APPENDIX E

STATE RARE SPECIES PROTECTION PLANS

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Connecticut River
Hydrilla Control Research and Demonstration Project
Lower Connecticut River, CT

Species Protection Plan
Chester Creek
Chester, CT

US Army Corps of Engineers ®
New England District

February 2025

Chester Creek Species Protection Plan

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1. Introduction

1.1 Connecticut River Hydrilla Information

Hydrilla (*Hydrilla verticillata*) was first identified in the Connecticut River near Glastonbury, CT in 2016 and has since spread south to Essex, CT infesting the river's many coves, tributaries, and boat basins. The Connecticut River hydrilla population has been shown to be genetically distinct from other known hydrilla strains (Tippery, et al., 2020), and the plant's biology is therefore largely unknown at this time. Following the discovery of the highly invasive aquatic plant in the Connecticut River in 2016, intensive vegetation surveys were conducted in 2019 and 2020 from Agawam, MA south to Long Island Sound to map the invasion extent. Hydrilla was found as far north as Agawam, MA, confirming that the plant spreads rapidly which poses significant risk to other regional waterbodies (Bugbee & Stebbins, 2022). Fragments of the plant, which are easily transported by boats and boat trailers, can sprout roots to establish new populations. Fragments also float and are capable of dispersing via wind and water currents. Due to the importance of the Connecticut River as an environmental resource and driver of the local economy, stakeholders are seeking an aggressive hydrilla management program.

1.2 Project Background

The U.S. Army Corps of Engineers (USACE), through its Engineer Research and Development Center's (ERDC) Aquatic Plant Control Research Program, is leading a research and demonstration project to verify the effectiveness of aquatic herbicides registered for use by the U.S. Environmental Protection Agency (EPA) to reduce and control the spread of the Connecticut River hydrilla safely and selectively. The project has been investigating hydrilla's growth patterns, site-specific water exchange dynamics and evaluating herbicide efficacy in laboratory conditions throughout 2023 to guide operational scale field demonstrations of herbicide efficacy in 2024. Chester Creek has been selected as a hydrilla treatment site for ERDC's 2025 field demonstration project.

1.3 Chester Creek Treatment Site

Chester Creek is a tidal creek off the mainstem of the Connecticut River located in Chester, Middlesex County, CT and centered at 41.409° N, 72.435° W. The treatment area is 37.9 acres with an estimated mean depth of 9 feet mean higher high water. The tidal creek contains multiple marinas and a yacht club.

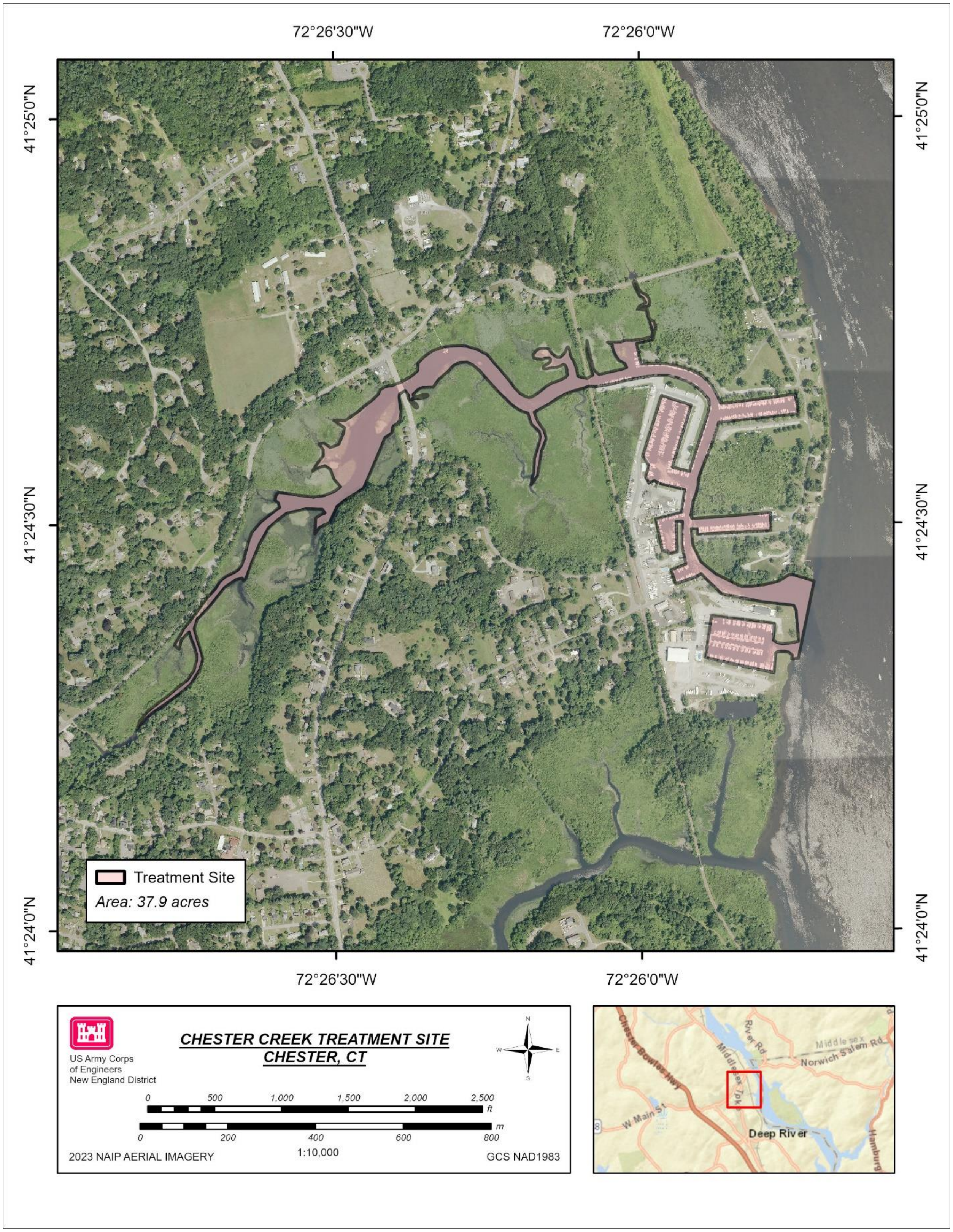

Figure 1. Chester Creek hydrilla treatment area in Chester, CT.

2. Proposed Treatment Activity

Diquat, dipotassium salt of endothall, florpyrauxifen-benzyl, or combinations thereof are proposed to be applied in Chester Creek for hydrilla control. The selected herbicide(s) will be applied at the maximum concentration rate, as described in the following sections. The herbicide(s) will be evenly distributed across the entire treatment area delineated in Figure 1 using boat-based, subsurface injection application methods. This section describes the proposed herbicides.

2.1 Diquat

Diquat dibromide is a state and federally registered herbicide approved for application in aquatic sites for invasive aquatic plant control. The herbicide is proposed to be applied at a concentration of 370 ppb. A Registration Standard for diquat dibromide was issued by the EPA in June 1986 (EPA, 1995). The active ingredient ((6,7-dihydrodipyrido (1,2a:2',1'-c) pyrazinediium dibromide)) is a fast-acting herbicide that interferes with photosynthesis, disrupts plant cell membranes, and results in plant death within a week of application in sensitive plant species (DNR, 2012).

2.2 Dipotassium salt of endothall

Dipotassium salt of endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid) is a state and federally registered aquatic herbicide and is approved for application in aquatic sites for the treatment of invasive aquatic plant species. The dipotassium salt of endothall was registered by EPA for aquatic use in 1960 at application rates between 0.5 and 5.0 ppm for aquatic plant control (Menninger, 2012). The herbicide is proposed to be applied at a concentration of 5 ppm. Dipotassium salt of endothall is a selective fast-acting herbicide that interferes with plant protein and lipid biosynthesis, disrupting respiration and plant membranes. This herbicide is highly effective for hydrilla control (Netherland et al.,1991).

2.3 Florpyrauxifen-benzyl

Florpyrauxifen-benzyl is a state and federally registered herbicide, and that is approved for invasive plant treatment in aquatic environments. The herbicide is proposed to be applied at a concentration of 48 ppb. This relatively new systemic herbicide mimics the plant growth hormone, auxin, killing susceptible plants by disrupting the plant cell growth process.

The active ingredient (4-amino-3chloro-6-(4-chloro-2-fluoro-3-methoxyphenyl) 5-fluoropyridine-2-benzyl ester) causes excessive plant cell elongation, ultimately resulting in plant cell death in sensitive plant species. Florpyrauxifen-benzyl is absorbed from the water through submersed plant shoots and leaves, and this herbicide has previously been demonstrated to be highly effective at selectively suppressing both dioecious and monoecious invasive hydrilla (Sperry et al., 2021; Mudge et al., 2021; Beets et al., 2019; Netherland & Richardson, 2016; Richardson et al., 2016) with

relatively short exposure times and lower application rates compared to other herbicides (DNR, 2022).

3. Potential Impacts for the Proposed Treatment Activity

3.1 State-Listed Native Plant Species

Preliminary assessments of the Natural Diversity Database maps and files identified three state-listed vascular plants that may potentially occur within the delineated Keeney Cove treatment area: Parker's pipewort (*Eriocaulon parkeri*, state endangered species), golden club (*Orontium aquaticum, s*tate special concern), and large yellow pond lily (*Nuphar advena,* state concern historical species). No plant surveys were performed to confirm species presence in Chester Creek.

Three plant species identified during the preliminary assessment are not likely to occur within the intertidal zone: woolly beach-heather (*Hudsonia tomentosa*), field paspalum (*Paspalum laeve)*, and hispid hedge-nettle (*Stachys hispida*). No impacts are expected to these species as the species occur outside of the proposed treatment area.

3.1.1 Diquat

No impacts are expected to yellow pond-lily (*Nuphar advena)*. A study on the application of diquat for egeria (*Egeria densa)* observed the effects on non-target macrophytes including the fragrant water lily (*Nymphaea odorata)*. Diquat was applied to an egeria-infested lake below the maximum concentration of 370 ppb. No adverse effects were observed to this native plant species from the diquat treatment (Parsons et al., 2007).

There is currently no published herbicide response or toxicology data available for parker's pipewort (*Eriocaulon parkeri)* and golden club (*Orontium aquaticum)*. A low exposure risk is anticipated for these species, as both species occupy tidal areas.

3.1.2 Dipotassium salt of endothall

No significant impacts are expected to the large yellow pond lily (*Nuphar advena)*. A mesocosm study evaluated the response of spatterdock (*Nuphar luteum)* to endothall with treatment rates of 0, 1, 2, and 5 mg/L and a static water-flow exposure period of 120 hours. Plant biomass samples were measured pretreatment, and at 3 and 6 weeks after treatment to measure plant response. Biomass reduction was observed in the spatterdock species at an application rate of 2 mg/L (Skogerboe & Getsinger, 2001). A lower risk of exposure is assumed for Chester Creek, as a 120-hour exposure time is not typically attainable under field use conditions. Therefore, no significant impacts are expected to this species.

No published herbicide response data is available for parker's pipewort and golden club. As discussed above, a low exposure risk is anticipated for these species and sub-surface methods will be utilized to minimize potential impacts.

3.1.3 Florpyrauxifen-benzyl

Temporary, short-term impacts may occur to yellow pond-lily (*Nuphar advena)*, although no long-term impacts are expected. A study on the application of florpyrauxifen-benzyl for hydrilla treatment in a Florida lake monitored the impacts to non-target species including American eelgrass *(Valisineria americana*) and yellow pond-lily (*Nuphar advena)*. No impacts to American eelgrass were observed during the study. Impacts to yellow pond-lily was typical of auxin-mimic herbicides and with symptoms of stem epinasty and leaf-curling. The study monitored aquatic plants for 289 days after treatment. New growth of yellow pond-lily at the end of the 289-day monitoring period indicated recovery from the herbicide exposure (Sperry et al., 2021).

No published herbicide response data is available for parker's pipewort and golden club. As discussed above, a low exposure risk is anticipated for these species and sub-surface methods will be utilized to minimize potential impacts.

3.2 State-Listed Invertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified two state-listed invertebrates that may be present within Chester Creek: tidewater mucket (*Leptodea ochracea,* state special concern), and eastern pondmussel (*Ligumia nasuta*, state special concern). No mussel surveys were completed to confirm the presence of these species within Chester Creek.

3.2.1 Diquat

No impacts are expected to the freshwater mussels from the application of diquat. One study tested the impacts of diquat on the New Zealand freshwater mussel (*Hyridella menziesi*) and concluded that diquat had no significant effects on freshwater mussels and, therefore, was considered to be non-toxic to these organisms when applied at rates needed to kill most aquatic weeds (Clayton & Severne, 2005).

3.2.2 Dipotassium salt of endothall

No impacts are expected to the freshwater mussels identified to potentially occur within Chester Creek. A study investigating impacts of dipotassium salt of endothall concentrations ranging from 0.5 to 1000 ppm on juvenile and glochidia fatmucket (*Lampsilis siliquoidea*) concluded that dipotassium salt of endothall was not found to be acutely toxic to fatmucket mussels at the proposed treatment rate. Median lethal concentrations for glochidia and juvenile mussels were substantially higher (6-34 times higher) than recommended dipotassium salt of endothall application rates for hydrilla treatment (1-5 ppm) (Archambault et al., 2015). The herbicide has also been tested on dreissenid mussels, specifically zebra and quagga mussels. At the highest concentration applied (5 ppm) maximum mortality of 5% was observed for quagga mussels at 20º C, and 2.5% at 25º C. Zebra mussels had zero mortality to any dipotassium salt of endothall concentration at either temperature regime (Claudi et al., 2013).

3.2.3 Florpyrauxifen-benzyl

No impacts are expected to the identified freshwater mussels, including: tidewater mucket (*Leptodea ochracea)* and eastern pondmussel (*Ligumia nasuta)*. A study examined the impacts of florpyrauxifen-benzyl applications on juvenile fatmucket (*Lampsilis siliquoidea*) and eastern lampmussel (*Lampsilis radiata*) and determined that this compound was not acutely toxic to juveniles of these species. The study determined that the short-term exposure risk of these freshwater mussels to florpyrauxifen-benzyl for the purposes of aquatic weed control are minimal (Buczek et al., 2020). Potential chronic or sub-lethal effects require further investigation to characterize.

3.3 State-Listed Vertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified five state-listed vertebrates, that may be present within Chester Creek: Mudpuppy (*Necturus maculosus,* state special concern), spotted turtle (*Clemmys guttata*, state special concern), blueback herring (*Alosa aestivalis*, state special concern), shortnose sturgeon (*Acipenser brevirostrum,* state and federally endangered), and Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus,* state and federally endangered). No vertebrate surveys were completed to confirm the presence of these species within Chester Creek.

3.3.1 Diquat

No impacts are expected to the spotted turtle (*Clemmys guttata)* with the risk of toxic impacts of diquat treatment considered to be minimal. One study on diquat and endothall toxicity to the eastern spiny softshell turtle (*Apalone spinifera spinifera*) monitored these aquatic turtles over time as they were exposed to a range of in-water herbicide concentrations. This study did not observe any toxic effects to any of the turtles and none of the turtles used in the experiment died during either the exposure or postexposure monitoring portions of the test. This study concluded that softshell turtles were not sensitive to diquat (Paul & Simonin, 2007).

No adverse effects are anticipated for the fish species of concern given that the proposed application rates are within the concentration limits specified on the EPA-approved herbicide label. Studies have found that diquat has relatively low toxicity to fish and does not appear to significantly bioaccumulate in fish tissue (BLM, 2005). The results of acute exposure studies on freshwater fish have been summarized as “slightly toxic to practically non-toxic for diquat dibromide” (Hartless & Lin, 2010). No impacts are anticipated to the mudpuppy, as fish data is used as surrogate data for amphibian species. As discussed, no impacts are anticipated for fish species therefore none are anticipated for any amphibian species of concern.

3.3.2 Dipotassium salt of endothall

No impacts are expected to the spotted turtle (*Clemmys guttata)* and the wood turtle. As discussed in Section 3.3.1, a study monitored diquat and endothall toxicity to spiny softshell turtle (*Apalone spinifera spinifera*) over a range of conditions. No toxic effects or morality was observed during exposure and post-exposure monitoring, and it concluded that the species was not sensitive to endothall (Paul & Simonin, 2007).

No adverse effects are anticipated to the mudpuppy (*Necturus maculosus),* blueback herring (*Alosa aestivalis*), shortnose sturgeon (*Acipenser brevirostrum*, state and federally endangered), or Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus).* The median effective concentration (EC_{50}) was determined for various freshwater species to evaluate ecotoxicity: bluegill sunfish (*Lepomis macrochirus*) at 1,071 ppm, rainbow trout (*Oncorhynchus mykiss)* at 363 ppm, and the sheepshead minnow (*Cyprinodon variegatus)* at 340 ppm (96-hour EC_{50}). The EC_{50} of these species are significantly greater than the proposed application rate of 5 ppm (UPL, 2019). Ecotoxicology response of fish provides surrogate information for amphibian species. Therefore, no adverse impacts to the mudpuppy (*Necturus maculosus)* are anticipated.

3.3.3 Florpyrauxifen-benzyl

Florpyrauxifen-benzyl is considered to be practically nontoxic to freshwater fish (DNR 2022; Levey, 2022; EPA, 2017). Studies of florpyrauxifen-benzyl impacts on fish and aquatic organisms largely did not observe toxicity even when applied up to its functional limit of solubility (Levey, 2022; EPA, 2017). Further, results of bioaccumulation studies in fish suggested rapid and extensive metabolism of florpyrauxifen-benzyl, indicating that bioaccumulation potential for this herbicide is low (EPA, 2017). Fish toxicity has not been previously reported in field or laboratory evaluations of florpyrauxifen-benzyl at the proposed application rate (48 ppb). Further, chronic toxicity in these species is also not considered to be a concern as the proposed treatment activity only includes one herbicide application, and florpyrauxifen-benzyl has been shown to rapidly degrade through aerobic aquatic metabolism and aqueous photolysis once applied (EPA, 2017). Florpyrauxifen-benzyl is considered practically non-toxic to fish on an acute basis [static 96-hour EC_{50} >120 mg/L for carp (*Cyprinus carpio*)] (SePro, 2017). As discussed previously, fish data provides surrogate information for the mudpuppy. Therefore no impacts are anticipated to the mudpuppy.

Likewise, no direct toxicology data is available for turtle species therefore bird toxicity response data is considered surrogate data. No impacts are expected to the spotted turtle (*Clemmys guttata)*. Florpyrauxifen-benzyl is considered practically non-toxic to birds on an acute basis. The oral median lethal dose (LD_{50}) was determined for the bobwhite quail (*Colinus virginianus*) at 2,500 mg/kg (SePRO, 2017).

4. Conservation Strategy for Endangered, Threatened and Special Concern Species

4.1 Herbicide Application Methods and Timing

Strategic herbicide application methods and timing will be employed throughout this demonstration project to minimize the potential risk of impacts to non-target and state-listed species of concern. The selected herbicide(s) will be applied by licensed applicators in accordance with the product's EPA-approved label.

4.2 Considerations for Vertebrates

Blueback herring is known to spawn over aquatic vegetation within the proposed treatment area between April 1 and June 30. To minimize potential impacts to these spawning events, the timing of treatment application will be delayed until after July 4, 2024.

6. Literature Cited

Archambault, J.M., Bergeron, C.M., Cope, G.W., Richardson, R.J., Heilman, M.A., Corey III, E.J., Netherland, M.D., & Heise, R.J. 2015. Sensitivity of freshwater molluscs to hydrilla-targeting herbicides: providing context for invasive aquatic weed control in diverse ecosystems. Journal of Freshwater Ecology. Vol. 30(3): 335-348.

Beets, J., Heilman, M., & Netherland, M.D. 2019. Large-Scale Mesocosm Evaluation of Florpyrauxifen-Benzyl, a Novel Arylpicolinate Herbicide, on Eurasian and Hybrid Watermilfoil and Seven Native Submersed Plants." Journal of Aquatic Plant Management. Vol. 57: 49-55

Buczek, S.B., Archambault, J.M., Cope, W.G., & Heilman, M.A. 2020. Evaluation of Juvenile Freshwater Mussel Sensitivity to Multiple Forms of Florpyrauxifen-Benzyl. Bulletin of Environmental Contamination and Toxicology. Volume 105: 588-594 https://doi.org/10.1007/s00128-020-02971-1.

Bugbee, G.J., & Stebbins, S.E. 2022. Invasive Aquatic Vegetation Survey Hydrilla Overwintering and Spread Management Options. Department of Environmental Science and Forestry.

Bureau of Land Management (BLM). 2005. Diquat Ecological Risk Assessment, Final Report. All U.S. Government Documents (Utah Regional Depository).

Claudi, R., Taraborelli, C., & Prescott, T.H. 2013. Efficacy of Endothall for Control of Adult Quagga and Zebra Mussels. Accessed 31 January 2025 from https://invasivemusselcollaborative.net/wp-content/uploads/2018/11/Claudi-et-al.-2013b.pdf.

Clayton, J., & Severne, C. 2005. Review of Diquat Reports of Relevance to Iwi Values in Lake Karapiro. Environment Waikato Technical Report 2006/03. Environment Waikato. https://www.waikatoregion.govt.nz/assets/WRC/WRC-2019/tr06-03.pdf.

Hartless, C., and Lin, J. 2010. "Risks of Diquat Dibromide Use to the Federally Threatened Delta Smelt."

Levey, R. 2022. Aquatic Nuisance Control Permit, ProcellaCOR EC Aquatic Toxicity Review. https://dec.vermont.gov/sites/dec/files/wsm/lakes/ANC/docs/ProcellaCor%20Aquatic%20Toxicity%20Review%20_03162022.pdf.

Menninger, H. 2012. Endothall FAQ. Cornell Cooperative Extension. 2012. http://ccetompkins.org/environment/aquatic-invasives/hydrilla/managementoptions/herbicides/endothall/endothall-faq.

Mudge, C.R., Sartain, B.T., Getsinger, K.D., & Netherland, M.D. 2021. Efficacy of Florpyrauxifen-Benzyl on Dioecious Hydrilla and Hybrid Water Milfoil - Concentration and Exposure Time Requirements. U.S. Engineer Research and Development Center. https://doi.org/10.21079/11681/42062.

Netherland, M.D., & Richardson, R.J. 2016. Evaluating Sensitivity of Five Aquatic Plants to a Novel Arylpicolinate Herbicide Utilizing an Organization for

Economic Cooperation and Development Protocol. Weed Science. Vol. 64(1): 181–90. https://doi.org/10.1614/WS-D-15-00092.1.
Netherland, M.D., Green, W.R., and Getsinger, K.D. 1991. Endothall Concentration and Exposure Time Relationships for the Control of Eurasian Watermilfoil and Hydrilla. Journal of Aquatic Plant Management. Vol. 29: 61–67.
Parsons, J.K., Hamel, K.S., & Wierenga, R. 2007. The Impact of Diquat on Macrophytes and Water Quality in Battle Ground Lake, Washington. Journal of Aquatic Plant Management. Vol. 45: 35-39.
Paul, E.A, & Simonin, H.A. 2007. Toxicity of Diquat and Endothall to Eastern Spiny Softshell Turtles (*Apalone spinifera spinifera)*. Journal of Aquatic Plant Management. Vol. 45: 52-44
Richardson, R., Haug, E.J., and Netherland, M.D. 2016. Response of Seven Aquatic Plants to a New Arylpicolinate Herbicide. Journal of Aquatic Plant Management. Vol. 54: 26–31.
SePRO Corporation (SePRO). 2017. Safety Data Sheet for ProcellaCOR EC Version 1.0. EPA Registration No. 67690-80.
Skogerboe, J.G., & Getsinger, K.D. 2001. Endothall species selectivity evaluation: Southern latitude aquatic plant community. Journal of Aquatic Plant Management. Vol. 39:129-135
Sperry, B.P, Leary, J.K., Dean Jones, K, & Ferrell, J.A. 2021. Observations of a Submersed Field Application of Florpyrauxifen-Benzyl Suppressing Hydrilla in a Small Lake in Central Florida. Journal of Aquatic Plant Management. Vol. 59: 20-26.
Tippery, N.P., Bugbee, G.J., & Stebbins, S.E. 2020. Evidence for a Genetically Distinct Strain of Introduced Hydrilla Verticillata (Hydrocharitaceae) in North America. Journal of Aquatic Plant Management. Vol. 58:1-6.
UPL Limited (UPL). 2019. Safety Data Sheet for AQUATHOL® K Aquatic Herbicide.
U.S. Environmental Protection Agency (EPA). 2017. The 2017 EPA Environmental Fate and Ecological Risk Assessment for Florpyrauxifen-Benzyl.
U.S. Environmental Protection Agency (EPA). 1995. Diquat Dibromide. https://archive.epa.gov/pesticides/reregistration/web/pdf/0288fact.pdf.
Wisconsin Department of Natural Resources (DNR). 2022. Florpyrauxifen-Benzyl Fact Sheet. https://apps.dnr.wi.gov/swims/Documents/DownloadDocument?id=332109305
Wisconsin Department of Natural Resources (DNR). 2012. Diquat Chemical Fact Sheet. https://www.noaa.gov/sites/default/files/legacy/document/2020/Oct/07354626838.pdf

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1.2 Project Background

The U.S. Army Corps of Engineers (USACE), through its Engineer Research and Development Center's (ERDC) Aquatic Plant Control Research Program, is leading a research and demonstration project to verify the effectiveness of aquatic herbicides registered for use by the U.S. Environmental Protection Agency (EPA) to reduce and control the spread of the Connecticut River hydrilla safely and selectively. The project has been investigating hydrilla's growth patterns, site-specific water exchange dynamics and evaluating herbicide efficacy in laboratory conditions throughout 2023 to guide operational scale field demonstrations of herbicide efficacy in 2024. Deep River has been selected as a hydrilla treatment site for ERDC's 2025 field demonstration project.

1.3 Deep River Treatment Site

Deep River is a tributary to the Connecticut River located in Deep River, Middlesex County, CT and is centered at 41.401° N, 72.434°W. The treatment area is 5.3 acres with a mean depth range of 7 feet mean higher high water.

The tributary contains emergent freshwater tidal marsh flora, with the littoral marsh dominated by annual wildrice (Zizania aquatica), cattail (Typha latifolia), and sweetflag (Acorus americanus). The open water is dominant by hydrilla (Hydrilla verticillata). Other species include pickerelweed (Pontederia cordata), broadleaf arrowhead (Sagittaria latifolia), green arrow arum (Peltandra virginica), cardinalflower (Lobelia cardinalis), variegated yellow pond-lily (Nuphar variegata), water chestnut (Trapa natans), coontail (Ceratophyllum demersum), giant duckweed (Spirodela polyrrhiza), eelgrass (Vallisneria americana), nuttall waterweed *(Elodea nuttalli),* common water-primrose *(Ludwigia palustris),* and Eurasian water-milfoil (*Myriophyllum spicatum)*.

Figure 1. Deep River hydrilla treatment area in Chester, CT.

2. Proposed Treatment Activity

Diquat, dipotassium salt of endothall, florpyrauxifen-benzyl, or combinations thereof are proposed to be applied in Deep River for hydrilla control. The selected herbicide(s) will be applied at the maximum concentration rate. The herbicide(s) will be evenly distributed across the entire treatment area delineated in Figure 1 using boat-based, subsurface injection application methods. This section describes the proposed herbicides.

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Diquat dibromide is a state and federally registered herbicide approved for application in aquatic sites for invasive aquatic plant control. A Registration Standard for diquat dibromide was issued by the EPA in June 1986 (EPA, 1995). The active ingredient ((6,7-dihydrodipyrido (1,2a:2',1'-c) pyrazinediium dibromide)) is a fast-acting herbicide that interferes with photosynthesis, disrupts plant cell membranes, and results in plant death within a week of application in sensitive plant species (DNR, 2012).

2.2 Dipotassium salt of endothall

Dipotassium salt of endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid) is a state and federally registered aquatic herbicide and is approved for application in aquatic sites for the treatment of invasive aquatic plant species. The dipotassium salt of endothall was registered by EPA for aquatic use in 1960 at application rates between 0.5 and 5.0 ppm for aquatic plant control (Menninger, 2012). Dipotassium salt of endothall is a selective fast-acting herbicide that interferes with plant protein and lipid biosynthesis, disrupting respiration and plant membranes. This herbicide is highly effective for hydrilla control (Netherland et al.,1991).

2.3 Florpyrauxifen-benzyl

Florpyrauxifen-benzyl is a state and federally registered herbicide, and that is approved for invasive plant treatment in aquatic environments. This relatively new systemic herbicide mimics the plant growth hormone, auxin, killing susceptible plants by disrupting the plant cell growth process.

The active ingredient (4-amino-3chloro-6-(4-chloro-2-fluoro-3-methoxyphenyl) 5-fluoropyridine-2-benzyl ester) causes excessive plant cell elongation, ultimately resulting in plant cell death in sensitive plant species. Florpyrauxifen-benzyl is absorbed from the water through submersed plant shoots and leaves, and this herbicide has previously been demonstrated to be highly effective at selectively suppressing both dioecious and monoecious invasive hydrilla (Sperry et al., 2021; Mudge et al., 2021; Beets et al., 2019; Netherland & Richardson, 2016; Richardson et al., 2016) with relatively short exposure times and lower application rates compared to other herbicides (DNR, 2022).

3. Potential Impacts of the Proposed Treatment Activity

3.1 State-Listed Native Plant Species

Preliminary assessments of the Natural Diversity Database maps and files identified one state-listed plant which may be present within Deep River: golden club (*Orontium aquaticum,* state special concern). The awl-leaved arrowhead (*Sagittaria subulata*, state special concern) may also be present with Deep River.

3.1.1 Diquat

There is currently no published herbicide response or toxicology data available for the state-listed plant species identified. A low exposure risk is anticipated for these species, as both species occupy tidal areas. Preliminary USACE research trials indicate that awl-leaved arrowhead (*Saggitaria subulata)* is tolerant to in-water diquat exposure.

3.1.2 Dipotassium salt of endothall

Preliminary USACE research trials indicate that awl-leaved arrowhead (*Saggitaria subulata)* is tolerant to endothall exposure using subsurface injection methods. The potential impacts to golden club (*Orontium aquaticum)* are not currently known, as there is no published data on this species' herbicide response. A low exposure risk is anticipated for the golden club as it inhabits tidal areas.

3.1.3 Florpyrauxifen-benzyl

No impacts are expected to awl-leaved arrowhead based on a mesocosm study on the effects of florpyrauxifen-benzyl on native plants, including the bulltongue arrowhead (*Saggitaria lancifolia)*. The species showed limited petiole bending during initial exposure. No significant impacts were observed on the bulltongue arrowhead under concentrations of 24 to 48 μg L^{-1} for 24- and 72-hour concentrations (Beets & Netherland, 2018).

The potential impacts to golden club (*Orontium aquaticum)* are not currently known, as there is no published data on this species' herbicide response. A low exposure risk is anticipated for the golden club as it inhabits tidal areas.

3.2 State-Listed Invertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified two state-listed invertebrates which may be present within Deep River: tidewater mucket (*Leptodea ochracea*, state special concern) and eastern pondmussel (*Ligumia nasuta*, state special concern). No mussel surveys were completed during the 2024 environmental studies to confirm the presence of these species within Deep River.

3.2.1 Diquat

No impacts are expected to the identified freshwater mussels from the application of diquat. One study tested the impacts of diquat on the New Zealand freshwater mussel (*Hyridella menziesi*) and concluded that diquat had no significant effects on freshwater mussels and, therefore, was considered to be non-toxic to these organisms when applied at rates needed to kill most aquatic weeds (Clayton & Severne, 2005).

3.2.2 Dipotassium salt of endothall

No impacts are expected to the identified freshwater mussels. A study investigating impacts of dipotassium salt of endothall concentrations ranging from 0.5 to 1000 ppm on juvenile and glochidia fatmucket (*Lampsilis siliquoidea*) concluded that dipotassium salt of endothall was not found to be acutely toxic to fatmucket mussels at the application rates needed for hydrilla treatment. Median lethal concentrations (LC_{50}) were substantially higher (6-34 times higher) than recommended dipotassium salt of endothall application rates for hydrilla treatment (1-5 ppm) (Archambault et al., 2015). Dipotassium salt of endothall has also been tested on dreissenid mussels, specifically zebra and quagga mussels, to evaluate impacts. At the highest concentration applied (5 ppm) maximum mortality of 5% was observed for quagga mussels at 20º C, and 2.5% at 25º C. Zebra mussels had zero mortality to any dipotassium salt of endothall concentration at either temperature regime (Claudi et al., 2013).

3.2.3 Florpyrauxifen-benzyl

No impacts are expected to the identified freshwater mussels. A study observed the toxicity of florpyrauxifen-benzyl applications on juvenile fatmucket (*Lampsilis siliquoidea*) and eastern lampmussel (*Lampsilis radiata*) and determined that this compound was not acutely toxic to juveniles of these species. While potential chronic or sub-lethal effects require further investigation to characterize, this study concluded that the short-term exposure risk of these freshwater mussels to florpyrauxifen-benzyl for aquatic weed control are minimal (Buczek et al., 2020).

3.3 State-Listed Vertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified two state-listed vertebrate animals that may be present within Deep River: mudpuppy (*Necturus maculosus,* state special concern) and spotted turtle (*Clemmys guttata*, state special concern). No vertebrate surveys were conducted at this site as there were no species of concern anticipated at this location.

3.3.1 Diquat

No impacts are expected to the spotted turtle (*Clemmys guttata)* with the risk of toxic impacts of endothall treatment considered to be minimal. One study on diquat and endothall toxicity to the eastern spiny softshell turtle (*Apalone spinifera spinifera*) monitored these aquatic turtles over time over a range of in-water herbicide concentrations. This study did not observe any toxic effects to any of the turtles and none of the turtles used in the experiment died during either the exposure or post-exposure monitoring portions of the test. This study concluded that softshell turtles were not sensitive to endothall (Paul & Simonin, 2007).

No adverse effects are anticipated for the mudpuppy (*Necturus maculosus)*, as no adverse effects are anticipated for fish species which serve as surrogates for amphibian toxicity. The proposed application rates are within the concentration limits specified on the EPA-approved herbicide label. Studies have found that diquat has relatively low toxicity to fish and does not appear to significantly bioaccumulate in fish tissue (BLM, 2005). The results of acute exposure studies on freshwater fish have been summarized as "slightly toxic to practically non-toxic for diquat dibromide" (Hartless & Lin, 2010).

3.3.2 Dipotassium salt of endothall

No impacts are expected to the spotted turtle (*Clemmys guttata*) from the application of dipotassium salt of endothall. No toxic effects were observed to the eastern spiny softshell turtle (*Apalone spinifera spinifera)* from the applications of diquat and endothall as described in Section 3.3.1.

No direct herbicide exposure data is available for the mudpuppy (*Necturus maculosus)*. Although no significant impacts are anticipated for this species. Fish data provides surrogate data for amphibian species in ecotoxicology studies. The effective concentration (EC_{50}) of various freshwater species to endothall was determined: bluegill sunfish (*Lepomis macrochirus*) at 1,071 ppm, rainbow trout (*Oncorhynchus mykiss)* at 363 ppm, and the sheepshead minnow (*Cyprinodon variegatus)* at 340 ppm (96-hour EC_{50}). The EC_{50} of these species are significantly greater than the proposed application rate of 5 ppm (UPL, 2019). Therefore, no impacts are expected to the mudpuppy.

3.3.3 Florpyrauxifen-benzyl

No direct herbicide response data is available for the application of florpyrauxifen-benzyl on the mudpuppy (*Necturus maculosus*) and the spotted turtle (*Clemmys guttata)*. As mentioned previously, fish toxicity data can provide information on amphibian response. No impacts are expected to the mudpuppy as the maximum use rate is significantly greater than the EC_{50} for fish species. For reptiles, bird species serve as surrogates for toxicological studies. Florpyrauxifen-benzyl is practically non-toxic to birds on an acute basis. The oral median lethal dose (LD_{50}) of florpyrauxifen-benzyl to the bobwhite quail (*Colinus virginianus)* is 2,500 mg/kg (SePRO, 2017).

4. Conservation Strategy for Endangered, Threatened and Special Concern Species

4.1 Herbicide Application Methods and Timing

Strategic herbicide application methods and timing will be employed throughout this demonstration project to minimize the potential risk of impacts to non-target and state-listed species of concern. Herbicides will be applied by licensed applicators at allowable concentrations in accordance with the product's EPA-approved label. Herbicides will be applied directly to the water and evenly distributed across the entire treatment area using boat-based, subsurface injection application methods to minimize airborne exposure risks to non-target species.

4.1 Considerations to Plant Species of Concern

Monitoring will occur if golden club (*Orontium aquaticum)* or awl-leaved arrowhead (*Sagittaria subulata)* are present. If a net loss in plant species is observed within two years of monitoring and is determined to be from herbicide application, replanting will occur to minimize potential impacts of individuals lost.

5. References

Archambault, J.M., Bergeron, C.M., Cope, G.W., Richardson, R.J., Heilman, M.A., Corey III, E.J., Netherland, M.D., & Heise, R.J. 2015. Sensitivity of freshwater molluscs to hydrilla-targeting herbicides: providing context for invasive aquatic weed control in diverse ecosystems. Journal of Freshwater Ecology. Vol. 30(3): 335-348.

Beets, J., Heilman, M., & Netherland, M.D. 2019. Large-Scale Mesocosm Evaluation of Florpyrauxifen-Benzyl, a Novel Arylpicolinate Herbicide, on Eurasian and Hybrid Watermilfoil and Seven Native Submersed Plants." Journal of Aquatic Plant Management. Vol. 57: 49-55

Buczek, S.B., Archambault, J.M., Cope, W.G., & Heilman, M.A. 2020. Evaluation of Juvenile Freshwater Mussel Sensitivity to Multiple Forms of Florpyrauxifen-Benzyl. Bulletin of Environmental Contamination and Toxicology. Volume 105: 588-594 https://doi.org/10.1007/s00128-020-02971-1.

Bugbee, G.J., & Stebbins, S.E. 2022. Invasive Aquatic Vegetation Survey Hydrilla Overwintering and Spread Management Options. Department of Environmental Science and Forestry.

Claudi, R., Taraborelli, C., & Prescott, T.H. 2013. Efficacy of Endothall for Control of Adult Quagga and Zebra Mussels. Accessed 31 January 2025 from https://invasivemusselcollaborative.net/wp-content/uploads/2018/11/Claudi-et-al.-2013b.pdf.

Clayton, J., & Severne, C. 2005. Review of Diquat Reports of Relevance to Iwi Values in Lake Karapiro. Environment Waikato Technical Report 2006/03. Environment Waikato. https://www.waikatoregion.govt.nz/assets/WRC/WRC-2019/tr06-03.pdf.

Menninger, H. 2012. Endothall FAQ. Cornell Cooperative Extension. 2012. http://ccetompkins.org/environment/aquatic-invasives/hydrilla/managementoptions/herbicides/endothall/endothall-faq.

Mudge, C.R., Sartain, B.T., Getsinger, K.D., & Netherland, M.D. 2021. Efficacy of Florpyrauxifen-Benzyl on Dioecious Hydrilla and Hybrid Water Milfoil - Concentration and Exposure Time Requirements. U.S. Engineer Research and Development Center. https://doi.org/10.21079/11681/42062.

Netherland, M.D., & Richardson, R.J. 2016. Evaluating Sensitivity of Five Aquatic Plants to a Novel Arylpicolinate Herbicide Utilizing an Organization for Economic Cooperation and Development Protocol. Weed Science. Vol. 64(1): 181–90. https://doi.org/10.1614/WS-D-15-00092.1.

Netherland, M.D., Green, W.R., and Getsinger, K.D. 1991. Endothall Concentration and Exposure Time Relationships for the Control of Eurasian Watermilfoil and Hydrilla. Journal of Aquatic Plant Management. Vol. 29: 61–67.

Paul, E.A, and Simonin, H.A. 2007. Toxicity of Diquat and Endothall to Eastern Spiny Softshell Turtles (*Apalone spinifera spinifera)*. Journal of Aquatic Plant Management. Vol. 45: 52-44

Richardson, R., Haug, E.J., & Netherland, M.D. 2016. Response of Seven

Aquatic Plants to a New Arylpicolinate Herbicide. Journal of Aquatic Plant Management. Vol. 54: 26–31.
SePRO Corporation (SePRO). 2017. Safety Data Sheet for ProcellaCOR EC Version 1.0. EPA Registration No. 67690-80.
Sperry, B.P, Leary, J.K., Dean Jones, K, & Ferrell, J.A. 2021. Observations of a Submersed Field Application of Florpyrauxifen-Benzyl Suppressing Hydrilla in a Small Lake in Central Florida. Journal of Aquatic Plant Management. Vol. 59: 20-26.
Tippery, N.P., Bugbee, G.J., & Stebbins, S.E. 2020. Evidence for a Genetically Distinct Strain of Introduced Hydrilla Verticillata (Hydrocharitaceae) in North America. Journal of Aquatic Plant Management. Vol. 58:1-6.
UPL Limited (UPL). 2019. Safety Data Sheet for AQUATHOL® K Aquatic Herbicide.
U.S. Environmental Protection Agency (EPA). 1995. Diquat Dibromide. https://archive.epa.gov/pesticides/reregistration/web/pdf/0288fact.pdf.
Wisconsin Department of Natural Resources (DNR). 2022. Florpyrauxifen-Benzyl Fact Sheet. https://apps.dnr.wi.gov/swims/Documents/DownloadDocument?id=332109305
Wisconsin Department of Natural Resources (DNR). 2012. Diquat Chemical Fact Sheet. https://www.noaa.gov/sites/default/files/legacy/document/2020/Oct/07354626838.pdf

Connecticut River
Hydrilla Control Research and Demonstration Project
Lower Connecticut River, CT

Species Protection Plan
Hamburg Cove
Lyme, CT

US Army Corps
of Engineers ®
New England District

February 2025

Hamburg Cove Species Protection Plan

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1. Introduction

1.1 Connecticut River Hydrilla Information

Hydrilla (*Hydrilla verticillata*) was first identified in the Connecticut River near Glastonbury, CT in 2016 and has since spread south to Essex, CT infesting the river's many coves, tributaries, and boat basins. The Connecticut River hydrilla population has been shown to be genetically distinct from other known hydrilla strains (Tippery, et al., 2020), and the plant's biology is therefore largely unknown at this time. Following the discovery of the highly invasive aquatic plant in the Connecticut River in 2016, intensive vegetation surveys were conducted in 2019 and 2020 from Agawam, MA south to Long Island Sound to map the invasion extent. Hydrilla was found as far north as Agawam, MA, confirming that the plant spreads rapidly which poses significant risk to other regional waterbodies (Bugbee & Stebbins, 2022). Fragments of the plant, which are easily transported by boats and boat trailers, can sprout roots to establish new populations. Fragments also float and are capable of dispersing via wind and water currents. Due to the importance of the Connecticut River as an environmental resource and driver of the local economy, stakeholders are seeking an aggressive hydrilla management program.

1.2 Project Background

The U.S. Army Corps of Engineers (USACE), through its Engineer Research and Development Center's (ERDC) Aquatic Plant Control Research Program, is leading a research and demonstration project to verify the effectiveness of aquatic herbicides registered for use by the U.S. Environmental Protection Agency (EPA) to reduce and control the spread of the Connecticut River hydrilla safely and selectively. The project has been investigating hydrilla's growth patterns, site-specific water exchange dynamics and evaluating herbicide efficacy in laboratory conditions throughout 2023 to guide operational scale field demonstrations of herbicide efficacy in 2024. Hamburg Cove has been selected as a hydrilla treatment site for ERDC's 2025 field demonstration project.

1.3 Hamburg Cove Treatment Site

Hamburg Cove is a tidal cove off the mainstem of the Connecticut that is located in Lyme, New London County, CT and centered at 41.379° N, 72.359° W. The treatment area is 178.8 acres with a mean depth of 11 feet mean higher high water. The cove has heavy recreational use, and includes numerous boat docks, a summer camp, two marinas, and a yacht club (Doherty et al., 2023).

The Connecticut Agricultural Experiment Station (CAES) preformed invasive aquatic plant surveys of Hamburg Cove in 2019 and 2022. Four invasive species were identified within Hamburg Cove: eurasian watermilfoil (*Myriophyllum spicatum*), hydrilla (*Hydrilla verticillata*), water chestnut (*Trapa natans)*, and variable-leaf watermilfoil (*Myriophyllum* *heterophyllum).* Transects were established during survey to determine the frequency of occurrence of the aquatic plant species. In 2022, Hydrilla was the dominant species within Hamburg Cove with an 80% frequency of occurrence. Other common aquatic species present include: coontail (*Ceratophyllum demersum*), western waterweed (*Elodea nuttalli*), white water lily (*Nymphaea odorata*), eurasian watermilfoil (*Myriophyllum spicatum)*, and eelgrass (*Valisineria americana)* (Doherty et al., 2023)

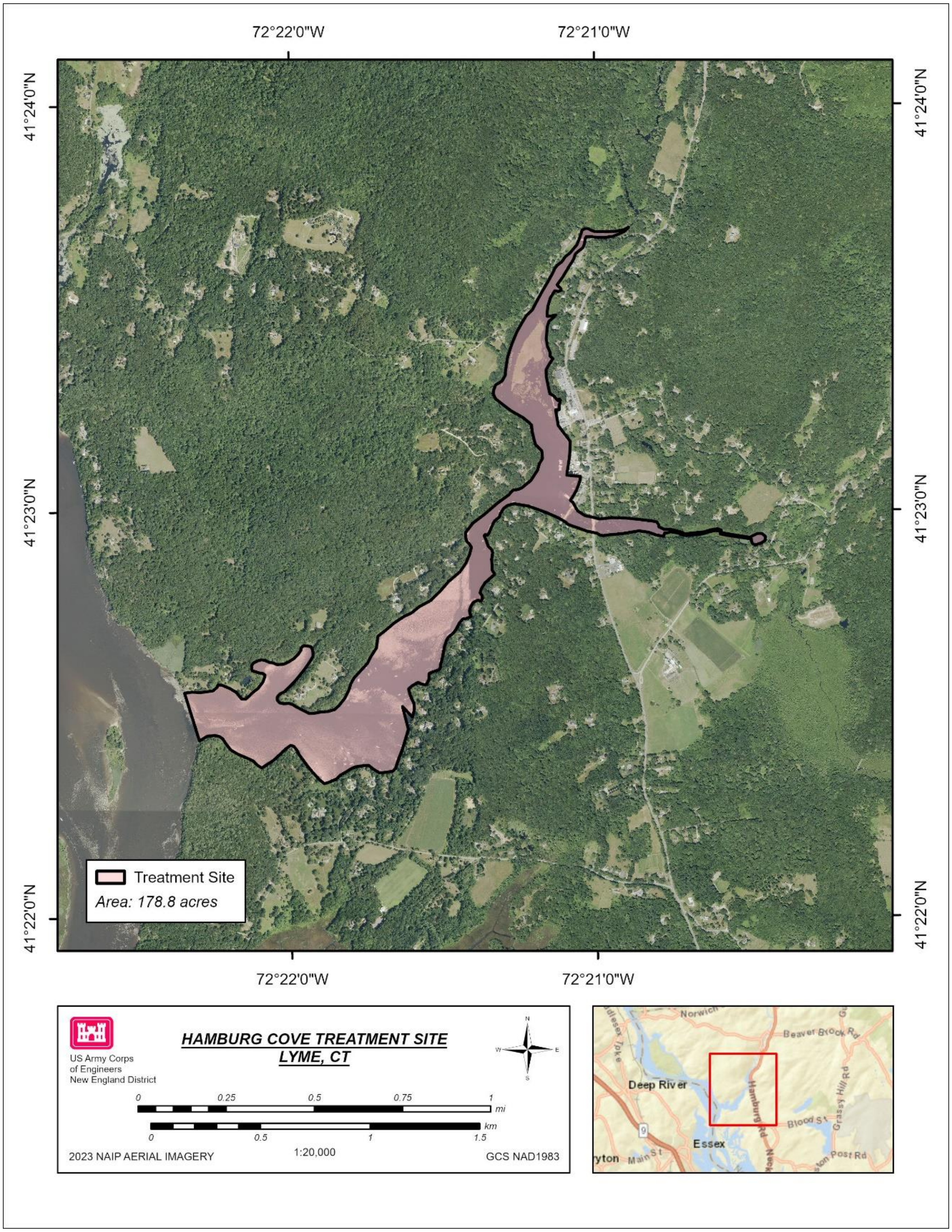

Figure 1. Hamburg Cove hydrilla treatment areas in Lyme, CT.

2. Proposed Treatment Activity

Diquat, dipotassium salt of endothall, florpyrauxifen-benzyl, or combinations thereof are proposed to be applied in Hamburg Cove for hydrilla control. The selected herbicide(s) will be applied at the maximum concentration rate, as described in the following sections. The herbicide(s) will be evenly distributed across the entire treatment area delineated in Figure 1 using boat-based, subsurface injection application methods.

2.1 Diquat

Diquat dibromide is a state and federally registered herbicide approved for application in aquatic sites for invasive aquatic plant control. The herbicide is proposed to be applied at a concentration of 370 ppb. A Registration Standard for diquat dibromide was issued by the EPA in June 1986 (EPA, 1995). The active ingredient ((6,7-dihydrodipyrido (1,2a:2',1'-c) pyrazinediium dibromide)) is a fast-acting herbicide that interferes with photosynthesis, disrupts plant cell membranes, and results in plant death within a week of application in sensitive plant species (DNR, 2012).

2.2 Dipotassium salt of endothall

Dipotassium salt of endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid) is a state and federally registered aquatic herbicide and is approved for application in aquatic sites for the treatment of invasive aquatic plant species. The dipotassium salt of endothall was registered by EPA for aquatic use in 1960 at application rates between 0.5 and 5.0 ppm for aquatic plant control (Menninger, 2012). The herbicide is proposed to be applied at a concentration of 5 ppm. Dipotassium salt of endothall is a selective fast-acting herbicide that interferes with plant protein and lipid biosynthesis, disrupting respiration and plant membranes. This herbicide is highly effective for hydrilla control (Netherland et al.,1991).

2.3 Florpyrauxifen-benzyl

Florpyrauxifen-benzyl is a state and federally registered herbicide, and that is approved for invasive plant treatment in aquatic environments. The herbicide is proposed to be applied at a concentration of 48 ppb. This relatively new systemic herbicide mimics the plant growth hormone, auxin, killing susceptible plants by disrupting the plant cell growth process.

The active ingredient (4-amino-3chloro-6-(4-chloro-2-fluoro-3-methoxyphenyl) 5-fluoropyridine-2-benzyl ester) causes excessive plant cell elongation, ultimately resulting in plant cell death in sensitive plant species. Florpyrauxifen-benzyl is absorbed from the water through submersed plant shoots and leaves, and this herbicide has previously been demonstrated to be highly effective at selectively suppressing both dioecious and monoecious invasive hydrilla (Sperry et al., 2021; Mudge et al., 2021; Beets et al., 2019; Netherland & Richardson, 2016; Richardson et al., 2016) with

relatively short exposure times and lower application rates compared to other herbicides (DNR, 2022).

3. Potential Impacts from the Proposed Treatment Activity

3.1 State-Listed Native Plant Species

Preliminary assessments of the Natural Diversity Database maps and files identified six state-listed vascular plants that may potentially occur within the delineated Hamburg Cove treatment area: parker's pipewort (*Eriocaulon parkeri*, state endangered), pygmyweed (Crassula aquatica, state endangered species), eaton's beggarticks (*Bidens eatonii,* state threatened), golden club (*Orontium aquaticum,* state special concern), awl-leaved arrowhead (*Saggitaria subulata,* state special concern), mudwort (*Limosella australis,* state special concern), and pale green orchid (*Platanthera flava var. herbiola,* state special concern). No submerged and emergent plant surveys were performed in 2024 to confirm the presence of these species in Hamburg Cove.

Four additional species identified during the preliminary assessment are not likely to occur within the intertidal zone of Hamburg Cove: hyssop skullcap (*Scutellaria integrifolia, s*tate endangered), starry campion (*Silene* stellata, state threatened), swamp lousewort (*Pedicularis lanceolata,* state threatened), violet wood-sorrel (*Oxalis violacea,* state special concern). No impacts are expected to these species as their occurrence is outside of the treatment area.

3.1.1 Diquat

No significant impacts are expected to eaton's beggarticks (*Bidens eatonii)*. A study on operational application of diquat observed the herbicide's effects to non-target plants including beck's water-marigold (*Bidens beckii)*. Diquat was applied to a 4-hectare treatment area within a lake, at the maximum concentration rate for a five-year period. No significant changes to beck's water marigold were observed during the study (Parsons et al., 2019).

The application of diquat may impact the pygmyweed (*Crassula aquatica)*. A study on the control of New Zealand pygmyweed (*Crassula helmsii)* in the UK evaluated herbicides under a range of conditions. The study found that *C. helmsii* was sensitive to subsurface diquat exposures (Dawson, 1996)

There is currently no published herbicide response data for parker's pipewort (*Eriocaulon parkeri*), golden club (*Orontium aquaticum*), awl-leaved arrowhead (*Sagittaria subulata)*, mudwort (*Limosella australis)*, and pale green orchid (*Platanthera flava var. herbiola)*. A low exposure risk is expected as these species inhabit tidal areas. Preliminary USACE research trials indicate that *Saggitaria subulata* is tolerant to in-water diquat exposure.

3.1.2 Dipotassium salt of endothall

No significant impacts are expected to eaton's beggarticks (*Bidens eatonii)*. A study observed the effects of submersed applications of endothall and triclopyr to Lake Minnetonka in Minnesota. Populations of beck's water-marigold (*Bidens beckii)* were not reduced following submersed applications of endothall plus triclopyr (Skogerboe & Netherland, 2008). A similar response is anticipated for eaton's beggarticks, with no significant impacts.

No endothall response data is available for parker's pipewort (*Eriocaulon parkeri)*, pygmyweed (*Crassula aquatica)*, golden club (*Orontium aquaticum)*, awl-leaved arrowhead (*Saggitaria subulata)*, mudwort (*Limosella australis)*, and the pale green ochid (*Platanthera flava var. herbiola)*. Endothall is not known to cause injury to emergent aquatic plant species when applied using subsurface methods. A lower risk is anticipated for these species as they are semi-aquatic. Additionally, a mesocosm study evaluated the response of arrowhead (*Saggitaria latifolia)* with treatment rates of 0, 1, 2, and 5 mg/L endothall and a static water-flow exposure period of 120 hours. Plant biomass samples were measured pretreatment, and at 3 and 6 weeks after treatment to measure plant response. Biomass reduction was observed in the arrowhead and spatterdock species at an application rate of 2 mg/L (Skogerboe & Getsinger, 2001). A lower risk of exposure is assumed for Hamburg Cove, as a 120-hour exposure time is not typically attainable under field use conditions. Therefore, no significant impacts are expected to the awl-leaved arrowhead.

3.1.3 Florpyrauxifen-benzyl

No impacts are expected to awl-leaved arrowhead based on a mesocosm study on the effects of florpyrauxifen-benzyl on native plants, including the bulltongue arrowhead (*Saggitaria lancifolia)*. The species showed limited petiole bending during initial exposure. No significant impacts were observed on the bulltongue arrowhead under concentrations of 24 to 48 µg L^{-1} for 24- and 72-hour concentrations (Beets & Netherland, 2018).

No significant impacts are expected to eaton's beggarticks (*Bidens eatonii)* from the application of florpyrauxifen-benzyl. Growth chamber and mesocosm studies indicate that a similar species, beck's water-marigold (*Bidens beckii)*, is tolerant to florpyrauxifen-benzyl. An estimated half maximal effective concentration (EC_{50}) was determined for *Bidens beckii* of 11.3 and 6.1 ppb from static exposures of 14 and 28 days, respectively (Netherland & Richardson, 2016). However, actual potential herbicide exposure times in most Connecticut River sites are less than 24 hours which poses significantly lower injury risk to this species compared to multi-week herbicide exposures in the reported experiments.

No florpyrauxifen-benzyl response data is available for parker's pipewort (*Eriocaulon parkeri)*, pygmyweed (*Crassula aquatica)*, golden club (*Orontium aquaticum),* mudwort (*Limosella australis)*, and the pale green ochid (*Platanthera flava var. herbiola)*. A lower risk is anticipated for these species as they are semi-aquatic. Additionally, subsurface applications of florpyrauxifen-benzyl are not known to impact emergent plant species.

3.2 State-Listed Invertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified three state-listed invertebrates that may be present within Hamburg Cove: brook floater (*Alasmidonta varicosa*, state endangered), midland clubtail (*Gomphus fraternus*, state threatened), and eastern pondmussel (*Ligumia nasuta*, state special concern). Mussel surveys were not completed during the 2024 environmental studies to confirm the presence of these species within Hamburg Cove.

3.2.1 Diquat

No impacts are expected to the freshwater mussels from the application of diquat. One study tested the impacts of diquat on the New Zealand freshwater mussel (*Hyridella menziesi*) and concluded that diquat had no significant effects on freshwater mussels and, therefore, was considered to be non-toxic to these organisms when applied at rates needed to kill most aquatic weeds (Clayton & Severne, 2005).

No impacts are expected to the midland clubtail (*Gomphus fraternus)* from the proposed application of diquat. The EPA considers diquat to be of minimal risk to non-target insects (EPA, 1995). Additionally, a study on insects observed that dragonflies and damselflies survived after being exposed to diquat concentrations 40 times higher than the recommended maximum field application rate (Gilderhus, 1967).

3.2.2 Dipotassium of endothall

No impacts are expected to the identified freshwater mussels. A study investigating impacts of dipotassium salt of endothall concentrations ranging from 0.5 to 1000 ppm on juvenile and glochidia fatmucket (*Lampsilis siliquoidea*) concluded that dipotassium salt of endothall was not found to be acutely toxic to fatmucket mussels at the proposed treatment rate. Median lethal concentrations (LC_{50}s) for glochidia and juvenile mussels were substantially higher (6-34 times higher) than recommended dipotassium salt of endothall application rates for hydrilla treatment (1-5 ppm) (Archambault et al., 2015). The herbicide has also been tested on dreissenid mussels, specifically zebra and quagga mussels. At the highest concentration applied (5 ppm) maximum mortality of 5% was observed for quagga mussels at 20º C, and 2.5% at 25º C. Zebra mussels had zero mortality to any dipotassium salt of endothall concentration at either temperature regime (Claudi et al., 2013).

The midland clubtail (*Gomphus fraternus)* is also not expected to be negatively impacted by the proposed treatment activity. When used at recommended application rates, dipotassium salt of endothall no significant adverse effects were observed on aquatic insects (e.g. snails, aquatic insects, and crayfish) (DNR, 2012).

3.2.3 Florpyrauxifen-benzyl

No impacts are expected to the brook floater (*Alasmidonta varicosa)* and eastern pondmussel (*Ligumia nasuta)*. A study examined the impacts of florpyrauxifen-benzyl applications on juvenile fatmucket (*Lampsilis siliquoidea*) and eastern lampmussel (*Lampsilis radiata*). The compound was not acutely toxic to juveniles of these species. While potential chronic or sub-lethal effects require further investigation to characterize, this study concluded that the short-term exposure risk of these freshwater mussels to florpyrauxifen-benzyl for the purposes of aquatic weed control are minimal (Buczek et al., 2020).

Florpyrauxifen-benzyl poses minimal risk to aquatic invertebrates according to ecotoxicological information required for registration by the EPA (SePRO, 2017). The midland clubtail (*Gomphus fraternus)* is not expected to be negatively impacted by the proposed treatment activity due to the in-water application methods under consideration. Previous studies have shown florpyrauxifen-benzyl to be essentially nontoxic on an acute basis to bees (Levey, 2022), thus risk of acute impacts to other insect species are also considered to be low. Additionally, this herbicide has been shown to have a relatively low potential for volatility from water due to low vapor pressure (EPA, 2017).

3.3 State-Listed Vertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified nine state-listed vertebrates that may be present within Hamburg Cove: shortnose sturgeon (*Acipenser brevirostrum*, state and federally endangered), Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*, state and federally endangered), blueback herring (*Alosa aestivalis*, state special concern), mudpuppy (*Necturus maculosus,* state special concern), eastern box turtle (Terrapene carolina carolina, state special concern), wood turtle (*Glyptemys insculpta*, state special concern), bald eagle (*Haliaeetus leucocephalus*, state threatened), peregrine falcon (*Falco peregrinus,* state threatened), cerulean warbler (*Setophaga cerulea,* state special concern), and whip-poor-will (*Caprimulgus vociferus,* state special concern).

The eastern box turtle (*Terrapene carolina carolina)* was also identified during the preliminary NDDB assessment. No impacts are expected to this species from any of the proposed herbicides. The selected herbicide(s) will be applied using subsurface injection methods. This species does not inhabit aquatic or intertidal habitat. Therefore, no impacts are likely from the proposed treatment.

3.3.1 Diquat

No adverse effects are anticipated for the fish species of concern given that the proposed application rates are within the concentration limits specified on the EPA-approved herbicide label. Studies have found that diquat has relatively low toxicity to fish and does not appear to significantly bioaccumulate in fish tissue (BLM, 2005). The results of acute exposure studies on freshwater fish have been summarized as “slightly toxic to practically non-toxic for diquat dibromide” (Hartless & Lin, 2010). Additionally, fish species are considered surrogates for amphibian toxicological data. Therefore, no adverse effects are expected to the mudpuppy (*Necturus maculosus)* based on the described fish toxicology impacts of diquat.

No adverse impacts are anticipated to the wood turtle (*Glyptemys insculpta).* A study monitored the impacts of diquat to the eastern spiny softshell turtle (*Apalone spinifera spinifera*) over a range of in-water herbicide concentrations. No mortality or effects were observed to the species during exposure or post-exposure monitoring. This study concluded that softshell turtles were not sensitive to diquat (Paul & Simonin, 2007).

No impacts are expected due to bird species of concern, including the bald eagle (*Haliaeetus leucocephalus)*, peregrine falcon (*Falco peregrinus)*, cerulean warbler (*Setophaga cerulea)*, and whip-poor-will (*Caprimulgus vociferus).* Herbicides will be applied using subsurface injection methods, no airborne exposure risks to nearby birds at the time of application are anticipated. While diquat dibromide has been found to be moderately toxic to birds in acute oral exposure studies (EPA, 1995; BLM, 2005; Emmett, 2002), many of these studies were conducted at much higher concentrations than the proposed treatment. Additionally, risks to piscivorous birds such as bald eagles were found to be low given that bioaccumulation in fish species is also low (BLM, 2005).

3.3.2 Dipotassium salt of endothall

No adverse effects are anticipated to the mudpuppy (*Necturus maculosus),* blueback herring (*Alosa aestivalis*), shortnose sturgeon (*Acipenser brevirostrum*, state and federally endangered), or Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus).* The median effective concentration (EC_{50}) was determined for various freshwater species to evaluate ecotoxicity: bluegill sunfish (*Lepomis macrochirus*) at 1,071 ppm, rainbow trout (*Oncorhynchus mykiss)* at 363 ppm, and the sheepshead minnow (*Cyprinodon variegatus)* at 340 ppm (96-hour EC_{50}). The EC_{50} of these species are significantly greater than the proposed application rate of 5 ppm (UPL, 2019). Ecotoxicology response of fish provides surrogate information for amphibian species. Therefore, no adverse impacts to the mudpuppy (*Necturus maculosus)* are anticipated.

No impacts are expected to the wood turtle (*Glyptemys insculpta)*. As discussed previously, a study monitored the diquat and endothall response of the eastern spiny softshell turtle (*Apalone spinifera spinifera*) over time with a range of in-water herbicide concentrations. This study did not observe any toxic effects to any of the turtles and none of the turtles used in the experiment died during either the exposure or postexposure monitoring portions of the test. This study concluded that softshell turtles were not sensitive to endothall (Paul & Simonin, 2007).

No adverse effects are anticipated to the bald eagle (*Haliaeetus leucocephalus)*, peregrine falcon (*Falco peregrinus)*, cerulean warbler (*Setophaga cerulea)*, and whip-poor-will (*Caprimulgus vociferus)*. No airborne exposure risks are anticipated to these species as subsurface injection methods will be utilized. Additionally, the proposed application rates are within the concentration limits specified on the EPA-approved herbicide label. The median lethal concentration (LC_{50}) of dipotassium salt of endothall is 325 mg/kg for the mallard duck (*Anas platyrhynchos*) (UPL, 2019). The proposed application rate of 5 ppm is significantly below this LC_{50}.

3.3.3 Florpyrauxifen-benzyl

No impacts are expected to the fish species of concern, as florpyrauxifen-benzyl is considered to be practically nontoxic to freshwater fish (DNR, 2022; Levey, 2022; EPA, 2017). Studies of florpyrauxifen-benzyl impacts on fish and aquatic organisms largely did not observe toxicity even when applied up to its functional limit of solubility (Levey, 2022; EPA, 2017). Further, results of bioaccumulation studies in fish suggested rapid and extensive metabolism of florpyrauxifen-benzyl, indicating that bioaccumulation potential for this herbicide is low (EPA, 2017). Fish toxicity has not been previously reported in field or laboratory evaluations of florpyrauxifen-benzyl at the proposed application rate (48 ppb). Additionally, chronic toxicity in these species are also not considered to be a concern as the proposed treatment activity only includes one herbicide application, and florpyrauxifen-benzyl has been shown to rapidly degrade through aerobic aquatic metabolism and aqueous photolysis once applied (EPA, 2017). Florpyrauxifen-benzyl is considered practically non-toxic to fish on an acute basis [static 96-hour EC50 >120 mg/L for carp (*Cyprinus carpio*)] (SePRO, 2017).

The direct response of the mudpuppy (*Necturus maculosus)* is not currently available. In ecotoxicology, fish species are considered surrogates for amphibians. No impacts are expected to the mudpuppy as the maximum produce use rate is significantly greater than the EC_{50} for fish species. Additionally, a lower risk is anticipated as a 96-hour exposure time is not practicable under field conditions at Hamburg Cove.

No impacts are expected due to bird species of concern, including the bald eagle (*Haliaeetus leucocephalus)*, peregrine falcon (*Falco peregrinus)*, cerulean warbler (*Setophaga cerulea)*, and whip-poor-will (*Caprimulgus vociferus)*. The risk of acute impacts to birds is considered to be low. Florpyrauxifen-benzyl has been shown to be non-toxic to multiple bird species with a reported LD50 >2,500 mg/kg bodyweight for Bobwhite quail (*Colinus virginianus*) (Levey, 2022; EPA, 2017; SePRO, 2017). Additionally, because herbicides will be applied using subsurface injection methods, no airborne exposure risks to nearby birds at the time of application are anticipated.

4. Conservation Strategy for Endangered, Threatened and Special Concern Species

4.1 Herbicide Application Methods and Timing

Strategic herbicide application methods and timing will be employed throughout this demonstration project to minimize the potential risk of impacts to non-target and state-listed species of concern. The selected herbicide(s) will be applied in accordance with the product's EPA-approved label.

4.2 Considerations for Plants

Monitoring of plant species of concern will occur if present within the treatment area. Revegetation will occur following herbicide treatment if the herbicide is determined to result in species mortality.

4.3 Considerations for Vertebrates

Alewife and blueback herring are known to spawn over aquatic vegetation within the proposed treatment area between April 1 and June 30. To minimize potential impacts to these spawning events, the timing of treatment application will be delayed until after July 4, 2024.

5. Literature Cited

Archambault, J.M., Bergeron, C.M., Cope, G.W., Richardson, R.J., Heilman, M.A., Corey III, E.J., Netherland, M.D., & Heise, R.J. 2015. Sensitivity of freshwater molluscs to hydrilla-targeting herbicides: providing context for invasive aquatic weed control in diverse ecosystems. Journal of Freshwater Ecology. Vol. 30(3): 335-348.

Beets, J., Heilman, M., & Netherland, M.D. 2019. Large-Scale Mesocosm Evaluation of Florpyrauxifen-Benzyl, a Novel Arylpicolinate Herbicide, on Eurasian and Hybrid Watermilfoil and Seven Native Submersed Plants." Journal of Aquatic Plant Management. Vol. 57: 49-55

Beets, J., & Netherland, M.D. 2018. Mesocosm response of crested floating heart, hydrilla, and two native emergent plants to florpyrauxifen-benzyl: A new arylpicolinate herbicide. Journal of Aquatic Plant Management. Vol. 56: 57-62

Buczek, S.B., Archambault, J.M., Cope, W.G., & Heilman, M.A. 2020. Evaluation of Juvenile Freshwater Mussel Sensitivity to Multiple Forms of Florpyrauxifen-Benzyl. Bulletin of Environmental Contamination and Toxicology. Volume 105: 588-594 https://doi.org/10.1007/s00128-020-02971-1.

Bugbee, G.J., & Stebbins, S.E. 2022. Invasive Aquatic Vegetation Survey Hydrilla Overwintering and Spread Management Options. Department of Environmental Science and Forestry.

Bureau of Land Management (BLM). 2005. Diquat Ecological Risk Assessment, Final Report. All U.S. Government Documents (Utah Regional Depository).

Claudi, R., Taraborelli, C., & Prescott, T.H. 2013. Efficacy of Endothall for Control of Adult Quagga and Zebra Mussels. Accessed 31 January 2025 from https://invasivemusselcollaborative.net/wp-content/uploads/2018/11/Claudi-et-al.-2013b.pdf.

Clayton, J., & Severne, C. 2005. Review of Diquat Reports of Relevance to Iwi Values in Lake Karapiro. Environment Waikato Technical Report 2006/03. Environment Waikato. https://www.waikatoregion.govt.nz/assets/WRC/WRC-2019/tr06-03.pdf.

Dawson, F.H. 1996. *Crassula helmsii:* attempts at elimination using herbicides. *Hydrobiologia*. Vol. 340: 241-245.

Doherty, R.S., Stebbins, S.E., & Bugbee, G.J. 2023. Hamburg Cove 2022 Invasive Aquatic Survey. The Connecticut Agricultural Experiment Station (CAES).

Emmett, K. 2002. "Appendix A: Final Risk Assessment for Diquat Bromide." 02-10–046. Washington State Department of Ecology

Gilderhus, P.A. 1967. Effects of diquat on bluegills and their food organisms: The Progressive Fish-Culturis. Vol. 29(2): 67-74. https://doi.org/10.1577/1548-8640(1967)29[67:EODOBA]2.0.CO;2

Hartless, C., and Lin, J. 2010. "Risks of Diquat Dibromide Use to the Federally Threatened Delta Smelt."

Levey, R. 2022. Aquatic Nuisance Control Permit, ProcellaCOR EC Aquatic Toxicity Review.

https://dec.vermont.gov/sites/dec/files/wsm/lakes/ANC/docs/ProcellaCor%20Aquatic%20Toxicity%20Review%20_03162022.pdf.

Menninger, H. 2012. Endothall FAQ. Cornell Cooperative Extension. 2012. http://ccetompkins.org/environment/aquatic-invasives/hydrilla/managementoptions/herbicides/endothall/endothall-faq.

Mudge, C.R., Sartain, B.T., Getsinger, K.D., & Netherland, M.D. 2021. Efficacy of Florpyrauxifen-Benzyl on Dioecious Hydrilla and Hybrid Water Milfoil - Concentration and Exposure Time Requirements. U.S. Engineer Research and Development Center. https://doi.org/10.21079/11681/42062.

Netherland, M.D., & Richardson, R.J. 2016. Evaluating Sensitivity of Five Aquatic Plants to a Novel Arylpicolinate Herbicide Utilizing an Organization for Economic Cooperation and Development Protocol. Weed Science. Vol. 64(1): 181–90. https://doi.org/10.1614/WS-D-15-00092.1.

Netherland, M.D., Green, W.R., and Getsinger, K.D. 1991. Endothall Concentration and Exposure Time Relationships for the Control of Eurasian Watermilfoil and Hydrilla. Journal of Aquatic Plant Management. Vol. 29: 61–67.

Parsons, J.K., Baldwin, L., & Lubliner, N. 2019. An operational study of repeated diquat treatments to control submersed flowering rush. Journal of Aquatic Plant Management. Vol. 47: 28-32.

Paul, E.A, & Simonin, H.A. 2007. Toxicity of Diquat and Endothall to Eastern Spiny Softshell Turtles (*Apalone spinifera spinifera)*. Journal of Aquatic Plant Management. Vol. 45: 52-44

Richardson, R., Haug, E.J., and Netherland, M.D. 2016. Response of Seven Aquatic Plants to a New Arylpicolinate Herbicide. Journal of Aquatic Plant Management. Vol. 54: 26–31.

SePRO Corporation (SePRO). 2017. Safety Data Sheet for ProcellaCOR EC Version 1.0. EPA Registration No. 67690-80.

Skogerboe, J.G., & Netherland, M.D. 2008. Draft report following April 2008 aquatic herbicide treatments of three bays on Lake Minnetonka. October. Report to the Minnesota Department of Natural Resources. https://lmcd.org/wp-content/uploads/2021/04/20081008-Lake-Minnetonka-Preliminary-Report-II-Skogerboe1.pdf

Skogerboe, J.G., & Getsinger, K.D. 2001. Endothall species selectivity evaluation: Southern latitude aquatic plant community. Journal of Aquatic Plant Management. Vol. 39:129-135

Sperry, B.P, Leary, J.K., Dean Jones, K, & Ferrell, J.A. 2021. Observations of a Submersed Field Application of Florpyrauxifen-Benzyl Suppressing Hydrilla in a Small Lake in Central Florida. Journal of Aquatic Plant Management. Vol. 59: 20-26.

Tippery, N.P., Bugbee, G.J., & Stebbins, S.E. 2020. Evidence for a Genetically Distinct Strain of Introduced Hydrilla Verticillata (Hydrocharitaceae) in North America. Journal of Aquatic Plant Management. Vol. 58:1-6.

UPL Limited (UPL). 2019. Safety Data Sheet for AQUATHOL® K Aquatic Herbicide.

U.S. Environmental Protection Agency (EPA). 2017. The 2017 EPA Environmental

Fate and Ecological Risk Assessment for Florpyrauxifen-Benzyl.
U.S. Environmental Protection Agency (EPA). 1995. Diquat Dibromide. https://archive.epa.gov/pesticides/reregistration/web/pdf/0288fact.pdf.
Wisconsin Department of Natural Resources (DNR). 2022. Florpyrauxifen-Benzyl Fact Sheet. https://apps.dnr.wi.gov/swims/Documents/DownloadDocument?id=332109305
Wisconsin Department of Natural Resources (DNR). 2012. Diquat Chemical Fact Sheet. https://www.noaa.gov/sites/default/files/legacy/document/2020/Oct/07354626838.pdf

Connecticut River
Hydrilla Control Research and Demonstration Project
Lower Connecticut River, CT

Species Protection Plan
Joshua Creek
Lyme, CT

US Army Corps
of Engineers ®
New England District

February 2025

Joshua Creek Species Protection Plan

Table of Contents

1. Introduction

1.1 Connecticut River Hydrilla Information

Hydrilla (*Hydrilla verticillata*) was first identified in the Connecticut River near Glastonbury, CT in 2016 and has since spread south to Essex, CT infesting the river's many coves, tributaries, and boat basins. The Connecticut River hydrilla population has been shown to be genetically distinct from other known hydrilla strains (Tippery, Bugbee, & Stebbins, 2020), and the plant's biology is therefore largely unknown at this time. Following the discovery of the highly invasive aquatic plant in the Connecticut River in 2016, intensive vegetation surveys were conducted in 2019 and 2020 from Agawam, MA south to Long Island Sound to map the invasion extent. Hydrilla was found as far north as Agawam, MA, confirming that the plant spreads rapidly which poses significant risk to other regional waterbodies (Bugbee & Stebbins, 2022). Fragments of the plant, which are easily transported by boats and boat trailers, can sprout roots to establish new populations. Fragments also float and are capable of dispersing via wind and water currents. Due to the importance of the Connecticut River as an environmental resource and driver of the local economy, stakeholders are seeking an aggressive hydrilla management program.

1.2 Project Background

The U.S. Army Corps of Engineers (USACE), through its Engineer Research and Development Center's (ERDC) Aquatic Plant Control Research Program, is leading a research and demonstration project to verify the effectiveness of aquatic herbicides registered for use by the U.S. Environmental Protection Agency (EPA) to reduce and control the spread of the Connecticut River hydrilla safely and selectively. The project has been investigating hydrilla's growth patterns, site-specific water exchange dynamics and evaluating herbicide efficacy in laboratory conditions throughout 2023 to guide operational scale field demonstrations of herbicide efficacy in 2024.

Preliminary laboratory experiments conducted in 2023 evaluated Connecticut River hydrilla control using the aquatic herbicide, florpyrauxifen-benzyl. Results from these experiments indicated that Connecticut River hydrilla has a similar response to florpyrauxifen-benzyl across multiple concentrations and exposure times as dioecious and monoecious hydrilla biotypes. In 2024, ERDC treated five sites as a part of the Connecticut River Hydrilla Control Research & Demonstration project. Joshua Creek has been selected as a hydrilla treatment site for ERDC's 2025 field demonstration project.

1.3 Joshua Creek Treatment Site

Joshua Creek is a tidal creek off the mainstem of the Connecticut River and located in Lyme, New London County, CT and centered at 41.395° N, 72.377° W. The treatment area is 20.74 acres with a mean depth of 6 feet mean higher high water. The creek is transected by two roads, with a culvert connecting the upper and lower ponds.

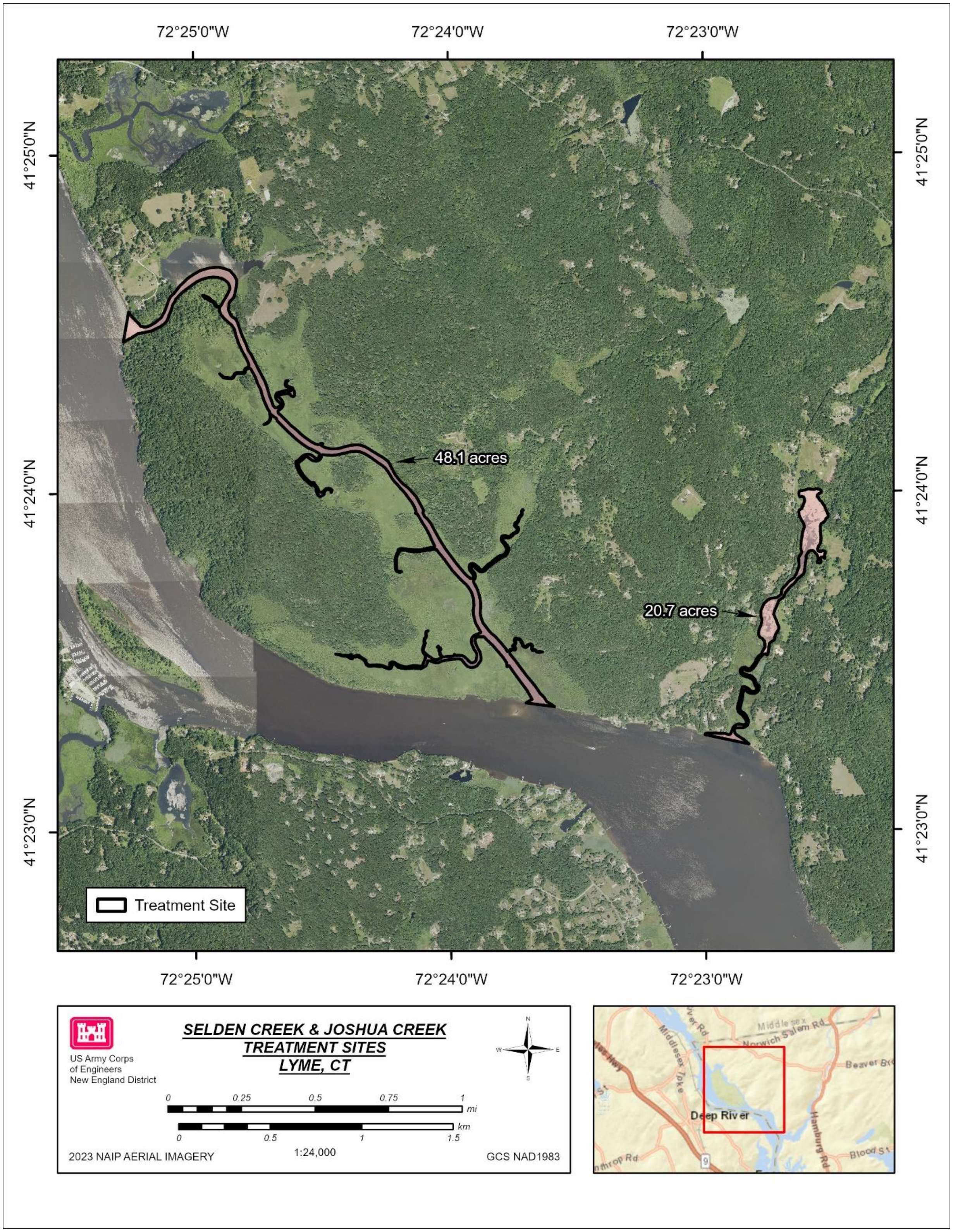

Figure 1. Selden Creek (left) and Joshua Creek (right) hydrilla treatment area in Lyme, CT.

2. Proposed Treatment Activity

Diquat, dipotassium salt of endothall, florpyrauxifen-benzyl, or combinations thereof are proposed to be applied in Joshua Creek for hydrilla control. The selected herbicide(s) will be applied at the maximum concentration rate. The herbicide(s) will be evenly distributed across the entire treatment area delineated in Figure 1 using boat-based, subsurface injection application methods. This section describes the proposed herbicides.

2.1 Diquat

Diquat dibromide is a state and federally registered herbicide approved for application in aquatic sites for invasive aquatic plant control. A Registration Standard for diquat dibromide was issued by the EPA in June 1986 (EPA, 1995). The active ingredient ((6,7-dihydrodipyrido (1,2a:2',1'-c) pyrazinediium dibromide)) is a fast-acting herbicide that interferes with photosynthesis, disrupts plant cell membranes, and results in plant death within a week of application in sensitive plant species (DNR, 2012).

2.2 Dipotassium salt of endothall

Dipotassium salt of endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid) is a state and federally registered aquatic herbicide and is approved for application in aquatic sites for the treatment of invasive aquatic plant species. The dipotassium salt of endothall was registered by EPA for aquatic use in 1960 at application rates between 0.5 and 5.0 ppm for aquatic plant control (Menninger, 2012). Dipotassium salt of endothall is a selective fast-acting herbicide that interferes with plant protein and lipid biosynthesis, disrupting respiration and plant membranes. This herbicide is highly effective for hydrilla control (Netherland et al.,1991).

2.3 Florpyrauxifen-benzyl

Florpyrauxifen-benzyl is a state and federally registered herbicide, and that is approved for invasive plant treatment in aquatic environments. This relatively new systemic herbicide mimics the plant growth hormone, auxin, killing susceptible plants by disrupting the plant cell growth process.

The active ingredient (4-amino-3chloro-6-(4-chloro-2-fluoro-3-methoxyphenyl) 5-fluoropyridine-2-benzyl ester) causes excessive plant cell elongation, ultimately resulting in plant cell death in sensitive plant species. Florpyrauxifen-benzyl is absorbed from the water through submersed plant shoots and leaves, and this herbicide has previously been demonstrated to be highly effective at selectively suppressing both dioecious and monoecious invasive hydrilla (Sperry et al., 2021; Mudge et al., 2021; Beets et al., 2019; Netherland & Richardson, 2016; Richardson et al., 2016) with relatively short exposure times and lower application rates compared to other herbicides (DNR, 2022).

3. Potential Impacts of the Proposed Treatment Activity

3.1 State-Listed Native Plant Species

Preliminary assessments of the Natural Diversity Database maps and files identified one state-listed vascular plant that may potentially occur within Joshua Creek: beck's water-marigold (*Bidens beckii*, state special concern). This species has historically occurred near Joshua Creek.

3.1.1 Diquat

No significant impacts are expected to beck's water marigold (*Bidens beckii)* from the application of diquat. A study on operational application of diquat observed the effects on non-target native plants. Diquat was applied to a 4-hectare treatment area within a lake, at the maximum concentration rate for a five-year period. No significant changes to beck's water marigold were observed during the study (Parsons et al., 2019).

3.1.2 Dipotassium salt of endothall

No significant impacts are expected to beck's water-marigold from the application of endothall. A study observed the effects of submersed applications of endothall and triclopyr to Lake Minnetonka in Minnesota. Populations were not reduced following submersed applications of endothall plus triclopyr (Skogerboe & Netherland, 2008). Additionally, endothall is not known to cause injury to emergent aquatic plant species when applied subsurface.

3.1.3 Florpyrauxifen-benzyl

No significant impacts are expected to beck's water-marigold from the application of florpyrauxifen-benzyl. Growth chamber and mesocosm studies indicate that this species is quite tolerant to florpyrauxifen-benzyl. An estimated half maximal effective concentration (EC50) was determined for *Bidens beckii* of 11.3 and 6.1 ppb from static exposures of 14 and 28 days, respectively (Netherland & Richardson, 2016). However, actual potential herbicide exposure times in most Connecticut River sites are less than 24 hours which poses significantly lower injury risk to this species compared to multi-week herbicide exposures in the reported experiments.

3.2 State-Listed Invertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified no state-listed invertebrate species. Therefore, no state-listed invertebrate species are considered at risk of impact from the proposed treatment actions at this location.

3.3 State-Listed Vertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified seven state-listed vertebrates that may be present within Joshua Creek: shortnose sturgeon (*Acipenser brevirostrum*, state and federally endangered), Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*, state and federally endangered), blueback herring (*Alosa aestivalis*, state special concern), mudpuppy (*Necturus maculosus,* state special concern), eastern box turtle (*Terrapene carolina carolina*, state special concern), peregrine falcon (*Falco peregrinus*, state threatened), and red bat (*Lasiurus borealis,* state special concern). No vertebrate surveys were completed during the 2024 environmental studies.

3.3.1 Diquat

No adverse effects are anticipated for the fish species of concern given that the proposed application rates are within the concentration limits specified on the EPA-approved herbicide label. Studies have found that diquat has relatively low toxicity to fish and does not appear to significantly bioaccumulate in fish tissue (BLM, 2005). The results of acute exposure studies on freshwater fish have been summarized as "slightly toxic to practically non-toxic for diquat dibromide" (Hartless & Lin, 2010).

No impacts are expected to the mudpuppy (*Necturus maculosus)* and the eastern box turtle (*Terrapene carolina carolina).* One study of diquat impacts on the northern leopard frog (*Lithobathes pipiens*) found that in a 16-day exposure period, adverse effects were observed at 5mg/L concentrations, however no adverse effects were observed at 2mg/L concentrations (Dial & Dial,1987). Both concentrations are substantially higher than the proposed treatment application rate, so the risk of negative impacts to amphibian species are expected to be minimal. Additionally, fish species are considered to be surrogates for amphibians in toxicological studies. As described above, diquat has relatively low toxicity to fish. The eastern box turtle is not likely the occur within the intertidal zone or aquatic habitat, and therefore no impacts are expected to occur under the proposed subsurface herbicide application.

No impacts are expected to the peregrine falcon (*Falco peregrinus)* or the red bat (*Lasiurus borealis)*. Herbicides will be applied using subsurface injection methods, no airborne exposure risks to nearby non-aquatic species at the time of application are anticipated. Additionally, while diquat dibromide has been found to be moderately toxic to birds in acute oral exposure studies (EPA, 1995; BLM, 2005; Emmett, 2002), many of these studies were conducted at much higher concentrations than the proposed treatment.

3.3.2 Dipotassium salt of endothall

No adverse effects are anticipated to any vertebrates of concern given that the proposed application rates are within the concentration limits specified on the EPA-approved herbicide label. The median effective concentration (EC_{50}) and median lethal concentration (LC_{50}) were determined to evaluate the ecotoxicity of Endothall dipotassium salt (Table 1). Although the response of the potential species is not known, no significant impacts are expected as endothall will be applied at the EPA maximum concentration rate of 5 ppm. This application rate is significantly below the rates described in Table 1. Additionally, herbicides will be applied using subsurface injection methods, no airborne exposure risks to nearby non-aquatic species at the time of application are anticipated.

Table 1. Vertebrate ecotoxicity of dipotassium salt of Endothall

Common Name	Scientific Name	Ecotoxicity
Bluegill sunfish	*Lepomis macrochirus*	1,071 ppm (EC_{50})
Rainbow trout	*Oncorhynchus mykiss*	363 ppm (EC_{50})
Sheepshead minnow	*Cyprinodon variegatus*	340 ppm (96-hour EC_{50})
Mallard	*Anas platyrhynchos*	328 mg/kg (LC_{50})

Source: (UPL, 2019).

No impacts are expected to the eastern box turtle (*Terrapene carolina carolina).* This species is not likely to occur within the intertidal zone or aquatic habitat, and therefore is not expected to be impacted by the herbicide application.

3.3.3 Florpyrauxifen-benzyl

Florpyrauxifen-benzyl is considered to be practically nontoxic to freshwater fish. Studies of florpyrauxifen-benzyl impacts on fish and aquatic organisms largely did not observe toxicity even when applied up to its functional limit of solubility (Levey, 2022; EPA, 2017). Further, results of bioaccumulation studies in fish suggested rapid and extensive metabolism of florpyrauxifen-benzyl, indicating that bioaccumulation potential for this herbicide is low (EPA, 2017). Fish toxicity has not been previously reported in field or laboratory evaluations of florpyrauxifen-benzyl at the proposed application rate (48 ppb). Although the response of the mudpuppy (*Necturus maculosus)* is unknown, fish species are considered surrogates for amphibians in toxicological studies. No impacts are expected to the mudpuppy as the maximum produce use rate is significantly greater than the EC_{50} for fish species (SePRO Corporation, 2017).

No significant impacts are expected to the peregrine falcon (*Falco peregrinus)*. The risk of acute impacts to birds is also considered to be low. Florpyrauxifen-benzyl has been shown to be non-toxic to multiple bird species with a reported LD50 >2,500 mg/kg bodyweight for Bobwhite quail (*Colinus virginianus*) (Levey, 2022; EPA, 2017; SePro, 2017). Additionally, because herbicides will be applied using subsurface injection methods, no airborne exposure risks to nearby birds or the red bat (*Lasiurus borealis*) at the time of application are anticipated. The LD_{50} was determined for mammalians using rats. The concentrations for both oral and dermal exposure were signicantly greater than the approved concentration rate, and were determined greater than 5,000 mg/kg (SePRO Corporation, 2017).

No significant impacts are expected to the eastern box turtle (*Terrapene carolina carolina).* This species is not likely to occur within the intertidal zone or aquatic habitat, and therefore is not expected to be impacted by the herbicide application.

4. Conservation Strategy for Endangered, Threatened and Special Concern Species

4.1 Herbicide Application Methods and Timing

Strategic herbicide application methods and timing will be employed throughout this demonstration project to minimize the potential risk of impacts to non-target and state-listed species of concern. The selected herbicide(s) will be applied in accordance with the product's EPA-approved label.

4.2 Considerations for Plants

Monitoring will occur if beck's water-marigold (*Bidens beckii)* is present. If a net loss in plant species is observed within two years of monitoring and is determined to be from herbicide application, replanting will occur to minimize potential impacts of individuals lost.

4.3 Considerations for Vertebrates

Alewife and blueback herring are known to spawn over aquatic vegetation within the proposed treatment area between April 1 and June 30. To minimize potential impacts to these spawning events, the timing of treatment application will be delayed until after July 4, 2025.

5. Literature Cited

Beets, J., Heilman, M., & Netherland, M.D. 2019. Large-Scale Mesocosm Evaluation of Florpyrauxifen-Benzyl, a Novel Arylpicolinate Herbicide, on Eurasian and Hybrid Watermilfoil and Seven Native Submersed Plants." Journal of Aquatic Plant Management. Vol. 57: 49-55

Bugbee, G.J., & Stebbins, S.E. 2022. Invasive Aquatic Vegetation Survey Hydrilla Overwintering and Spread Management Options. Department of Environmental Science and Forestry.

Bureau of Land Management (BLM). 2005. Diquat Ecological Risk Assessment, Final Report. All U.S. Government Documents (Utah Regional Depository).

Dial, N.A., & Bauer Dial, C.A. 1987. Lethal Effects of Diquat and Paraquat on Developing Frog Embryos and 15-Day-Old Tadpoles, *Rana pipiens*. Bulletin of Environmental Contamination and Toxicology. Vol. 38(6): 1006–1011. https://doi.org/10.1007/BF01609088.

Emmett, K. 2002. "Appendix A: Final Risk Assessment for Diquat Bromide." 02-10–046. Washington State Department of Ecology

Hartless, C., and Lin, J. 2010. "Risks of Diquat Dibromide Use to the Federally Threatened Delta Smelt."

Levey, R. 2022. Aquatic Nuisance Control Permit, ProcellaCOR EC Aquatic Toxicity Review. https://dec.vermont.gov/sites/dec/files/wsm/lakes/ANC/docs/ProcellaCor%20Aquatic%20Toxicity%20Review%20_03162022.pdf.

Menninger, H. 2012. Endothall FAQ. Cornell Cooperative Extension. 2012. http://ccetompkins.org/environment/aquatic-invasives/hydrilla/managementoptions/herbicides/endothall/endothall-faq.

Mudge, C.R., Sartain, B.T., Getsinger, K.D., & Netherland, M.D. 2021. Efficacy of Florpyrauxifen-Benzyl on Dioecious Hydrilla and Hybrid Water Milfoil - Concentration and Exposure Time Requirements. U.S. Engineer Research and Development Center. https://doi.org/10.21079/11681/42062.

Netherland, M.D., & Richardson, R.J. 2016. Evaluating Sensitivity of Five Aquatic Plants to a Novel Arylpicolinate Herbicide Utilizing an Organization for Economic Cooperation and Development Protocol. Weed Science. Vol. 64(1): 181–90. https://doi.org/10.1614/WS-D-15-00092.1.

Netherland, M.D., Green, W.R., and Getsinger, K.D. 1991. Endothall Concentration and Exposure Time Relationships for the Control of Eurasian Watermilfoil and Hydrilla. Journal of Aquatic Plant Management. Vol. 29: 61–67.

Parsons, J.K., Baldwin, L., & Lubliner, N. 2019. An operational study of repeated diquat treatments to control submersed flowering rush. Journal of Aquatic Plant Management. Vol. 47: 28-32.

Richardson, R., Haug, E.J., and Netherland, M.D. 2016. Response of Seven Aquatic Plants to a New Arylpicolinate Herbicide. Journal of Aquatic Plant Management. Vol. 54: 26–31.

SePRO Corporation. 2017. Safety Data Sheet for ProcellaCOR EC Version 1.0. EPA Registration No. 67690-80.

Skogerboe, J.G., & Netherland, M.D. 2008. Draft report following April 2008 aquatic herbicide treatments of three bays on Lake Minnetonka. October. Report to the Minnesota Department of Natural Resources. https://lmcd.org/wp-content/uploads/2021/04/20081008-Lake-Minnetonka-Preliminary-Report-II-Skogerboe1.pdf

Sperry, B.P, Leary, J.K., Dean Jones, K, & Ferrell, J.A. 2021. Observations of a Submersed Field Application of Florpyrauxifen-Benzyl Suppressing Hydrilla in a Small Lake in Central Florida. Journal of Aquatic Plant Management. Vol. 59: 20-26.

Tippery, N.P., Bugbee, G.J., & Stebbins, S.E. 2020. Evidence for a Genetically Distinct Strain of Introduced Hydrilla Verticillata (Hydrocharitaceae) in North America. Journal of Aquatic Plant Management. Vol. 58:1-6.

UPL Limited (UPL). 2019. Safety Data Sheet for AQUATHOL® K Aquatic Herbicide.

U.S. Environmental Protection Agency (EPA). 2017. The 2017 EPA Environmental Fate and Ecological Risk Assessment for Florpyrauxifen-Benzyl.

U.S. Environmental Protection Agency (EPA). 1995. Diquat Dibromide. https://archive.epa.gov/pesticides/reregistration/web/pdf/0288fact.pdf.

Wisconsin Department of Natural Resources (DNR). 2022. Florpyrauxifen-Benzyl Fact Sheet. https://apps.dnr.wi.gov/swims/Documents/DownloadDocument?id=332109305

Wisconsin Department of Natural Resources (DNR). 2012. Diquat Chemical Fact Sheet. https://www.noaa.gov/sites/default/files/legacy/document/2020/Oct/07354626838.pdf

Connecticut River
Hydrilla Control Research and Demonstration Project
Lower Connecticut River, CT

Species Protection Plan
Mattabesset River
Middletown, CT

US Army Corps of Engineers ®
New England District

March 2025

Mattabesset River Species Protection Plan

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1. Introduction

1.1 Connecticut River Hydrilla Information

Hydrilla (*Hydrilla verticillata*) was first identified in the Connecticut River near Glastonbury, CT in 2016 and has since spread south to Essex, CT infesting the river's many coves, tributaries, and boat basins. The Connecticut River hydrilla population has been shown to be genetically distinct from other known hydrilla strains (Tippery, Bugbee, & Stebbins, 2020), and the plant's biology is therefore largely unknown at this time. Following the discovery of the highly invasive aquatic plant in the Connecticut River in 2016, intensive vegetation surveys were conducted in 2019 and 2020 from Agawam, MA south to Long Island Sound to map the invasion extent. Hydrilla was found as far north as Agawam, MA, confirming that the plant spreads rapidly which poses significant risk to other regional waterbodies (Bugbee & Stebbins, 2022). Fragments of the plant, which are easily transported by boats and boat trailers, can sprout roots to establish new populations. Fragments also float and are capable of dispersing via wind and water currents. Due to the importance of the Connecticut River as an environmental resource and driver of the local economy, stakeholders are seeking an aggressive hydrilla management program.

1.2 Project Background

The U.S. Army Corps of Engineers (USACE), through its Engineer Research and Development Center's (ERDC) Aquatic Plant Control Research Program, is leading a research and demonstration project to verify the effectiveness of aquatic herbicides registered for use by the U.S. Environmental Protection Agency (EPA) to reduce and control the spread of the Connecticut River hydrilla safely and selectively. The project has been investigating hydrilla's growth patterns, site-specific water exchange dynamics and evaluating herbicide efficacy in laboratory conditions throughout 2023 to guide operational scale field demonstrations of herbicide efficacy in 2024.

Preliminary laboratory experiments conducted in 2023 evaluated Connecticut River hydrilla control using the aquatic herbicide, florpyrauxifen-benzyl. Results from these experiments indicated that Connecticut River hydrilla has a similar response to florpyrauxifen-benzyl across multiple concentrations and exposure times as dioecious and monoecious hydrilla biotypes. In 2024, ERDC treated five sites as a part of the Connecticut River Hydrilla Control Research & Demonstration project. Joshua Creek has been selected as a hydrilla treatment site for ERDC's 2025 field demonstration project.

1.3 Mattabesset River Treatment Site

Mattabesset River is a tidal river off the mainstem of the Connecticut River and located in Middletown, Middlesex County, CT and centered at 41.583° N, 72.663° W. The treatment area is 65.60 acres with a mean depth of 7 feet mean higher high water.

The river is surrounded by freshwater marsh that is dominated by river bulrush (*Bolboschoenus fluviatilis*) and arrow arum (*Peltandra* spp*.)*. The southern section, near its confluence to the Connecticut River, is surrounded by floodplain woodlands. The woodlands contain species such as sensitive fern (*Onoclea sensibilis)*, spikesedge (*Eleocharis spp.),* iris (*Iris* spp.), and grasses.

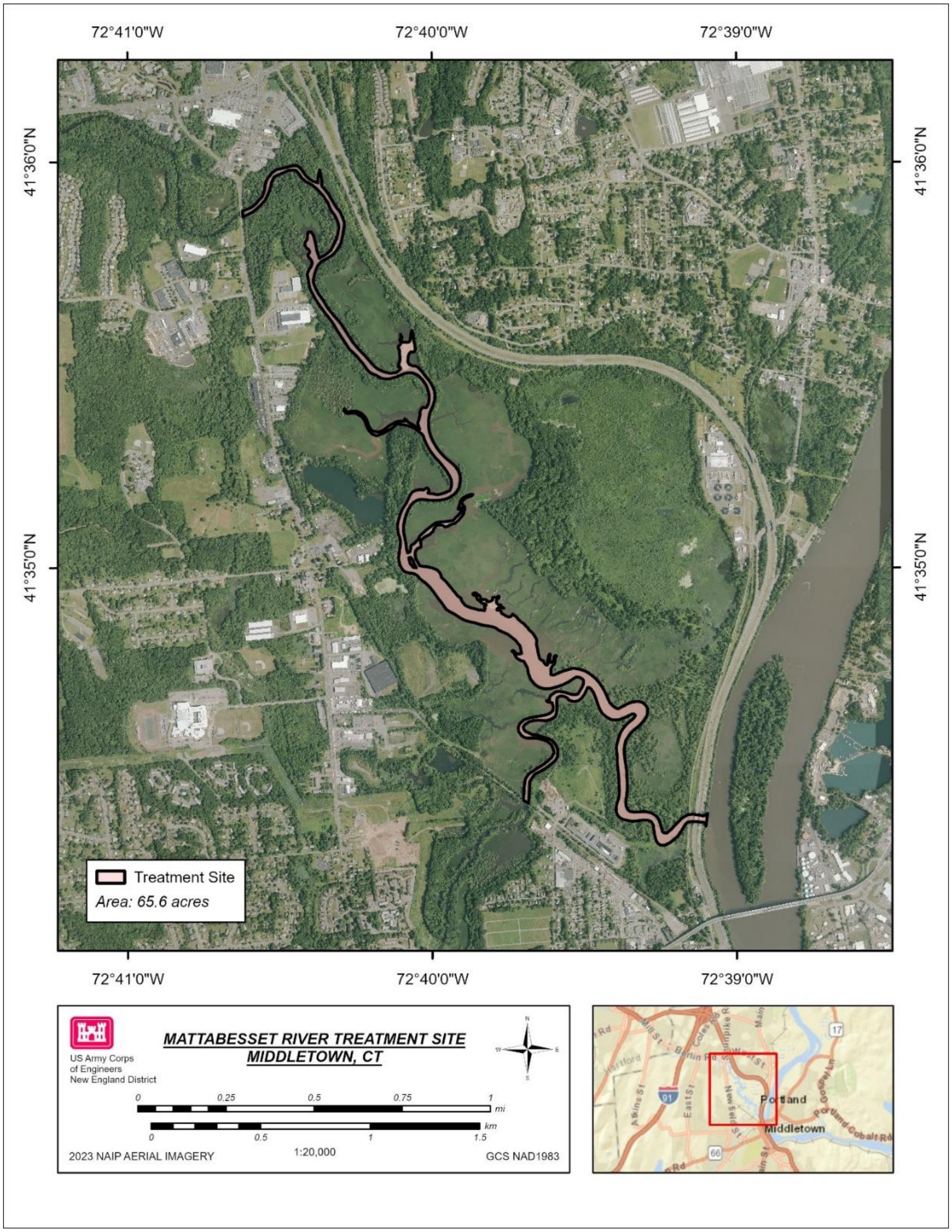

Figure 1. Mattabesset River hydrilla treatment area in Middletown, CT.

2. Proposed Treatment Activity

Diquat, dipotassium salt of endothall, florpyrauxifen-benzyl, fluridone or combinations thereof are proposed to be applied in Mattabesset River for hydrilla control. The selected herbicide(s) will be applied at the maximum concentration rate. The herbicide(s) will be evenly distributed across the entire treatment area delineated in Figure 1 using boat-based, subsurface injection application methods. This section describes the proposed herbicides.

2.1 Diquat

Diquat dibromide is a state and federally registered herbicide approved for application in aquatic sites for invasive aquatic plant control. A Registration Standard for diquat dibromide was issued by the EPA in June 1986 (EPA, 1995). The herbicide is proposed to be applied at a concentration of 370 ppb. The active ingredient ((6,7-dihydrodipyrido (1,2a:2',1'-c) pyrazinediium dibromide)) is a fast-acting herbicide that interferes with photosynthesis, disrupts plant cell membranes, and results in plant death within a week of application in sensitive plant species (DNR, 2012).

2.2 Dipotassium salt of endothall

Dipotassium salt of endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid) is a state and federally registered aquatic herbicide, and is approved for application in aquatic sites for the treatment of invasive aquatic plant species. The dipotassium salt of endothall was registered by EPA for aquatic use in 1960 at application rates between 0.5 and 5.0 ppm for aquatic plant control (Menninger, 2012). The herbicide is proposed to be applied at a concentration of 5 ppm. Dipotassium salt of endothall is a selective fast-acting herbicide that interferes with plant protein and lipid biosynthesis, disrupting respiration and plant membranes. This herbicide is highly effective for hydrilla control (Netherland et al.,1991).

2.3 Florpyrauxifen-benzyl

Florpyrauxifen-benzyl is a state and federally registered herbicide, that is approved for invasive plant treatment in aquatic environments. The herbicide is proposed to be applied at a concentration of 48 ppb. This relatively new systemic herbicide mimics the plant growth hormone, auxin, killing susceptible plants by disrupting the plant cell growth process.

The active ingredient (4-amino-3chloro-6-(4-chloro-2-fluoro-3-methoxyphenyl) 5-fluoropyridine-2-benzyl ester) causes excessive plant cell elongation, ultimately resulting in plant cell death in sensitive plant species. Florpyrauxifen-benzyl is absorbed from the water through submersed plant shoots and leaves, and this herbicide has previously been demonstrated to be highly effective at selectively suppressing both dioecious and monoecious invasive hydrilla (Sperry et al., 2021; Mudge et al., 2021; Beets et al., 2019; Netherland & Richardson, 2016; Richardson et al., 2016) with relatively short exposure times and lower application rates compared to other herbicides (DNR, 2022a).

2.4 Fluridone

Fluridone is a state and federally registered pesticide that is registered for aquatic use to control submerged, emergent, and floating-leaf vegetation. The proposed herbicide is to be applied at a concentration of 15 ppb. Fluridone is a systematic herbicide that inhibits phytoene desaturase (PDS), an enzyme that protects the plant from sun damage. Through inhibition of PDS, chlorophyll is susceptible to photolysis in which sunlight breaks down the plant's chlorophyll (DNR, 2022b)

3. Potential Impacts of the Proposed Treatment Activity

3.1 State-Listed Native Plant Species

Preliminary assessments of the Natural Diversity Database maps and files identified four state-listed vascular plant that may potentially occur within Mattabesset River: the hispid hedge-nettle (*Stachys hispida,* state threatened), swamp cottonwood (*Populus heterophylla*, state threatened), purple milkweed (*Asclepias purpurascens,* state special concern), and the violet wood-sorrel (*Oxalis violacea,* state special concern).

No impacts are expected to these species as the proposed treatment area will be restricted to the intertidal and aquatic zones. These species are not likely to occur below the intertidal zone, therefore the risk of herbicide impacts is low.

3.2 State-Listed Invertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified four state-listed invertebrate species: the tidewater mucket (*Leptodea ochracea,* state special concern), eastern pondmussel (*Ligumia nasuta,* state special concern), slender walker (*Pomatiopsis lapidaria,* state special concern), and the bronze copper (*Lycaena hyllus,* state special concern). No invertebrate surveys were completed during the 2024 environmental studies.

3.2.1 Diquat

No impacts are expected to the freshwater mussels from the application of diquat. One study tested the impacts of diquat on the New Zealand freshwater mussel (*Hyridella menziesi)* and concluded that diquat had no significant effects on freshwater mussels and, therefore, was considered to be non-toxic to these organisms when applied at rates needed to kill most aquatic weeds (Clayton & Severne, 2005).

The bronze copper (*Lycaena hyllus)*, and slender walker (*Pomatiopsis lapidaria*) are also not expected to be negatively impacted by the proposed treatment activity due to the in-water application methods under consideration. The EPA considers diquat to be of minimal risk to non-target insects (EPA, 1995). No impacts are anticipated to the slender walker. The acute toxicity of diquat was determined for the Florida applesnail

(*Pomacea paludosa)*. Diquat was determined moderately toxic to *P. paludosa*, with a 96-hour EC_{50} of 1.1ppm (Mayer & Ellersieck, 1986). The risk of exposure is lower for Mattabesset River as 96-hour exposure is not typically attainable under field use conditions. Additionally, this value is greater than the maximum use concentration.

3.2.2 Dipotassium of endothall

No impacts are expected to the tidewater mucket (*Leptodea ochracea)* and eastern pondmussel (*Ligumia nasuta)*. A study investigating impacts of dipotassium salt of endothall concentrations ranging from 0.5 to 1000 ppm on juvenile and glochidia fatmucket (*Lampsilis siliquoidea*) concluded that dipotassium salt of endothall was not found to be acutely toxic to fatmucket mussels at the application rates needed for hydrilla treatment. Median lethal concentrations (LC_{50}s) for glochidia and juvenile mussels were substantially higher (6-34 times higher) than recommended dipotassium salt of endothall application rates for hydrilla treatment (1-5 ppm) (Archambault et al., 2015). Dipotassium salt of endothall has also been tested on dreissenid mussels, specifically zebra and quagga mussels, to evaluate impacts. At the highest concentration applied (5 ppm) maximum mortality of 5% was observed for quagga mussels at 20º C, and 2.5% at 25º C. Zebra mussels had zero mortality to any dipotassium salt of endothall concentration at either temperature regime (Claudi et al., 2013).

The bronze copper (*Lycaena hyllus)* and slender walker (*Pomatiopsis lapidaria)* are also not expected to be negatively impacted by the proposed treatment activity. When used at recommended application rates, dipotassium salt of endothall no significant adverse effects were observed on aquatic insects (e.g. snails, aquatic insects, and crayfish) (DNR, 2012). Additionally, the proposed herbicide(s) will be applied using subsurface methods, therefore a low risk of exposure is anticipated for the bronze copper.

3.2.3 Florpyrauxifen-benzyl

No impacts are expected to the tidewater mucket (*Leptodea ochracea)* and eastern pondmussel (*Ligumia nasuta)*. A study on the impacts of florpyrauxifen-benzyl applications on juvenile fatmucket (*Lampsilis siliquoidea*) and eastern lampmussel (*Lampsilis radiata*) determined that this compound was not acutely toxic to juveniles of these species. While potential chronic or sub-lethal effects require further investigation to characterize, short-term exposure risk of these freshwater mussels to florpyrauxifen-benzyl for the purposes of aquatic weed control are minimal (Buczek et al., 2020).

The bronze copper (*Lycaena hyllus)* is not expected to be negatively impacted by the proposed treatment activity due to the in-water application methods under consideration. Previous studies have shown florpyrauxifen-benzyl to be essentially nontoxic on an acute basis to bees (Levey, 2022), thus risk of acute impacts to other insect species are also considered to be low. Additionally, this herbicide has been shown to have a relatively low potential for volatility from water due to low vapor pressure, and is not expected to have vapor drift impacts to this insect species (USEPA, 2017).

No impacts are expected to the slender walker (*Pomatiopsis lapidaria)*, as the herbicide poses minimal toxicological risk to aquatic invertebrates For the model ecotoxicological species, water flea (*Daphnia magna*), the 48-hour EC_{50} value reported is 49 mg/L [parts per million (ppm)] which is over 1,000-fold greater than the product's maximum use rate of 48 µg/L [parts per billion (ppb)] (SePRO, 2017a).

3.2.4 Fluridone

No impacts are anticipated to the tidewater mucket (*Leptodea ochracea*) or the eastern pondmussel (*Ligumia nasuta*). Juvenile, glochidia, and adult stage *Lampsilis* mussels have been tolerant to fluridone at concentrations and exposure times much greater than the typical field use rate (Archambault et al., 2015). Toxicological studies were conducted to determine the half maximal effective concentration (EC_{50}) of fluridone on model invertebrate species. The 48-hour EC_{50} of fluridone on Daphnia (*Daphnia magna)* and *Eucyclops spp.* is 3 and 8 mg L^{-1} according product safety data sheets (SePro, 2017b). These concentrations are significantly greater than the proposed treatment use rate of 15 ppb. 300- and 800-times greater than the typical fluridone use rate for hydrilla (10 ppb). These toxicological data in combination with no known toxicity issues in other treated systems suggests that risk to molluscs is minimal.

No impacts are anticipated to the slender walker (*Pomatiopsis lapidaria*). A study on freshwater snail sensitivities to fluridone reported the 30 day exposures of fluridone up to 1500 ppb did not affect adult snail survival, egg hatch, or hatching success on vinyl cards (Archambault & Cope, 2016). Fluridone did delay egg hatching on adult shells only when concentrations reach 1,334 ppb. These concentrations are significantly greater than the proposed treatment use rate of 15 ppb, therefore, risk of damage to freshwater snail is minimal.

No impacts are anticipated to the bronze copper (*Lycaena hyllus).* As described above, the toxicological data on model invertebrates resulted in impacts at concentrations significantly greater than the proposed action. Additionally, this species is anticipated to have a lower risk of exposure to subsurface applications due to its life history and habitat.

3.3 State-Listed Vertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified eight state-listed vertebrates that may be present within Mattabesset River: shortnose sturgeon (*Acipenser brevirostrum*, state and federally endangered), Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*, state and federally endangered), blueback herring (*Alosa aestivalis*, state special concern), mudpuppy (*Necturus maculosus,* state special concern), northern leopard frog (*Rana pipiens*, state special concern), peregrine falcon (*Falco peregrinus*, state threatened), pied-billed grebe (*Podilymbus podiceps,* state endangered), and the bald eagle (*Haliaeetus leucocephalus,* state threatened). No vertebrate surveys were completed during the 2024 environmental studies.

3.3.1 Diquat

No adverse effects are anticipated for the fish species of concern given that the proposed application rates are within the concentration limits specified on the EPA-approved herbicide label. Studies have found that diquat has relatively low toxicity to fish and does not appear to significantly bioaccumulate in fish tissue (BLM, 2005). The results of acute exposure studies on freshwater fish have been summarized as "slightly toxic to practically non-toxic for diquat dibromide" (Hartless & Lin, 2010).

No impacts are expected to the mudpuppy (*Necturus maculosus)* and the northern leopard frog (*Rana pipiens*). One study of diquat impacts on the northern leopard frog (*Rana pipiens*) found that in a 16-day exposure period, adverse effects were observed at 5mg/L concentrations, however no adverse effects were observed at 2mg/L concentrations (Dial & Dial,1987). Both concentrations are substantially higher than the proposed treatment application rate, so the risk of negative impacts to amphibian species are expected to be minimal. Additionally, the northern leopard frog is a semi-terrestrial species, utilizing aquatic environments for winter hibernation and breeding in the spring, but spending summer months primarily out of the water feeding in grasslands and woodlands (FWS, n.d.). Given the timing of the proposed treatment activity (late July through early August) adult northern leopard frogs are not anticipated to be present in the aquatic environment in which the treatment will be applied, further minimizing the risk of potential impacts to these species.

No impacts are expected to the peregrine falcon (*Falco peregrinus),* pied-billed grebe (*Podilymbus podiceps)*, or the bald eagle (*Haliaeetus leucocephalus)*. Herbicides will be applied using subsurface injection methods, no airborne exposure risks to nearby non-aquatic species at the time of application are anticipated. Additionally, while diquat dibromide has been found to be moderately toxic to birds in acute oral exposure studies (EPA, 1995; BLM, 2005; Emmett, 2002), many of these studies were conducted at much higher concentrations than the proposed treatment. Risks to piscivorous birds, such as bald eagles, were found to be low given that bioaccumulation in fish species is also low (BLM, 2005).

3.3.2 Dipotassium salt of endothall

No adverse effects are anticipated to any fish or bird species of concern given that the proposed application rates are within the concentration limits specified on the EPA-approved herbicide label. The median effective concentration (EC_{50}) and median lethal concentration (LC_{50}) were determined to evaluate the ecotoxicity of Endothall dipotassium salt (Table 1). Although the response of the potential species is not known, no significant impacts are expected as endothall will be applied at the EPA maximum concentration rate of 5 ppm. This application rate is significantly below the EC_{50} and LC_{50} rates described for fish and bird species in Table 1. Additionally, herbicides will be applied using subsurface injection methods, no airborne exposure risks to nearby non-aquatic species at the time of application are anticipated.

Table 1. Vertebrate ecotoxicity of dipotassium salt of Endothall

Common Name	Scientific Name	Ecotoxicity
Bluegill sunfish	*Lepomis macrochirus*	1,071 ppm (EC_{50})
Rainbow trout	*Oncorhynchus mykiss*	363 ppm (EC_{50})
Sheepshead minnow	*Cyprinodon variegatus*	340 ppm (96-hour EC_{50})
Mallard	*Anas platyrhynchos*	328 mg/kg (LC_{50})

Source: (UPL, 2019).

3.3.3 Florpyrauxifen-benzyl

Florpyrauxifen-benzyl is considered to be practically nontoxic to freshwater fish. Studies of florpyrauxifen-benzyl impacts on fish and aquatic organisms largely did not observe toxicity even when applied up to its functional limit of solubility (Levey, 2022; EPA, 2017). Further, results of bioaccumulation studies in fish suggested rapid and extensive metabolism of florpyrauxifen-benzyl, indicating that bioaccumulation potential for this herbicide is low (EPA, 2017). Fish toxicity has not been previously reported in field or laboratory evaluations of florpyrauxifen-benzyl at the proposed application rate (48 ppb). Although the response of the mudpuppy (*Necturus maculosus)* is unknown, fish species are considered surrogates for amphibians in toxicological studies. No impacts are expected to the mudpuppy as the maximum produce use rate is significantly greater than the EC_{50} for fish species (SePRO, 2017a).

No significant impacts are expected to the peregrine falcon (*Falco peregrinus)*. The risk of acute impacts to birds is also considered to be low. Florpyrauxifen-benzyl has been shown to be non-toxic to multiple bird species with a reported LD50 >2,500 mg/kg bodyweight for Bobwhite quail (*Colinus virginianus*) (Levey, 2022; EPA, 2017; SePro, 2017a). Additionally, because herbicides will be applied using subsurface injection methods, no airborne exposure risks to nearby birds or the red bat (*Lasiurus borealis*) at the time of application are anticipated. The LD_{50} was determined for mammalians using rats. The concentrations for both oral and dermal exposure were signicantly greater than the approved concentration rate, and were determined greater than 5,000 mg/kg (SePRO, 2017a).

No significant impacts are expected to the eastern box turtle (*Terrapene carolina carolina).* This species is not likely to occur within the intertidal zone or aquatic habitat, and therefore is not expected to be impacted by the herbicide application.

3.3.4 Fluridone

No impacts are anticipated to the state-listed fish and amphibian species of concern. The median lethal concentration (LC_{50}) at 96-hour was determined for model fish species, the sheepshead minnow (*Cyprinodon variegatus)* and the fathead minnow (*Pimephales promelas)*. The 96-hour LC_{50} was determined to be 5.2 mg/L and 6.5 mg/L

(SePro, 2017b). These rates are significantly greater than the proposed use rate of 15 ppb. In addition, fish toxicological data is widely accepted as a surrogate for amphibians. These data in conjunction with a lack of reports of toxicity issues from operational use of this herbicide suggest that there is little to no risk of fish or amphibian harm when the product is used according to the product label.

No impacts are anticipated to the bird species of concern. There is no evidence suggesting short-term or long-term exposure risk to birds. The oral median lethal dose (LD_{50}) of bobwhite quail (*Colinus virginianus)* is >2000 mg/kg (EPA, 1986). This is significantly greater than the proposed use rate of 15 ppb. Additionally, there are no known reports of avian impacts from operational use. Therefore, there is little to no risk to birds when the product is used according to standard application procedures.

4. Conservation Strategy for Endangered, Threatened and Special Concern Species

4.1 Herbicide Application Methods and Timing

Strategic herbicide application methods and timing will be employed throughout this demonstration project to minimize the potential risk of impacts to non-target and state-listed species of concern. The selected herbicide(s) will be applied by licensed applicators in accordance with the product's EPA-approved label.

4.2 Considerations for Vertebrates

Alewife and blueback herring are known to spawn over aquatic vegetation within the proposed treatment area between April 1 and June 30. To minimize potential impacts to these spawning events, the timing of treatment application will be delayed until after July 4, 2025.

5. Literature Cited

Archambault, J.M., & Cope, W.G. 2016. Life stage sensitivity of a freshwater snail to herbicides used in invasive aquatic weed control. Freshwater Mollusk Conservation Society. Vol 19: 69-79.

Archambault, J.M., Bergeron, C.M., Cope, G.W., Richardson, R.J., Heilman, M.A., Corey III, E.J., Netherland, M.D., & Heise, R.J. 2015. Sensitivity of freshwater molluscs to hydrilla-targeting herbicides: providing context for invasive aquatic weed control in diverse ecosystems. Journal of Freshwater Ecology. Vol. 30(3): 335-348.

Beets, J., Heilman, M., & Netherland, M.D. 2019. Large-Scale Mesocosm Evaluation of Florpyrauxifen-Benzyl, a Novel Arylpicolinate Herbicide, on Eurasian and Hybrid Watermilfoil and Seven Native Submersed Plants." Journal of Aquatic Plant Management. Vol. 57: 49-55

Bugbee, G.J., & Stebbins, S.E. 2022. Invasive Aquatic Vegetation Survey Hydrilla Overwintering and Spread Management Options. Department of Environmental Science and Forestry.

Bureau of Land Management (BLM). 2005. Diquat Ecological Risk Assessment, Final Report. All U.S. Government Documents (Utah Regional Depository).

Dial, N.A., & Bauer Dial, C.A. 1987. Lethal Effects of Diquat and Paraquat on Developing Frog Embryos and 15-Day-Old Tadpoles, *Rana pipiens*. Bulletin of Environmental Contamination and Toxicology. Vol. 38(6): 1006–1011. https://doi.org/10.1007/BF01609088.

Emmett, K. 2002. "Appendix A: Final Risk Assessment for Diquat Bromide." 02-10–046. Washington State Department of Ecology

Hartless, C., and Lin, J. 2010. "Risks of Diquat Dibromide Use to the Federally Threatened Delta Smelt."

Levey, R. 2022. Aquatic Nuisance Control Permit, ProcellaCOR EC Aquatic Toxicity Review. https://dec.vermont.gov/sites/dec/files/wsm/lakes/ANC/docs/ProcellaCor%20Aquatic%20Toxicity%20Review%20_03162022.pdf.

Menninger, H. 2012. Endothall FAQ. Cornell Cooperative Extension. 2012. http://ccetompkins.org/environment/aquatic-invasives/hydrilla/managementoptions/ herbicides/endothall/endothall-faq.

Mudge, C.R., Sartain, B.T., Getsinger, K.D., & Netherland, M.D. 2021. Efficacy of Florpyrauxifen-Benzyl on Dioecious Hydrilla and Hybrid Water Milfoil - Concentration and Exposure Time Requirements. U.S. Engineer Research and Development Center. https://doi.org/10.21079/11681/42062.

Netherland, M.D., & Richardson, R.J. 2016. Evaluating Sensitivity of Five Aquatic Plants to a Novel Arylpicolinate Herbicide Utilizing an Organization for Economic Cooperation and Development Protocol. Weed Science. Vol. 64(1): 181–90. https://doi.org/10.1614/WS-D-15-00092.1.

Netherland, M.D., Green, W.R., and Getsinger, K.D. 1991. Endothall Concentration and Exposure Time Relationships for the Control of Eurasian Watermilfoil and Hydrilla. Journal of Aquatic Plant Management. Vol. 29: 61–67.

Parsons, J.K., Baldwin, L., & Lubliner, N. 2019. An operational study of repeated diquat treatments to control submersed flowering rush. Journal of Aquatic Plant Management. Vol. 47: 28-32.
Richardson, R., Haug, E.J., and Netherland, M.D. 2016. Response of Seven Aquatic Plants to a New Arylpicolinate Herbicide. Journal of Aquatic Plant Management. Vol. 54: 26–31.
SePRO Corporation (SePRO). 2017a. Safety Data Sheet for ProcellaCOR EC Version 1.0 EPA Registration No. 67690-80.
SePRO Corporation (SePRO). 2017b. Safety Data Sheet for Sonar A.S. Aquatic Herbicide. EPA Registration No. 67690-4.
Skogerboe, J.G., & Netherland, M.D. 2008. Draft report following April 2008 aquatic herbicide treatments of three bays on Lake Minnetonka. October. Report to the Minnesota Department of Natural Resources. https://lmcd.org/wp-content/uploads/2021/04/20081008-Lake-Minnetonka-Preliminary-Report-II-Skogerboe1.pdf
Sperry, B.P, Leary, J.K., Dean Jones, K, & Ferrell, J.A. 2021. Observations of a Submersed Field Application of Florpyrauxifen-Benzyl Suppressing Hydrilla in a Small Lake in Central Florida. Journal of Aquatic Plant Management. Vol. 59: 20-26.
Tippery, N.P., Bugbee, G.J., & Stebbins, S.E. 2020. Evidence for a Genetically Distinct Strain of Introduced Hydrilla Verticillata (Hydrocharitaceae) in North America. Journal of Aquatic Plant Management. Vol. 58:1-6.
UPL Limited (UPL). 2019. Safety Data Sheet for AQUATHOL® K Aquatic Herbicide.
U.S. Environmental Protection Agency (EPA). 2017. The 2017 EPA Environmental Fate and Ecological Risk Assessment for Florpyrauxifen-Benzyl.
U.S. Environmental Protection Agency (EPA). 1995. Diquat Dibromide. https://archive.epa.gov/pesticides/reregistration/web/pdf/0288fact.pdf.
U.S. Environmental Protection Agency (EPA). 1986. Pesticide Fact Sheet Fluridone.
Wisconsin Department of Natural Resources (DNR). 2022a. Florpyrauxifen-Benzyl Fact Sheet. https://apps.dnr.wi.gov/swims/Documents/DownloadDocument?id=332109305
Wisconsin Department of Natural Resource (DNR). 2022b. Fluridone Chemical Fact Sheet. https://apps.dnr.wi.gov/swims/Documents/DownloadDocument?id=330738067
Wisconsin Department of Natural Resources (DNR). 2012. Diquat Chemical Fact Sheet. https://www.noaa.gov/sites/default/files/legacy/document/2020/Oct/07354626838.pdf

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Pameacha Pond Species Protection Plan

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1. Introduction

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Hydrilla (*Hydrilla verticillata*) was first identified in the Connecticut River near Glastonbury, CT in 2016 and has since spread south to Essex, CT infesting the river's many coves, tributaries, and boat basins. The Connecticut River hydrilla population has been shown to be genetically distinct from other known hydrilla strains (Tippery et al., 2020), and the plant's biology is largely unknown at this time. Following the discovery of the highly invasive aquatic plant in the Connecticut River in 2016, intensive vegetation surveys were conducted in 2019 and 2020 from Agawam, MA south to Long Island Sound to map the invasion extent. Hydrilla was found as far north as Agawam, MA, confirming that the plant spreads rapidly which poses significant risk to other regional waterbodies (Bugbee & Stebbins, 2022). Fragments of the plant, which are easily transported by boats and boat trailers, can sprout roots to establish new populations. Fragments also float and are capable of dispersing via wind and water currents. Due to the importance of the Connecticut River as an environmental resource and driver of the local economy, stakeholders are seeking an aggressive hydrilla management program.

1.2 Project Background

The U.S. Army Corps of Engineers (USACE), through its Engineer Research and Development Center's (ERDC) Aquatic Plant Control Research Program, is leading a research and demonstration project to verify the effectiveness of aquatic herbicides registered for use by the U.S. Environmental Protection Agency (EPA) to reduce and control the spread of the Connecticut River hydrilla safely and selectively. The project has been investigating hydrilla's growth patterns, site-specific water exchange dynamics and evaluating herbicide efficacy in laboratory conditions throughout 2023 to guide operational scale field demonstrations of herbicide efficacy in 2024. Deep River has been selected as a hydrilla treatment site for ERDC's 2025 field demonstration project.

1.3 Pameacha Pond Treatment Site

Pameacha Pond is a pond connected to the Connecticut River located in Middletown, Middlesex County, CT and is centered at 41.544° N, 72.653°W. The treatment area is 18.79 acres. Surrounding lands are highly developed, with residential and commercial use. The pond is connected to Long Hill Brook, which flows into Sumner Brook, that is directly connected to the Connecticut River. Surrounding land use is highly developed.

In 2024, the Connecticut Agricultural Experiment Station (CAES) conducted an aquatic plant survey at Pameacha Pond. Northern hydrilla (*Hydrilla verticillata ssp. lithuanica)* was determined to be the most abundant invasive species. Other invasive species included curlyleaf pondweed (*Potamogeton crispus)*, minor naiad (*Najas minor)*, phragmites (*Phragmites australis)*, purple loosestrife (*Lythrum salicaria)*, and water chestnut (*Trapa natans)*.

Native plant species include coontail (*Ceratophyllum demersum*), watermeal (*Wolffia* sp.), duckweed (*Spirodela polyrhiza)*, white waterlily (*Nymphaea odorata)*, yellow waterlily (*Nuphar variegata)*, Berchtold's pondweed (*Potamogeton berchtoldii)*, and western waterweed (*Elodea nuttallii)*. Emergent species included arrowhead (*Saggitaria* sp.), bur-reed (*Sparganium sp.)*, cattail (*Typha sp.)*, pickerelweed (*Pontedaria cordata)*, and rush (*Juncus* sp.*)* (CAES, 2024).

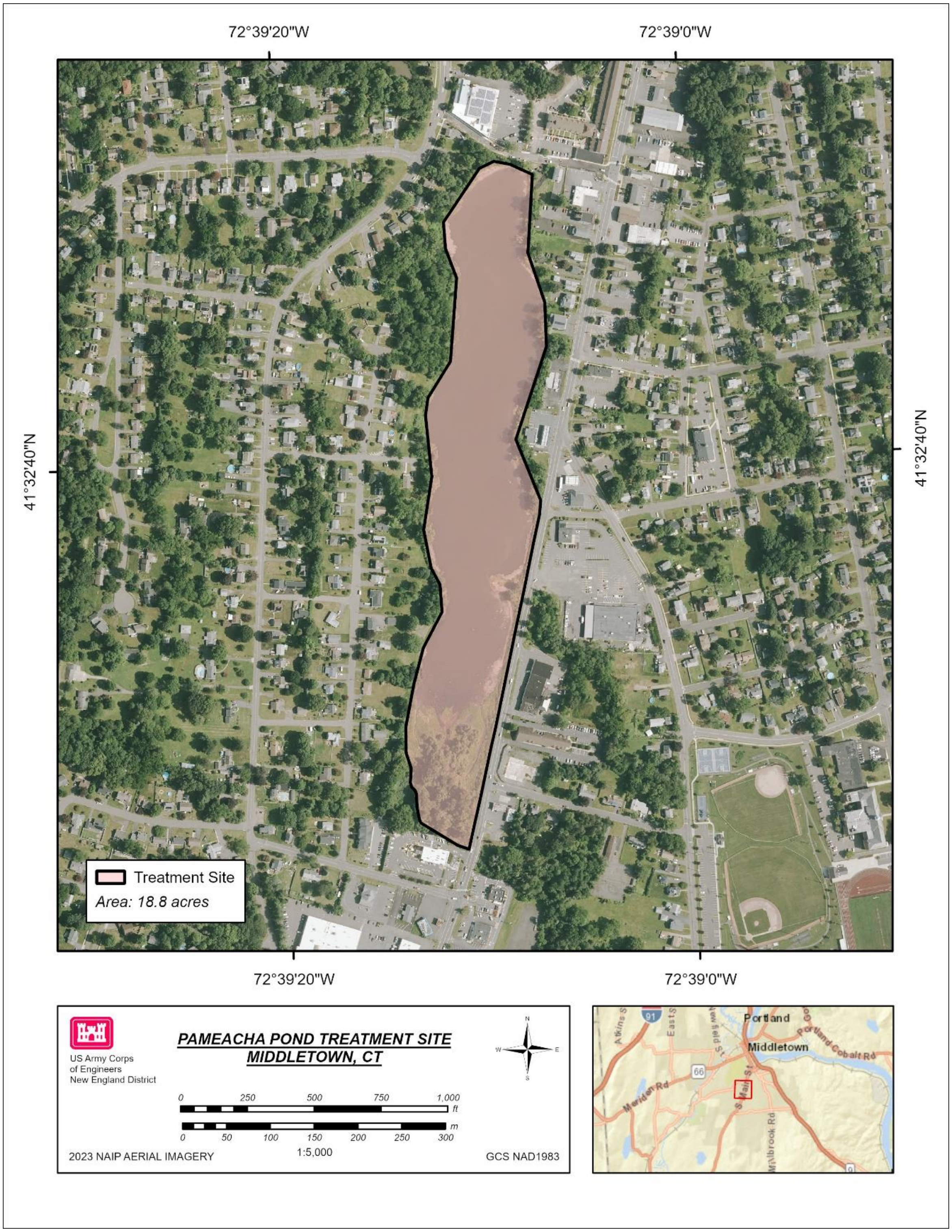

Figure 1. Pameacha Pond hydrilla treatment area in Middletown, CT.

2. Proposed Treatment Activity

Fluridone, bispyribac-sodium, dipotassium salt of endothall, florpyrauxifen-benzyl or combinations thereof are proposed to be applied in Pameacha Pond for hydrilla control. The selected herbicide(s) will be applied at the maximum concentration rate. The herbicide(s) will be evenly distributed across the entire treatment area delineated in Figure 1 using boat-based, subsurface injection application methods. This section describes the proposed herbicides.

2.1 Fluridone

Fluridone is a state and federally registered pesticide that is registered for aquatic use to control invasive submerged, emergent, and floating-leaf vegetation. The proposed herbicide is to be applied at a concentration of 15 ppb. Fluridone is a systematic herbicide that inhibits phytoene desaturase (PDS), an enzyme that protects the plant from sun damage. Through inhibition of PDS, chlorophyll is susceptible to photolysis in which sunlight breaks down the plant's chlorophyll (DNR, 2022a)

2.2 Bispyribac-sodium

Bispyribac-sodium is a state and federally registered pesticide that is registered for aquatic use for the control of invasive emergent, floating-leaf, and submerged vegetation through foliar or subsurface applications. The pesticide was registered by the EPA for aquatic use in 2012. The proposed herbicide is to be applied at a concentration of 40 ppb. Bispyribac-sodium is a systemic herbicide that inhibits the acetolactate synthase (ALS), an enzyme essential for plant growth. Herbicide application results in ceased plant growth, with gradual decomposition over several weeks to months (DNR, 2022b).

2.3 Dipotassium salt of endothall

Dipotassium salt of endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid) is a state and federally registered aquatic herbicide and is approved for application in aquatic sites for the treatment of invasive aquatic plant species. The dipotassium salt of endothall was registered by EPA for aquatic use in 1960 at application rates between 0.5 and 5.0 ppm for aquatic plant control (Menninger, 2012). The proposed herbicide is to be applied at a concentration of 5 ppm. Dipotassium salt of endothall is a selective fast-acting herbicide that interferes with plant protein and lipid biosynthesis, disrupting respiration and plant membranes. This herbicide is highly effective for hydrilla control (Netherland et al.,1991).

2.4 Florpyrauxifen-benzyl

Florpyrauxifen-benzyl is a state and federally registered herbicide, and that is approved for invasive plant treatment in aquatic environments. The proposed herbicide is to be applied at a concentration of 48 ppb. This relatively new systemic herbicide mimics the plant growth hormone, auxin, killing susceptible plants by disrupting the plant cell growth process.

The active ingredient (4-amino-3chloro-6-(4-chloro-2-fluoro-3-methoxyphenyl) 5-fluoropyridine-2-benzyl ester) causes excessive plant cell elongation, ultimately resulting in plant cell death in sensitive plant species. Florpyrauxifen-benzyl is absorbed from the water through submersed plant shoots and leaves, and this herbicide has previously been demonstrated to be highly effective at selectively suppressing both dioecious and monoecious invasive hydrilla (Sperry et al., 2021; Mudge et al., 2021; Beets et al., 2019; Netherland & Richardson, 2016; Richardson et al., 2016) with relatively short exposure times and lower application rates compared to other herbicides (DNR, 2022c).

3. Potential Impacts of the Proposed Treatment Activity

3.1 State-Listed Native Plant Species

Preliminary assessments of the Natural Diversity Database maps and files identified no state-listed plant species that may occur within the Pameacha Pond treatment area.

3.2 State-Listed Invertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified one state-listed invertebrates which may be present within Pameacha Pond: tidewater mucket (*Leptodea ochracea*, state special concern). No mussel surveys were completed to confirm the presence of these species within Pameacha Pond.

3.2.1 Fluridone

No impacts are anticipated to the tidewater mucket (*Leptodea ochracea*). Juvenile, glochidia, and adult stage *Lampsilis* mussels have been tolerant to fluridone at concentrations and exposure times much greater than the typical field use rate (Archambault et al., 2016). In addition, toxicological studies were conducted to determine the half maximal effective concentration (EC_{50}) of fluridone on model invertebrate species. The 48-hour EC_{50} of fluridone on Daphnia (*Daphnia magna)* and *Eucyclops spp.* is 3 and 8 mg L^{-1} according product safety data sheets (SePro, 2017). These concentrations are significantly greater than the proposed treatment use rate of 15 ppb. 300- and 800-times greater than the proposed use rate of 15 ppb. These toxicological data in combination with no known toxicity issues in other treated systems suggests that risk to mollusks is minimal.

3.2.2 Bispyribac-sodium

No impacts are anticipated to the tidewater mucket (*Leptodea ochracea*). Bispyribac-sodium is practically non-toxic to aquatic invertebrates. According to ecotoxicological data, the, 96-hour median lethal concentration (LC_{50})for model invertebrate species was greater than 100 ppm. The 96-hour LC_{50} was determined for waterfleas (*Daphnia magna)*, Mysid shrimp, and oysters. The proposed use rate of 40 pbb is significantly below the LC_{50} observed for these model species. This toxicology data suggest that risk to tidewater mucket is minimal.

3.2.3 Dipotassium salt of endothall

No impacts are expected to the tidewater mucket (*Lepotdea ochracea)*. A study investigating impacts of dipotassium salt of endothall concentrations ranging from 0.5 to 1000 ppm on juvenile and glochidia fatmucket (*Lampsilis siliquoidea*) concluded that dipotassium salt of endothall was not found to be acutely toxic to fatmucket mussels at the application rates needed for hydrilla treatment. Median lethal concentrations (LC_{50}) were substantially higher (6-34 times higher) than recommended dipotassium salt of endothall application rates for hydrilla treatment (1-5 ppm) (Archambault et al., 2015). Dipotassium salt of endothall has also been tested on dreissenid mussels, specifically zebra and quagga mussels, to evaluate impacts. At the highest concentration applied (5 ppm) maximum mortality of 5% was observed for quagga mussels at 20º C, and 2.5% at 25º C. Zebra mussels had zero mortality to any dipotassium salt of endothall concentration at either temperature regime (Claudi et al., 2013).

3.2.4 Florpyrauxifen-benzyl

No impacts are expected to the identified freshwater mussel. A study observed the toxicity of florpyrauxifen-benzyl applications on juvenile fatmucket (*Lampsilis siliquoidea*) and eastern lampmussel (*Lampsilis radiata*) and determined that this compound was not acutely toxic to juveniles of these species. While potential chronic or sub-lethal effects require further investigation to characterize, this study concluded that the short-term exposure risk of these freshwater mussels to florpyrauxifen-benzyl for aquatic weed control are minimal (Buczek et al., 2020).

3.3 State-Listed Vertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified no state-listed vertebrate species that may be present within Pameacha Pond.

4. Conservation Strategy for Endangered, Threatened and Special Concern Species

4.1 Herbicide Application Methods and Timing

Strategic herbicide application methods and timing will be employed throughout this demonstration project to minimize the potential risk of impacts to non-target and state-listed species of concern. Herbicides will be applied by licensed applicators at allowable concentrations in accordance with the product's EPA-approved label. Herbicides will be applied directly to the water and evenly distributed across the entire treatment area using boat-based, subsurface injection application methods to minimize airborne exposure risks to non-target species.

5. References

Archambault, J.M., & Cope, W.G. 2016. Life stage sensitivity of a freshwater snail to herbicides used in invasive aquatic weed control. Freshwater Mollusk Conservation Society. Vol 19: 69-79.

Archambault, J.M., Bergeron, C.M., Cope, G.W., Richardson, R.J., Heilman, M.A., Corey III, E.J., Netherland, M.D., & Heise, R.J. 2015. Sensitivity of freshwater molluscs to hydrilla-targeting herbicides: providing context for invasive aquatic weed control in diverse ecosystems. Journal of Freshwater Ecology. Vol. 30(3): 335-348.

Beets, J., Heilman, M., & Netherland, M.D. 2019. Large-Scale Mesocosm Evaluation of Florpyrauxifen-Benzyl, a Novel Arylpicolinate Herbicide, on Eurasian and Hybrid Watermilfoil and Seven Native Submersed Plants." Journal of Aquatic Plant Management. Vol. 57: 49-55

Buczek, S.B., Archambault, J.M., Cope, W.G., & Heilman, M.A. 2020. Evaluation of Juvenile Freshwater Mussel Sensitivity to Multiple Forms of Florpyrauxifen-Benzyl. Bulletin of Environmental Contamination and Toxicology. Volume 105: 588-594 https://doi.org/10.1007/s00128-020-02971-1.

Bugbee, G.J., & Stebbins, S.E. 2022. Invasive Aquatic Vegetation Survey Hydrilla Overwintering and Spread Management Options. Department of Environmental Science and Forestry.

Claudi, R., Taraborelli, C., & Prescott, T.H. 2013. Efficacy of Endothall for Control of Adult Quagga and Zebra Mussels. Accessed 31 January 2025 from https://invasivemusselcollaborative.net/wp-content/uploads/2018/11/Claudi-et-al.-2013b.pdf.

Connecticut Agricultural Experiment Station (CAES). 2024. Pameacha Pond 2024. Accessed on February 19th, 2025

Menninger, H. 2012. Endothall FAQ. Cornell Cooperative Extension. 2012. http://ccetompkins.org/environment/aquatic-invasives/hydrilla/managementoptions/herbicides/endothall/endothall-faq.

Mudge, C.R., Sartain, B.T., Getsinger, K.D., & Netherland, M.D. 2021. Efficacy of Florpyrauxifen-Benzyl on Dioecious Hydrilla and Hybrid Water Milfoil - Concentration and Exposure Time Requirements. U.S. Engineer Research and Development Center. https://doi.org/10.21079/11681/42062.

Netherland, M.D., & Richardson, R.J. 2016. Evaluating Sensitivity of Five Aquatic Plants to a Novel Arylpicolinate Herbicide Utilizing an Organization for Economic Cooperation and Development Protocol. Weed Science. Vol. 64(1): 181–90. https://doi.org/10.1614/WS-D-15-00092.1.

Netherland, M.D., Green, W.R., and Getsinger, K.D. 1991. Endothall Concentration and Exposure Time Relationships for the Control of Eurasian Watermilfoil and Hydrilla. Journal of Aquatic Plant Management. Vol. 29: 61–67.

Richardson, R., Haug, E.J., & Netherland, M.D. 2016. Response of Seven Aquatic Plants to a New Arylpicolinate Herbicide. Journal of Aquatic Plant Management. Vol. 54: 26–31.

SePRO Corporation (SePRO). 2017. Safety Data Sheet for Sonar A.S. Aquatic

Herbicide. EPA Registration No. 67690-4.
Sperry, B.P, Leary, J.K., Dean Jones, K, & Ferrell, J.A. 2021. Observations of a Submersed Field Application of Florpyrauxifen-Benzyl Suppressing Hydrilla in a Small Lake in Central Florida. Journal of Aquatic Plant Management. Vol. 59: 20-26.
Tippery, N.P., Bugbee, G.J., & Stebbins, S.E. 2020. Evidence for a Genetically Distinct Strain of Introduced Hydrilla Verticillata (Hydrocharitaceae) in North America. Journal of Aquatic Plant Management. Vol. 58:1-6.
Valent U.S.A. Corporation (Valent). 2020. Tradewind Herbicide Safety Data Sheet – GHS. EPA Registration No.59639-165.
Wisconsin Department of Natural Resources (DNR). 2022a. Fluridone Chemical Fact Sheet. https://apps.dnr.wi.gov/swims/Documents/DownloadDocument?id=330738067
Wisconsin Department of Natural Resources (DNR). 2022b. Bispyribac-Sodium Chemical Fact Sheet. https://apps.dnr.wi.gov/swims/Documents/DownloadDocument?id=330737992#:~:text=Bispyribac%2Dsodium%20is%20a%20systemic,become%20reddish%20at%20the%20tips.
Wisconsin Department of Natural Resources (DNR). 2022c. Florpyrauxifen-Benzyl Chemical Fact Sheet.
https://apps.dnr.wi.gov/swims/Documents/DownloadDocument?id=332109305Wisconsin Department of Natural Resources (DNR). 2012. Diquat Chemical Fact Sheet. https://www.noaa.gov/sites/default/files/legacy/document/2020/Oct/07354626838.pdf

Connecticut River
Hydrilla Control Research and Demonstration Project
Lower Connecticut River, CT

Species Protection Plan
Parkers Point
Chester, CT

US Army Corps of Engineers ®
New England District

February 2025

Parkers Point Species Protection Plan

Table of Contents

1. Introduction

1.1 Connecticut River Hydrilla Information

Hydrilla (*Hydrilla verticillata*) was first identified in the Connecticut River near Glastonbury, CT in 2016 and has since spread south to Essex, CT infesting the river's many coves, tributaries, and boat basins. The Connecticut River hydrilla population has been shown to be genetically distinct from other known hydrilla strains (Tippery, et al., 2020), and the plant's biology is therefore largely unknown at this time. Following the discovery of the highly invasive aquatic plant in the Connecticut River in 2016, intensive vegetation surveys were conducted in 2019 and 2020 from Agawam, MA south to Long Island Sound to map the invasion extent. Hydrilla was found as far north as Agawam, MA, confirming that the plant spreads rapidly which poses significant risk to other regional waterbodies (Bugbee & Stebbins, 2022). Fragments of the plant, which are easily transported by boats and boat trailers, can sprout roots to establish new populations. Fragments also float and are capable of dispersing via wind and water currents. Due to the importance of the Connecticut River as an environmental resource and driver of the local economy, stakeholders are seeking an aggressive hydrilla management program.

1.2 Project Background

The U.S. Army Corps of Engineers (USACE), through its Engineer Research and Development Center's (ERDC) Aquatic Plant Control Research Program, is leading a research and demonstration project to verify the effectiveness of aquatic herbicides registered for use by the U.S. Environmental Protection Agency (EPA) to reduce and control the spread of the Connecticut River hydrilla safely and selectively. The project has been investigating hydrilla's growth patterns, site-specific water exchange dynamics and evaluating herbicide efficacy in laboratory conditions throughout 2023 to guide operational scale field demonstrations of herbicide efficacy in 2024. Parkers Point has been selected as a hydrilla treatment site for ERDC's 2025 field demonstration project.

1.3 Parkers Point Treatment Site

Parkers Point is located on the mainstem of the Connecticut River in Chester, Middlesex County, CT and centered at 41.431° N, 72.449° W. The treatment area is 3 acres with a mean depth of 6 feet mean higher high water.

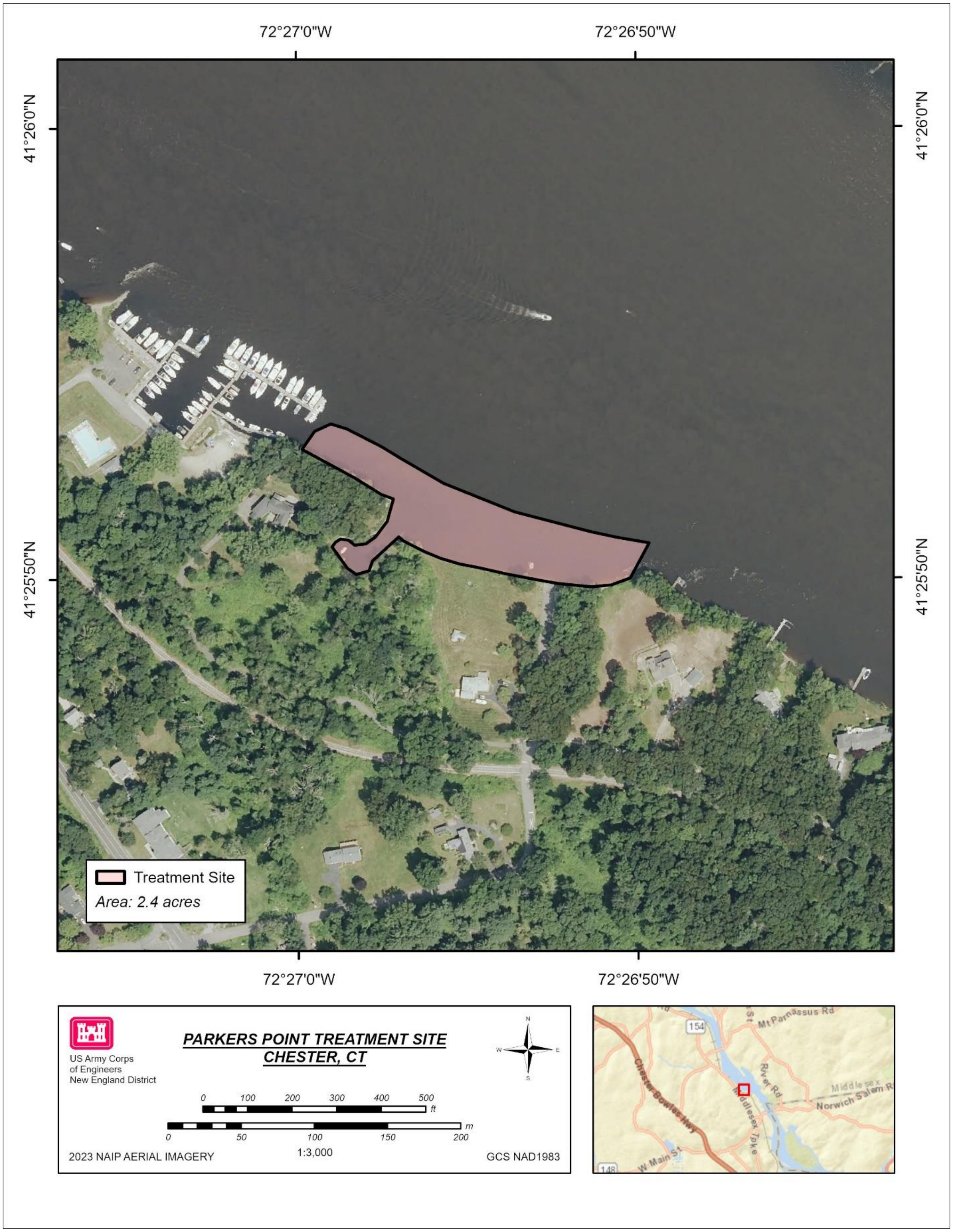

Figure 1. Parkers Point hydrilla treatment area in Chester, CT.

2. Proposed Treatment Activity

Diquat, dipotassium salt of endothall, florpyrauxifen-benzyl, or combinations thereof are proposed to be applied in Parkers Point for hydrilla control. The selected herbicide(s) will be applied at the maximum concentration rate, as described in the following sections. The herbicide(s) will be evenly distributed across the entire treatment area delineated in Figure 1 using boat-based, subsurface injection application methods. This section describes the proposed herbicides.

2.1 Diquat

Diquat dibromide is a state and federally registered herbicide approved for application in aquatic sites for invasive aquatic plant control. The herbicide is proposed to be applied at a concentration of 370 ppb. A Registration Standard for diquat dibromide was issued by the EPA in June 1986 (EPA, 1995). The active ingredient ((6,7-dihydrodipyrido (1,2a:2',1'-c) pyrazinediium dibromide)) is a fast-acting herbicide that interferes with photosynthesis, disrupts plant cell membranes, and results in plant death within a week of application in sensitive plant species (DNR, 2012).

2.2 Dipotassium salt of endothall

Dipotassium salt of endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid) is a state and federally registered aquatic herbicide and is approved for application in aquatic sites for the treatment of invasive aquatic plant species. The dipotassium salt of endothall was registered by EPA for aquatic use in 1960 at application rates between 0.5 and 5.0 ppm for aquatic plant control (Menninger, 2012). The herbicide is proposed to be applied at a concentration of 5 ppm. Dipotassium salt of endothall is a selective fast-acting herbicide that interferes with plant protein and lipid biosynthesis, disrupting respiration and plant membranes. This herbicide is highly effective for hydrilla control (Netherland et al.,1991).

2.3 Florpyrauxifen-benzyl

Florpyrauxifen-benzyl is a state and federally registered herbicide, and that is approved for invasive plant treatment in aquatic environments. The herbicide is proposed to be applied at a concentration of 48 ppb. This relatively new systemic herbicide mimics the plant growth hormone, auxin, killing susceptible plants by disrupting the plant cell growth process.

The active ingredient (4-amino-3chloro-6-(4-chloro-2-fluoro-3-methoxyphenyl) 5-fluoropyridine-2-benzyl ester) causes excessive plant cell elongation, ultimately resulting in plant cell death in sensitive plant species. Florpyrauxifen-benzyl is absorbed from the water through submersed plant shoots and leaves, and this herbicide has previously been demonstrated to be highly effective at selectively suppressing both dioecious and monoecious invasive hydrilla (Sperry et al., 2021; Mudge et al., 2021;

Beets et al., 2019; Netherland & Richardson, 2016; Richardson et al., 2016) with relatively short exposure times and lower application rates compared to other herbicides (DNR, 2022).

3. Potential Impacts of the Proposed Treatment Activity

3.1 State-Listed Native Plant Species

Preliminary assessments of the Natural Diversity Database maps and files identified no state-listed vascular plants that may potentially occur within the delineated Parkers Point treatment area.

3.2 State-Listed Invertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified three state-listed invertebrates that may be present within Parkers Point: the riverine clubtail (*Stylurus amnicola*, state threatened), tidewater mucket (*Leptodea ochracea*, state special concern), and eastern pondmussel (*Ligumia nasuta*, state special concern). No invertebrate surveys were completed to confirm the presence of these species within Parkers Point.

3.2.1 Diquat

The riverine clubtail (*Stylurus amnicola*) is not expected to be impacted from the proposed application of diquat. The herbicide is considered minimal risk to non-target insects (EPA, 1995). A study on diquat response observed dragonflies and damselflies. The study observed survival after exposure to diquat concentrations 40 times higher than the recommended maximum field application rate (Gilderhus, 1967).

No impacts are expected to the tidewater mucket (*Leptodea ochracea*) and eastern pondmussel (*Ligumia nasuta*) from the application of diquat. One study tested the impacts of diquat on the New Zealand freshwater mussel (*Hyridella menziesi*) and concluded that diquat had no significant effects on freshwater mussels and, therefore, was considered to be non-toxic to these organisms when applied at rates needed to kill most aquatic weeds (Clayton & Severne, 2005).

3.2.2 Dipotassium salt of endothall

The riverine clubtail (*Stylurus* amnicola) is not expected to be negatively impacted by the proposed treatment activity. When used at recommended application rates, dipotassium salt of endothall no significant adverse effects were observed on aquatic insects (e.g. snails, aquatic insects, and crayfish) (DNR, 2012).

No impacts are expected to tidewater mucket (*Leptodea ochracea)* and eastern pondmussel (*Ligumia nasuta).* A study investigating impacts of dipotassium salt of endothall concentrations ranging from 0.5 to 1000 ppm on juvenile and glochidia fatmucket (*Lampsilis siliquoidea*) concluded that dipotassium salt of endothall was not found to be acutely toxic to fatmucket mussels at the application rates needed for hydrilla treatment. Median lethal concentrations (LC_{50}s) were substantially higher (6-34 times higher) than recommended dipotassium salt of endothall application rates for hydrilla treatment (1-5 ppm) (Archambault et al., 2015). Dipotassium salt of endothall has also been tested on dreissenid mussels, specifically zebra and quagga mussels, to evaluate impacts. At the highest concentration applied (5 ppm) maximum mortality of 5% was observed for quagga mussels at 20º C, and 2.5% at 25º C. Zebra mussels had zero mortality to any dipotassium salt of endothall concentration at either temperature regime (Claudi et al., 2013).

3.2.3 Florpyrauxifen-benzyl

The riverine clubtail (*Stylurus* amnicola) is not expected to be negatively impacted by the proposed treatment activity. Previous studies have shown florpyrauxifen-benzyl to be essentially nontoxic on an acute basis to bees (Levey, 2022), thus risk of acute impacts to other insect species are also considered to be low. Additionally, this herbicide has been shown to have a relatively low potential for volatility from water due to low vapor pressure (EPA, 2017) and is not expected to have vapor drift impacts to this insect species.

No impacts are expected to the identified freshwater mussels. A recent study examined the impacts of florpyrauxifen-benzyl applications on juvenile fatmucket (*Lampsilis siliquoidea*) and eastern lampmussel (*Lampsilis radiata*) and determined that this compound was not acutely toxic to juveniles of these species. While potential chronic or sub-lethal effects require further investigation to characterize, this study concluded that the short-term exposure risk of these freshwater mussels to florpyrauxifen-benzyl for the purposes of aquatic weed control are minimal (Buczek et al., 2020).

3.3 State-Listed Vertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified four state-listed vertebrates that may be present within Parkers Point: mudpuppy (*Necturus maculosus,* state special concern), shortnose sturgeon (*Acipenser brevirostrum*, state and federally endangered), Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*, state and federally endangered), and blueback herring (*Alosa aestivalis*, state special concern). No vertebrate surveys were not completed during the 2024 environmental studies to confirm the presence of these species.

The eastern box turtle (*Terrapene carolina carolina,* state special concern) was identified during preliminary review. No impacts to these species are likely, as it does not occupy intertidal or aquatic habitat. Therefore, the species is not likely to occur within the treatment zone. No airborne risks to surrounding habitat is anticipated as the treatment will utilize sub-surface injection methods. As a result, this species was excluded from further discussion of herbicide impacts.

3.3.1 Diquat

No adverse effects are anticipated for the fish species of concern or mudpuppy (*Necturus maculosus*) given that the proposed application rates are within the concentration limits specified on the EPA-approved herbicide label. Studies have found that diquat has relatively low toxicity to fish and does not appear to significantly bioaccumulate in fish tissue (BLM, 2005). The results of acute exposure studies on freshwater fish have been summarized as "slightly toxic to practically non-toxic for diquat dibromide" (Hartless & Lin, 2010). There is no published data available on the ecotoxicity of diquat to the mudpuppy. Amphibian ecotoxicity data can be determined from fish data as it provides surrogate data on ecotoxicity. No adverse effects are anticipated based on the herbicide response data for fish species.

3.3.2 Dipotassium salt of endothall

No adverse effects are anticipated to the mudpuppy (*Necturus maculosus),* blueback herring (*Alosa aestivalis*), shortnose sturgeon (*Acipenser brevirostrum*, state and federally endangered), or Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus).* The median effective concentration (EC_{50}) was determined for various freshwater species to evaluate ecotoxicity: bluegill sunfish (*Lepomis macrochirus*) at 1,071 ppm, rainbow trout (*Oncorhynchus mykiss)* at 363 ppm, and the sheepshead minnow (*Cyprinodon variegatus)* at 340 ppm (96-hour EC_{50}). The EC_{50} of these species are significantly greater than the proposed application rate of 5 ppm (UPL, 2019). Ecotoxicology response of fish provides surrogate information for amphibian species. Therefore, no adverse impacts to the mudpuppy (*Necturus maculosus)* are anticipated.

3.3.3 Florpyrauxifen-benzyl

Florpyrauxifen-benzyl is considered to be practically nontoxic to freshwater fish (DNR 2022; Levey, 2022; EPA, 2017). Studies of florpyrauxifen-benzyl impacts on fish and aquatic organisms largely did not observe toxicity even when applied up to its functional limit of solubility (Levey, 2022; EPA, 2017). Further, results of bioaccumulation studies in fish suggested rapid and extensive metabolism of florpyrauxifen-benzyl, indicating that bioaccumulation potential for this herbicide is low (EPA, 2017). Fish toxicity has not been previously reported in field or laboratory evaluations of florpyrauxifen-benzyl at the proposed application rate (48 ppb). Florpyrauxifen-benzyl is considered practically non-toxic to fish on an acute basis [static 96-hour EC50 >120 mg/L for carp (*Cyprinus carpio*)] (SePro, 2017). The proposed treatment activity is not expected to impact the mudpuppy (*Necturus maculosus)*. The response of this species is not known, but fish species are surrogates for amphibians in toxicological studies. Based on the fish toxicology data, described above, no significant impacts are expected to the mudpuppy.

4. Conservation Strategy for Endangered, Threatened and Special Concern Species

4.1 Herbicide Application Methods and Timing

Strategic herbicide application methods and timing will be employed throughout this demonstration project to minimize the potential risk of impacts to non-target and state-listed species of concern. The selected herbicide(s) will be applied by licensed applicators in accordance with the product's EPA-approved label.

4.2 Considerations for Vertebrates

Blueback herring is known to spawn over aquatic vegetation within the proposed treatment area between April 1 and June 30. To minimize potential impacts to these spawning events, the timing of treatment application will be delayed until after July 4, 2025.

5. Literature Cited

Archambault, J.M., Bergeron, C.M., Cope, G.W., Richardson, R.J., Heilman, M.A., Corey III, E.J., Netherland, M.D., & Heise, R.J. 2015. Sensitivity of freshwater molluscs to hydrilla-targeting herbicides: providing context for invasive aquatic weed control in diverse ecosystems. Journal of Freshwater Ecology. Vol. 30(3): 335-348.

Beets, J., Heilman, M., & Netherland, M.D. 2019. Large-Scale Mesocosm Evaluation of Florpyrauxifen-Benzyl, a Novel Arylpicolinate Herbicide, on Eurasian and Hybrid Watermilfoil and Seven Native Submersed Plants." Journal of Aquatic Plant Management. Vol. 57: 49-55

Buczek, S.B., Archambault, J.M., Cope, W.G., & Heilman, M.A. 2020. Evaluation of Juvenile Freshwater Mussel Sensitivity to Multiple Forms of Florpyrauxifen-Benzyl. Bulletin of Environmental Contamination and Toxicology. Volume 105: 588-594 https://doi.org/10.1007/s00128-020-02971-1.

Bugbee, G.J., & Stebbins, S.E. 2022. Invasive Aquatic Vegetation Survey Hydrilla Overwintering and Spread Management Options. Department of Environmental Science and Forestry.

Bureau of Land Management (BLM). 2005. Diquat Ecological Risk Assessment, Final Report. All U.S. Government Documents (Utah Regional Depository).

Claudi, R., Taraborelli, C., & Prescott, T.H. 2013. Efficacy of Endothall for Control of Adult Quagga and Zebra Mussels. Accessed 31 January 2025 from https://invasivemusselcollaborative.net/wp-content/uploads/2018/11/Claudi-et-al.-2013b.pdf.

Clayton, J., & Severne, C. 2005. Review of Diquat Reports of Relevance to Iwi Values in Lake Karapiro. Environment Waikato Technical Report 2006/03. Environment Waikato. https://www.waikatoregion.govt.nz/assets/WRC/WRC-2019/tr06-03.pdf.

Gilderhus, P.A. 1967. Effects of diquat on bluegills and their food organisms: The Progressive Fish-Culturis. Vol. 29(2): 67-74. https://doi.org/10.1577/1548-8640(1967)29[67:EODOBA]2.0.CO;2

Hartless, C., and Lin, J. 2010. "Risks of Diquat Dibromide Use to the Federally Threatened Delta Smelt."

Levey, R. 2022. Aquatic Nuisance Control Permit, ProcellaCOR EC Aquatic Toxicity Review. https://dec.vermont.gov/sites/dec/files/wsm/lakes/ANC/docs/ProcellaCor%20Aquatic%20Toxicity%20Review%20_03162022.pdf.

Menninger, H. 2012. Endothall FAQ. Cornell Cooperative Extension. 2012. http://ccetompkins.org/environment/aquatic-invasives/hydrilla/managementoptions/herbicides/endothall/endothall-faq.

Mudge, C.R., Sartain, B.T., Getsinger, K.D., & Netherland, M.D. 2021. Efficacy of Florpyrauxifen-Benzyl on Dioecious Hydrilla and Hybrid Water Milfoil - Concentration and Exposure Time Requirements. U.S. Engineer Research and

Development Center. https://doi.org/10.21079/11681/42062.
Netherland, M.D., & Richardson, R.J. 2016. Evaluating Sensitivity of Five Aquatic Plants to a Novel Arylpicolinate Herbicide Utilizing an Organization for Economic Cooperation and Development Protocol. Weed Science. Vol. 64(1): 181–90. https://doi.org/10.1614/WS-D-15-00092.1.
Netherland, M.D., Green, W.R., and Getsinger, K.D. 1991. Endothall Concentration and Exposure Time Relationships for the Control of Eurasian Watermilfoil and Hydrilla. Journal of Aquatic Plant Management. Vol. 29: 61–67.
Richardson, R., Haug, E.J., and Netherland, M.D. 2016. Response of Seven Aquatic Plants to a New Arylpicolinate Herbicide. Journal of Aquatic Plant Management. Vol. 54: 26–31.
SePRO Corporation (SePRO). 2017. Safety Data Sheet for ProcellaCOR EC Version 1.0. EPA Registration No. 67690-80.
Sperry, B.P, Leary, J.K., Dean Jones, K, & Ferrell, J.A. 2021. Observations of a Submersed Field Application of Florpyrauxifen-Benzyl Suppressing Hydrilla in a Small Lake in Central Florida. Journal of Aquatic Plant Management. Vol. 59: 20-26.
Tippery, N.P., Bugbee, G.J., & Stebbins, S.E. 2020. Evidence for a Genetically Distinct Strain of Introduced Hydrilla Verticillata (Hydrocharitaceae) in North America. Journal of Aquatic Plant Management. Vol. 58:1-6.
UPL Limited (UPL). 2019. Safety Data Sheet for AQUATHOL® K Aquatic Herbicide.
U.S. Environmental Protection Agency (EPA). 2017. The 2017 EPA Environmental Fate and Ecological Risk Assessment for Florpyrauxifen-Benzyl.
U.S. Environmental Protection Agency (EPA). 1995. Diquat Dibromide. https://archive.epa.gov/pesticides/reregistration/web/pdf/0288fact.pdf.
Wisconsin Department of Natural Resources (DNR). 2022. Florpyrauxifen-Benzyl Fact Sheet. https://apps.dnr.wi.gov/swims/Documents/DownloadDocument?id=332109305
Wisconsin Department of Natural Resources (DNR). 2012. Diquat Chemical Fact Sheet. https://www.noaa.gov/sites/default/files/legacy/document/2020/Oct/07354626838.pdf

Connecticut River
Hydrilla Control Research and Demonstration Project
Lower Connecticut River, CT

Species Protection Plan
Portland Boat Works
Portland, CT

US Army Corps
of Engineers ®
New England District

February 2025

Portland Boat Works Species Protection Plan

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1 Introduction

1.1 Connecticut River Hydrilla Information

Hydrilla (*Hydrilla verticillata*) was first identified in the Connecticut River near Glastonbury, CT in 2016 and has since spread south to Essex, CT infesting the river's many coves, tributaries, and boat basins. The Connecticut River hydrilla population has been shown to be genetically distinct from other known hydrilla strains (Tippery et al., 2020), and the plant's biology is therefore largely unknown at this time. Following the discovery of the highly invasive aquatic plant in the Connecticut River in 2016, intensive vegetation surveys were conducted in 2019 and 2020 from Agawam, MA south to Long Island Sound to map the invasion extent. Hydrilla was found as far north as Agawam, MA, confirming that the plant spreads rapidly which poses significant risk to other regional waterbodies (Bugbee & Stebbins, 2022). Fragments of the plant, which are easily transported by boats and boat trailers, can sprout roots to establish new populations. Fragments also float and are capable of dispersing via wind and water currents. Due to the importance of the Connecticut River as an environmental resource and driver of the local economy, stakeholders are seeking an aggressive hydrilla management program.

1.2 Project Background

The U.S. Army Corps of Engineers (USACE), through Engineer Research and Development Center's (ERDC) Aquatic Plant Control Research Program, is leading a research and demonstration project to verify the effectiveness of aquatic herbicides registered for use by the U.S. Environmental Protection Agency (USEPA) to reduce and control the spread of the Connecticut River hydrilla safely and selectively. The project has been investigating hydrilla's growth patterns, site-specific water exchange dynamics and evaluating herbicide efficacy in laboratory conditions throughout 2023 to guide operational scale field demonstrations of herbicide efficacy in 2024.

Results from preliminary laboratory studies in 2023 indicated Connecticut River hydrilla was either more sensitive or equally sensitive to diquat compared to monoecious and dioecious hydrilla. Diquat dibromide is a fast-acting herbicide that can provide hydrilla control under very short exposure times. To assess onsite water exchange dynamics, USACE performed a dye study in August 2023. Rhodamine Water Tracer (RWT) dye was applied to the waters in the same manner herbicide would be. The concentrations of the dye in the water were collected after application and then analyzed to determine the half-life of the dye at Portland Boat Works. This tracer dye study resulted in a half-life of 21 minutes in Portland Boat Works when applied at low tide. Based on the results of these preliminary studies, Portland Boat Works was selected as a hydrilla treatment site for ERDC's 2024 field demonstration project. Following this demonstration, Portland Boat Works was selected for the 2025 field demonstration project. This protection plan was developed for the expanded site.

1.3 Portland Boat Works Treatment Site

Portland Boat Works is an operating marina located in Portland, Middlesex County, CT and centered at 41.562° N, 72.624° W. The marina is located along the shore of the main stem of the Connecticut River. Portland Boat Works was identified through ERDC's 2023 environmental studies to be significantly hydrilla-dominated, with over 70% hydrilla coverage throughout the waterbody.

Portland Boat Works was treated for the 2024 field demonstration, and an NDDB determination letter was obtained on January 16th, 2024. The Portland Boat Works site will be expanded for the 2025 field demonstration. The original 2024 field demonstration site had a treatment area of 0.6 acres with a mean depth of 0.9 to 3.2 feet mean lower low water. The 2025 expanded treatment site has an area of 3.8 acres with an estimate mean depth of 5 feet mean higher high water.

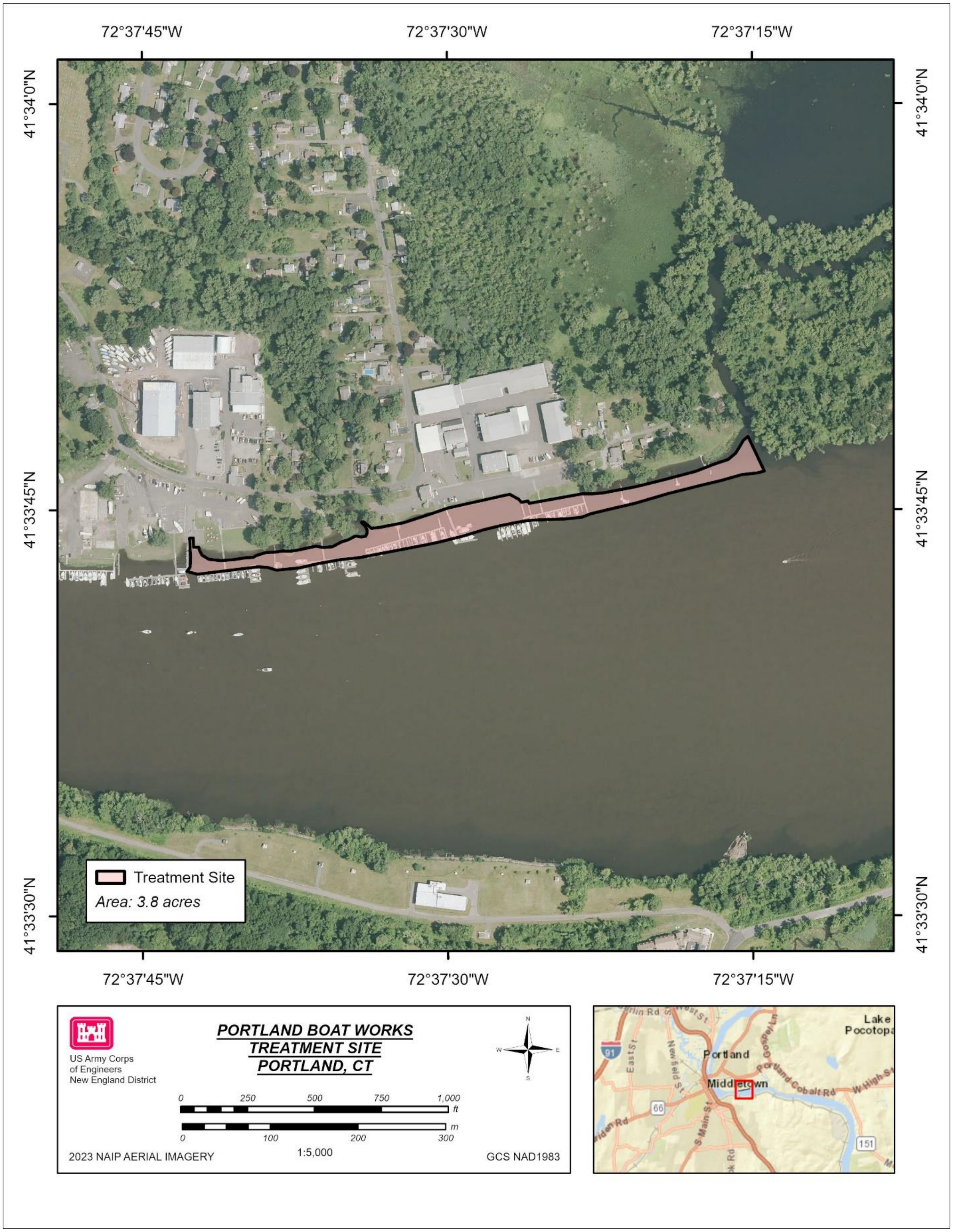

Figure 1. Portland Boat Works hydrilla treatment area in Portland, CT.

2 Proposed Treatment Activity

Diquat, dipotassium salt of endothall, florpyrauxifen-benzyl, or combinations thereof are proposed to be applied in Portland Boat Works for hydrilla control. The selected herbicide(s) will be applied at the maximum concentration rate. The herbicide(s) will be evenly distributed across the entire treatment area delineated in Figure 1 using boat-based, subsurface injection application methods. This section describes the proposed herbicides.

2.1 Diquat

Diquat dibromide is a state and federally registered herbicide approved for application in aquatic sites for invasive aquatic plant control. A Registration Standard for diquat dibromide was issued by the EPA in June 1986 (EPA, 1995). The active ingredient ((6,7-dihydrodipyrido (1,2a:2',1'-c) pyrazinediium dibromide)) is a fast-acting herbicide that interferes with photosynthesis, disrupts plant cell membranes, and results in plant death within a week of application in sensitive plant species (DNR, 2012).

2.2 Dipotassium salt of endothall

Dipotassium salt of endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid) is a state and federally registered aquatic herbicide and is approved for application in aquatic sites for the treatment of invasive aquatic plant species. The dipotassium salt of endothall was registered by EPA for aquatic use in 1960 at application rates between 0.5 and 5.0 ppm for aquatic plant control (Menninger, 2012). Dipotassium salt of endothall is a selective fast-acting herbicide that interferes with plant protein and lipid biosynthesis, disrupting respiration and plant membranes. This herbicide is highly effective for hydrilla control (Netherland et al.,1991).

2.3 Florpyrauxifen-benzyl

Florpyrauxifen-benzyl is a state and federally registered herbicide, and that is approved for invasive plant treatment in aquatic environments. This relatively new systemic herbicide mimics the plant growth hormone, auxin, killing susceptible plants by disrupting the plant cell growth process.

The active ingredient (4-amino-3chloro-6-(4-chloro-2-fluoro-3-methoxyphenyl) 5-fluoropyridine-2-benzyl ester) causes excessive plant cell elongation, ultimately resulting in plant cell death in sensitive plant species. Florpyrauxifen-benzyl is absorbed from the water through submersed plant shoots and leaves, and this herbicide has previously been demonstrated to be highly effective at selectively suppressing both dioecious and monoecious invasive hydrilla (Sperry et al., 2021; Mudge et al., 2021; Beets et al., 2019; Netherland & Richardson, 2016; Richardson et al., 2016) with relatively short exposure times and lower application rates compared to other herbicides (DNR, 2022).

3 Potential Impacts of the Proposed Treatment Activity

3.1 State-Listed Native Plant Species

Preliminary assessments of the Natural Diversity Database maps and files identified no state-listed plants within the delineated Portland Boat Works treatment area. Aquatic plant surveys were not conducted at this site as there were no species of concern anticipated at this location.

3.2 State-Listed Invertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified three state-listed invertebrates that may be present within Portland Boat Works: tidewater mucket (*Leptodea ochracea*, state special concern), eastern pondmussel (*Ligumia nasuta*, state special concern), and cobra clubtail (*Gomphus vastus*, state special concern). Neither mussel surveys nor insect surveys were completed during the environmental studies to confirm the presence of these species within Portland Boat Works.

3.2.1 Diquat

No impacts are expected to the freshwater mussels from the application of diquat. One study tested the impacts of diquat on the New Zealand freshwater mussel (*Hyridella menziesi*) and concluded that diquat had no significant effects on freshwater mussels and, therefore, was considered to be non-toxic to these organisms when applied at rates needed to kill most aquatic weeds (Clayton & Severne, 2005).

No impacts are expected to the cobra clubtail (*Gomphus vastus)* from the application of diquat. Herbicides will be applied using subsurface injection methods, and no airborne exposure risks are expected to the cobra clubtail. The EPA considers diquat to be of minimal risk to non-target insects (EPA, 1995). Additionally, a study on insects observed that dragonflies and damselflies survived after being exposed to diquat concentrations 40 times higher than the recommended maximum field application rate (Gilderhus, 1967).

3.2.2 Dipotassium salt of endothall

No impacts are expected to the tidewater mucket (*Leptodea ochracea)* and the eastern pondmussel (*Ligumia nasuta).* A study investigating impacts of dipotassium salt of endothall concentrations ranging from 0.5 to 1000 ppm on juvenile and glochidia fatmucket (*Lampsilis siliquoidea*) concluded that dipotassium salt of endothall was not found to be acutely toxic to fatmucket mussels at the application rates needed for hydrilla treatment. Median lethal concentrations (LC_{50}s) for glochidia mussels were found to be 31.2 ppm for 24 hr. exposure periods and 27.6 ppm for 48 hr. exposure periods. LC_{50}s for juvenile mussels were found to be 214 ppm for 48 hr. exposure periods and 34.4 ppm for 96 hr. exposure periods. Median lethal concentrations were substantially higher (6-34 times higher) than recommended dipotassium salt of endothall application rates for hydrilla treatment (1-5 ppm) (Archambault et al., 2015). Dipotassium salt of endothall has also been tested on dreissenid mussels, specifically zebra and quagga mussels, to evaluate impacts. At the highest concentration applied (5 ppm) maximum mortality of 5% was observed for quagga mussels at 20º C, and 2.5% at 25º C. Zebra mussels had zero mortality to any dipotassium salt of endothall concentration at either temperature regime (Claudi et al., 2013).

The cobra clubtail (*Gomphus vastus)* is also not expected to be negatively impacted by the proposed treatment activity. When used at recommended application rates, dipotassium salt of endothall no significant adverse effects were observed on aquatic insects (e.g. snails, aquatic insects, and crayfish) (DNR, 2012).

3.2.3 Florpyrauxifen-benzyl

No impacts are expected to the tidewater mucket (*Leptodea ochracea)* and the eastern pondmussel (*Ligumia nasuta)*. A recent study examined the impacts of florpyrauxifen-benzyl applications on juvenile fatmucket (*Lampsilis siliquoidea*) and eastern lampmussel (*Lampsilis radiata*) and determined that this compound was not acutely toxic to juveniles of these species. While potential chronic or sub-lethal effects require further investigation to characterize, this study concluded that the short-term exposure risk of these freshwater mussels to florpyrauxifen-benzyl for the purposes of aquatic weed control are minimal (Buczek et al., 2020).

The cobra clubtail (*Gomphus vastus)* is not expected to be negatively impacted by the proposed treatment activity due to the in-water application methods under consideration. Previous studies have shown florpyrauxifen-benzyl to be essentially nontoxic on an acute basis to bees (Levey, 2022), thus risk of acute impacts to other insect species are also considered to be low. Additionally, this herbicide has been shown to have a relatively low potential for volatility from water due to low vapor pressure (EPA, 2017) and is not expected to have vapor drift impacts to this insect species.

3.3 State-Listed Vertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified six state-listed vertebrates that may be present within Portland Boat Works: shortnose sturgeon (*Acipenser brevirostrum*, state and federally endangered), Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*, state and federally endangered), blueback herring (*Alosa aestivalis*, state special concern), spotted turtle (*Clemmys guttata*, state special concern), mud puppy (*Necturus maculosus,* state special concern*)* and the bald eagle (*Haliaeetus leucocephalus*, state threatened). Neither fish nor bird surveys were completed during the environmental studies to confirm the presence of these species.

3.3.1 Diquat

No adverse effects are anticipated for the fish species of concern given that the proposed application rates are within the concentration limits specified on the EPA-approved herbicide label. Studies have found that diquat has relatively low toxicity to fish and does not appear to significantly bioaccumulate in fish tissue (BLM, 2005). The results of acute exposure studies on freshwater fish have been summarized as “slightly toxic to practically non-toxic for diquat dibromide” (Hartless & Lin, 2010).

No impacts are expected to the spotted turtle (*Clemmys guttata)* and the mudpuppy (*Necturus maculosus)*. One study on diquat and endothall toxicity to the eastern spiny softshell turtle (*Apalone spinifera spinifera*) monitored these aquatic turtles over time as they were exposed to a range of in-water herbicide concentrations. This study did not observe any toxic effects to any of the turtles and none of the turtles used in the experiment died during either the exposure or postexposure monitoring portions of the test. This study concluded that softshell turtles were not sensitive to diquat (Paul & Simonin, 2007). No impacts are expected to the mudpuppy (*Necturus maculosus)*. Fish toxicological data is typically used to represent amphibians in ecotoxicology studies. As discussed above, diquat will have no adverse effects to fish with relatively low toxicity. A study on the northern leopard frog (*Rana pipiens)* found no adverse effects at concentrations of 2 mg/L. This application rate is significantly higher than the maximum application rate for diquat (Dial & Bauer Dial, 1987).

No impacts are expected to the bald eagle (*Haliaeetus leucocephalus)*. Herbicides will be applied using subsurface injection methods, no airborne exposure risks to nearby birds at the time of application are anticipated. While diquat dibromide has been found to be moderately toxic to birds in acute oral exposure studies (EPA, 1995; BLM, 2005; Emmett, 2002), many of these studies were conducted at much higher concentrations than the proposed treatment. Additionally, risks to piscivorous birds such as bald eagles were found to be low given that bioaccumulation in fish species is also low (BLM, 2005).

3.3.2 Dipotassium salt of endothall

No adverse impacts are expected to the shortnose sturgeon (*Acipenser brevirostrum*, state and federally endangered), Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*, state and federally endangered), blueback herring (*Alosa aestivalis*, state special concern). The proposed application will occur outside of the blueback herring spawning period, as described in Section 4.2, to avoid potential impacts to spawning habitat. The proposed application rate will be 5 ppm, which is significantly below various fish ecotoxicity rates (Table 1).

Table 1. Fish ecotoxicity of dipotassium salt of Endothall

Common Name	Scientific Name	Ecotoxicity
Bluegill sunfish	*Lepomis macrochirus*	1,071 ppm (EC_{50})
Rainbow trout	*Oncorhynchus mykiss*	363 ppm (EC_{50})
Sheepshead minnow	*Cyprinodon variegatus*	340 ppm (96-hour EC_{50})

Source: (UPL, 2019).

No impacts are expected to the spotted turtle (*Clemmys guttata)* with the risk of toxic impacts of endothall treatment considered to be minimal. As discussed in Section 3.3.1, a study monitored diquat and endothall toxicity to the eastern spiny softshell turtle. This study did not observe any toxic effects to any of the turtles, with no mortality during either the exposure or postexposure monitoring periods. This study concluded that softshell turtles were not sensitive to endothall (Paul & Simonin, 2007).

No impacts are expected to the bald eagle (*Haliaeetus leucocephalus)*. The risk of acute impacts to birds is considered to be low. Endothall has been shown to be non-toxic to bird species with a reported LD50 325 mg/kg bodyweight for the mallard duck (*Anas platyrhynchos*) (UPL, 2019). Additionally, because herbicides will be applied using subsurface injection methods, no airborne exposure risks to nearby birds at the time of application are anticipated.

3.3.3 Florpyrauxifen-benzyl

Florpyrauxifen-benzyl is considered to be practically nontoxic to freshwater fish (DNR, 2022; Levey, 2022; EPA, 2017). Studies of florpyrauxifen-benzyl impacts on fish and aquatic organisms largely did not observe toxicity even when applied up to its functional limit of solubility (Levey, 2022; EPA, 2017). Further, results of bioaccumulation studies in fish suggested rapid and extensive metabolism of florpyrauxifen-benzyl, indicating that bioaccumulation potential for this herbicide is low (EPA, 2017). Fish toxicity has not been previously reported in field or laboratory evaluations of florpyrauxifen-benzyl at the proposed application rate (48 ppb). Further, chronic toxicity in these species are also not considered to be a concern as the proposed treatment activity only includes one herbicide application, and florpyrauxifen-benzyl has been shown to rapidly degrade through aerobic aquatic metabolism and aqueous photolysis once applied (EPA, 2017). Florpyrauxifen-benzyl is considered practically non-toxic to fish on an acute basis [static 96-hour EC50 >120 mg/L for carp (*Cyprinus carpio*)] (SePRO, 2017).

No impacts are expected to the bald eagle (*Haliaeetus leucocephalus)* or the spotted turtle (*Clemmys guttata).* The risk of acute impacts to birds is considered to be low. Florpyrauxifen-benzyl has been shown to be non-toxic to multiple bird species with a reported LD50 >2,500 mg/kg bodyweight for Bobwhite quail (*Colinus virginianus*) (Levey, 2022; EPA, 2017; SePRO, 2017). Additionally, because herbicides will be applied using subsurface injection methods, no airborne exposure risks to nearby birds at the time of application are anticipated. While the response of the spotted turtle (*Clemmys guttata)* is not known, bird species are considered surrogates for reptiles in toxicological studies. Based on the risk to bird species, the spotted turtle is also not expected to have impacts associated with the proposed application.

No impacts are expected to the mudpuppy (*Necturus maculosus)*. While the species response is unknown, fish species are considered surrogates for amphibians in toxicological studies. No impacts are expected to the mudpuppy as the maximum produce use rate is significantly greater than the EC_{50} for fish species (SePRO, 2017).

4 Conservation Strategy for Endangered, Threatened and Special Concern Species

4.1 Herbicide Application Methods and Timing

Strategic herbicide application methods and timing will be employed throughout this demonstration project to minimize the potential risk of impacts to non-target and state-listed species of concern. Herbicide will be applied directly to the water and evenly distributed across the entire treatment area using boat-based, subsurface injection application methods to minimize airborne exposure risks to non-target species.

4.2 Considerations for Vertebrates

Alewife and blueback herring are known to spawn over aquatic vegetation within the proposed treatment area between April 1 and June 30. To minimize potential impacts to these spawning events, the timing of treatment application will be delayed until after July 4, 2025.

5 References

Archambault, J.M., Bergeron, C.M., Cope, G.W., Richardson, R.J., Heilman, M.A., Corey III, E.J., Netherland, M.D., & Heise, R.J. 2015. Sensitivity of freshwater molluscs to hydrilla-targeting herbicides: providing context for invasive aquatic weed control in diverse ecosystems. Journal of Freshwater Ecology. Vol. 30(3): 335-348.

Beets, J., Heilman, M., & Netherland, M.D. 2019. Large-Scale Mesocosm Evaluation of Florpyrauxifen-Benzyl, a Novel Arylpicolinate Herbicide, on Eurasian and Hybrid Watermilfoil and Seven Native Submersed Plants." Journal of Aquatic Plant Management. Vol. 57: 49-55

Buczek, S.B., Archambault, J.M., Cope, W.G., & Heilman, M.A. 2020. Evaluation of Juvenile Freshwater Mussel Sensitivity to Multiple Forms of Florpyrauxifen-Benzyl. Bulletin of Environmental Contamination and Toxicology. Volume 105: 588-594 https://doi.org/10.1007/s00128-020-02971-1.

Bugbee, G.J., & Stebbins, S.E. 2022. Invasive Aquatic Vegetation Survey Hydrilla Overwintering and Spread Management Options. Department of Environmental Science and Forestry.

Bureau of Land Management (BLM). 2005. Diquat Ecological Risk Assessment, Final Report. All U.S. Government Documents (Utah Regional Depository).

Claudi, R., Taraborelli, C., & Prescott, T.H. 2013. Efficacy of Endothall for Control of Adult Quagga and Zebra Mussels. Accessed 31 January 2025 from https://invasivemusselcollaborative.net/wp-content/uploads/2018/11/Claudi-et-al.-2013b.pdf.

Clayton, J., & Severne, C. 2005. Review of Diquat Reports of Relevance to Iwi Values in Lake Karapiro. Environment Waikato Technical Report 2006/03. Environment Waikato. https://www.waikatoregion.govt.nz/assets/WRC/WRC-2019/tr06-03.pdf.

Dial, N.A., & Bauer Dial, C.A. 1987. Lethal Effects of Diquat and Paraquat on Developing Frog Embryos and 15-Day-Old Tadpoles, *Rana pipiens*. Bulletin of Environmental Contamination and Toxicology. Vol. 38(6): 1006–1011. https://doi.org/10.1007/BF01609088.

Emmett, K. 2002. Appendix A: Final Risk Assessment for Diquat Bromide. 02-10–046. Washington State Department of Ecology

Gilderhus, P.A. 1967. Effects of diquat on bluegills and their food organisms: The Progressive Fish-Culturis. Vol. 29(2): 67-74. https://doi.org/10.1577/1548-8640(1967)29[67:EODOBA]2.0.CO;2

Hartless, C., & Lin, J. 2010. Risks of Diquat Dibromide Use to the Federally Threatened Delta Smelt.

Levey, R. 2022. Aquatic Nuisance Control Permit, ProcellaCOR EC Aquatic Toxicity Review. https://dec.vermont.gov/sites/dec/files/wsm/lakes/ANC/docs/ProcellaCor%20Aqu

atic%20Toxicity%20Review%20_03162022.pdf.
Menninger, H. 2012. Endothall FAQ. Cornell Cooperative Extension. 2012. http://ccetompkins.org/environment/aquatic-invasives/hydrilla/managementoptions/herbicides/endothall/endothall-faq.
Mudge, C.R., Sartain, B.T., Getsinger, K.D., & Netherland, M.D. 2021. Efficacy of Florpyrauxifen-Benzyl on Dioecious Hydrilla and Hybrid Water Milfoil - Concentration and Exposure Time Requirements. U.S. Engineer Research and Development Center. https://doi.org/10.21079/11681/42062.
Netherland, M.D., & Richardson, R.J. 2016. Evaluating Sensitivity of Five Aquatic Plants to a Novel Arylpicolinate Herbicide Utilizing an Organization for Economic Cooperation and Development Protocol. Weed Science. Vol. 64(1): 181–90. https://doi.org/10.1614/WS-D-15-00092.1.
Netherland, M.D., Green, W.R., & Getsinger, K.D. 1991. Endothall Concentration and Exposure Time Relationships for the Control of Eurasian Watermilfoil and Hydrilla. Journal of Aquatic Plant Management. Vol. 29: 61–67.
Paul, E.A, & Simonin, H.A. 2007. Toxicity of Diquat and Endothall to Eastern Spiny Softshell Turtles (*Apalone spinifera spinifera)*. Journal of Aquatic Plant Management. Vol. 45: 52-44
Richardson, R., Haug, E.J., & Netherland, M.D. 2016. Response of Seven Aquatic Plants to a New Arylpicolinate Herbicide. Journal of Aquatic Plant Management. Vol. 54: 26–31.
SePRO Corporation (SePRO). 2017. Safety Data Sheet for ProcellaCOR EC Version 1.0. EPA Registration No. 67690-80.
Sperry, B.P, Leary, J.K., Dean Jones, K, & Ferrell, J.A. 2021. Observations of a Submersed Field Application of Florpyrauxifen-Benzyl Suppressing Hydrilla in a Small Lake in Central Florida. Journal of Aquatic Plant Management. Vol. 59: 20-26.
Tippery, N.P., Bugbee, G.J., & Stebbins, S.E. 2020. Evidence for a Genetically Distinct Strain of Introduced Hydrilla Verticillata (Hydrocharitaceae) in North America. Journal of Aquatic Plant Management. Vol. 58:1-6.
UPL Limited (UPL). 2019. Safety Data Sheet for AQUATHOL® K Aquatic Herbicide.
U.S. Environmental Protection Agency (EPA). 2017. The 2017 EPA Environmental Fate and Ecological Risk Assessment for Florpyrauxifen-Benzyl.
U.S. Environmental Protection Agency (EPA). 1995. Diquat Dibromide. https://archive.epa.gov/pesticides/reregistration/web/pdf/0288fact.pdf.
Wisconsin Department of Natural Resources (DNR). 2022. Florpyrauxifen-Benzyl Fact Sheet. https://apps.dnr.wi.gov/swims/Documents/DownloadDocument?id=332109305
Wisconsin Department of Natural Resources (DNR). 2012. Diquat Chemical Fact Sheet. https://www.noaa.gov/sites/default/files/legacy/document/2020/Oct/07354626838.pdf

Connecticut River
Hydrilla Control Research and Demonstration Project
Lower Connecticut River, CT

Species Protection Plan
Post and Pratt Coves
Deep River, CT

US Army Corps
of Engineers ®
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Post and Pratt Coves Species Protection Plan

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1. Introduction

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Hydrilla (*Hydrilla verticillata*) was first identified in the Connecticut River near Glastonbury, CT in 2016 and has since spread south to Essex, CT infesting the river's many coves, tributaries, and boat basins. The Connecticut River hydrilla population has been shown to be genetically distinct from other known hydrilla strains (Tippery et al., 2020), and the plant's biology is largely unknown at this time. Following the discovery of the highly invasive aquatic plant in the Connecticut River in 2016, intensive vegetation surveys were conducted in 2019 and 2020 from Agawam, MA south to Long Island Sound to map the invasion extent. Hydrilla was found as far north as Agawam, MA, confirming that the plant spreads rapidly which poses significant risk to other regional waterbodies (Bugbee & Stebbins, 2022). Fragments of the plant, which are easily transported by boats and boat trailers, can sprout roots to establish new populations. Fragments also float and are capable of dispersing via wind and water currents. Due to the importance of the Connecticut River as an environmental resource and driver of the local economy, stakeholders are seeking an aggressive hydrilla management program.

1.2 Project Background

The U.S. Army Corps of Engineers (USACE), through its Engineer Research and Development Center's (ERDC) Aquatic Plant Control Research Program, is leading a research and demonstration project to verify the effectiveness of aquatic herbicides registered for use by the U.S. Environmental Protection Agency (EPA) to reduce and control the spread of the Connecticut River hydrilla safely and selectively. The project has been investigating hydrilla's growth patterns, site-specific water exchange dynamics and evaluating herbicide efficacy in laboratory conditions throughout 2023 to guide operational scale field demonstrations of herbicide efficacy in 2024. Deep River has been selected as a hydrilla treatment site for ERDC's 2025 field demonstration project.

1.3 Post and Pratt Coves Treatment Site

Post and Pratt coves are tidal coves off the main stem of the Connecticut River located in Deep River, Middlesex County, CT and centered at 41.386° N, 72.421° W. The treatment area is 35.5 acres with a mean tidal depth of 6 feet mean higher high water.

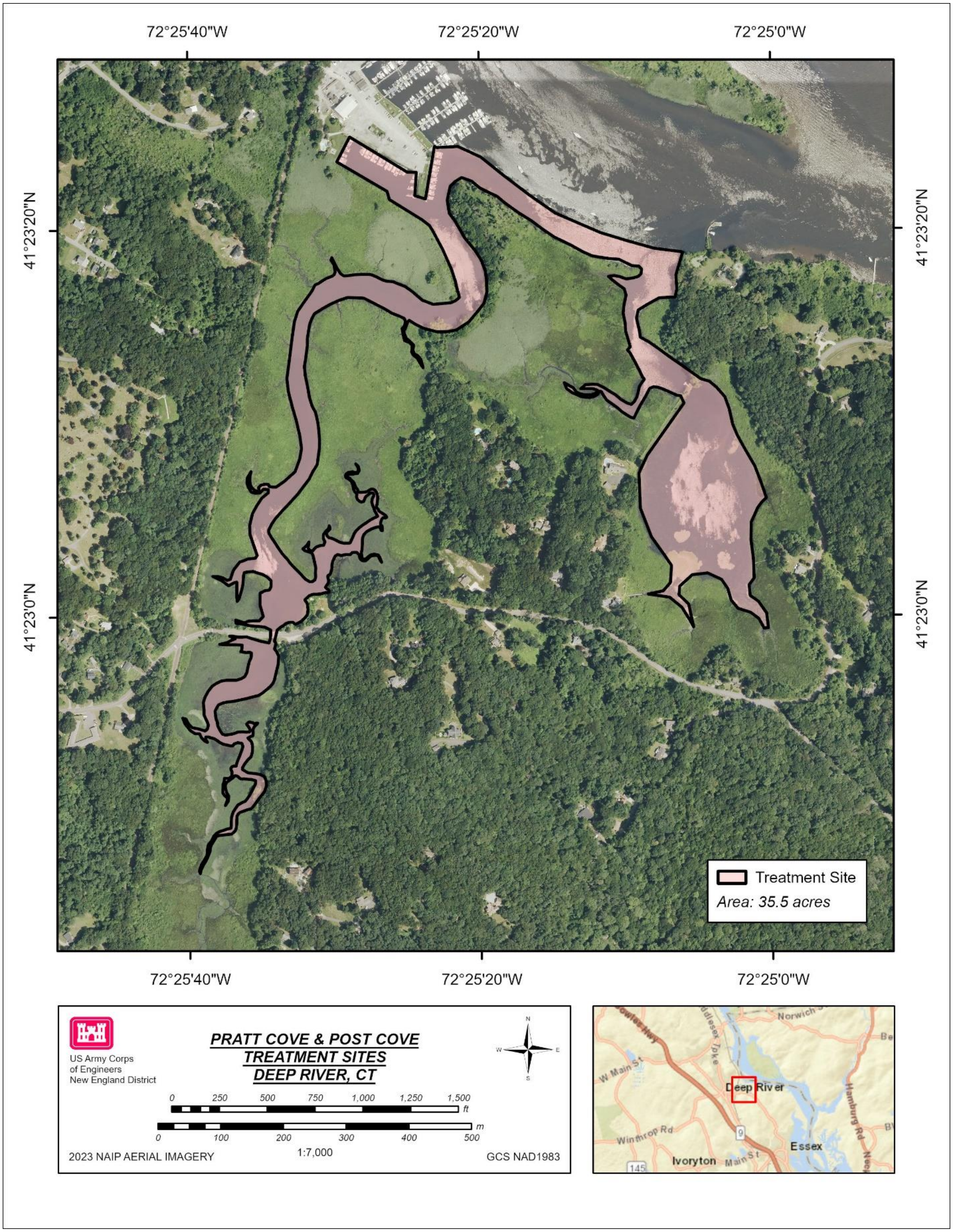

Figure 1. Deep River hydrilla treatment area in Chester, CT.

2. Proposed Treatment Activity

Diquat, dipotassium salt of endothall, florpyrauxifen-benzyl, or combinations thereof are proposed to be applied in Post and Pratt coves for hydrilla control. The selected herbicide(s) will be applied at the maximum concentration rate. The herbicide(s) will be evenly distributed across the entire treatment area delineated in Figure 1 using boat-based, subsurface injection application methods. This section describes the proposed herbicides.

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Diquat dibromide is a state and federally registered herbicide approved for application in aquatic sites for invasive aquatic plant control. A Registration Standard for diquat dibromide was issued by the EPA in June 1986 (EPA, 1995). The active ingredient ((6,7-dihydrodipyrido (1,2a:2',1'-c) pyrazinediium dibromide)) is a fast-acting herbicide that interferes with photosynthesis, disrupts plant cell membranes, and results in plant death within a week of application in sensitive plant species (DNR, 2012).

2.2 Dipotassium salt of endothall

Dipotassium salt of endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid) is a state and federally registered aquatic herbicide and is approved for application in aquatic sites for the treatment of invasive aquatic plant species. The dipotassium salt of endothall was registered by EPA for aquatic use in 1960 at application rates between 0.5 and 5.0 ppm for aquatic plant control (Menninger, 2012). Dipotassium salt of endothall is a selective fast-acting herbicide that interferes with plant protein and lipid biosynthesis, disrupting respiration and plant membranes. This herbicide is highly effective for hydrilla control (Netherland et al.,1991).

2.3 Florpyrauxifen-benzyl

Florpyrauxifen-benzyl is a state and federally registered herbicide, and that is approved for invasive plant treatment in aquatic environments. This relatively new systemic herbicide mimics the plant growth hormone, auxin, killing susceptible plants by disrupting the plant cell growth process.

The active ingredient (4-amino-3chloro-6-(4-chloro-2-fluoro-3-methoxyphenyl) 5-fluoropyridine-2-benzyl ester) causes excessive plant cell elongation, ultimately resulting in plant cell death in sensitive plant species. Florpyrauxifen-benzyl is absorbed from the water through submersed plant shoots and leaves, and this herbicide has previously been demonstrated to be highly effective at selectively suppressing both dioecious and monoecious invasive hydrilla (Sperry et al., 2021; Mudge et al., 2021; Beets et al., 2019; Netherland & Richardson, 2016; Richardson et al., 2016) with relatively short exposure times and lower application rates compared to other herbicides (DNR, 2022).

3. Potential Impacts of the Proposed Treatment Activity

3.1 State-Listed Native Plant Species

Preliminary assessments of the Natural Diversity Database maps and files identified two state-listed vascular plants that may potentially occur within the delineated Prat and Post Coves treatment area: golden club (*Orontium aquaticum*, state special concern), awl-leaved arrowhead (*Sagittaria subulata*, state special concern). No submergent or emergent plant studies were conducted to confirm the presence of these species within the treatment area.

Additionally, dillenius' tick-trefoil (*Desmodium glabellum,* state special concern) was identified during preliminary review. This species is not likely to occur in the treatment area as it does not inhabit aquatic or intertidal zones. Therefore, no impacts were further considered from the application of the proposed herbicides.

3.1.1 Diquat

There is currently no published herbicide response or toxicology data available for the state-listed plant species identified. A low exposure risk is anticipated for these species, as both species occupy tidal areas. Preliminary USACE research trials indicate that awl-leaved arrowhead (*Saggitaria subulata)* is tolerant to in-water diquat exposure.

3.1.2 Dipotassium salt of endothall

Preliminary USACE research trials indicate that awl-leaved arrowhead (*Saggitaria subulata)* is tolerant to endothall exposure using subsurface injection methods. The potential impacts to golden club (*Orontium aquaticum)* are not currently known, as there is no published data on this species' herbicide response. A low exposure risk is anticipated for the golden club as it inhabits tidal areas.

3.1.3 Florpyrauxifen-benzyl

No impacts are expected to awl-leaved arrowhead based on a mesocosm study on the effects of florpyrauxifen-benzyl on native plants, including the bulltongue arrowhead (*Saggitaria lancifolia)*. The species showed limited petiole bending during initial exposure. No significant impacts were observed on the bulltongue arrowhead under concentrations of 24 to 48 µg L^{-1} for 24- and 72-hour concentrations (Beets & Netherland, 2018).

The potential impacts to golden club (*Orontium aquaticum)* are not currently known, as there is no published data on this species' herbicide response. A low exposure risk is anticipated for the golden club as it inhabits tidal areas.

3.2 State-Listed Invertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified three state-listed invertebrate species that may be present within Pratt and Post Coves:

tidewater mucket (*Leptodea ochracea*, eastern pondmussel (*Ligumia nasuta*, state special concern), and woodland pondsnail (*Stagnicola catascopium,* state special concern). No invertebrate surveys were completed during the 2024 environmental studies to confirm the presence of these species within Pratt and Post Coves.

3.2.1 Diquat

No impacts are expected to the identified freshwater mussels from the application of diquat. One study tested the impacts of diquat on the New Zealand freshwater mussel (*Hyridella menziesi*) and concluded that diquat had no significant effects on freshwater mussels and, therefore, was considered to be non-toxic to these organisms when applied at rates needed to kill most aquatic weeds (Clayton & Severne, 2005).

No adverse impacts are expected for the woodland pondsnail (*Stagnicola catascopium)*. The acute toxicity of diquat was determined for the Florida applesnail (*Pomacea paludosa)*. Diquat was determined moderately toxic to *P. paludosa*, with a 96-hour EC_{50} of 1.1ppm (Mayer & Ellersieck, 1986). The risk of exposure is lower for Salmon River as 96-hour exposure is not typically attainable under field use conditions. Additionally, this value is greater than the maximum use concentration.

3.2.2 Dipotassium salt of endothall

No impacts are expected to the identified freshwater mussels. A study investigating impacts of dipotassium salt of endothall concentrations ranging from 0.5 to 1000 ppm on juvenile and glochidia fatmucket (*Lampsilis siliquoidea*) concluded that dipotassium salt of endothall was not found to be acutely toxic to fatmucket mussels at the application rates needed for hydrilla treatment. Median lethal concentrations (LC_{50}) were substantially higher (6-34 times higher) than recommended dipotassium salt of endothall application rates for hydrilla treatment (1-5 ppm) (Archambault et al., 2015). Dipotassium salt of endothall has also been tested on dreissenid mussels, specifically zebra and quagga mussels, to evaluate impacts. At the highest concentration applied (5 ppm) maximum mortality of 5% was observed for quagga mussels at 20º C, and 2.5% at 25º C. Zebra mussels had zero mortality to any dipotassium salt of endothall concentration at either temperature regime (Claudi et al., 2013).

The woodland pondsnail (*Stagnicola catascopium)* is not expected to be negatively impacted by the proposed treatment activity. When used at recommended application rates, dipotassium salt of endothall no significant adverse effects were observed on aquatic insects (e.g. snails, aquatic insects, and crayfish) (DNR, 2012).

3.2.3 Florpyrauxifen-benzyl

No impacts are expected to the identified freshwater mussels. A study observed the toxicity of florpyrauxifen-benzyl applications on juvenile fatmucket (*Lampsilis siliquoidea*) and eastern lampmussel (*Lampsilis radiata*) and determined that this compound was not acutely toxic to juveniles of these species. While potential chronic or sub-lethal effects require further investigation to characterize, this study concluded that the short-term exposure risk of these freshwater mussels to florpyrauxifen-benzyl for aquatic weed control are minimal (Buczek et al., 2020).

No adverse impacts are expected to the woodland pondsnail (*Stagnicola catascopium)* as Florpyrauxifen-benzyl poses minimal risk to aquatic invertebrates according to the ecotoxicity information required for EPA registration. For the model ecotoxicological species, water flea (*Daphnia magna*), the 48-hour EC_{50} value reported is 49 mg/L [parts per million (ppm)] which is over 1,000-fold greater than the product's maximum use rate of 48 µg/L [parts per billion (ppb)] (SePRO, 2017).

3.3 State-Listed Vertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified four state-listed vertebrate animals that may be present within Deep River: mudpuppy (*Necturus maculosus,* state special concern), shortnose sturgeon (*Acipenser brevirostrum,* state and federally endangered*)*, Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus,* state and federally endangered*)*, and the blueback herring (*Alosa aestivalis,* state special concern*)*.

3.3.1 Diquat

No adverse effects are anticipated for the fish species of concern given that the proposed application rates are within the concentration limits specified on the EPA-approved herbicide label. Studies have found that diquat has relatively low toxicity to fish and does not appear to significantly bioaccumulate in fish tissue (BLM, 2005). The results of acute exposure studies on freshwater fish have been summarized as "slightly toxic to practically non-toxic for diquat dibromide" (Hartless & Lin, 2010). Fish species serve as surrogates for amphibians in ecotoxicity studies. Therefore, no adverse effects are anticipated for the mudpuppy (*Necturus maculosus)*.

3.3.2 Dipotassium salt of endothall

No direct herbicide exposure data is available for the mudpuppy (*Necturus maculosus)*. Although no significant impacts are anticipated for this species as well as the identified fish species of concern. Fish data provides surrogate data for amphibian species in ecotoxicology studies. The effective concentration (EC_{50}) of various freshwater species to endothall was determined: bluegill sunfish (*Lepomis macrochirus*) at 1,071 ppm, rainbow trout (*Oncorhynchus mykiss)* at 363 ppm, and the sheepshead minnow (*Cyprinodon variegatus)* at 340 ppm (96-hour EC_{50}). The EC_{50} of these species are significantly greater than the proposed application rate of 5 ppm (UPL, 2019).

3.3.3 Florpyrauxifen-benzyl

No adverse effects are anticipated for fish species of concern and the mudpuppy. No direct herbicide response data is available for the application of florpyrauxifen-benzyl on the mudpuppy. As mentioned previously, fish toxicity data can provide information on amphibian response. No impacts are expected to the mudpuppy as the maximum use rate is significantly greater than the EC_{50} for fish species. Florpyrauxifen-benzyl is considered practically non-toxic to fish on an acute basis [static 96-hour EC50 >120 mg/L for carp (*Cyprinus carpio*)]. Studies of florpyrauxifen-benzyl impacts on fish and aquatic organisms largely did not observe toxicity even when applied up to its functional limit of solubility (Levey, 2022; EPA, 2017). Further, results of bioaccumulation studies in fish suggested rapid and extensive metabolism of florpyrauxifen-benzyl, indicating that bioaccumulation potential for this herbicide is low (EPA, 2017).

4. Conservation Strategy for Endangered, Threatened and Special Concern Species

4.1 Herbicide Application Methods and Timing

Strategic herbicide application methods and timing will be employed throughout this demonstration project to minimize the potential risk of impacts to non-target and state-listed species of concern. Herbicides will be applied by licensed applicators at allowable concentrations in accordance with the product's EPA-approved label. Herbicides will be applied directly to the water and evenly distributed across the entire treatment area using boat-based, subsurface injection application methods to minimize airborne exposure risks to non-target species.

4.1 Considerations to Plant Species of Concern

Monitoring will occur if the identified plant species of concern are present. If a net loss in plant species is observed within two years of monitoring and is determined to be from herbicide application, replanting will occur to minimize potential impacts of individuals lost.

4.1 Considerations to Invertebrate Species of Concern

Blueback herring is known to spawn over aquatic vegetation within the proposed treatment area between April 1 and June 30. To minimize potential impacts to these spawning events, the timing of treatment application will be delayed until after July 4, 2024.

5. References

Archambault, J.M., Bergeron, C.M., Cope, G.W., Richardson, R.J., Heilman, M.A., Corey III, E.J., Netherland, M.D., & Heise, R.J. 2015. Sensitivity of freshwater molluscs to hydrilla-targeting herbicides: providing context for invasive aquatic weed control in diverse ecosystems. Journal of Freshwater Ecology. Vol. 30(3): 335-348.

Beets, J., Heilman, M., & Netherland, M.D. 2019. Large-Scale Mesocosm Evaluation of Florpyrauxifen-Benzyl, a Novel Arylpicolinate Herbicide, on Eurasian and Hybrid Watermilfoil and Seven Native Submersed Plants." Journal of Aquatic Plant Management. Vol. 57: 49-55

Buczek, S.B., Archambault, J.M., Cope, W.G., & Heilman, M.A. 2020. Evaluation of Juvenile Freshwater Mussel Sensitivity to Multiple Forms of Florpyrauxifen-Benzyl. Bulletin of Environmental Contamination and Toxicology. Volume 105: 588-594 https://doi.org/10.1007/s00128-020-02971-1.

Bugbee, G.J., & Stebbins, S.E. 2022. Invasive Aquatic Vegetation Survey Hydrilla Overwintering and Spread Management Options. Department of Environmental Science and Forestry.

Claudi, R., Taraborelli, C., & Prescott, T.H. 2013. Efficacy of Endothall for Control of Adult Quagga and Zebra Mussels. Accessed 31 January 2025 from https://invasivemusselcollaborative.net/wp-content/uploads/2018/11/Claudi-et-al.-2013b.pdf.

Clayton, J., & Severne, C. 2005. Review of Diquat Reports of Relevance to Iwi Values in Lake Karapiro. Environment Waikato Technical Report 2006/03. Environment Waikato. https://www.waikatoregion.govt.nz/assets/WRC/WRC-2019/tr06-03.pdf.

Mayer, F.L, & Ellersieck, M.R. 1986. Manual of acute toxicity: interpretation and data base for 410 chemicals and 66 species of freshwater animals. No. 160. US Department of the Interior, Fish and Wildlife Service

Menninger, H. 2012. Endothall FAQ. Cornell Cooperative Extension. 2012. http://ccetompkins.org/environment/aquatic-invasives/hydrilla/managementoptions/herbicides/endothall/endothall-faq.

Mudge, C.R., Sartain, B.T., Getsinger, K.D., & Netherland, M.D. 2021. Efficacy of Florpyrauxifen-Benzyl on Dioecious Hydrilla and Hybrid Water Milfoil - Concentration and Exposure Time Requirements. U.S. Engineer Research and Development Center. https://doi.org/10.21079/11681/42062.

Netherland, M.D., & Richardson, R.J. 2016. Evaluating Sensitivity of Five Aquatic Plants to a Novel Arylpicolinate Herbicide Utilizing an Organization for Economic Cooperation and Development Protocol. Weed Science. Vol. 64(1): 181–90. https://doi.org/10.1614/WS-D-15-00092.1.

Netherland, M.D., Green, W.R., and Getsinger, K.D. 1991. Endothall Concentration and Exposure Time Relationships for the Control of Eurasian Watermilfoil and Hydrilla. Journal of Aquatic Plant Management. Vol. 29: 61–67.

Paul, E.A, and Simonin, H.A. 2007. Toxicity of Diquat and Endothall to Eastern Spiny

Softshell Turtles (*Apalone spinifera spinifera)*. Journal of Aquatic Plant Management. Vol. 45: 52-44

Richardson, R., Haug, E.J., & Netherland, M.D. 2016. Response of Seven Aquatic Plants to a New Arylpicolinate Herbicide. Journal of Aquatic Plant Management. Vol. 54: 26–31.

SePRO Corporation (SePRO). 2017. Safety Data Sheet for ProcellaCOR EC Version 1.0. EPA Registration No. 67690-80.

Sperry, B.P, Leary, J.K., Dean Jones, K, & Ferrell, J.A. 2021. Observations of a Submersed Field Application of Florpyrauxifen-Benzyl Suppressing Hydrilla in a Small Lake in Central Florida. Journal of Aquatic Plant Management. Vol. 59: 20-26.

Tippery, N.P., Bugbee, G.J., & Stebbins, S.E. 2020. Evidence for a Genetically Distinct Strain of Introduced Hydrilla Verticillata (Hydrocharitaceae) in North America. Journal of Aquatic Plant Management. Vol. 58:1-6.

UPL Limited (UPL). 2019. Safety Data Sheet for AQUATHOL® K Aquatic Herbicide.

U.S. Environmental Protection Agency (EPA). 1995. Diquat Dibromide. https://archive.epa.gov/pesticides/reregistration/web/pdf/0288fact.pdf.

Wisconsin Department of Natural Resources (DNR). 2022. Florpyrauxifen-Benzyl Fact Sheet. https://apps.dnr.wi.gov/swims/Documents/DownloadDocument?id=332109305

Wisconsin Department of Natural Resources (DNR). 2012. Diquat Chemical Fact Sheet. https://www.noaa.gov/sites/default/files/legacy/document/2020/Oct/07354626838.pdf

Connecticut River
Hydrilla Control Research and Demonstration Project
Lower Connecticut River, CT

Species Protection Plan
Salmon River
East Haddam, CT

US Army Corps of Engineers ®
New England District

February 2025

Salmon River Species Protection Plan

Table of Contents

1. Introduction

1.1 Connecticut River Hydrilla Information

Hydrilla (*Hydrilla verticillata*) was first identified in the Connecticut River near Glastonbury, CT in 2016 and has since spread south to Essex, CT infesting the river's many coves, tributaries, and boat basins. The Connecticut River hydrilla population has been shown to be genetically distinct from other known hydrilla strains (Tippery et al., 2020), and the plant's biology is therefore largely unknown at this time. Following the discovery of the highly invasive aquatic plant in the Connecticut River in 2016, intensive vegetation surveys were conducted in 2019 and 2020 from Agawam, MA south to Long Island Sound to map the invasion extent. Hydrilla was found as far north as Agawam, MA, confirming that the plant spreads rapidly which poses significant risk to other regional waterbodies (Bugbee & Stebbins, 2022). Fragments of the plant, which are easily transported by boats and boat trailers, can sprout roots to establish new populations. Fragments also float and are capable of dispersing via wind and water currents. Due to the importance of the Connecticut River as an environmental resource and driver of the local economy, stakeholders are seeking an aggressive hydrilla management program.

1.2 Project Background

The U.S. Army Corps of Engineers (USACE), through its Engineer Research and Development Center's (ERDC) Aquatic Plant Control Research Program, is leading a research and demonstration project to verify the effectiveness of aquatic herbicides registered for use by the U.S. Environmental Protection Agency (EPA) to reduce and control the spread of the Connecticut River hydrilla safely and selectively. The project has been investigating hydrilla's growth patterns, site-specific water exchange dynamics and evaluating herbicide efficacy in laboratory conditions throughout 2023 to guide operational scale field demonstrations of herbicide efficacy in 2024.

Preliminary laboratory experiments conducted in 2023 evaluated Connecticut River hydrilla control using the aquatic herbicide, florpyrauxifen-benzyl. Results from these experiments indicated that Connecticut River hydrilla has a similar response to florpyrauxifen-benzyl across multiple concentrations and exposure times as dioecious and monoecious hydrilla biotypes. Salmon River has been selected as a hydrilla treatment site for ERDC's 2025 field demonstration project.

1.3 Salmon River Treatment Site

Salmon River is a river off the mainstem of the Connecticut River located in East Haddam and Haddam, Middlesex County, CT and centered at 41.484° N, 72.478° W. The treatment area is 274.31 acres with a mean depth of 2.7 to 4.5 feet mean lower low water.

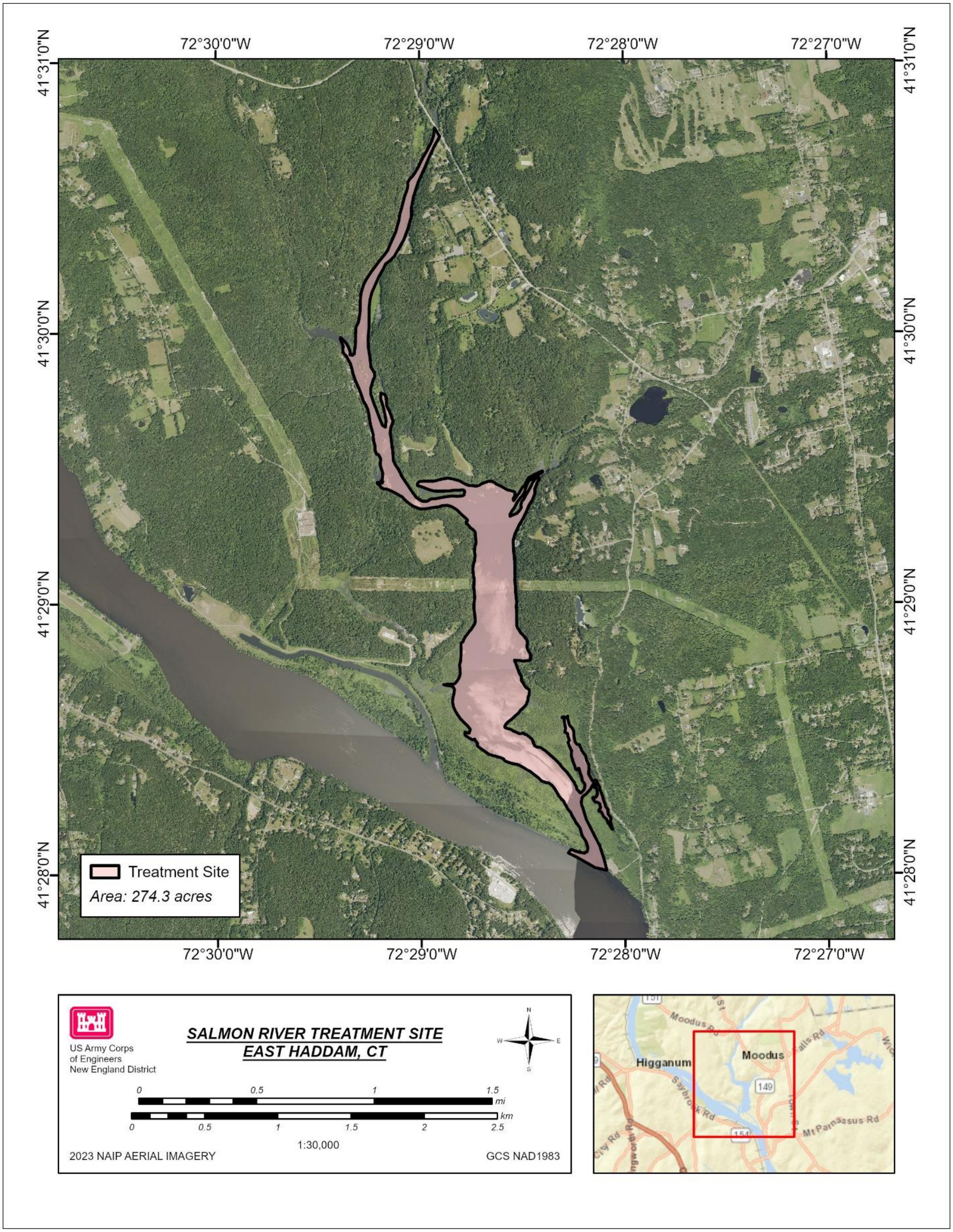

Figure 1. Salmon River hydrilla treatment area in East Haddam, CT.

2. Proposed Treatment Activity

Diquat, dipotassium salt of endothall, florpyrauxifen-benzyl, or combinations thereof are proposed to be applied in Salmon River for hydrilla control. The selected herbicide(s) will be applied at the maximum concentration rate. The herbicide(s) will be evenly distributed across the entire treatment area delineated in Figure 1 using boat-based, subsurface injection application methods. This section describes the proposed herbicides.

2.1 Diquat

Diquat dibromide is a state and federally registered herbicide approved for application in aquatic sites for invasive aquatic plant control. A Registration Standard for diquat dibromide was issued by the EPA in June 1986 (EPA, 1995). The active ingredient ((6,7-dihydrodipyrido (1,2a:2',1'-c) pyrazinediium dibromide)) is a fast-acting herbicide that interferes with photosynthesis, disrupts plant cell membranes, and results in plant death within a week of application in sensitive plant species (DNR, 2012).

2.2 Dipotassium salt of endothall

Dipotassium salt of endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid) is a state and federally registered aquatic herbicide and is approved for application in aquatic sites for the treatment of invasive aquatic plant species. The dipotassium salt of endothall was registered by EPA for aquatic use in 1960 at application rates between 0.5 and 5.0 ppm for aquatic plant control (Menninger, 2012). Dipotassium salt of endothall is a selective fast-acting herbicide that interferes with plant protein and lipid biosynthesis, disrupting respiration and plant membranes. This herbicide is highly effective for hydrilla control (Netherland et al.,1991).

2.3 Florpyrauxifen-benzyl

Florpyrauxifen-benzyl is a state and federally registered herbicide, and that is approved for invasive plant treatment in aquatic environments. This relatively new systemic herbicide mimics the plant growth hormone, auxin, killing susceptible plants by disrupting the plant cell growth process.

The active ingredient (4-amino-3chloro-6-(4-chloro-2-fluoro-3-methoxyphenyl) 5-fluoropyridine-2-benzyl ester) causes excessive plant cell elongation, ultimately resulting in plant cell death in sensitive plant species. Florpyrauxifen-benzyl is absorbed from the water through submersed plant shoots and leaves, and this herbicide has previously been demonstrated to be highly effective at selectively suppressing both dioecious and monoecious invasive hydrilla (Sperry et al., 2021; Mudge et al., 2021; Beets et al., 2019; Netherland & Richardson, 2016; Richardson et al., 2016) with relatively short exposure times and lower application rates compared to other herbicides (DNR, 2022).

3. Potential Impacts of the Proposed Treatment Activity

3.1 State-Listed Native Plant Species

Preliminary assessments of the Natural Diversity Database maps and files identified five state-listed vascular plants that may potentially occur within the delineated Salmon River treatment area: pale green orchid (*Platanthera flava var. herbiola,* state special concern), parker's pipewort (*Eriocaulon parkeri*, state endangered), eaton's beggarticks (*Bidens eatonii*, state threatened), wild senna (*Senna hebecarpa,* state threatened), and golden club (*Orontium aquaticum*, state special concern). No Submerged and emergent plant surveys were performed in Salmon River to identify any state-listed native species within the proposed treatment area.

Two plant species identified during the preliminary assessment are not likely to occur within the intertidal zone: Hyssop skullcap (*Scutellaria integrifolia)* and low frostweed (*Crocanthemum propinquum).* No impacts are expected to these species as the species occur outside of the proposed treatment area.

3.1.1 Diquat

No significant impacts are expected to eaton's beggarticks (*Bidens eatonii)*. A study on operational application of diquat observed the effects on non-target native plants. Diquat was applied to a 4-hectare treatment area within a lake, at the maximum concentration rate for a five-year period. The study observed no significant changes to beck's water marigold (*Bidens beckii)* were observed during the study (Parsons et al., 2019). While no direct herbicide response data is available for eaton's beggarticks, a similar herbicide response is anticipated.

There is currently no published herbicide response or toxicology data available for the pale green orchid (*Platanthera flava var. herbiola)*, parker's pipewort (*Eriocaulon parkeri)*, wild senna (*Senna hebecarpa)*, and goldenclub (*Orontium aquaticum)*. A low exposure risk is anticipated for these species, as these species occupy tidal areas. Additionally, preliminary USACE research trials indicate that awl-leaved arrowhead (*Saggitaria subulata)* is tolerant to in-water diquat exposure.

3.1.2 Dipotassium salt of endothall

No impacts are expected to eaton's beggarticks (*Bidens eatonii)*. *Bidens beckii* populations were not reduced following submersed applications of endothall plus triclopyr in Minnesota (Skogerboe & Netherland 2008). Additionally, repeated treatments of another fast-acting herbicide, diquat, did not significantly reduce *Bidens beckii* populations in Washington (Parsons et al. 2019). Response of *Bidens eatonii* has not yet been documented; however, this emergent tidal species has very little risk of subsurface-applied herbicide exposure. Additionally, endothall is not known to cause injury to emergent aquatic plant species when applied subsurface.

There is currently no published herbicide response or toxicology data available for the pale green orchid (*Platanthera flava var. herbiola)*, parker's pipewort (*Eriocaulon parkeri)*, wild senna (*Senna hebecarpa)*, and goldenclub (*Orontium aquaticum)*. A low exposure risk is anticipated for these species, as these species occupy tidal areas. Additionally, preliminary USACE research trials indicate that awl-leaved arrowhead (*Saggitaria subulata)* is tolerant to in-water endothall exposure.

3.1.3 Florpyrauxifen-benzyl

No impacts are expected to awl-leaved arrowhead based on a mesocosm study on the effects of florpyrauxifen-benzyl on native plants, including the bulltongue arrowhead (*Saggitaria lancifolia)*. The species showed limited petiole bending during initial exposure. No significant impacts were observed on the bulltongue arrowhead under concentrations of 24 to 48 µg L^{-1} for 24- and 72-hour concentrations (Beets & Netherland, 2018).

Response to florpyrauxifen-benzyl has not yet been documented for *Bidens eatonii*; however, based on the documented response of another species in the same genus beck's water-marigold (*Bidens beckii*) and *Bidens eatonii*'s growth habit (wetland non-submersed) in tidal areas, we anticipate minimal herbicide exposure and minimal to no herbicide injury. Growth chamber and mesocosm studies indicate that *B. beckii* is quite tolerant to florpyrauxifen-benzyl (Netherland & Richardson 2016). The study estimates EC_{50} for *Bidens beckii* of 11.3 and 6.1 ppb from static exposures of 14 and 28 days, respectively. However, actual potential herbicide exposure times in most Connecticut River sites are less than 24 hours which poses significantly lower injury risk to *B. beckii* species, with a similar minimal exposure time expected for *B. eatonii*.

There is no direct herbicide response data for the pale green orchid (*Platanthera flava var. herbiola)* and wild senna (*Senna hebecarpa)*. The response of species within the same genera to auxin-mimic herbicides has been determined. A study on sicklepod (*Senna obtusifolia)* documented tolerance to synthetic auxin herbicide exposure (Leon et al., 2016). A study on the western prairie fringed orchid (*Platanthera praeclara)*, had a high tolerance to high rates of quinclorac, another synthetic auxin herbicide similar to florpyrauxifen-benzyl (Erickson et al., 2006). Therefore, a low risk of exposure is anticipated for the pale green orchid from the application. Additionally, wild senna and the pale green orchid have a low potential for extended herbicide exposure as it is an emergent wetland plant.

The potential impacts to golden club (*Orontium aquaticum)* and parker's pipewort (*Eriocaulon parkeri)* are not currently known, as there is no published data on these species' herbicide response. A low exposure risk is anticipated for these as it inhabits tidal areas.

3.2 State-Listed Invertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified nine state-listed invertebrates that may be present within Salmon River: riverine clubtail (*Stylurus amnicola*, state threatened), midland clubtail (*Comphus fraternus,* state threatened), tiger spiketail (*Cordulegaster erronea,* state threatened), tidewater mucket (*Leptodea ochracea*, state special concern), eastern pearlshell (*Margaritifera margaritifera,* state special concern), eastern pondmussel (*Ligumia nasuta*, state special concern), little bluet (*Enallagma minusculum,* state special concern), woodland pondsnail (*Stagnicola catascopoium,* state special concern), and cobra clubtail (*Gomphus vastus,* state special concern). No invertebrate surveys were completed during the 2024 environmental studies to confirm the presence of these species within Salmon River.

3.2.1 Diquat

No impacts are expected to the tidewater mucket (*Leptodea ochracea),* eastern pearlshell (*Margaritifera margaritifera),* and eastern pondmussel (*Ligumia nasuta)* from the application of diquat. One study tested the impacts of diquat on the New Zealand freshwater mussel (*Hyridella menziesi*) and concluded that diquat had no significant effects on freshwater mussels and, therefore, was considered to be non-toxic to these organisms when applied at rates needed to kill most aquatic weeds (Clayton & Severne, 2005).

No impacts are expected to the dragonfly species of concern including: the riverine clubtail (*Stylurus amnicola*, state threatened), midland clubtail (*Comphus fraternus,* state threatened), tiger spiketail (*Cordulegaster erronea,* state threatened), little bluet (*Enallagma minusculum,* state special concern), and cobra clubtail (*Gomphus vastus,* state special concern). A study on insects observed that dragonflies and damselflies survived after being exposed to diquat concentrations 40 times higher than the recommended maximum field application rate (Gilderhus, 1967).

No adverse impacts are expected for the woodland pondsnail (*Stagnicola catascopium)*. The acute toxicity of diquat was determined for the Florida applesnail (*Pomacea paludosa)*. Diquat was determined moderately toxic to *P. paludosa*, with a 96-hour EC_{50} of 1.1ppm (Mayer & Ellersieck, 1986). The risk of exposure is lower for Salmon River as 96-hour exposure is not typically attainable under field use conditions. Additionally, this value is greater than the maximum use concentration.

3.2.2 Dipotassium salt of endothall

No impacts are expected to the identified freshwater mussels. A study investigating impacts of dipotassium salt of endothall concentrations ranging from 0.5 to 1000 ppm on juvenile and glochidia fatmucket (*Lampsilis siliquoidea*) concluded that dipotassium salt of endothall was not found to be acutely toxic to fatmucket mussels at the application rates needed for hydrilla treatment. Median lethal concentrations (LC_{50}) were substantially higher (6-34 times higher) than recommended dipotassium salt of endothall application rates for hydrilla treatment (1-5 ppm) (Archambault et al., 2015). Dipotassium salt of endothall has also been tested on dreissenid mussels, specifically zebra and quagga mussels, to evaluate impacts. At the highest concentration applied (5 ppm) maximum mortality of 5% was observed for quagga mussels at 20º C, and 2.5% at 25º C. Zebra mussels had zero mortality to any dipotassium salt of endothall concentration at either temperature regime (Claudi et al., 2013).

The tiger spiketail (*Cordulegaster erronea)*, little bluet (*Enallagma minusculum)*, midland clubtail (*Gomphus fraternus)*, cobra clubtail (*Gomphus vastus)*, woodland pondsnail (*Stagnicola catascopium)*, and riverine clubtail (*Stylurus* amnicola) are also not expected to be negatively impacted by the proposed treatment activity. When used at recommended application rates, dipotassium salt of endothall no significant adverse effects were observed on aquatic insects (e.g. snails, aquatic insects, and crayfish) (DNR, 2012).

3.2.3 Florpyrauxifen-benzyl

No impacts are expected to the identified freshwater mussels. A study observed the toxicity of florpyrauxifen-benzyl applications on juvenile fatmucket (*Lampsilis siliquoidea*) and eastern lampmussel (*Lampsilis radiata*) and determined that this compound was not acutely toxic to juveniles of these species. While potential chronic or sub-lethal effects require further investigation to characterize, this study concluded that the short-term exposure risk of these freshwater mussels to florpyrauxifen-benzyl for aquatic weed control are minimal (Buczek et al., 2020).

The identified dragonfly species are also not expected to be negatively impacted by the proposed treatment activity due to the in-water application methods under consideration. Previous studies have shown florpyrauxifen-benzyl to be essentially nontoxic on an acute basis to bees (Levey, 2022), thus risk of acute impacts to other insect species are also considered to be low. Additionally, this herbicide has been shown to have a relatively low potential for volatility from water due to low vapor pressure (EPA, 2017) and is not expected to have vapor drift impacts to this insect species.

No adverse impacts are expected to the woodland pondsnail (*Stagnicola catascopium)* as Florpyrauxifen-benzyl poses minimal risk to aquatic invertebrates according to the ecotoxicity information required for EPA registration. For the model ecotoxicological species, water flea (*Daphnia magna*), the 48-hour EC_{50} value reported is 49 mg/L [parts per million (ppm)] which is over 1,000-fold greater than the product’s maximum use rate of 48 µg/L [parts per billion (ppb)] (SePRO, 2017).

3.3 State-Listed Vertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified nine state-listed vertebrates that may be present within Salmon River: mudpuppy (*Necturus maculosus,* state special concern), wood turtle (*Glyptemys insculpta,* state special concern), bald eagle (*Haliaeetus leucocephalus,* state threatened), shortnose sturgeon (*Acipenser brevirostrum*, state and federally endangered), Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*, state and federally endangered), blueback herring (*Alosa aestivalis*, state special concern), and bridle shiner (*Notropis bifrenatus,* state special concern).

The preliminary assessment also included two reptile species, the eastern box turtle (*Terrapene carolina carolina)* and the eastern hognose snake (*Heterodon platirhinos)*. These species are not likely to occur within intertidal zones or other aquatic habitat, therefore the species were not discussed further.

3.3.1 Diquat

No impacts are expected to the wood turtle (*Glyptemys insculpta)* with the risk of toxic impacts of endothall treatment considered to be minimal. One study on diquat and endothall toxicity to the eastern spiny softshell turtle (*Apalone spinifera spinifera*) monitored these aquatic turtles over time over a range of in-water herbicide concentrations. This study did not observe any toxic effects to any of the turtles and none of the turtles used in the experiment died during either the exposure or post-exposure monitoring portions of the test. This study concluded that softshell turtles were not sensitive to endothall (Paul & Simonin, 2007).

No adverse effects are anticipated to the fish species of concern. The proposed application rates are within the concentration limits specified on the EPA-approved herbicide label. Studies have found that diquat has relatively low toxicity to fish and does not appear to significantly bioaccumulate in fish tissue (BLM, 2005). The results of acute exposure studies on freshwater fish have been summarized as “slightly toxic to practically non-toxic for diquat dibromide” (Hartless & Lin, 2010).

No direct ecotoxicity data is available for the mudpuppy (*Necturus maculosus)*. No impacts are anticipated to this species based on the described toxicity data for surrogate fish ecotoxicity data.

No impacts are expected to the bald eagle (*Haliaeetus leucocephalus).* Herbicides will be applied using subsurface injection methods, no airborne exposure risks to nearby birds at the time of application are anticipated. While diquat dibromide has been found to be moderately toxic to birds in acute oral exposure studies (EPA, 1995; BLM, 2005; Emmett, 2002), many of these studies were conducted at much higher concentrations than the proposed treatment. Additionally, risks to bald eagles were found to be low given that bioaccumulation in fish species is also low (BLM, 2005).

3.3.2 Dipotassium salt of endothall

No impacts are expected to the wood turtle (*Glyptemys insculpta)* from the application of dipotassium salt of endothall. No toxic effects were observed to the eastern spiny softshell turtle (*Apalone spinifera spinifera)* from the applications of diquat and endothall as described in Section 3.3.1.

No direct herbicide exposure data is available for the mudpuppy (*Necturus maculosus)*. Although no significant impacts are anticipated for this species or fish species of concern. Fish data provides surrogate data for amphibian species in ecotoxicology studies. The effective concentration (EC_{50}) of various freshwater species to endothall was determined: bluegill sunfish (*Lepomis macrochirus*) at 1,071 ppm, rainbow trout (*Oncorhynchus mykiss)* at 363 ppm, and the sheepshead minnow (*Cyprinodon variegatus)* at 340 ppm (96-hour EC_{50}). The EC_{50} of these species are significantly greater than the proposed application rate of 5 ppm (UPL, 2019). Therefore, no impacts are expected to the mudpuppy or fish species.

No adverse effects are anticipated to the bald eagle (*Haliaeetus leucocephalus)*, as no airborne exposure risks are anticipated to these species as subsurface injection methods will be utilized. Additionally, the proposed application rates are within the concentration limits specified on the EPA-approved herbicide label. The median lethal concentration (LC_{50}) of dipotassium salt of endothall is 325 mg/kg for the mallard duck (*Anas platyrhynchos*) (UPL, 2019). The proposed application rate of 5 ppm is significantly below this LC_{50}.

3.3.3 Florpyrauxifen-benzyl

No direct herbicide response data is available for the application of florpyrauxifen-benzyl on the mudpuppy (*Necturus maculosus*) and the wood turtle (*Glyptemys insculpta)*. As mentioned previously, fish toxicity data can provide information on amphibian response. No impacts are expected to the mudpuppy as the maximum use rate is significantly greater than the EC_{50} for fish species. For reptiles, bird species serve as surrogates for toxicological studies. Florpyrauxifen-benzyl is practically non-toxic to birds on an acute basis. The oral median lethal dose (LD_{50}) of florpyrauxifen-benzyl to the bobwhite quail (*Colinus virginianus)* is 2,500 mg/kg (SePRO, 2017).

As discussed previously, the median effective concentration (EC_{50}) is significantly greater than the maximum use rate for fish species. Therefore, no adverse impacts are anticipated to fish species. Further, results of bioaccumulation studies in fish suggested rapid and extensive metabolism of florpyrauxifen-benzyl, indicating that bioaccumulation potential for this herbicide is low (EPA, 2017). Chronic toxicity in these species are also not considered to be a concern as the proposed treatment activity only includes one herbicide application, and florpyrauxifen-benzyl has been shown to rapidly degrade through aerobic aquatic metabolism and aqueous photolysis once applied (EPA, 2017).

No impacts are expected to the bald eagle (*Haliaeetus leucocephalus)*. The risk of acute impacts to birds is considered to be low. Florpyrauxifen-benzyl has been shown to be non-toxic to multiple bird species with a reported LD_{50} >2,500 mg/kg bodyweight for Bobwhite quail (*Colinus virginianus*) (Levey, 2022; EPA, 2017; SePro, 2017). Additionally, because herbicides will be applied using subsurface injection methods, no airborne exposure risks to nearby bald eagles at the time of application are anticipated.

4. Conservation Strategy for Endangered, Threatened and Special Concern Species

4.1 Herbicide Application Methods and Timing

Strategic herbicide application methods and timing will be employed throughout this demonstration project to minimize the potential risk of impacts to non-target and state-listed species of concern. Herbicides will be applied by licensed applicators at allowable concentrations in accordance with the product's EPA-approved label. Herbicides will be applied directly to the water and evenly distributed across the entire treatment area using boat-based, subsurface injection application methods to minimize airborne exposure risks to non-target species.

4.2 Considerations to Plant Species of Concern

Monitoring will occur if the identified plant species of concern are present. If a net loss in plant species is observed within two years of monitoring and is determined to be from herbicide application, replanting will occur to minimize potential impacts of individuals lost.

4.3 Considerations for Vertebrates

Blueback herring is known to spawn over aquatic vegetation within the proposed treatment area between April 1 and June 30. To minimize potential impacts to these spawning events, the timing of treatment application will be delayed until after July 4, 2024.

5. Literature Cited

Archambault, J.M., Bergeron, C.M., Cope, G.W., Richardson, R.J., Heilman, M.A., Corey III, E.J., Netherland, M.D., & Heise, R.J. 2015. Sensitivity of freshwater molluscs to hydrilla-targeting herbicides: providing context for invasive aquatic weed control in diverse ecosystems. Journal of Freshwater Ecology. Vol. 30(3): 335-348.

Beets, J., Heilman, M., & Netherland, M.D. 2019. Large-Scale Mesocosm Evaluation of Florpyrauxifen-Benzyl, a Novel Arylpicolinate Herbicide, on Eurasian and Hybrid Watermilfoil and Seven Native Submersed Plants." Journal of Aquatic Plant Management. Vol. 57: 49-55

Beets, J., & Netherland, M.D. 2018. Mesocosm response of crested floating heart, hydrilla, and two native emergent plants to florpyrauxifen-benzyl: A new arylpicolinate herbicide. Journal of Aquatic Plant Management. Vol. 56: 57-62

Buczek, S.B., Archambault, J.M., Cope, W.G., & Heilman, M.A. 2020. Evaluation of Juvenile Freshwater Mussel Sensitivity to Multiple Forms of Florpyrauxifen-Benzyl. Bulletin of Environmental Contamination and Toxicology. Volume 105: 588-594 https://doi.org/10.1007/s00128-020-02971-1.

Bugbee, G.J., & Stebbins, S.E. 2022. Invasive Aquatic Vegetation Survey Hydrilla Overwintering and Spread Management Options. Department of Environmental Science and Forestry.

Bureau of Land Management (BLM). 2005. Diquat Ecological Risk Assessment, Final Report. All U.S. Government Documents (Utah Regional Depository).

Claudi, R., Taraborelli, C., & Prescott, T.H. 2013. Efficacy of Endothall for Control of Adult Quagga and Zebra Mussels. Accessed 31 January 2025 from https://invasivemusselcollaborative.net/wp-content/uploads/2018/11/Claudi-et-al.-2013b.pdf.

Clayton, J., & Severne, C. 2005. Review of Diquat Reports of Relevance to Iwi Values in Lake Karapiro. Environment Waikato Technical Report 2006/03. Environment Waikato. https://www.waikatoregion.govt.nz/assets/WRC/WRC-2019/tr06-03.pdf.

Dawson, F.H. 1996. *Crassula helmsii*: attempts at elimination using herbicides. Hydrobiologia 340:241-245

Emmett, K. 2002. "Appendix A: Final Risk Assessment for Diquat Bromide." 02-10–046. Washington State Department of Ecology

Erickson, A.M., Lym, R.G., & Kirby, D. 2006. Effect of herbicides for leafy spurge control on the western prairie fringed orchid. Rangeland Ecology and Management. Vol. 59:462-467

Gilderhus, P.A. 1967. Effects of diquat on bluegills and their food organisms: The Progressive Fish-Culturis. Vol. 29(2): 67-74. https://doi.org/10.1577/1548-8640(1967)29[67:EODOBA]2.0.CO;2

Hartless, C., and Lin, J. 2010. "Risks of Diquat Dibromide Use to the Federally Threatened Delta Smelt."

Leon, R.G., Ferrell, J.A, & Sellers, B.A. 2016. Seed production and control of sicklepod (*Senna obtusifolia*) and pitted morningglory (*Ipomoea lacunosa*) with 2,4-D, dicamba, and glyphosate combinations. Weed Technology. Vol. 30:76-84

Levey, R. 2022. Aquatic Nuisance Control Permit, ProcellaCOR EC Aquatic Toxicity Review. https://dec.vermont.gov/sites/dec/files/wsm/lakes/ANC/docs/ProcellaCor%20Aquatic%20Toxicity%20Review%20_03162022.pdf.

Mayer, F.L, & Ellersieck, M.R. 1986. Manual of acute toxicity: interpretation and data base for 410 chemicals and 66 species of freshwater animals. No. 160. US Department of the Interior, Fish and Wildlife Service

Menninger, H. 2012. Endothall FAQ. Cornell Cooperative Extension. 2012. http://ccetompkins.org/environment/aquatic-invasives/hydrilla/managementoptions/herbicides/endothall/endothall-faq.

Mudge, C.R., Sartain, B.T., Getsinger, K.D., & Netherland, M.D. 2021. Efficacy of Florpyrauxifen-Benzyl on Dioecious Hydrilla and Hybrid Water Milfoil - Concentration and Exposure Time Requirements. U.S. Engineer Research and Development Center. https://doi.org/10.21079/11681/42062.

Netherland, M.D., & Richardson, R.J. 2016. Evaluating Sensitivity of Five Aquatic Plants to a Novel Arylpicolinate Herbicide Utilizing an Organization for Economic Cooperation and Development Protocol. Weed Science. Vol. 64(1): 181–90. https://doi.org/10.1614/WS-D-15-00092.1.

Netherland, M.D., Green, W.R., and Getsinger, K.D. 1991. Endothall Concentration and Exposure Time Relationships for the Control of Eurasian Watermilfoil and Hydrilla. Journal of Aquatic Plant Management. Vol. 29: 61–67.

Parsons, J.K., Baldwin, L., & Lubliner, N. 2019. An operational study of repeated diquat treatments to control submersed flowering rush. Journal of Aquatic Plant Management. Vol. 47: 28-32.

Paul, E.A, & Simonin, H.A. 2007. Toxicity of Diquat and Endothall to Eastern Spiny Softshell Turtles (*Apalone spinifera spinifera)*. Journal of Aquatic Plant Management. Vol. 45: 52-44

Richardson, R., Haug, E.J., and Netherland, M.D. 2016. Response of Seven Aquatic Plants to a New Arylpicolinate Herbicide. Journal of Aquatic Plant Management. Vol. 54: 26–31.

SePRO Corporation (SePRO). 2017. Safety Data Sheet for ProcellaCOR EC Version 1.0. EPA Registration No. 67690-80.

Skogerboe, J.G., & Netherland, M.D. 2008. Draft report following April 2008 aquatic herbicide treatments of three bays on Lake Minnetonka. October. Report to the Minnesota Department of Natural Resources. https://lmcd.org/wp-content/uploads/2021/04/20081008-Lake-Minnetonka-Preliminary-Report-II-Skogerboe1.pdf

Sperry, B.P, Leary, J.K., Dean Jones, K, & Ferrell, J.A. 2021. Observations of a Submersed Field Application of Florpyrauxifen-Benzyl Suppressing Hydrilla in a Small Lake in Central Florida. Journal of Aquatic Plant Management. Vol. 59: 20-26.

Tippery, N.P., Bugbee, G.J., & Stebbins, S.E. 2020. Evidence for a Genetically Distinct Strain of Introduced Hydrilla Verticillata (Hydrocharitaceae) in North America. Journal of Aquatic Plant Management. Vol. 58:1-6.

UPL Limited (UPL). 2019. Safety Data Sheet for AQUATHOL® K Aquatic Herbicide.

U.S. Environmental Protection Agency (EPA). 2017. The 2017 EPA Environmental Fate and Ecological Risk Assessment for Florpyrauxifen-Benzyl.

U.S. Environmental Protection Agency (EPA). 1995. Diquat Dibromide. https://archive.epa.gov/pesticides/reregistration/web/pdf/0288fact.pdf.

Wisconsin Department of Natural Resources (DNR). 2022. Florpyrauxifen-Benzyl Fact Sheet. https://apps.dnr.wi.gov/swims/Documents/DownloadDocument?id=332109305

Wisconsin Department of Natural Resources (DNR). 2012. Diquat Chemical Fact Sheet. https://www.noaa.gov/sites/default/files/legacy/document/2020/Oct/07354626838.pdf

Connecticut River
Hydrilla Control Research and Demonstration Project
Lower Connecticut River, CT

Species Protection Plan
Selden Creek
Lyme, CT

US Army Corps
of Engineers ®
New England District

February 2025

Selden Creek Species Protection Plan

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1. Introduction

1.1 Connecticut River Hydrilla Information

Hydrilla (*Hydrilla verticillata*) was first identified in the Connecticut River near Glastonbury, CT in 2016 and has since spread south to Essex, CT infesting the river's many coves, tributaries, and boat basins. The Connecticut River hydrilla population has been shown to be genetically distinct from other known hydrilla strains (Tippery, et al., 2020), and the plant's biology is therefore largely unknown at this time. Following the discovery of the highly invasive aquatic plant in the Connecticut River in 2016, intensive vegetation surveys were conducted in 2019 and 2020 from Agawam, MA south to Long Island Sound to map the invasion extent. Hydrilla was found as far north as Agawam, MA, confirming that the plant spreads rapidly which poses significant risk to other regional waterbodies (Bugbee & Stebbins, 2022). Fragments of the plant, which are easily transported by boats and boat trailers, can sprout roots to establish new populations. Fragments also float and are capable of dispersing via wind and water currents. Due to the importance of the Connecticut River as an environmental resource and driver of the local economy, stakeholders are seeking an aggressive hydrilla management program.

1.2 Project Background

The U.S. Army Corps of Engineers (USACE), through its Engineer Research and Development Center's (ERDC) Aquatic Plant Control Research Program, is leading a research and demonstration project to verify the effectiveness of aquatic herbicides registered for use by the U.S. Environmental Protection Agency (EPA) to reduce and control the spread of the Connecticut River hydrilla safely and selectively. The project has been investigating hydrilla's growth patterns, site-specific water exchange dynamics and evaluating herbicide efficacy in laboratory conditions throughout 2023 to guide operational scale field demonstrations of herbicide efficacy in 2024. Selden Creek has been selected as a hydrilla treatment site for ERDC's 2025 field demonstration project.

1.3 Selden Creek Treatment Site

Selden Creek is a tidal creek off the mainstem of the Connecticut River located in Lyme, New London County, CT and centered at 41.400° N, 72.406° W. The treatment area is 48.08 acres with an estimated mean depth of 12 feet mean higher high water.

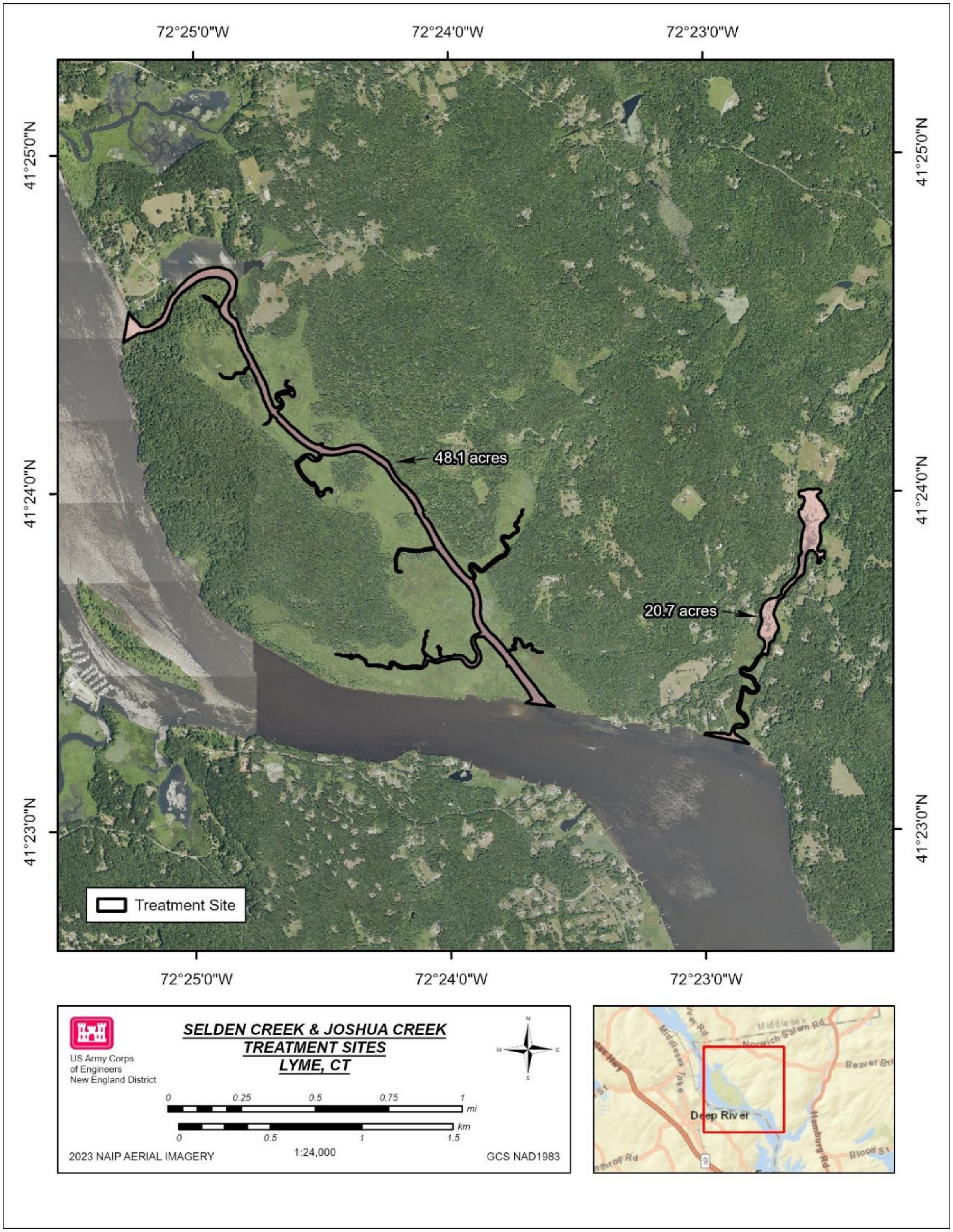

Figure 1. Selden Creek (left) and Joshua Creek hydrilla treatment areas in Lyme, CT.

2. Proposed Treatment Activity

Diquat, dipotassium salt of endothall, florpyrauxifen-benzyl, or combinations thereof are proposed to be applied in Selden Creek for hydrilla control. The selected herbicide(s) will be applied at the maximum concentration rate, as described in the following sections. The herbicide(s) will be evenly distributed across the entire treatment area delineated in Figure 1 using boat-based, subsurface injection application methods. This section describes the proposed herbicides.

2.1 Diquat

Diquat dibromide is a state and federally registered herbicide approved for application in aquatic sites for invasive aquatic plant control. The herbicide is proposed to be applied at a concentration of 370 ppb. A Registration Standard for diquat dibromide was issued by the EPA in June 1986 (EPA, 1995). The active ingredient ((6,7-dihydrodipyrido (1,2a:2',1'-c) pyrazinediium dibromide)) is a fast-acting herbicide that interferes with photosynthesis, disrupts plant cell membranes, and results in plant death within a week of application in sensitive plant species (DNR, 2012).

2.2 Dipotassium salt of endothall

Dipotassium salt of endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid) is a state and federally registered aquatic herbicide and is approved for application in aquatic sites for the treatment of invasive aquatic plant species. The dipotassium salt of endothall was registered by EPA for aquatic use in 1960 at application rates between 0.5 and 5.0 ppm for aquatic plant control (Menninger, 2012). The herbicide is proposed to be applied at a concentration of 5 ppm. Dipotassium salt of endothall is a selective fast-acting herbicide that interferes with plant protein and lipid biosynthesis, disrupting respiration and plant membranes. This herbicide is highly effective for hydrilla control (Netherland et al.,1991).

2.3 Florpyrauxifen-benzyl

Florpyrauxifen-benzyl is a state and federally registered herbicide, and that is approved for invasive plant treatment in aquatic environments. The herbicide is proposed to be applied at a concentration of 48 ppb. This relatively new systemic herbicide mimics the plant growth hormone, auxin, killing susceptible plants by disrupting the plant cell growth process.

The active ingredient (4-amino-3chloro-6-(4-chloro-2-fluoro-3-methoxyphenyl) 5-fluoropyridine-2-benzyl ester) causes excessive plant cell elongation, ultimately resulting in plant cell death in sensitive plant species. Florpyrauxifen-benzyl is absorbed from the water through submersed plant shoots and leaves, and this herbicide has previously been demonstrated to be highly effective at selectively suppressing both dioecious and monoecious invasive hydrilla (Sperry et al., 2021; Mudge et al., 2021; Beets et al., 2019; Netherland & Richardson, 2016; Richardson et al., 2016) with

relatively short exposure times and lower application rates compared to other herbicides (DNR, 2022).

3. Potential Impacts from the Proposed Treatment Activity

3.1 State-Listed Native Plant Species

Preliminary assessments of the Natural Diversity Database maps and files identified eight state-listed vascular plants that may potentially occur within the delineated Selden Creek treatment area: Parker's pipewort (*Eriocaulon parkeri,* state endangered species), Torrey bulrush (*Schoenoplectus torreyi*, state threatened species), awl-leaved arrowhead (*Sagittaria subulata,* state special concern species), golden club (*Orontium aquaticum,* state special concern), tufted hairgrass (*Deschampsia cespitosa,* state special concern), american reed (*Phragmites americanus*, state special concern), and beck's water-marigold (*Bidens beckii*, state special concern), and small yellow pondlily (*Nuphar microphylla,* state special concern*)*. No Submerged and emergent plant surveys were performed in Selden Creek.

Additionally, the cattail sedge (*Carex typhina)*, Virginia snakeroot (*Endodeca serpentaria*), eastern prickly pair (*Opuntia humifusa)*, swamp lousewort (*Pedicularis lanceolata*), hispid hedge-nettle (*Stachys hispida*), and bristly buttercup (*Ranunculus pensylvanicus*) were identified during the preliminary assessment. The potential impacts to these species were not considered below as they are not likely to occur below the intertidal zone or aquatic areas. No impacts are anticipated to these species from the proposed treatment activity.

3.1.1 Diquat

No significant impacts are expected to beck's water marigold (*Bidens beckii)* or small yellow pond-lily (*Nuphar microphylla)* from the application of diquat. A study on operational application of diquat observed the effects on non-target native plants. Diquat was applied to a 4-hectare treatment area within a lake, at the maximum concentration rate for a five-year period. No significant changes to beck's water marigold were observed during the study (Parsons et al., 2019). Another study on the application of diquat observed no adverse effects to the fragrant water lily (*Nymphaea odorata)*. The study applied diquat to an egeria-infested lake below the maximum concentration of 370 ppb (Parsons et al., 2007).

There is currently no published herbicide response data for parker's pipewort (*Eriocaulon parkeri*), torrey bulrush (*Schoenoplectus torreyi*), awl-leaved arrowhead (*Sagittara subulate)*, and golden club (*Orontium aquaticum)*. A low exposure risk is expected as these species inhabit tidal areas. Preliminary USACE research trials, including Selden Creek and Cove sites, indicate *Saggitaria subulate* is tolerant to in-water diquat exposure.

No impacts are expected to the tufted hairgrass (*Deschampsia cespitosa*) or the american reed (*Phragmites americanus*). Members of the Poaceae family are generally tolerant to subsurface diquat exposures. During the 2024 treatment of Chester Boat Basin, no impacts were observed to wild rice (*Zizania spp.),* therefore no impacts are anticipated to these species.

3.1.2 Dipotassium salt of endothall

No significant impacts are expected to beck's water-marigold (*Bidens beckii)*, tufted hairgrass (*Deschampsia cespitosa)*, and american reed (*Phragmites americanus)* from the application of endothall. A study observed the effects of submersed applications of endothall and triclopyr to Lake Minnetonka in Minnesota. Populations of beck's water-marigold were not reduced following submersed applications of endothall plus triclopyr (Skogerboe & Netherland, 2008). Additionally, these species are emergent plant species. Endothall is not known to cause injury to emergent grass or aquatic plant species when applied using subsurface methods. There is no published response data for parker's pipewort (*Eriocaulon parkeri)* and golden club (*Orontium aquaticum)*. A low risk of exposure is anticipated for these species as they inhabit tidal areas.

No significant impacts are expected to the small yellow pond-lily (*Nuphar microphylla)*, torrey bulrush (*Schoenoplectus torreyi*), or awl-leaved arrowhead (*Saggitaria subulate)*. The species selectivity of dipotassium salt of endothall was evaluated on various emergent plants, including the soft-stem bulrush (*Scirpus validus*), spatterdock (*Nuphar luteum*), and arrowhead (*Saggitaria latifolia)*. A mesocosm study evaluated the response of emergent and floating-leaf species with treatment rates of 0, 1, 2, and 5 mg/L endothall and a static water-flow exposure period of 120 hours. Plant biomass samples were measured pretreatment, and at 3 and 6 weeks after treatment to measure plant response. No effects to the soft-stem bulrush were observed following herbicide exposure. Biomass reduction was observed in the arrowhead and spatterdock species at an application rate of 2 mg/L (Skogerboe & Getsinger, 2001). A lower risk of exposure is assumed for Selden Creek, as a 120-hour exposure time is not typically attainable under field use conditions. Therefore, no significant impacts are expected to these species.

3.1.3 Florpyrauxifen-benzyl

No impacts are expected to awl-leaved arrowhead based on a mesocosm study on the effects of florpyrauxifen-benzyl on native plants, including the bulltongue arrowhead (*Saggitaria lancifolia)*. The species showed limited petiole bending during initial exposure. No significant impacts were observed on the bulltongue arrowhead under concentrations of 24 to 48 $\mu g\ L^{-1}$ for 24- and 72-hour concentrations (Beets & Netherland, 2018).

Temporary, short-term impacts may occur to yellow pond-lily (*Nuphar advena)* and small yellow pond-lily (*Nuphar microphylla),* although no long-term impacts are expected. A study on the application of florpyrauxifen-benzyl for hydrilla treatment in a Florida lake monitored the impacts to non-target species including American eelgrass *(Valisineria americana*), yellow pond-lily (*Nuphar advena)*, American lotus (*Nelumbo lutea*), and fragrant water-lily (*Nymphaea odorata*)**.** No impacts to American eelgrass were observed during the study. Impacts to yellow pond-lily, American lotus, and fragrant water-lily were typical of auxin-mimic herbicides with symptoms of stem epinasty and leaf-curling. The study monitored aquatic plants for 289 days after treatment. New growth of yellow pond-lily at the end of the 289-day monitoring period indicated recovery from the herbicide exposure (Sperry et al., 2021).

No significant impacts are expected to beck's water-marigold from the application of florpyrauxifen-benzyl. Growth chamber and mesocosm studies indicate that this species is quite tolerant to florpyrauxifen-benzyl. An estimated half maximal effective concentration (EC_{50}) was determined for *Bidens beckii* of 11.3 and 6.1 ppb from static exposures of 14 and 28 days, respectively (Netherland & Richardson, 2016). However, actual potential herbicide exposure times in most Connecticut River sites are less than 24 hours which poses significantly lower injury risk to this species compared to multi-week herbicide exposures in the reported experiments.

The response to florpyrauxifen-benzyl to the following state-listed plant species is not currently known: parker's pipewort (*Eriocaulon parkeri),* torrey bulrush (*Schoenoplectus torreyi*), golden club (*Orontium aquaticum)*, tufted hairgrass (*Deschampsia cepitosa)*, and american reed (*Phragmites americanus)*. These species are considered emergent plant species. Subsurface injection methods will be utilized to minimize potential impacts to emergent species, therefore a low risk is anticipated. The Poaceae species (*D. cepitosa* and *P. americanus*) are not expected to be responsive to florpyrauxifen-benzyl. Auxin-mimic herbicides, including florpyrauxifen-benzyl, generally lack activity on the Poaceae family. Additionally, subsurface applications of florpyrauxifen-benzyl is frequently used to selectively control invasive plants across the U.S. in stands of rush species. Therefore, no significant impacts are anticipated to the bulrush species of concern (*S. torreyi*).

3.2 State-Listed Invertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified two state-listed invertebrates, both of which are freshwater mussels that may be present within Selden Creek: tidewater mucket (*Leptodea ochracea*, state special concern) and eastern pondmussel (*Ligumia nasuta*, state special concern). Mussel surveys were not completed during the 2024 environmental studies to confirm the presence of these species within Selden Creek.

3.2.1 Diquat

No impacts are expected to the freshwater mussels from the application of diquat. One study tested the impacts of diquat on the New Zealand freshwater mussel (*Hyridella menziesi*) and concluded that diquat had no significant effects on freshwater mussels and, therefore, was considered to be non-toxic to these organisms when applied at rates needed to kill most aquatic weeds (Clayton & Severne, 2005).

3.2.2 Dipotassium of endothall

No impacts are expected to the freshwater mussels identified to potentially occur within Selden Creek. A study investigating impacts of dipotassium salt of endothall concentrations ranging from 0.5 to 1000 ppm on juvenile and glochidia fatmucket (*Lampsilis siliquoidea*) concluded that dipotassium salt of endothall was not found to be acutely toxic to fatmucket mussels at the proposed treatment rate. Median lethal concentrations for glochidia and juvenile mussels were substantially higher (6-34 times higher) than recommended dipotassium salt of endothall application rates for hydrilla treatment (1-5 ppm) (Archambault et al., 2015). The herbicide has also been tested on dreissenid mussels, specifically zebra and quagga mussels. At the highest concentration applied (5 ppm) maximum mortality of 5% was observed for quagga mussels at 20º C, and 2.5% at 25º C. Zebra mussels had zero mortality to any dipotassium salt of endothall concentration at either temperature regime (Claudi et al., 2013).

3.2.3 Florpyrauxifen-benzyl

Florpyrauxifen-benzyl poses minimal risk to aquatic invertebrates according to ecotoxicological information required for registration by the EPA (SePRO, 2017). No impacts are expected to the tidewater mucket (*Leptodea ochracea)* and eastern pondmussel (*Ligumia nasuta)*. A study examined the impacts of florpyrauxifen-benzyl applications on juvenile fatmucket (*Lampsilis siliquoidea*) and eastern lampmussel (*Lampsilis radiata*). The compound was not acutely toxic to juveniles of these species. While potential chronic or sub-lethal effects require further investigation to characterize, this study concluded that the short-term exposure risk of these freshwater mussels to florpyrauxifen-benzyl for the purposes of aquatic weed control are minimal (Buczek et al., 2020).

3.3 State-Listed Vertebrate Animals

Preliminary assessments of the Natural Diversity Database maps and files identified five state-listed vertebrates that may be present within Selden Creek: mudpuppy (*Necturus maculosus,* state special concern), spotted turtle (*Clemmys guttata,* state special concern), wood turtle (*Glyptemys insculpta,* state special concern), least bittern (*Ixobrychus exilis,* state threatened), and red bat (*Lasiurus borealis,* state special concern species). No vertebrate surveys were completed during the 2024 environmental studies to confirm the presence of these species.

Additionally, the eastern box turtle (*Terrapene carolina carolina,* state special concern) and smooth green snake (*Opheodrys vernalis,* state special concern) were identified during the preliminary concern. These species are not likely to inhabit the proposed treatment area, as they do not inhabit aquatic or intertidal zones.

3.3.1 Diquat

No adverse effects are anticipated for the mudpuppy (*Necturus maculosus)* based on surrogate toxicology data for fish species. Studies have found that diquat has relatively low toxicity to fish and does not appear to significantly bioaccumulate in fish tissue (BLM, 2005). The results of acute exposure studies on freshwater fish have been summarized as "slightly toxic to practically non-toxic for diquat dibromide" (Hartless & Lin, 2010). Therefore, no adverse effects are expected to the mudpuppy (*Necturus maculosus)* based on the described fish toxicology impacts of diquat.

No impacts are expected to the spotted turtle (*Clemmys guttata)* and the wood turtle (*Glyptemys insculpta)*, with the risk of toxic impacts of diquat treatment considered to be minimal. One study on diquat and endothall toxicity to the eastern spiny softshell turtle (*Apalone spinifera spinifera*) monitored these aquatic turtles over time as they were exposed to a range of in-water herbicide concentrations. This study did not observe any toxic effects to any of the turtles and none of the turtles used in the experiment died during either the exposure or postexposure monitoring portions of the test. This study concluded that softshell turtles were not sensitive to diquat (Paul & Simonin, 2007).

No impacts are expected due to the least bittern (*Ixobrychus exilis)*. Herbicides will be applied using subsurface injection methods, no airborne exposure risks to nearby birds at the time of application are anticipated. While diquat dibromide has been found to be moderately toxic to birds in acute oral exposure studies (EPA, 1995; BLM, 2005; Emmett, 2002), many of these studies were conducted at much higher concentrations than the proposed treatment. Additionally, the red bat (*Lasiurus borealis)* is also anticipated to have no airborne exposure risks as it is a non-aquatic species.

3.3.2 Dipotassium salt of endothall

No adverse effects are anticipated to the mudpuppy (*Necturus maculosus)* based on ecotoxicity data for fish species. The median effective concentration (EC_{50}) was determined for various freshwater species to evaluate ecotoxicity: bluegill sunfish (*Lepomis macrochirus*) at 1,071 ppm, rainbow trout (*Oncorhynchus mykiss)* at 363 ppm, and the sheepshead minnow (*Cyprinodon variegatus)* at 340 ppm (96-hour EC_{50}). The EC_{50} of these species are significantly greater than the proposed application rate of 5 ppm (UPL, 2019). Ecotoxicology response of fish provides surrogate information for amphibian species. Therefore, no adverse impacts to the mudpuppy (*Necturus maculosus)* are anticipated.

No impacts are expected to the spotted turtle (*Clemmys guttata)* and the wood turtle (*Glyptemys insculpta)*, with the risk of toxic impacts of endothall treatment considered to be minimal. As described in Section 3.3.1, a study observed endothall toxicity to the eastern spiny softshell turtle (*Apalone spinifera spinifera*) over time with a range of in-water herbicide concentrations. This study did not observe any toxic effects to any of the turtles and none of the turtles used in the experiment died during either the exposure or postexposure monitoring portions of the test. This study concluded that softshell turtles were not sensitive to endothall (Paul & Simonin, 2007).

No adverse effects are anticipated to the least bittern (*Ixobrychus exilis*). Ecotoxicity data was determined for the mallard *(Anas platyrhynchos),* with a median lethal concentration (LC_{50}) of 325 mg/kg (UPL, 2019). The proposed application rate of 5 ppm is significantly below this rate.

No impacts are expected to the red bat (*Lasiurus borealis)* from the application of dipotassium of endothall. Herbicides will be applied using subsurface injection methods; therefore, no airborne exposure risks are anticipated to this species.

3.3.3 Florpyrauxifen-benzyl

No impacts are expected to the mudpuppy (*Necturus maculosus)* as no impacts are anticipated to fish species, which provide surrogate toxicity data to amphibians. Florpyrauxifen-benzyl is considered to be practically nontoxic to freshwater fish. Studies of its impacts on fish and aquatic organisms largely did not observe toxicity even when applied up to its functional limit of solubility (Levey, 2022; EPA, 2017). Fish toxicity has not been previously reported in field or laboratory evaluations of florpyrauxifen-benzyl at the proposed application rate (48 ppb). Additionally, Chronic toxicity is not likely as florpyrauxifen-benzyl has been shown to rapidly degrade through aerobic aquatic metabolism and aqueous photolysis once applied (EPA, 2017).

Likewise, no direct toxicology data is available for turtle species therefore bird toxicity response data is considered surrogate data. No impacts are expected to potential turtle species as well as the least bittern (*Ixobrychus exilis*). Florpyrauxifen-benzyl is considered practically non-toxic to birds on an acute basis. The oral median lethal dose (LD_{50}) was determined for the bobwhite quail (*Colinus virginianus*) at 2,500 mg/kg (SePRO, 2017). Therefore, no adverse impacts are expected to the spotted turtle (*Clemmys guttata)* or the wood turtle (*Glyptemys insculpta)*.

No impacts are anticipated to the red bat (*Lasiurus borealis)*. Herbicides will be applied using subsurface injection methods to minimize airborne exposure risks to this species. Additionally, the median lethal dose (LD_{50}) was determined for mammalians using rats. Both oral and dermal exposures were significantly greater than the approved concentration rate and were >5,000 mg/kg (SePRO, 2017).

4. Conservation Strategy for Endangered, Threatened and Special Concern Species

4.1 Herbicide Application Methods and Timing

Strategic herbicide application methods and timing will be employed throughout this demonstration project to minimize the potential risk of impacts to non-target and state-listed species of concern. The selected herbicide(s) will be applied in accordance with the product's EPA-approved label.

4.2 Considerations for Plant Species of Concern

Monitoring will occur if the identified plant species of concern are present. If a net loss in plant species is observed within two years of monitoring and is determined to be from herbicide application, replanting will occur to minimize potential impacts of individuals lost.

5. Literature Cited

Archambault, J.M., Bergeron, C.M., Cope, G.W., Richardson, R.J., Heilman, M.A., Corey III, E.J., Netherland, M.D., & Heise, R.J. 2015. Sensitivity of freshwater molluscs to hydrilla-targeting herbicides: providing context for invasive aquatic weed control in diverse ecosystems. Journal of Freshwater Ecology. Vol. 30(3): 335-348.

Beets, J., Heilman, M., & Netherland, M.D. 2019. Large-Scale Mesocosm Evaluation of Florpyrauxifen-Benzyl, a Novel Arylpicolinate Herbicide, on Eurasian and Hybrid Watermilfoil and Seven Native Submersed Plants." Journal of Aquatic Plant Management. Vol. 57: 49-55

Beets, J., & Netherland, M.D. 2018. Mesocosm response of crested floating heart, hydrilla, and two native emergent plants to florpyrauxifen-benzyl: A new arylpicolinate herbicide. Journal of Aquatic Plant Management. Vol. 56: 57-62

Buczek, S.B., Archambault, J.M., Cope, W.G., & Heilman, M.A. 2020. Evaluation of Juvenile Freshwater Mussel Sensitivity to Multiple Forms of Florpyrauxifen-Benzyl. Bulletin of Environmental Contamination and Toxicology. Volume 105: 588-594 https://doi.org/10.1007/s00128-020-02971-1.

Bugbee, G.J., & Stebbins, S.E. 2022. Invasive Aquatic Vegetation Survey Hydrilla Overwintering and Spread Management Options. Department of Environmental Science and Forestry.

Bureau of Land Management (BLM). 2005. Diquat Ecological Risk Assessment, Final Report. All U.S. Government Documents (Utah Regional Depository).

Claudi, R., Taraborelli, C., & Prescott, T.H. 2013. Efficacy of Endothall for Control of Adult Quagga and Zebra Mussels. Accessed 31 January 2025 from https://invasivemusselcollaborative.net/wp-content/uploads/2018/11/Claudi-et-al.-2013b.pdf.

Clayton, J., & Severne, C. 2005. Review of Diquat Reports of Relevance to Iwi Values in Lake Karapiro. Environment Waikato Technical Report 2006/03. Environment Waikato. https://www.waikatoregion.govt.nz/assets/WRC/WRC-2019/tr06-03.pdf.

Hartless, C., and Lin, J. 2010. "Risks of Diquat Dibromide Use to the Federally Threatened Delta Smelt."

Levey, R. 2022. Aquatic Nuisance Control Permit, ProcellaCOR EC Aquatic Toxicity Review. https://dec.vermont.gov/sites/dec/files/wsm/lakes/ANC/docs/ProcellaCor%20Aquatic%20Toxicity%20Review%20_03162022.pdf.

Menninger, H. 2012. Endothall FAQ. Cornell Cooperative Extension. 2012. http://ccetompkins.org/environment/aquatic-invasives/hydrilla/managementoptions/herbicides/endothall/endothall-faq.

Mudge, C.R., Sartain, B.T., Getsinger, K.D., & Netherland, M.D. 2021. Efficacy of Florpyrauxifen-Benzyl on Dioecious Hydrilla and Hybrid Water Milfoil - Concentration and Exposure Time Requirements. U.S. Engineer Research and

Development Center. https://doi.org/10.21079/11681/42062.
Netherland, M.D., & Richardson, R.J. 2016. Evaluating Sensitivity of Five Aquatic Plants to a Novel Arylpicolinate Herbicide Utilizing an Organization for Economic Cooperation and Development Protocol. Weed Science. Vol. 64(1): 181–90. https://doi.org/10.1614/WS-D-15-00092.1.
Netherland, M.D., Green, W.R., and Getsinger, K.D. 1991. Endothall Concentration and Exposure Time Relationships for the Control of Eurasian Watermilfoil and Hydrilla. Journal of Aquatic Plant Management. Vol. 29: 61–67.
Parsons, J.K., Baldwin, L., & Lubliner, N. 2019. An operational study of repeated diquat treatments to control submersed flowering rush. Journal of Aquatic Plant Management. Vol. 47: 28-32.
Parsons, J.K., Hamel, K.S., & Wierenga, R. 2007. The Impact of Diquat on Macrophytes and Water Quality in Battle Ground Lake, Washington. Journal of Aquatic Plant Management. Vol. 45: 35-39.
Richardson, R., Haug, E.J., and Netherland, M.D. 2016. Response of Seven Aquatic Plants to a New Arylpicolinate Herbicide. Journal of Aquatic Plant Management. Vol. 54: 26–31.
SePRO Corporation (SePRO). 2017. Safety Data Sheet for ProcellaCOR EC Version 1.0. EPA Registration No. 67690-80.
Skogerboe, J.G., & Getsinger, K.D. 2001. Endothall species selectivity evaluation: Southern latitude aquatic plant community. Journal of Aquatic Plant Management. Vol. 39:129-135
Skogerboe, J.G., & Netherland, M.D. 2008. Draft report following April 2008 aquatic herbicide treatments of three bays on Lake Minnetonka. October. Report to the Minnesota Department of Natural Resources. https://lmcd.org/wp-content/uploads/2021/04/20081008-Lake-Minnetonka-Preliminary-Report-II-Skogerboe1.pdf
Sperry, B.P, Leary, J.K., Dean Jones, K, & Ferrell, J.A. 2021. Observations of a Submersed Field Application of Florpyrauxifen-Benzyl Suppressing Hydrilla in a Small Lake in Central Florida. Journal of Aquatic Plant Management. Vol. 59: 20-26.
Tippery, N.P., Bugbee, G.J., & Stebbins, S.E. 2020. Evidence for a Genetically Distinct Strain of Introduced Hydrilla Verticillata (Hydrocharitaceae) in North America. Journal of Aquatic Plant Management. Vol. 58:1-6.
UPL Limited (UPL). 2019. Safety Data Sheet for AQUATHOL® K Aquatic Herbicide.
U.S. Environmental Protection Agency (EPA). 2017. The 2017 EPA Environmental Fate and Ecological Risk Assessment for Florpyrauxifen-Benzyl.
U.S. Environmental Protection Agency (EPA). 1995. Diquat Dibromide. https://archive.epa.gov/pesticides/reregistration/web/pdf/0288fact.pdf.
Wisconsin Department of Natural Resources (DNR). 2022. Florpyrauxifen-Benzyl Fact Sheet. https://apps.dnr.wi.gov/swims/Documents/DownloadDocument?id=332109305
Wisconsin Department of Natural Resources (DNR). 2012. Diquat Chemical Fact Sheet. https://www.noaa.gov/sites/default/files/legacy/document/2020/Oct/07354626838.pdf