There would need to be conveyance with the capacity to handle the flow and volume associated with the 0.2% chance storm event.

To effectively capture and convey the storm water for these reservoirs a series of conveyance tunnels would be needed. These tunnels would be extremely similar to the existing TARP tunnels, and likely located around 300 feet underground. To capture the water from the North Shore Channel a 13.1 mile long, 22 foot diameter tunnel would run approximately under the channel to the Chicago Lock. At the Chicago Lock it would join a new tunnel that also captures storm water from the Chicago River. This new tunnel would then run to the new 6.5 Billion Gallon Reservoir at McCook (IL) and would be 12.5 miles long and 42 feet in diameter. These tunnels would address the Chicago River branch of the CAWS.

For the Calumet branch of the CAWS, there would be a tunnel starting near the physical barrier in Calumet City (IL) and would discharge into the new 9.1 Billion Gallon reservoir in Thornton (IL). This tunnel would be 5.5 miles long and 30 feet in diameter.

The last tunnel in this alternative is the previously mentioned Hammond (IL) tunnel. This tunnel would run from the Lakeside of the physical barrier at Hammond (IL) to a new 4.4 Billion Gallon Reservoir at Thornton (IL). The tunnel would be 7.2 miles long and 14 feet in diameter.

The third part of the FRM mitigation is to return the water stored in the reservoirs back to the CAWS. As is the case with traditional reservoirs, the storm water stored in the reservoirs in this alternative would be returned to the CAWS when water levels returned to pre-storm conditions to ensure they would not be a burden on the system. The 6.5 Billion Gallon Reservoir at McCook (IL) and the 9.1 Billion Gallon Reservoir at Thornton (IL) both collect water from the River Side of their respective physical barriers and would return their water to the River Side of the CAWS. As previously stated, the 4.4 Billion Gallon Reservoir at Thornton (IL) would collect water from the Lake Side of the Hammond (IN) physical barrier and the water would be returned to the Lake Side.

At first the PDT planned on merely storing the water in their respective reservoirs, with aeration systems to prevent the water from becoming stagnant, and then returning the water to the CAWS under normal (non-storm) conditions. After many discussions with various stakeholder groups, the PDT felt that this would not be the most complete (permittable) plan because it did not treat the captured CSOs that would be stored in the reservoir before returning it to the CAWS. While current conditions allow the CSOs to enter the CAWS, by storing them in the reservoir and releasing them at a later time, this alternative would in effect be increasing the concentration of the CSO contaminants in the CAWS because water levels are lower during normal conditions than they are during storm conditions. The PDT determined the most appropriate course of action would be to treat any storm water detained in a reservoir to the same WQ standards as the existing Stickney WRP before returning it to the CAWS.

This determination of the PDT resulted in the combination of the 9.1 Billion Gallon (River Side) reservoir and the 4.4 Billion Gallon (Lake Side) reservoir in Thornton (IL). Again, these reservoirs were originally kept separate because they stored untreated water from different basins; by treating the water in the reservoirs, under the GLMRIS definition of hydrologic separation, the water can be combined in one single location for a reservoir with a total volume of 13.5 Billion Gallons. This combined reservoir would discharge it’s volume of water to the river side of the CAWS, which would further alleviate any concerns about the difference in WQ standards for Lake Michigan versus that of the CAWS.

The final FRM mitigation measures for the Lakefront Hydrologic Separation Alternative are:

- New 6.5 Billion Gallon Reservoir at McCook (IL) would address FRM impacts on the CSSC, Chicago River and North Shore Channel of the system.
- Conveyance Tunnel from Wilmette (IL) to Chicago (IL) estimated at 13 miles long and 22 foot diameter.
- Conveyance Tunnel from Chicago (IL) to McCook (IL) estimated at 13 miles long and 42 foot diameter.
- A new 13.5 Billion Gallon Reservoir at Thornton (IL) would address FRM impacts on the Cal-Sag channel, Calumet, Grand Calumet and Little Calumet Rivers in the system.
- Conveyance Tunnel from Calumet City (IL) to Thornton (IL) estimated at 6 miles long and 30 foot diameter.
- Conveyance Tunnel from Hammond (IN) to Thornton (IL) estimated at 7 miles long and 14 foot diameter.

# ATTACHMENT L

# NEGATIVE ENVIRONMENTAL IMPACTS

**Negative Environmental Impacts**

The environment is defined as the totality of physical and biological factors (climate, soil, living things, etc.) surrounding an organism or group of organisms that influences the growth, development and survival of organisms. An environmental impact is a change in the environment that could have a negative effect on or non-desirable alteration of the environment under consideration. For instance, an impact could be caused by a land development, industrial, or infrastructural project or by the release of a substance. The effect of these activities can result in loss of native plant cover, mortality of desirable wildlife species, decrease in regional biodiversity and levels of pollution harmful to human health. The following section describes potential negative environmental impacts that may result from the implementation of the GLMRIS Alternative Plans.

At this time, the GLMRIS Team has not identified any threatened or endangered species that move through the aquatic pathways of the CAWS. If an alternative proceeds to implementation, the study team in conjunction with the USFWS will determine if T&E species would be affected or not based on the site specific locations of the components of the alternative. Any ANS Control selected for further study would be planned and designed to efficiently and cost-effectively accommodate the needs of endangered and threatened species and critical habitats. Any measures adopted by the USACE to implement its ESA responsibilities would be within the Corps' legal authorities, consistent with the Corps' missions and responsibilities, and feasible from both a technological and economic point of view.

**No New Federal Action**

This alternative would not involve new actions being taken by the USACE to impede the transfer of Aquatic Nuance Species (ANS) between basins. No new actions would result in no new negative environmental impacts.

**Nonstructural Alternative**

Measures would include a variety of treatment and control methods including, anti-fouling substance, biological control, chemical (e.g., pesticides), mechanical and physical methods of removing, screening, killing and otherwise targeting known and suspected populations of ANS. Anti-fouling materials applied to boat hauls are intended to inhibit the attachment of live organisms or fragments of organisms and subsequently their transport through aquatic water bodies as hitch hikers. The intent of some of the anti-fouling substances is the slow release of chemicals into the area surrounding the boat. These chemicals can be harmful to non-target organisms and could result in impacts to native fauna and flora. Biological control is the intentional release of a new organism into the environment with the intention of reducing or eradicating a target nuisance species. Historically, frequencies of successful releases of biocontrol organisms have been less than desired. Some biocontrol organisms have become nuisance species themselves and have negatively altered their new environment causing as much if not more harm than their intended target. However, increased rigorous extended testing periods have reduced the deliberate introduction of environmentally harmful biocontrol agents. Use of pesticides to kill or injure organisms could result in the release of chemicals into the environment. Some pesticides are general (non-selective) in nature and will kill or harm any organism it comes into to contact with. For example, rotenone is a general pesticide (pesticides being an umbrella term used to define any application of a substance formulated to kill a non-desirable organism) that will kill any fish within the area treated. Pesticides used in a manner not in compliance with manufacture's specifications may result in harm or death of humans in contact with the pesticide. Some pesticides may stay active in the environment after application and may migrate to untreated areas causing unintended harm to non-target organisms. Mechanical removal will remove all organisms within the treated area, causing harm to non-target species. Aquatic plant harvesting equipment (mechanical method) may be designed to remove all but fragments of the aquatic plant biomass within a treated area, removing invasive and desirable native plant species and smaller wildlife species living within the plant material. Other physical removal methods such as fish nets may also catch and cause mortality or harm to non-target aquatic wildlife species, such as desirable game fish and reptiles. The effects of these potential non-structural measures would include direct mortality of non-target species, reduction in native plant and wildlife species within treated areas, reduction in regional biodiversity with the loss of non-target species and alteration of ecosystem function with loss of biodiversity. The following alternatives include non-structural measures as a feature, thus, all of the abovementioned impacts would apply to all proceeding alternatives.

The implementation of this alternative would result in a Low negative impact to the environment, because of the harmful effects of the various control methods, but somewhat limited in the landscape to the CAWS or area of known or suspected populations of ANS.

**Mid-System Control Technologies without a Buffer Zone**

This alternative involves constructing two GLRMIS Lock structures with their associated water treatment plants, one in Stickney and the other in Alsip, Illinois. In general, construction activities would result in a temporary impact to air quality from the release of dust particulates. Also, there would be temporary water quality impact from construction activities within a waterbody as a result from the disturbance of bottom substrate and increased sediment transport. The GLMRIS Lock would include an electric barrier on each end, approaching and leaving the lock. Electric barriers are non-selective in their treatment of aquatic species, harming or killing many that come into contact with the electric field. Also, non-aquatic wildlife that swim or fall into the electric barrier will also be harmed or kill (e.g., raccoon, deer, otter, muskrat, etc.). Building the GLRMIS Lock, lock and electric barrier operations building, ANS water treatment plant, storm water conveyance tunnel and reservoir additions would develop approximately 513-acres of lands and waterways. The land that would be developed is predominantly disturbed soil (e.g., urban fill) from previous land development projects in the region. The primary vegetation cover is old field secondary succession of shrubs and trees, with a patchy herbaceous layer. The dominant vegetation is non-native in origin and weedy (e.g., invasive plant species). Generalist wildlife species that utilize edge habitat and tolerate close proximity to human activities occur in these habitats, they are very common within the region. Although dominant vegetation is non-native in origin, migratory bird species use vegetated areas for resting and foraging during migration. These species are funneled through this area by way of the Southern Lake Michigan flyway. Loss of vegetative cover, generalist wildlife habitat and migratory stopover points would be direct impacts of the land development activities. The construction of the GLRMIS Lock would not significantly alter the already homogenized aquatic habitat (e.g., substrate and geomorphololgy of stream channel) within the CAWS. The ANS water treatment plant would treat all organism collected, a non-selective application of treatment. This would impact native fish and other native aquatic organisms that make up the food web of the CAWS. This disruption would impact ecosystem function and structure. Additionally, non-structural measures would include anti-fouling substance, biological control, chemical (e.g., pesticides), mechanical and physical methods of removing, screening, killing and otherwise targeting known and suspected populations of ANS. These methods are in large part non-selective in nature and would result in harm or mortality to desirable native fauna and flora.

The negative impact of this alternative will be medium because of the effects of localized land development, non-selective treatment of CAWS water and electric barriers.

**Control Technology with Buffer Zone**

Alternative includes a new water control structure at Wilmette and three GLMRIS Lock structures, 1) near current Chicago Lock, 2) TJ O'Brien Lock, 3) Brandon Road Lock, and two physical separation barriers, one on the Grand Calumet River and the other near Hammond, IN along the Little Calumet River. The development of lands and waterways would total approximately 314-acres. Construction activities would result in a temporary impact to air quality from the release of dust particulates. Also, there would be temporary water quality impact from construction activities within a waterbody as a result from the disturbance of bottom substrate and increased sediment transport. Electric barriers, which are a part of the GLMRIS Locks, are non-selective in their treatment of aquatic species, harming or killing many that come into contact with the electric field. Also, non-aquatic wildlife that swim or fall into the electric barrier will also be harmed or killed (e.g., raccoon, deer, otter, muskrat, etc.).The footprint of the water control structure and ANS removal treatment plant at Wilmette would impact previously disturbed habitat of low quality to regional wildlife. Vegetative cover is predominantly mowed lawn with a perimeter of non-native and aggressive weedy native trees and shrubs. Although dominant vegetation is non-native in origin, migratory bird species use vegetated areas for resting and foraging during migration. These species are funneled through this area by way of the Southern Lake Michigan flyway. The effect of land development at Wilmette would result in the loss of low quality vegetation and wildlife habitat. The construction of the water control structure is predominantly within the foot print of the current water control structure, resulting in minimal disturbance outside of the current infrastructure. The construction of a GLRMIS Lock near the current Chicago Lock would not significantly alter the current function of this section of the CAWS. The section is within the highly urbanized and built up Chicago downtown area that is dominated by sheet pile, concrete embankments and rip rap stream banks resulting in almost no vegetation or suitable wildlife habitat. The construction of the GLMRIS Lock at TJ O'Brien would involve filling in a section of the CAWS upstream of the approach channel. Although this aquatic habitat is highly degraded from navigation and maintenance activities, the filling in of this area would result in the loss of aquatic habitat. The construction of the lock and dam at TJ O'Brien would result in minimal alteration of the aquatic habitat within the CAWS due to the current level of degradation. The construction of the ANS removal treatment plant at TJ O'Brien would develop an area that is predominantly disturbed soil from previous land development projects in the region. Similar to other disturbed areas within the region, the area is dominated by non-native and invasive plant species, although regional wildlife species do occur within these secondary successional patches. Development of this area for the ANS removal treatment plant would result in the loss of vegetative cover and low quality wildlife habitat. The construction of the GLMRIS Lock and associated ANS removal treatment plant at Brandon Road Lock would mirror impacts described for the TJ O'Brien with the exception of filling in part of the CAWS upstream of the approach channel. The two physical separation barriers along the Grand Calumet and Little Calumet Rivers would impede the dispersal of native species within their respective rivers. Native fish need the ability to disperse within these two rivers to forage and find suitable breeding habitat. Native mussels depend on fish to disperse as a part of their reproductive cycle. Populations would become fragmented. This could lead to degradation of the genetic pool through genetic drift and possibly extirpation of vulnerable populations. Habitat fragmentation within these rivers will also cause a disruption of energy and material flow between fragments, impacting the base of the food chain, with cascading effects throughout the food web. Implementation of physical separation barriers within the Grand Calumet and Little Calumet Rivers will impact regional native populations and ecosystem function and structure. The result could be the extirpation of vulnerable native species and disruption of the food web. Additionally, non-structural measures would include anti-fouling substance, biological control, chemical (e.g., pesticides), mechanical and physical methods of removing, screening, killing and otherwise targeting known and suspected populations of ANS. These methods are in large part non-selective in nature and would result in harm or mortality to desirable native fauna and flora.

The implementation of this alternative would result in a high negative impact to the environment because of the effects of the GLMRIS Locks, electric barriers and physical separation barriers.

**Lakefront Hydrologic Separation**

Project features include physical separation barriers at Wilmette, near Chicago Lock, Calumet City, IL (Grand Calumet river) and Hammond, IN (Little Calumet River). In addition to the barriers there will be an ANS removal treatment plant at Wilmette, Chicago and Hammond, IN. The approximate amount of lands and waters developed as a result of project features is 544-acres. Construction activities would result in a temporary impact to air quality from the release of dust particulates. Also, there would be temporary water quality impact from construction activities within a waterbody as a result from the disturbance of bottom substrate and increased sediment transport. A physical separation barrier at Wilmette will fragment the North Branch of the Chicago River from Lake Michigan. Even though this connection is intermittent because of the operations of the current water control structure, this did allow native species to disperse between Lake Michigan and the Chicago River. In combination with a physical barrier within the Chicago Lock, this would completely disconnect the Chicago River from Lake Michigan. The impact of these barriers would impede native species from moving between the Lake and the Chicago River. The effect of fragmentation could result in the local extirpation of native aquatic species that depend on the ability to move between the river and the lake for breeding and foraging. The two physical separation barriers along the Grand Calumet and Little Calumet Rivers would impede the dispersal of native species within their respective rivers. Native fish need the ability to disperse within their respective rivers to forage and find suitable breeding habitat. Native mussels depend on fish to disperse as a part of their reproductive cycle. Populations would become fragmented. This could lead to degradation of the genetic pool through genetic drift and possibly extirpation of vulnerable populations. Habitat fragmentation within these rivers will also cause a disruption of energy and material flow between fragments, impacting the base of the food chain, with cascading effects throughout the food web. Implementation of physical separation barriers within the Grand Calumet and Little Calumet Rivers will impact regional native populations and ecosystem function and structure. The result could be the extirpation of vulnerable native species and disruption of the food web. Additionally, non-structural measures would include anti-fouling substance, biological control, chemical (e.g., pesticides), mechanical and physical methods of removing, screening, killing and otherwise targeting known and suspected populations of ANS. These methods are in large part non-selective in nature and would result in harm or mortality to desirable native fauna and flora.
The implementation of this alternative would result in a high negative impact to the environment because of the effects of the physical separation barriers.

**Mid-System Hydrologic Separation**

Alternative includes physical separation barriers and ANS removal treatment plants at Stickney and Alsip. There are approximately 582-acres of lands and waters to be developed associated with this alternative. Generally, construction activities would result in a temporary impact to air quality from the release of dust particulates. Also, there would be a temporary water quality impact from construction activities within a waterbody as a result from the disturbance of bottom substrate and increased sediment transport. The Stickney separation barrier is located close to the previous separation point between the Mississippi River and Great Lakes Basins. This location will impact the ability of native aquatic species to disperse between basins and therefore between populations, but it is ultimately reversing an environmental impact from previous human activities. The physical separation barrier at Alsip will fragment the Cal-Sag channel such that native aquatic species will no longer be able to freely move within the channel, however, the barrier is located close to the original divide between basins. This is a reversal of a previous negative environmental impact and the effects will be a temporary period of adjustment for native aquatic species. The foot print of the barrier will be a loss of low quality aquatic habitat. Additionally, non-

structural measures would include anti-fouling substance, biological control, chemical (e.g., pesticides), mechanical and physical methods of removing, screening, killing and otherwise targeting known and suspected populations of ANS. These methods are in large part non-selective in nature and would result in harm or mortality to desirable native fauna and flora.
The implementation of this alternative would result in a Low negative impact to the environment, because of the temporary period of adjustment for native populations to the reversal of pervious environmental degradation.

**Mid-System Separation Cal-Sag Open Control Technologies with a Buffer Zone**

Physical separation barriers at Stickney, Grand Calumet River and Little Calumet River, and GLRMIS Locks at TJ O'Brien Lock and Brandon Road Lock are features of this alternative. The approximate total lands and waters impact is 601-acres. Generally, construction activities would result in a temporary impact to air quality from the release of dust particulates. Also, there would be temporary water quality impact from construction activities within a waterbody as a result from the disturbance of bottom substrate and increased sediment transport. The impacts of the physical separation barriers on the Grand Calumet and Little Calumet Rivers would result in the fragmentation of the aquatic habitat for regional populations of flora and fauna. Habitat fragmentation could result in the extirpation of vulnerable populations within these rivers and a disruption of energy and material flow leading to a degradation of ecosystem function. The Stickney separation barrier is located close to the previous separation point between the Mississippi River and Great Lakes Basins. This location will impact the ability of native aquatic species to disperse between basins and therefore between populations, but it is ultimately reversing an environmental impact from previous human activities. The foot print of the barrier will result in a loss of low quality aquatic habitat. Electric barriers, which are a part of the GLMRIS Locks, are non-selective in their treatment of aquatic species, harming or killing many that come into contact with the electric field. Also, non-aquatic wildlife that swim or fall into the electric barrier will also be harmed or killed (e.g., raccoon, deer, otter, muskrat, etc.). The construction of the GLMRIS Lock at TJ O'Brien would involve filling in a section of the CAWS upstream of the approach channel. Although this aquatic habitat is highly degraded from navigation and maintenance activities, the filling in of this area would result in the loss of aquatic habitat. The construction of the lock and dam at TJ O'Brien would result in minimal alteration of the aquatic habitat within the CAWS due to the current level of degradation. The construction of the ANS removal treatment plant at TJ O'Brien would develop an area that is predominantly disturbed soil from previous land development projects in the region. Similar to other disturbed areas within the region, the area is dominated by non-native and invasive plant species, although regional wildlife species do occur within these secondary successional patches. Although dominant vegetation is non-native in origin, migratory bird species use vegetated areas for resting and foraging during migration. These species are funneled through this area by way of the Southern Lake Michigan flyway. Development of this area for the ANS removal treatment plant would result in the loss of vegetative cover and low quality wildlife habitat. The construction of the GLMRIS Lock and associated ANS removal treatment plant at Brandon Road Lock would mirror impacts described for the TJ O'Brien with the exception of filling in part of the CAWS upstream of the approach channel. Additionally, non-structural measures would include anti-fouling substance, biological control, chemical (e.g., pesticides), mechanical and physical methods of removing, screening, killing and otherwise targeting known and suspected populations of ANS. These methods are in large part non-selective in nature and would result in harm or mortality to desirable native fauna and flora.

The implementation of this alternative would result in a high negative impact to the environment because of the effects of the GLMRIS Locks, electric barriers and physical separation barriers.

**Mid- System Separation CSSC Open Control Technologies with a Buffer Zone**

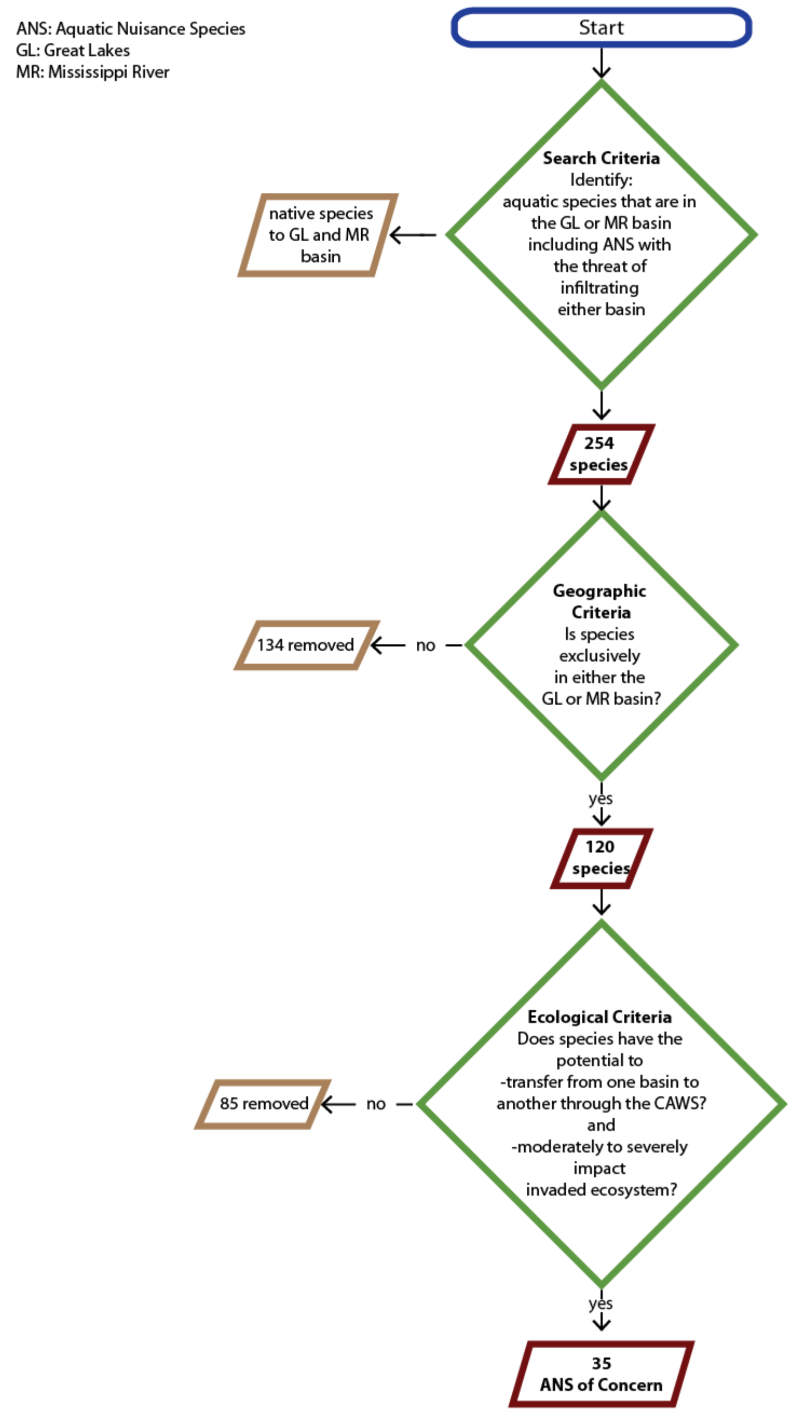
This alternative includes an improved water control structure and ANS removal treatment plant at Wilmette, GLMRIS Locks near current Chicago Lock and Brandon Road Lock and one physical separation barrier at Alsip, IL. There is approximately 318-ascres of lands and waters impacts as a result of the development of project features. In general, construction activities would result in a temporary impact to air quality from the release of dust particulates. Also, there would be temporary water quality impact from construction activities within a waterbody as a result from the disturbance of bottom substrate and increased sediment transport. Electric barriers, which are a part of the GLMRIS Locks, are non-selective in their treatment of aquatic species, harming or killing many that come into contact with the electric field. Also, non-aquatic wildlife that swim or fall into the electric barrier will also be harmed or killed (e.g., raccoon, deer, otter, muskrat, etc.).The footprint of the water control structure and ANS removal treatment plant at Wilmette would impact previously disturbed ground of low quality to regional wildlife. Vegetative cover is predominantly mowed lawn with a perimeter of non-native and weedy aggressive native trees and shrubs. Although dominant vegetation is non-native in origin, migratory bird species use vegetated areas for resting and foraging during migration. These species are funneled through this area by way of the Southern Lake Michigan flyway. The effect of land development at Wilmette would result in the loss of low quality vegetation and wildlife habitat. The construction of the water control structure is predominantly within the foot print of the current water control structure, resulting in minimal disturbance outside of the current infrastructure. The construction of a GLRMIS Lock near the current Chicago Lock would not significantly alter the current function of this section of the CAWS. The section is within the highly urbanized and built up Chicago downtown area that is dominated by sheet pile, concrete embankments and rip rap stream banks resulting in almost no vegetation or suitable wildlife habitat. The construction of the lock and dam at Brandon Road would result in minimal alteration of the aquatic habitat within the CAWS due to the current level of degradation. The construction of the ANS removal treatment plant at Brandon Road would develop an area that is predominantly disturbed soil from previous land development projects in the region. Similar to other disturbed areas within the region, the area is dominated by non-native and invasive plant species, although regional wildlife species do occur within these secondary successional patches. Although dominant vegetation is non-native in origin, migratory bird species use vegetated areas for resting and foraging during migration. These species are funneled through this area by way of the Southern Lake Michigan flyway. Development of this area for the ANS removal treatment plant would result in the loss of vegetative cover and low quality wildlife habitat. The physical separation barrier at Alsip will fragment the Cal-Sag channel such that native aquatic species will no longer be able to freely move within the channel, however, the barrier is located close to the original divide between basins. This is a reversal of a previous negative environmental impact and the effects will be a temporary period of adjustment for native aquatic species. The foot print of the barrier will be a loss of low quality aquatic habitat. Additionally, non-structural measures would include anti-fouling substance, biological control, chemical (e.g., pesticides), mechanical and physical methods of removing, screening, killing and otherwise targeting known and suspected populations of ANS. These methods are in large part non-selective in nature and would result in harm or mortality to desirable native fauna and flora.

The negative impact of this alternative will be medium because of the effects of localized land development, non-selective treatment of CAWS water and electric barriers.

# ATTACHMENT M

# ANS SCREENING PROCESS FLOWCHART

ANS of Concern Screening Process




<u>ANS Established in the Great Lakes Basin with potential to transfer into the Mississippi River Basin:</u>
threespine stickleback, sea lamprey, water flea, swamp sedge, testate amoeba, grass kelp, water chestnut, diatom, red macro-algae, reed sweetgrass, European stream valvata, greater European pea clam, European fingernail clam, fish-hook water flea, harpacticoid copepod, parasitic copepod, tubenose goby, bloody red shrimp, blueback herring, cryptic algae, bryozoans, ruffe, and VHS.

<u>ANS Established in the Mississippi River Basin with potential to transfer into the Great Lakes Basin:</u>
marsh dewflower, northern snakehead, skipjack herring, silver carp, scud, bighead carp, black carp, Cuban bulrush, dotted duckweed, and inland silverside.

# ATTACHMENT N

# CAWS TOPOGRAPHIC MAP

Topographic Map of the Chicago Area Waterway System