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Estimating Present Value Cost of Invasive Emerald Ash Borer (*Agrilus planipennis*) on USACE Project Lands

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PURPOSE: The US Army Corps of Engineers (USACE) is responsible for stewardship of approximately 12.5 million acres across the United States. USACE's Environmental Stewardship program mission is to protect, preserve, and restore significant ecological resources on USACE project lands. Since the early 2000s, non-native and invasive Emerald Ash Borer (EAB) has killed hundreds of millions of ash trees in the US, becoming the most destructive and costly invasive forest insect in North America. This research effort estimates the cost of managing EAB damage to USACE projects including treatment, removal, or removal and replacement of dying/dead ash trees. The results suggest potential impact to more than 122,800 USACE project acres in currently infested counties including 181,000 ash trees. While not all damaged trees require removal, many USACE recreation sites have ash trees that pose an increased risk to humans and structures thus requiring removal of EAB infected trees. The widespread and pervasive impacts of EAB will have significant costs associated with removal and replacement of ash trees that could be hazardous to recreational users at the projects. Data from the United States Department of Agriculture (USDA), Forest Inventory and Analysis (FIA) database, and methods developed by Kovacs et al. (2010) were utilized to calculate yearly present value costs of EAB to USACE projects from 2006-2026. Overall EAB impacts are estimated at $121.6 million across 201 USACE projects evaluated in this study. Increased efforts to limit EAB spread and perform measures of control are warranted to reduce potential cost to USACE.

BACKGROUND: The Emerald Ash Borer (*Agrilus planipennis* Fairmaire; EAB) is a wood-boring invasive beetle (Coleoptera: Buprestidae) native to Northeast Asia that feeds on ash (*Fraxinus* sp.) trees. EAB was likely introduced into the US in the early 1990s via wooden shipping materials originating from Asia; however, it was not discovered until 2002 in southeastern Michigan following significant mortality of ash trees (Cappaert et al. 2005; Poland and McCullough 2006; McCullough 2020). At present, EAB has been reported in 35 states, killed hundreds of millions of ash trees in the US, and has become the most destructive and costly invasive forest insect in North America (McCullough 2020).

Kovacs et al. (2010) developed a methodology to determine the present value cost of treatment, removal, or removal and replacement of EAB infested ash trees within US communities across a 25-state study area between 2009-2019. The simulations predicted expanding EAB infestations encompassing most of the assessment area with an estimated discounted cost of $10.7 billion, over the 10-yr horizon. In this report, methods described by Kovacs et al. (2010) are employed to apply a present value cost (i.e., value determined at date of valuation) to estimate EAB impacts on USACE managed lands.

METHODS AND DATA ANALYSIS: The methodology used in Kovacs et al. (2010) is the basis for the analysis performed in this report. In their study, 25 states were predicted to have EAB infestation 10 years into the future (i.e., 2019). A decade was chosen for planning a policy-level response to EAB invasion. Kovacs et al. (2010) estimated the discounted cost of ash treatment, removal, and replacement with three primary components: (1) estimate the number of ash trees on developed land, (2) predict the counties that will be infested with EAB over a 10-yr horizon, and (3) predict the number of trees that will be treated or removed and replaced in response to infestation and compute the total discounted cost of these activities.

In this study, the present value cost for removal and replacement of EAB-impacted ash trees on publicly accessible lands managed by USACE were evaluated. Only USACE projects within the known range of EAB (as of 2017; Figure 1) were utilized in the study. Additionally, only projects with identified EAB detection (prior to 2019) were evaluated with a total of 201 USACE projects assessed in the study (see Appendix for list of projects).

Only public-use areas (PUAs) were evaluated for each USACE project assessed. This included all forested areas surrounding and within camping areas, recreation trails, etc., where increased likelihood of management action following EAB-related mortality would be required. Additionally, no estimates of timber/wildlife value were included. Any projects not open to the public were defined as having zero applicable acres and a no-EAB impact assessment was performed. For each applicable USACE project, ash tree abundance was estimated within each PUA utilizing the trees per acre (TPA) estimates for ash reported at county-level by the United States—Department of Agriculture (USDA), Forest Service (FS), and the Forest Inventory and Analysis (FIA) database (FIA 2012).

The years 2006 and 2017 were selected for querying ash tree abundance from the FIA database. The first year of EAB detection at a USACE project is represented by 2006 and 2017 represents the most recent year FIA data was available during the time of the analysis. Additionally, only ash trees with a minimum of 7” diameter at breast height (DBH) were used in the analysis. All ash trees smaller than 7” DBH were assumed to be managed by USACE project personnel and/or staff within normal operations and without additional site management costs.

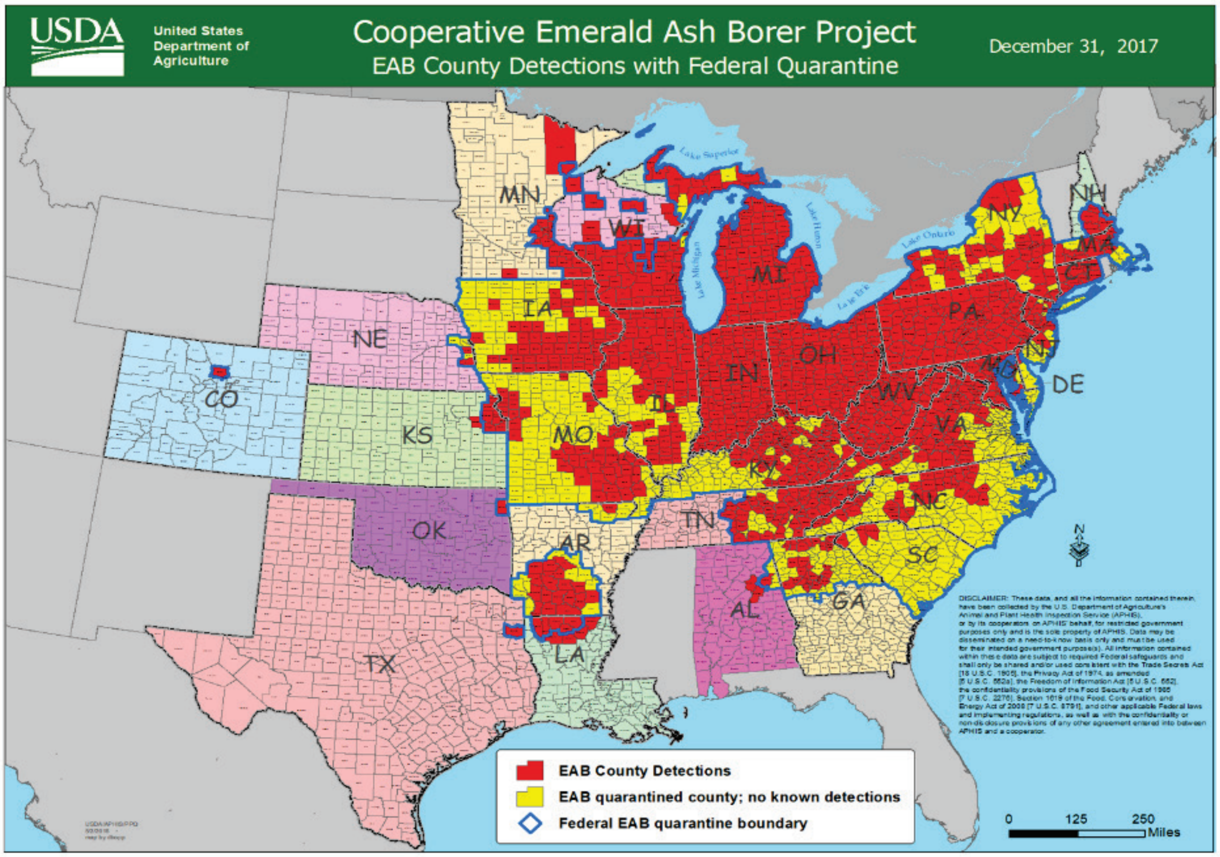

Figure 1. Emerald ash borer county detections as part of the Cooperative Emerald Ash Borer Project, as of December 31, 2017.

The FIA program also provides abundance data by county for standing dead trees (i.e., snags) that was utilized to assess and average ash tree mortality rate. Using TPA for snags in the 27 counties with EAB detection prior to 2009, an annual loss rate of 26% was calculated for ash trees using FIA data. A conservative annual loss rate (i.e., tree mortality) following EAB infestation of 20% per year was utilized; assuming 6% of mortality occurred naturally (i.e., not EAB induced). Therefore, following 20% cumulative mortality per year, complete ash tree mortality for trees >7" DBH would occur after five years following the onset of EAB.

Using the county-level FIA ash density data from 2017, TPA were estimated for all USACE projects within each respective county. South Carolina, Louisiana, and several counties from other states did not report tree inventory data. As a result, the nine USACE projects in these areas were assigned average ash TPA and an average loss rate value calculated by averaging the other 192 projects. Next, PUA acreages were estimated to determine the total number of ash trees at a given project likely to be affected and require management action (Equation 1). Therefore, projects not open to the public would be defined as having zero applicable acres in this evaluation. For projects with zero applicable acres, no EAB impact analyses were performed. The PUA acreage estimate, as well as EAB initial detection timeline, is provided for each USACE project in the Appendix.

$$Ash\ Tree\ Count = TPA * PUA\ acres \quad (1)$$

where:

TPA = trees per acre as determined by FIA data by county for ash ≥7 in. DBH
PUA acres = Public-use area acreage for a specific USACE project

Present Value Factor is the opportunity cost of the money spent treating or removing and replacing ash trees impacted by EAB. Costs estimated to have happened in the past need to reflect their value if they had not been spent. Instead, that money could have been invested and generated a return. Conversely, costs estimated to happen in the future need to reflect the fact that they have not occurred yet. Money earmarked for future activities could be invested now and generate a return up to that point. Equation 2 identifies the Present Value Factor used to determine present value of management cost estimates prior to and after 2019—the present value year.

$$Present\ Value\ Factor = \frac{1}{(1+\mathrm{DR})^{ECY-PVY}} \quad (2)$$

where:

DR = Discount Rate (2%)
ECY = Estimated Cost Year
PVY = Present Value Year (2019)

Note: The 2% real discount was used by Kovacs et al. (2010) and provides a present value estimate for annual removal and replacement of ash trees. Additionally, Howarth (2009) observes that the future benefits of a public good, such as the removal and replacement of a dead ash tree, should be discounted at a rate close to the market rate of return for risk-free financial assets. This holds true even when the public good has risk characteristics equivalent to those of risky forms of wealth such as corporate stocks.

To determine the present value EAB cost to USACE, Equation 3 was used. Following EAB infestation, each project was assumed to have a 20% loss per year (i.e., tree mortality) for each county over a five-yr period.

$$EAB\ Cost = \sum(\ Ash\ Tree\ Count * 20\% *\ Management\ Cost * PV\ Factor) \quad (3)$$

where:

Ash Tree Count= See Equation 1
20% = Fixed Annual EAB Mortality Rate
Management Cost = cost per tree based on Kovacs et al. (2010) based on state-level estimate
PV Factor = Present value factor calculated for each year of EAB management action

Evidence from the FIA data suggests that catastrophic ash mortality in a county primarily occurs five years after initial EAB detection (Kovacs et al. 2010). Following the Kovacs et al.

methodology, we incorporated a linear rate (i.e., 20% per year) of infested ash trees five years following the initial presence of EAB. Additionally, since EAB detection requires visible signs and symptoms, there is an assumed one-year delay in EAB detection. For example, if a USACE project identified EAB presence in 2011, the initial infestation year would be 2010. With a five-year window prior to catastrophic mortality, the infestation range prior to management action would be 2010-2014. Therefore, beginning in 2015, a five-year range of mortality would be modeled to occur until 2019, with 20% annual mortality and associated present value management cost (i.e., 2019 dollars) estimated for 2015-2019.

Lastly, Kovacs et al. (2010) developed an ash management cost per tree (CPT) which was based on actual costs from 25 states based on their specific mitigation methods (i.e., treatment; removal; replacement). When data were available for a project, the CPT was calculated using the total cost for a project divided by the total number of ash trees requiring mitigation/management. This resulted in each of the 25 states having a unique CPT. State-specific CPT was utilized for USACE projects based on their location. Costs were calculated using the Consumer Price Index (CPI), indexed from 2009 to 2019 for each state in the study. For USACE projects with ash trees and potential exposure to EAB, a weighted average CPT of total trees to total indexed 2019 cost from all 25 states was utilized following Kovacs et al. (2010).

To determine the PV cost of management, an example USACE project EAB timeline is provided in Table 1. Initial detection was determined in 2011, making the initial infestation year begin in 2010. Next, a five-year window prior to catastrophic mortality is assumed, with no mortality assumed until 2015 (5 years post estimated infestation date). Beginning in 2015, a five-year range of mortality would be modeled to occur until 2019 with 20% annual mortality occurring each year and the estimated PV management cost of that removal and replacement. The estimated PV cost is calculated for the example in Table 1 by using a CPT of $656.28, PV factor of 1.08, and an average ash TPA abundance of 0.5 throughout 133 acres identified as a PUA.

Table 1. EAB-impacted project example (Nolin Lake, Kentucky) with initial detection occurring in 2011 and estimated present value (PV) cost of management five years following initial infestation.

Year	Action	Estimated PV cost
2010	Estimated EAB infestation	
2011	Initial detection	
2012		
2013		
2014		
2015	20% EAB-induced mortality	$ 22,512
2016	20% EAB-induced mortality	$ 22,071
2017	20% EAB-induced mortality	$ 21,638
2018	20% EAB-induced mortality	$ 21,214
2019	20% EAB-induced mortality	$ 20,798
	Total	$108,233

RESULTS: The cost estimate for nationwide EAB-related ash tree management across USACE projects would be $121.6 million in 2019 dollars for the PV modeled timespan of 2006-2026. A total of 122,800 acres would be impacted in this assessment, including 181,000 ash trees that would require management by either removal, removal and replacement, or treatment. A present value cost estimate by USACE District and Division is provided in Table 2 and Table 3**,** respectively. Each table provides the number of projects, acres to be managed/impacted, estimated ash trees loss, and the PV cost of management derived from CPT calculations using Kovacs et al. 2010.

Table 2. Estimated acreage, ash tree mortality, and present value cost by USACE District given during the timespan 2006-2026.

District	Division	Number of Projects	Acres	Ash Tree Mortality Count	Present Value Cost
Buffalo (LRB)	Great Lakes and Ohio River (LRD)	2	563	915	$ 554,496
Chicago (LRC)	Great Lakes and Ohio River (LRD)	8	68	131	$ 88,654
Huntington (LRH)	Great Lakes and Ohio River (LRD)	43	7,127	17,277	$ 14,189,779
Louisville (LRL)	Great Lakes and Ohio River (LRD)	26	10,051	40,267	$ 31,616,726
Nashville (LRN)	Great Lakes and Ohio River (LRD)	10	9,936	15,179	$ 7,989,660
Pittsburgh (LRP)	Great Lakes and Ohio River (LRD)	16	4,897	4,071	$ 2,984,464
Vicksburg (MVK)	Mississippi Valley (MVD)	10	4,131	1,211	$ 706,395
St. Paul (MVP)	Mississippi Valley (MVD)	2	150	153	$ 103,479
Rock Island (MVR)	Mississippi Valley (MVD)	6	3,901	3,477	$ 2,114,283
St. Louis (MVS)	Mississippi Valley (MVD)	8	23,559	20,367	$ 13,825,299
Baltimore (NAB)	North Atlantic (NAD)	14	3,414	3,100	$ 2,100,324
New England (NAE)	North Atlantic (NAD)	26	1,111	1,502	$ 700,007
Philadelphia (NAP)	North Atlantic (NAD)	4	1,030	2,506	$ 1,689,877
Kansas City (NWK)	Northwestern (NWD)	9	16,082	8,890	$ 5,479,271
Omaha (NWO)	Northwestern (NWD)	2	16,410	52,435	$ 31,766,778
Mobile (SAM)	South Atlantic (SAD)	3	4,711	3,816	$ 2,435,257
Savannah (SAS)	South Atlantic (SAD)	1	1,569	2,353	$ 1,281,332
Wilmington (SAW)	South Atlantic (SAD)	4	9,434	1,555	$ 961,052
Fort Worth (SWF)	Southwestern (SWD)	2	971	81	$ 48,524
Little Rock (SWL)	Southwestern (SWD)	5	3,692	1,734	$ 939,501
	Total	**201**	**122,807**	**181,020**	**$ 121,575,158**

Table 3. Estimated acreage, ash tree mortality, and present value cost by USACE Division given during the timespan 2006-2026.

Division	Number of Projects	Acres	Ash Tree Mortality Count	Present Value Cost
Great Lakes and Ohio River (LRD)	105	32,642	77,840	$ 57,423,779
Mississippi Valley (MVD)	26	31,741	25,208	$ 16,749,456
North Atlantic (NAD)	44	5,555	7,108	$ 4,490,208
Northwestern (NWD)	11	32,492	61,325	$ 37,246,049
South Atlantic (SAD)	8	15,714	7,724	$ 4,677,641
Southwestern (SWD)	7	4,663	1,815	$ 988,025
Total	**201**	**122,807**	**181,020**	**$ 121,575,158**

Across USACE districts, the Louisville (LRL) and Omaha (NWO) districts possessed the largest total estimated ash tree densities—approximately 93K trees across 26K acres. As a result of the ash density and large acreage of these two districts collectively, they represented greater than 52% of the PV cost (i.e., $63.4M of $121.6M). The Louisville District has a total of 26 project locations with 10K acres represented, while the Omaha District has only two projects with 16K acres considered as PUAs (Table 2; Appendix).

For USACE divisions, the Great Lakes and Ohio River Division (LRD) was estimated to have the greatest number of impacted USACE projects (n=105); an estimated PV cost of $57.4M. The Northwest Division (NWD) was the second most impacted USACE division, with only 11 projects impacted but at an estimated PV cost of a $37.2M. Collectively, these two divisions comprise >75% of the $121.6M estimated cost of EAB impact on USACE projects and include >50% of the total acres impacted. The Appendix provides the total PV cost for each USACE project assessed in this study. The PV cost by year for all USACE projects is provided in Table 4. The PV cost per year provides a yearly cost for management assuming the initial detection and timeline where ash mortality for each project is estimated to occur (see the Appendix for individual project timelines).

Table 4. Annual Present Value cost estimate for EAB management for 2006-2026.

Year	Present Value Cost
2006	$ -
2007	$ -
2008	$ -
2009	$ 1,624,809
2010	$ 2,386,958
2011	$ 3,405,983
2012	$ 4,501,598
2013	$ 6,686,467
2014	$ 5,387,457
2015	$ 4,816,532
2016	$ 4,962,623
2017	$ 6,980,164

2018	$ 8,585,387
2019	$ 9,411,285
2020	$ 13,982,488
2021	$ 13,283,097
2022	$ 12,866,752
2023	$ 9,171,837
2024	$ 7,842,314
2025	$ 3,172,864
2026	$ 2,506,543

DISCUSSION: This analysis was performed to present the potential impact EAB has on USACE and its managed land and is intended to be a straightforward extension of the work done by Kovacs et al. 2010. The analysis did not attempt to look at ways to lower costs through pre-mitigation and control efforts. It also did not attempt to identify additional impacts beyond that laid out in Kovacs et al. 2010. However, the goal of this analysis was to provide a valuation for EAB impacts to USACE lands, when and where EAB mortality is predicted to occur.

Though the analysis is from 2006 to 2026, no project was estimated to have costs associated with EAB until 2009. USACE projects at the Detroit River and Grand Haven Harbor in Michigan were estimated to have management costs beginning 2006 and 2007, respectively. However, given the screening metric, both projects had zero acres on which management was necessary and as a result, no costs. Based on the assumptions utilized, no projects were expected to have costs beginning in 2008 in this study.

The major challenge in this analysis is accurately estimating acreages requiring management. As noted in the methods and data section, some USACE projects have zero acres that need management even though ash trees could be on land adjacent to USACE facilities or infrastructure. Conversely, there is the potential for overestimation considering the inclusion of all publicly accessible project acres. Not all these acres may require ash tree management. This overvaluation is more likely than the potential for undervaluing acreage and trees that need to be mitigated.

An example of this potential overvaluation would be the Northwest Division projects Papillion Creek and Tributaries and Salt Creek and Tributaries. These projects had 4,157 and 12,253 acres, respectively, and 34,055 and 18,380 trees, respectively, that needed to be managed for potential EAB impact. That led to present value mitigation costs of $20.9 million and $10.9 million, for Papillion Creek and Tributaries and Salt Creek and Tributaries, respectively. These projects combined account for 26% of the total EAB present value cost estimate in our study. Realistically, it is highly unlikely that management to such a large acreage at these projects would be feasible.

Conversely, some of the expected overvaluation could be captured by the continued expansion of EAB to counties which do not currently have EAB impacts but do have USACE projects. Therefore, it may be best stated that EAB has the potential to cost the USACE upwards of $122 million in 2019 dollars for the period between 2006 and 2026. This analysis was done to highlight the impact EAB has and will continue to have on federal facilities. It should also highlight the need to continue to spend federal dollars to aggressively fight invasive species before they can drastically spread and impact the ecosystem. EAB is estimated to have cost USACE millions of dollars annually over the past decade and will continue to do so over the next decade and beyond as it continues to spread and more USACE projects are impacted.

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APPENDIX

USACE Projects (by Division and District) acreage and locations, with date of EAB presence, damage assessment date and estimated total Present Value (PV) costs for Emerald Ash Borer (EAB) management for ash trees ≥7" DBH within USACE Public-Use Areas (PUA's).

DIVISION Abbreviation	DISTRICT Abbreviation	USACE PROJECT	County	State	EAB INITIAL DETECT	EAB Mortality Start Date
LRD	LRB	BLACK ROCK CHANNEL AND TONAWANDA HARBOR	Erie	New York	6/10/2011	6/10/2015
LRD	LRB	MT MORRIS LAKE	Livingston	New York	8/2/2010	8/2/2014
LRD	LRE	DETROIT RIVER	Wayne	Michigan	7/9/2002	7/9/2006
LRD	LRE	DULUTH-SUPERIOR HARBOR	St. Louis	Minnesota	10/22/2015	10/22/2019
LRD	LRE	FOX RIVER	Outagamie	Wisconsin	2/5/2015	2/5/2019
LRD	LRE	GRAND HAVEN HARBOR	Ottawa	Michigan	8/15/2003	8/15/2007
LRD	LRE	KEWAUNEE HARBOR	Kewaunee	Wisconsin	8/15/2018	8/15/2022
LRD	LRE	KEWEENAW WATERWAY	Houghton	Michigan	8/5/2008	8/5/2012
LRD	LRE	ST. MARYS RIVER	Chippewa	Michigan	9/12/2005	9/12/2009
LRD	LRE	STURGEON BAY AND LAKE MICHIGAN CANAL	Door	Wisconsin	6/10/2014	6/10/2018
LRD	LRH	ALUM CREEK LAKE	Delaware	Ohio	7/14/2005	7/14/2009
LRD	LRH	ATWOOD LAKE	Carroll	Ohio	7/16/2015	7/16/2019
LRD	LRH	BEACH CITY LAKE	Tuscarawas	Ohio	7/22/2013	7/22/2017
LRD	LRH	BEECH FORK LAKE	Cabell	West Virginia	2/4/2015	2/4/2019
LRD	LRH	BELLEVILLE LOCK - OHIO RIVER LOCKS AND DAMS HUNTINGTON	Meigs	Ohio	5/28/2014	5/28/2018
LRD	LRH	BLUESTONE LAKE	Summers	West Virginia	8/10/2011	8/10/2015
LRD	LRH	BOLIVAR DAM	Tuscarawas	Ohio	7/22/2013	7/22/2017
LRD	LRH	BURNSVILLE LAKE	Braxton	West Virginia	7/24/2012	7/24/2016
LRD	LRH	CAPTAIN ANTHONY MELDAHL LOCK - OHIO R. LOCKS AND DAMS HUNT.	Meigs	Ohio	10/10/2008	10/10/2012
LRD	LRH	CHARLES MILL LAKE	Ashland	Ohio	7/20/2009	7/20/2013
LRD	LRH	CLENDENING LAKE	Harrison	Ohio	7/11/2014	7/11/2018
LRD	LRH	DEER CREEK LAKE	Pickaway	Ohio	10/19/2009	10/19/2013
LRD	LRH	DELAWARE LAKE	Delaware	Ohio	7/14/2005	7/14/2009
LRD	LRH	DEWEY LAKE	Floyd	Kentucky	10/11/2012	10/11/2016
LRD	LRH	DILLON LAKE	Licking	Ohio	9/11/2008	9/11/2012
LRD	LRH	DOVER DAM	Tuscarawas	Ohio	7/22/2013	7/22/2017
LRD	LRH	EAST LYNN LAKE	Wayne	West Virginia	2/12/2015	2/12/2019
LRD	LRH	FISHTRAP LAKE	Pike	Kentucky	10/11/2012	10/11/2016
LRD	LRH	GRAYSON LAKE	Carter	Kentucky	3/2/2016	3/2/2020
LRD	LRH	GREENUP LOCK - OHIO RIVER LOCKS AND DAMS HUNTINGTON	Greenup	Kentucky	10/23/2009	10/23/2013
LRD	LRH	JOHN W FLANNAGAN DAM AND RESERVOIR	Dickenson	Virginia	10/1/2018	10/1/2022
LRD	LRH	LEESVILLE LAKE	Carroll	Ohio	7/16/2015	7/16/2019

DIVISION Abbreviation	DISTRICT Abbreviation	USACE PROJECT	County	State	EAB INITIAL DETECT	EAB Mortality Start Date
LRD	LRH	LONDON LOCK - KANAWHA RIVER LOCKS AND DAMS	Kanawha	West Virginia	6/15/2011	6/15/2015
LRD	LRH	MOHAWK DAM	Knox	Ohio	6/15/2012	6/15/2016
LRD	LRH	MOHICANVILLE DAM	Wayne	Ohio	8/20/2008	8/20/2012
LRD	LRH	NORTH BRANCH KOKOSING RIVER LAKE	Knox	Ohio	6/15/2012	6/15/2016
LRD	LRH	NORTH FORK OF POUND LAKE	Wise	Virginia	6/6/2016	6/6/2020
LRD	LRH	PAINT CREEK LAKE	Fayette	Ohio	5/31/2013	5/31/2017
LRD	LRH	PAINTSVILLE LAKE	Johnson	Kentucky	10/10/2014	10/10/2018
LRD	LRH	PIEDMONT LAKE	Belmont	Ohio	6/15/2012	6/15/2016
LRD	LRH	PLEASANT HILL LAKE	Richland	Ohio	7/10/2009	7/10/2013
LRD	LRH	R D BAILEY LAKE	Mingo	West Virginia	6/16/2011	6/16/2015
LRD	LRH	RACINE LOCK - OHIO RIVER LOCKS AND DAMS HUNTINGTON	Mason	West Virginia	6/10/2014	6/10/2018
LRD	LRH	ROBERT C. BYRD LOCK - OHIO RIVER LOCKS AND DAMS HUNTINGTON	Mason	West Virginia	6/10/2014	6/10/2018
LRD	LRH	SENECAVILLE LAKE	Guernsey	Ohio	3/30/2012	3/30/2016
LRD	LRH	SUMMERSVILLE LAKE	Nicholas	West Virginia	9/20/2010	9/20/2014
LRD	LRH	SUTTON LAKE	Webster	West Virginia	5/23/2011	5/23/2015
LRD	LRH	TAPPAN LAKE	Harrison	Ohio	7/11/2014	7/11/2018
LRD	LRH	TOM JENKINS DAM	Athens	Ohio	7/2/2014	7/2/2018
LRD	LRH	WILLOW ISLAND LOCK - OHIO RIVER LOCKS AND DAMS HUNTINGTON	Pleasants	West Virginia	5/29/2014	5/29/2018
LRD	LRH	WILLS CREEK LAKE	Muskingum	Ohio	5/21/2012	5/21/2016
LRD	LRH	WINFIELD LOCK - KANAWHA RIVER LOCKS AND DAMS	Putnam	West Virginia	10/25/2013	10/25/2017
LRD	LRH	YATESVILLE LAKE	Lawrence	Kentucky	10/10/2014	10/10/2018
LRD	LRL	BARREN RIVER LAKE	Allen	Kentucky	1/1/2013	1/1/2017
LRD	LRL	BROOKVILLE LAKE	Fayette	Indiana	10/24/2013	10/24/2017
LRD	LRL	BUCKHORN LAKE	Leslie	Kentucky	6/23/2016	6/23/2020
LRD	LRL	CAESAR CREEK LAKE	Warren	Ohio	9/29/2006	9/29/2010
LRD	LRL	CAGLES MILL LAKE	Putnam	Indiana	2/28/2013	2/28/2017
LRD	LRL	CANNELTON LOCK - OHIO RIVER LOCKS AND DAMS	Perry	Indiana	8/1/2013	8/1/2017
LRD	LRL	CARR CREEK LAKE	Knott	Kentucky	6/23/2016	6/23/2020
LRD	LRL	CAVE RUN LAKE	Rowan	Kentucky	6/10/2014	6/10/2018
LRD	LRL	CECIL M HARDEN LAKE	Putnam	Indiana	2/28/2013	2/28/2017
LRD	LRL	CLARENCE J BROWN DAM	Clark	Ohio	6/16/2009	6/16/2013
LRD	LRL	FALLS OF THE OHIO NATIONAL WILDLIFE CONSERVATION AREA	Jefferson	Kentucky	6/8/2009	6/8/2013
LRD	LRL	GREEN RIVER LAKE	Casey	Kentucky	7/20/2016	7/20/2020
LRD	LRL	J. EDWARD ROUSH LAKE	Huntington	Indiana	2/7/2006	2/7/2010
LRD	LRL	JOHN T. MYERS LOCK - OHIO RIVER LOCKS AND DAMS	WMaSrrick	Indiana	9/30/2014	9/30/2018

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LRD	LRL	MARKLAND LOCK - OHIO RIVER LOCKS AND DAMS	Hamilton	Ohio	5/23/2007	5/23/2011
LRD	LRL	MCALPINE LOCK - OHIO RIVER LOCKS AND DAMS	Floyd	Indiana	7/31/2008	7/31/2012
LRD	LRL	MISSISSINEWA LAKE	Miami	Indiana	10/26/2009	10/26/2013
LRD	LRL	MONROE LAKE	Brown	Indiana	9/17/2008	9/17/2012
LRD	LRL	NOLIN LAKE	Hardin	Kentucky	10/19/2011	10/19/2015
LRD	LRL	PATOKA LAKE	Orange	Indiana	5/12/2009	5/12/2013
LRD	LRL	ROUGH RIVER LAKE	Hardin	Kentucky	10/19/2011	10/19/2015
LRD	LRL	SALAMONIE LAKE	Huntington	Indiana	2/7/2006	2/7/2010
LRD	LRL	SMITHLAND LOCK - OHIO RIVER LOCKS AND DAMS	Posey	Indiana	12/1/2015	12/1/2019
LRD	LRL	TAYLORSVILLE LAKE	Spencer	Kentucky	12/5/2014	12/5/2018
LRD	LRL	WEST FORK OF MILL CREEK LAKE	Hamilton	Ohio	5/23/2007	5/23/2011
LRD	LRL	WILLIAM H HARSHA LAKE	Clermont	Ohio	10/10/2008	10/10/2012
LRD	LRN	BARKLEY DAM AND LAKE BARKLEY	Cheatham	Tennessee	7/20/2018	7/20/2022
LRD	LRN	CENTER HILL LAKE	Putnam	Tennessee	5/16/2014	5/16/2018
LRD	LRN	CHEATHAM LOCK AND DAM	Davidson	Tennessee	9/19/2014	9/19/2018
LRD	LRN	CORDELL HULL DAM AND RESERVOIR	Smith	Tennessee	9/11/2012	9/11/2016
LRD	LRN	DALE HOLLOW LAKE	Fentress	Tennessee	7/11/2014	7/11/2018
LRD	LRN	J PERCY PRIEST DAM AND RESERVOIR	Davidson	Tennessee	9/19/2014	9/19/2018
LRD	LRN	LAUREL RIVER LAKE	Whitley	Kentucky	4/25/2013	4/25/2017
LRD	LRN	MARTINS FORK LAKE	Harlan	Kentucky	6/22/2015	6/22/2019
LRD	LRN	OLD HICKORY LOCK AND DAM	Smith	Tennessee	9/11/2012	9/11/2016
LRD	LRN	WOLF CREEK DAM - LAKE CUMBERLAND	Pulaski	Kentucky	6/10/2014	6/10/2018
LRD	LRP	BERLIN LAKE	Mahoning	Ohio	6/20/2007	6/20/2011
LRD	LRP	CONEMAUGH RIVER LAKE	Westmoreland	Pennsylvania	6/8/2009	6/8/2013
LRD	LRP	CROOKED CREEK LAKE	Armstrong	Pennsylvania	7/8/2009	7/8/2013
LRD	LRP	EAST BRANCH CLARION RIVER LAKE	Elk	Pennsylvania	6/28/2013	6/28/2017
LRD	LRP	KINZUA DAM AND ALLEGHENY RESERVOIR	Cattaraugus	New York	6/17/2009	6/17/2013
LRD	LRP	LOYALHANNA LAKE	Westmoreland	Pennsylvania	6/8/2009	6/8/2013
LRD	LRP	MAHONING CREEK LAKE	Armstrong	Pennsylvania	7/8/2009	7/8/2013
LRD	LRP	MICHAEL J KIRWAN DAM AND RESERVOIR	Portage	Ohio	11/9/2007	11/9/2011
LRD	LRP	MOSQUITO CREEK LAKE	Trumbull	Ohio	4/27/2011	4/27/2015
LRD	LRP	SHENANGO RIVER LAKE	Mercer	Pennsylvania	6/25/2008	6/25/2012
LRD	LRP	STONEWALL JACKSON LAKE	Lewis	West Virginia	10/4/2012	10/4/2016
LRD	LRP	TIONESTA LAKE	Forest	Pennsylvania	6/7/2013	6/7/2017
LRD	LRP	TYGART LAKE	Taylor	West Virginia	2/29/2016	2/29/2020
LRD	LRP	UNION CITY LAKE	Erie	Pennsylvania	8/13/2013	8/13/2017
LRD	LRP	WOODCOCK CREEK LAKE	Crawford	Pennsylvania	8/12/2014	8/12/2018

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LRD	LRP	YOUGHIOGHENY RIVER LAKE	Somerset	Pennsylvania	6/25/2010	6/25/2014
MVD	MVK	BAYOU BODCAU RESERVOIR	Webster	Louisiana	2/11/2015	2/11/2019
MVD	MVK	BLAKELY MT DAM-LAKE OUACHITA	Montgomery	Arkansas	4/26/2017	4/26/2021
MVD	MVK	CADDO LAKE	Caddo	Louisiana	6/28/2018	6/28/2022
MVD	MVK	DEGRAY LAKE	Hot Spring	Arkansas	7/18/2014	7/18/2018
MVD	MVK	FELSENTHAL LOCK AND DAM - OUACHITA AND BLACK RIVERS	Union	Arkansas	5/28/2015	5/28/2019
MVD	MVK	H. K. THATCHER LOCK AND DAM - OUACHITA AND BLACK RIVERS	Union	Arkansas	5/28/2015	5/28/2019
MVD	MVK	J. BENNETT JOHNSTON WATERWAY	Bossier	Louisiana	6/22/2015	6/22/2019
MVD	MVK	MISSISSIPPI RIVER LEVEES AR IL KY LA MS MO TN(MR&T)	Ouachita	Louisiana	7/20/2017	7/20/2021
MVD	MVK	NARROWS DAM-LAKE GREESON	Pike	Arkansas	5/2/2017	5/2/2021
MVD	MVK	WALLACE LAKE	Caddo	Louisiana	6/28/2018	6/28/2022
MVD	MVP	EAU GALLE RIVER LAKE WISCONSIN	St. Croix	Wisconsin	7/10/2018	7/10/2022
MVD	MVP	MISSISSIPPI RIVER BETWEEN MISSOURI RIVER AND MINNEAPOLIS	Vernon	Wisconsin	4/6/2009	4/6/2013
MVD	MVR	CORALVILLE LAKE	Johnson	Iowa	6/12/2014	6/12/2018
MVD	MVR	FARM CREEK RESERVOIRS	Tazewell	Illinois	7/1/2014	7/1/2018
MVD	MVR	ILLINOIS WATERWAY	Cook	Illinois	7/12/2006	7/12/2010
MVD	MVR	MISSISSIPPI RIVER BETWEEN MISSOURI RIVER AND MINNEAPOLIS	Whiteside	Illinois	7/18/2013	7/18/2017
MVD	MVR	RED ROCK DAM - LAKE RED ROCK	Jasper	Iowa	3/21/2014	3/21/2018
MVD	MVR	SAYLORVILLE LAKE	Boone	Iowa	7/31/2014	7/31/2018
MVD	MVS	CARLYLE LAKE	Bond	Illinois	9/18/2015	9/18/2019
MVD	MVS	CLARENCE CANNON DAM & MARK TWAIN LAKE	Ralls	Missouri	6/14/2017	6/14/2021
MVD	MVS	ILLINOIS WATERWAY	St. Charles	Missouri	5/27/2014	5/27/2018
MVD	MVS	LAKE SHELBYVILLE	Shelby	Illinois	9/30/2014	9/30/2018
MVD	MVS	MISSISSIPPI RIVER BETWEEN MISSOURI RIVER AND MINNEAPOLIS	St. Charles	Missouri	5/27/2014	5/27/2018
MVD	MVS	REND LAKE	Franklin	Illinois	7/22/2016	7/22/2020
MVD	MVS	REND LAKE	Jefferson	Illinois	9/18/2015	9/18/2019
MVD	MVS	WAPPAPELLO LAKE	Wayne	Missouri	7/23/2008	7/23/2012
NAD	NAB	ALMOND LAKE	Steuben	New York	7/19/2010	7/19/2014
NAD	NAB	ALVIN R BUSH DAM	Clinton	Pennsylvania	8/23/2012	8/23/2016
NAD	NAB	ARKPORT	Steuben	New York	7/19/2010	7/19/2014
NAD	NAB	AYLESWORTH	Lackawanna	Pennsylvania	5/19/2016	5/19/2020
NAD	NAB	COWANESQUE LAKE	Tioga	Pennsylvania	8/27/2013	8/27/2017
NAD	NAB	CURWENSVILLE	Clearfield	Pennsylvania	7/22/2013	7/22/2017
NAD	NAB	EAST SIDNEY LAKE	Delaware	New York	5/1/2013	5/1/2017

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NAD	NAB	FOSTER J SAYERS	Centre	Pennsylvania	6/18/2010	6/18/2014
NAD	NAB	JENNINGS RANDOLPH LAKE	Garrett	Maryland	7/24/2012	7/24/2016
NAD	NAB	RAYSTOWN LAKE	Bedford	Pennsylvania	5/13/2010	5/13/2014
NAD	NAB	STILLWATER LAKE	Susquehanna	Pennsylvania	3/27/2014	3/27/2018
NAD	NAB	TIOGA-HAMMOND LAKES	Tioga	Pennsylvania	8/27/2013	8/27/2017
NAD	NAB	WHITNEY POINT LAKE	Broome	New York	10/31/2014	10/31/2018
NAD	NAB	YORK INDIAN ROCK DAM	York	Pennsylvania	8/7/2014	8/7/2018
NAD	NAE	BARRE FALLS DAM	Worcester	Massachusetts	12/7/2015	12/7/2019
NAD	NAE	BIRCH HILL DAM	Worcester	Massachusetts	12/7/2015	12/7/2019
NAD	NAE	BLACK ROCK LAKE	Litchfield	Connecticut	8/2/2013	8/2/2017
NAD	NAE	BLACKWATER DAM	Merrimack	New Hampshire	4/2/2013	4/2/2017
NAD	NAE	BUFFUMVILLE LAKE	Worcester	Massachusetts	12/7/2015	12/7/2019
NAD	NAE	CHARLES RIVER NATURAL VALLEY STORAGE AREA	Norfolk	Massachusetts	7/21/2017	7/21/2021
NAD	NAE	COLEBROOK RIVER LAKE	Berkshire	Massachusetts	9/5/2012	9/5/2016
NAD	NAE	CONANT BROOK DAM	Hampden	Massachusetts	5/4/2016	5/4/2020
NAD	NAE	EAST BRIMFIELD LAKE	Worcester	Massachusetts	12/7/2015	12/7/2019
NAD	NAE	EDWARD MACDOWELL LAKE	Hillsborough	New Hampshire	10/14/2014	10/14/2018
NAD	NAE	FRANKLIN FALLS DAM	Merrimack	New Hampshire	4/2/2013	4/2/2017
NAD	NAE	HANCOCK BROOK LAKE	Litchfield	Connecticut	8/2/2013	8/2/2017
NAD	NAE	HODGES VILLAGE DAM	Worcester	Massachusetts	12/7/2015	12/7/2019
NAD	NAE	HOP BROOK LAKE	New Haven	Connecticut	7/17/2012	7/17/2016
NAD	NAE	HOPKINTON-EVERETT LAKES	Hillsborough	New Hampshire	10/14/2014	10/14/2018
NAD	NAE	KNIGHTVILLE DAM	Hampshire	Massachusetts	11/22/2017	11/22/2021
NAD	NAE	LITTLEVILLE LAKE	Hampden	Massachusetts	5/4/2016	5/4/2020
NAD	NAE	MANSFIELD HOLLOW LAKE	Tolland	Connecticut	7/17/2015	7/17/2019
NAD	NAE	NORTHFIELD BROOK LAKE	Litchfield	Connecticut	8/2/2013	8/2/2017
NAD	NAE	STAMFORD HURRICANE BARRIER	Fairfield	Connecticut	7/23/2013	7/23/2017
NAD	NAE	THOMASTON DAM	Litchfield	Connecticut	8/2/2013	8/2/2017
NAD	NAE	TULLY LAKE	Worcester	Massachusetts	12/7/2015	12/7/2019
NAD	NAE	UNION VILLAGE DAM	Orange	Vermont	2/27/2018	2/27/2022
NAD	NAE	WEST HILL DAM	Worcester	Massachusetts	12/7/2015	12/7/2019
NAD	NAE	WEST THOMPSON LAKE	Windham	Connecticut	2/4/2016	2/4/2020
NAD	NAE	WESTVILLE LAKE	Worcester	Massachusetts	12/7/2015	12/7/2019
NAD	NAP	BELTZVILLE LAKE	Carbon	Pennsylvania	5/4/2016	5/4/2020
NAD	NAP	BLUE MARSH LAKE	Berks	Pennsylvania	4/10/2014	4/10/2018
NAD	NAP	FRANCIS E WALTER DAM	Luzerne	Pennsylvania	8/29/2013	8/29/2017
NAD	NAP	PROMPTON LAKE	Wayne	Pennsylvania	3/14/2017	3/14/2021
NWD	NWK	CLINTON LAKE	Douglas	Kansas	10/8/2015	10/8/2019
NWD	NWK	HARRY S. TRUMAN DAM AND RESERVOIR	Camden	Missouri	1/25/2017	1/25/2021
NWD	NWK	HILLSDALE LAKE	Johnson	Kansas	7/11/2013	7/11/2017

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NWD	NWK	LITTLE BLUE RIVER LAKES	Jackson	Missouri	7/29/2013	7/29/2017
NWD	NWK	PERRY LAKE	Jefferson	Kansas	10/23/2015	10/23/2019
NWD	NWK	POMME DE TERRE LAKE	Polk	Missouri	7/17/2018	7/17/2022
NWD	NWK	RATHBUN LAKE	Lucas	Iowa	11/28/2014	11/28/2018
NWD	NWK	SMITHVILLE LAKE	Platte	Missouri	7/20/2012	7/20/2016
NWD	NWK	STOCKTON LAKE	Polk	Missouri	7/17/2018	7/17/2022
NWD	NWO	PAPILLION CREEK AND TRIBUTARIES LAKES	Douglas	Nebraska	6/8/2016	6/8/2020
NWD	NWO	SALT CREEK AND TRIBUTARIES	Lancaster	Nebraska	8/17/2018	8/17/2022
SAD	SAM	ALLATOONA LAKE	Cobb	Georgia	7/21/2014	7/21/2018
SAD	SAM	CARTERS DAM AND LAKE	Murray	Georgia	6/29/2015	6/29/2019
SAD	SAM	GEORGE W ANDREWS L&D-APALACHICOLA CHATTAHOOCHEE & FLINT RVRS	Fulton	Georgia	7/22/2013	7/22/2017
SAD	SAS	HARTWELL DAM AND LAKE	Oconee	South Carolina	8/9/2017	8/9/2021
SAD	SAW	B EVERETT JORDAN DAM AND LAKE	Wake	North Carolina	6/24/2015	6/24/2019
SAD	SAW	FALLS LAKE	Granville	North Carolina	5/31/2013	5/31/2017
SAD	SAW	JOHN H KERR DAM AND RESERVOIR	Charlotte	Virginia	6/12/2012	6/12/2016
SAD	SAW	PHILPOTT LAKE	Franklin	Virginia	7/1/2017	7/1/2021
SWD	SWF	FERRELLS BRIDGE DAM - LAKE O' THE PINES	Harrison	Texas	5/6/2016	5/6/2020
SWD	SWF	WRIGHT PATMAN DAM AND LAKE	Cass	Texas	6/26/2018	6/26/2022
SWD	SWL	BULL SHOALS LAKE	Baxter	Arkansas	8/9/2018	8/9/2022
SWD	SWL	CLEARWATER LAKE	Wayne	Missouri	7/23/2008	7/23/2012
SWD	SWL	GILLHAM LAKE	Polk	Arkansas	8/9/2018	8/9/2022
SWD	SWL	MILLWOOD LAKE	Hempstead	Arkansas	11/9/2016	11/9/2020
SWD	SWL	NORFORK LAKE	Baxter	Arkansas	8/9/2018	8/9/2022