



Invasive Species Costs to Corps Civil Works Activities

by *Jim E. Henderson*

PURPOSE: The purpose of this technical note is to document the estimation of invasive species costs to the Corps. The procedures and data sources used for the estimate are documented so that the procedures or assumptions supporting the procedures may be revised in the future.

BACKGROUND: The U.S. Army Corps of Engineers' (the Corps') missions of navigation, flood risk reduction, and ecosystem restoration respond and adapt to constraints levied from political, technical, and natural sources. The economic costs associated with such constraints become important when one considers whether it's possible to maintain or increase the level of outputs for those missions,¹ especially during times of Federal budgetary limitations. During the last two decades, in particular, the impact of invasive species on Corps missions has become evident as the agency has modified its procedures in response to such aquatic species as hydrilla (*Hydrilla verticillata*), Eurasian watermilfoil (*Myriophyllum spicatum*) and – more recently – the zebra (*Dreissena polymorpha*) and quagga mussels (*Dreissena rostriformis bugensis*). The Corps has also been forced to modify its procedures in response to terrestrial wetland and riparian species such as the salt cedar (*Tamarix spp.*).

Previously, costs associated with the Corps' management of invasive species were not addressed explicitly, most likely because the invasive costs were normally subsumed within the total costs for a project. As academic and applied economic work on the costs and benefits associated with invasives management became available (Pimentel et al. 2000 and 2004; U.S. Congress Office of Technology Assessment (OTA) 1993; and Rockwell 2003) and familiarity with invasives' costs became a general part of the natural resources knowledge base, interest has increased in identifying Corps costs for invasive species.

There are a number of institutional circumstances that make estimating the costs of invasive species for the Corps challenging. The Corps' budgetary cycle, linked to the larger Federal budget, is proposed two years ahead of actual program execution. Consequently, when rangers at Wappapello Lake found the Emerald Ash Borer (EAB) in 2008, the rangers' activities were funded from budgets proposed in 2006, and EAB reconnaissance was not accounted for in the budget request. Corps natural resource management focuses on managing ecosystems, so objectives may be termed something like: "to ensure healthy and sustainable natural resources," so that costs for invasive species are included with the costs for all other components. Ensuring the visibility of invasives in the budget preparation process becomes difficult when invasives are not explicitly recognized and the connection to ecosystem integrity is not documented. The public good character of the benefits of invasive species management

¹ Outputs are the products, goods, and services produced by Corps activities. Business line outputs are the significant products resulting from Corps activities, e.g., hydropower, flood risks avoided, ecosystem components restored. Outputs are measured in both monetary and non-monetary terms.

and of natural resources managed by the Corps complicate the process of identifying what the Corps is responsible for.

Corps costs resulting from invasives are a mix of two kinds of costs. First, costs that are readily identified – such as the costs of contracted control, prevention efforts or of labor that goes into coordination and education or management — and second, costs that are more difficult to identify, such as costs of increased maintenance, the value of lost fishery production, or reduced capacity for hydropower or water supply.

Development of Cost Estimating Procedures for the Corps' Invasive Species As invasives became more visible in plans for small- and large-scale Corps projects and for long-range management, questions more frequently arose about the costs of invasive species for the Corps, apart from the national costs that had been identified in previous academic work. The Corps' Invasive Species Leadership Team (ISLT) asked the Engineer Research and Development Center (ERDC) to estimate the costs of invasive species to Corps activities. The ISLT had been formed by the Corps to provide coordination and leadership when the organization addressed challenges or problems posed by invasives. The request for cost information by the ISLT was in part so they would be able to respond to annual requests for invasive species costs from the National Invasive Species Council (NISC). In Fiscal Year (FY) 2009, the Aquatic Nuisance Species Research Program (ANSRP) at ERDC funded work to implement the Invasive Species Costs Template (cost template) (Henderson 2012a), a Web-based database whereby Corps project, District, and Division personnel, identified by the ISLT, reported the costs for invasive species for the previous fiscal year, fiscal year 2008 (FY08). A call for FY08 expenditures was executed in spring 2009.

In May, 2009, ERDC received a Congressional Research Service (CRS) inquiry for information about how much the Corps was spending on invasive species during FY09; that is, what was being spent in the ongoing timeframe, not what the Corps spent in the last Fiscal Year, the data requested for the cost template. Responding to the CRS request required the use of current budget allocations for the Corps' business lines, research, and other expenditures, and quantifying the amount that Corps costs were impacted by invasives. The President's Budget for Fiscal Year 2009 (Department of the Army (DA) 2008) provided the current budgets, supplemented by research budget numbers from ERDC. The information on the impact to the Corps' costs for Navigation, Environmental Stewardship, and other business lines had been collected as part of discussions with field personnel in preparation for the cost template. Surrogate costs (Regulatory) were identified where there were no Corps data available or an obvious way to estimate costs.

The cost estimation procedures developed to respond to the CRS request provided an approach that included all Corps activities affected by invasive species, an alternative to the cost template approach. These procedures are described in the "Methods" section. By the summer of 2009, the Fiscal Year 2010 (FY10) President's Budget (DA 2009) was available. Using the developed procedures, Corps costs for FY10 were estimated using the FY10 President's Budget. The Costs for FY09 and FY10 were presented to the ISLT in September 2009, and the costs and documentation of the procedures were reviewed by Dr. David Pimentel of Cornell (Pimentel Comments 2009). Subsequently, the cost estimation procedures have been used to estimate costs for FY11 and FY12 (DA 2010 and DA 2011). The business line and budget item costs are reported separately for FY09 (Table 2) in the section, "Results" and the Corps cost totals for FY09 to FY12 are reported in Table 3.

The NISC annual cost reporting documents the costs all Federal agencies incur in addressing the seven goals¹ of the NISC National Management Plans (NISC 2001, 2008). The ISLT had organized their activities to basically follow the NISC leadership with ISLT responsibilities for the seven goals. The cost categories in the Invasive Species Costs Template (Henderson 2012a) mirrored the goals and cost categories of the NISC. To report the Corps' costs to NISC, the business line and budget item (e.g., Research) costs were allocated to the seven cost categories of NISC. That is, the Navigation, Water Supply and other business line costs were allocated to the NISC cost categories of Prevention, Restoration, Research and so on. These Corps Cost Category submittals are in Table 4 of the "Results."

METHODS: Answering the question "What are the costs associated with invasive species?" becomes a task of tracing out the costs of all the effects of invasives. The costs resulting from complications such as increased maintenance, a decrease in power production, and a reduction of timber sales (e.g., due to damages from the Emerald Ash Borer) are difficult to separate from total costs of planning and operations; costs resulting from complications are even difficult to completely identify. An effort to estimate costs through a costs template (Henderson 2012a) similar to the Threatened and Endangered Species Costs Template (Henderson 2012b) demonstrated that direct costs (labor, materials, contracted efforts) were usually reported, but costs resulting from changes in regular maintenance actions and costs from decreased hydropower or water supply capacity will likely not be reported. This leads to a less than complete characterization of the costs and of invasives' impact.

Corps goal setting and budget formulation is organized around ten Corps business lines. The business lines are constructed so that all of the activities related to a Corps output, such as Navigation or Hydropower capacities, are contained within a single business line management structure. Such organization does help identify necessary support — for example, needed construction to support the success of operations — but the business line format complicates pulling together all sources of costs from invasive species.

Approach Used to Estimate Costs of Invasive Species for the Corps. The two components of Corps costs estimation, i.e., identifying business line costs and then allocating those costs to Prevention, Early Detection and Rapid Response, Control, Restoration, Research, Education and Public Awareness, and Leadership/International Cooperation, were accomplished in two steps for Fiscal Years 2009 – 2012.

Business Line and Budget Item Estimates: Identifying and estimating invasive species costs from the President's Budget required using five different estimate methods, depending on the availability of business line cost information and estimates concerning the impact of invasives. The calculations of these business line invasives' costs are explained in the Calculation of Costs below. In addition, the costs for two items, Research and Removal of Aquatic Growth (RAG) were taken directly from the President's Budget, and did not require calculations for their use.

Allocation of Corps Business Line Costs to NISC Cost Categories: The Corps' activities and costs reflect the NISC cost categories, which are based on the goals and objectives of the National Invasive Species Management Plans (NISC 2001 and 2008). Estimation of the business line and budget items costs (Table 2) reflect the invasive species activities funded, but not the objective, intent, or goal

¹ The NISC goals are: Prevention, Early Detection and Rapid Response, Control, Research, Restoration, Education and Public Awareness, and Leadership/International Cooperation.

of the activity. To allocate the Table 2 costs to the cost categories (Prevention, Early Detection and Rapid Response, Control, Research, Restoration, Education and Public Awareness, and Leadership/International Cooperation), judgments were made on the contribution of each business line/budget item to each of the cost categories. Discussion of the business line/budget item costs (Table 2) and contributions to the cost categories were undertaken by Mr. Jon Lane (SAJ), Dr. Linda Nelson, Manager of ANSRP (ERDC) and Mr. Jim Henderson (ERDC).

The allocation of Table 2 costs to the seven cost categories answered the question, “How should the business line/budget item costs be apportioned to each of the NISC cost categories?” This is equivalent to asking, for instance, what are Hydropower costs spent on? Research would go to the Research category, but given the myriad actions that Navigation undertakes regarding aquatic plants and invasives, how should the Navigation costs be allocated?

Consideration of all the Corps’ costs for invasives led to an allocation process that has been used to allocate the Corps’ invasives costs to the NISC Cost Categories, presented as Table 4 in the “Results.”

METHODS: CALCULATION OF COSTS

The methods used for estimating costs of the business lines and the other budget items are described below. As noted, a few direct cost data, e.g., Removal of Aquatic Growth, were available, but most cost estimates were calculated using the approaches found in Pimentel (2000 and 2004), OTA (1993), and Rockwell (2003) and applying them to the Corps’ invasive activities. The invasive costs for the different Corps activities are described below and the sources of costs or estimate calculation procedures are summarized in Table 1 below.

Table 1. Summary of cost procedures and data.		
Source of Costs or Cost Estimate	Business Line or Budget Item	Source or Procedures Followed
1. Budget Amounts Available	<ul style="list-style-type: none"> • Research • Removal of Aquatic Growth • Construction: Invasive Species • Construction: Sec 206 Aquatic Ecosystem Restoration • Construction: Sec 1135 Project Modifications for the Improvement of the Environment 	President’s Budget (2008 – 2011) FY2011 Work Plans from Continuing Resolution Authority
2. Region or District Estimate Expanded Corps-wide	<ul style="list-style-type: none"> • Water Supply and Water Quality 	Rockwell 2003
3. Expert Opinion by Corps Personnel for Increased O&M Due to Invasive Species	<ul style="list-style-type: none"> • Navigation O&M • Natural Resource Management 	Pimentel et al. 2000 and 2004
4. Other Agency Costs Applied to Corps Activities	<ul style="list-style-type: none"> • Hydropower 	O’Neill 1997
5. Related Corps Costs Applied to Invasive Species	<ul style="list-style-type: none"> • Regulatory • Planning 	Expenditures for Threatened and Endangered Species (TES) (Henderson 2012b) O&M estimates

Hydropower. These cost estimates were prepared after the Hydropower business line had responded to aquatic plant and zebra mussel infestations by revising operations procedures to ensure there was no impairment to hydropower production. Field hydropower production personnel, when answering questions about the costs of invasives, indicated that invasive species were “a nuisance but not a problem.” That is, ongoing aquatic plant treatments and installation (in the 1990s) of equipment for chlorine injection and straining for cooling water (for zebra mussels) are effective, prevention and control are ongoing parts of operations, and costs for invasives are subsumed in the total maintenance costs. The Hydropower Analysis Center, Portland District, has reiterated that the Corps has not had significant problems with quagga and zebra mussels, but the U.S. Bureau of Reclamation (USBR) has an extensive monitoring and control program in place to protect hydropower production at Hoover Dam, Lower Colorado Region, USBR. To estimate a cost for hydropower invasives, O’Neill’s (1997) survey of infrastructure facilities was used. For the period 1990 – 1995, O’Neill identified an average annual cost of \$113,407 per hydropower unit (this number was adjusted for inflation since 1995) and a total annual cost of \$674,257 for the twenty-three hydropower units surveyed. Using this cost per hydropower unit gives an annual cost of \$2,296,800.

Navigation. Aquatic vegetation and other invasives result in increased operations and maintenance costs for navigation infrastructure, locks, spillways and access points. Increased operations and maintenance costs include more frequent and extensive prevention and removal of biomass and mechanical, chemical and biological management of aquatic plants for preventing infestations. Discussions with navigation engineers on the Arkansas River revealed that operations and maintenance costs increased an estimated four to five percent¹ after the appearance of zebra mussels. This estimate is consistent with the 2005 estimate of a five percent increase in operations and maintenance costs for navigation infrastructure in the Mississippi River Valley.²

Using the five percent estimate for an increase in O&M costs due to invasives, with the FY09 costs for Inland and Coastal Navigation O&M gives an estimate of \$67,300,000 for invasives’ costs (Table 2). The RAG costs, also part of the Navigation business line, are a separate item in the President’s Budget and are considered separately here.

Environment. The Environment business line includes Aquatic Ecosystem Restoration, Environmental Stewardship, and the Formerly Used Remedial Action Plan (FUSRAP). Investigations (Planning), Construction, and Operations and Maintenance amounts are budgeted for Aquatic Ecosystem Restoration and O&M costs are budgeted for Environmental Stewardship. FUSRAP was not budgeted in the FY2009 budget (DA 2008).

Aquatic Ecosystem Restoration. Ecosystem Restoration became a Corps mission in the early 1990s after experience with smaller mitigation and conservation efforts and with larger-scale (e.g., Kissimmee River and the Everglades) restoration efforts (Henderson in preparation). Increased costs to planning and construction have resulted from the establishment of invasives in disturbed hydrologic and geomorphic conditions that are part of Corps projects. Using an estimate of five percent attributed to invasives, costs were estimated for planning studies (Investigations), Preconstruction Engineer and Design (PED), and Construction budgets for projects identified as Environmental Restoration in the FY09 budget (DA 2008).

¹ 2009. Personal Communication. Aaron McGee. Russellville Field Office, Arkansas River Project, CESWL, Russellville, AR
² 2009. Personal Communication. Al Cofrancesco. U.S. Army Engineer Research and Development Center, Vicksburg, MS

Table 2. Fiscal Year 2009 Corps cost of invasive species.	
Hydropower	\$2,296,800
Navigation O&M	\$67,300,000
Environmental Stewardship	
Pest Management	\$2,140,239
Natural Resource Management	\$4,565,400
Regulatory	\$2,030,558
Water Supply & Quality	\$65,150
Planning	\$1,280,700
Construction	
Invasive Species Construction	\$5,750,000
Addl. Barrier Chicago	\$500,000
Sec. 206 Aquatic Ecosystem Restoration	\$10,295,000
Sec. 1135 Project Mod. For Improvement of Env.	\$6,544,000
Research	\$4,490,000
Removal of Aquatic Growth	\$6,167,000
Total	\$113,424,847
ARRA 2009 (Stimulus)	\$13,326,000
Total with Stimulus	\$126,750,847

Aquatic Ecosystem Restoration: Planning and Preconstruction Engineering and Design (PED). The total funding request for Environmental Restoration Investigations is \$24,859,000 and PED is \$755,000. Five percent is \$1,242,950 and \$37,750, respectively. Adding the Investigations and PED costs gives a cost for Planning (Investigations) of \$1,280,700 (Table 2).

Aquatic Ecosystem Restoration: Construction. For Construction, the only projects identifiable as specific to invasive species are the dispersal barriers for the Chicago River Sanitary and Ship Canal. The costs are \$5,750,000 for the Dispersal Barrier and \$500,000 for the Second Barrier. Construction for restoration in the Continuing Authority Programs is \$6,544,000 for Section 1135¹ and \$10,295,000 for Section 206 projects.

Environmental Stewardship. Environmental Stewardship refers to actions that preserve and protect the integrity of Corps lands and waters and ensure the ability of the resources to provide value and produce the intended Corps outcomes. This leads to the stewardship of many natural resources (e.g., cultural resources, forest and timber contracts), and intersects with the Recreation business line in that the results of the Environmental Stewardship efforts will be a sustainable base of natural resources to support recreation opportunities. An example of this interaction (i.e., Environmental Stewardship and Recreation business lines) is the response to the Emerald Ash Borer (*Agrius planipennis*) and the associated restrictions on the importation of firewood from outside campgrounds and on the removal of potentially infested timber for commercial milling. The budget for the Environmental Stewardship business line is developed using the Environment-Stewardship Budget Evaluation System (ES-BEST) tool (Headquarters 2011a), capturing costs of maintaining the land resources; the Corps' Pest Management Program is the active management and control of noxious invertebrates, e.g., mosquitoes; and vertebrates, e.g., non-native or invasive fish, species as

¹ Section 1135 is Project Modifications for Improvement of the Environment, and Section 206 is Aquatic Ecosystem Restoration, both authorities under the Continuing Authority Program

well as noxious and invasive plants. Quarterly expenditures for Pest Management are reported in the OMBIL (Headquarters 2011b). Reported Pest Management expenditures for the first two quarters of FY2009 were used to estimate the annual Pest Management costs, estimated at \$2,140,239. For the Natural Resource Management component of Environmental Stewardship, an estimate of four to five percent was provided for the increase in costs¹ due to invasives for Corps Environmental Stewardship. Using the operations costs for all projects, FY09 Environmental Stewardship costs were \$91,308,000;² five percent is \$4,565,400, the estimated invasives cost for Environmental Stewardship (Table 2).

Regulatory. Actions taken under the Corps Regulatory Authorities (i.e., permits) require consideration of the effects of invasive species when reviewing permit applications and when inspecting sites to determine mitigation requirements. Unlike TES, documentation of permit actions that include invasives is included in the permit reporting system. Lacking available formal and informal permit consultation activities for invasives, a surrogate estimate for invasives costs is used for regulatory actions, taken from the FY08 Expenditure Reporting for the TES (Other Expenditures (primarily Regulatory)) — \$2,030,558.

Water Supply. The costs for Water Supply were expanded nationwide from an estimate for invasive treatment costs for the Southwestern Division, which has the majority of water supply contracts. Estimated nationwide costs are \$65,150. There is anecdotal evidence that additional costs for invasives prevention are borne by the water districts and municipalities buying water from the Corps.

Research. The research costs in Table 2 included \$690,000 for the Aquatic Nuisance Species Research Program, \$3,500,000 for the Aquatic Plant Control Research Program, and \$300,000 for ERDC fisheries research to support Rock Island District, for a total of \$4,490,000 for research.

Removal of Aquatic Growth (RAG). The RAG program supports navigation and is funded separately from Navigation O&M. RAG funding is for the Gulf of Mexico districts. The RAG funding is listed as a separate item for Table 2, since it is a distinct funding source.

2009 Economic Stimulus Funding. As part of the 2009 economic stimulus program of the Administration, the Corps received \$4.6 B for the civil works program (Headquarters 2009a). Of that amount, invasives projects were allocated \$8,915,000 from Operations and Maintenance activities (Headquarters 2009b) and \$4,411,000 were for Construction actions for invasives (Headquarters 2009c). The emphasis in stimulus funding was to enable private sector employment, so stimulus projects were for contracted efforts aimed at eradication, treatment, and removal of invasives (O&M) and for construction of infrastructure to restore areas after invasive infestations. In some cases, contracted efforts included invasives work along with work for TES and other natural resources efforts.

Results

Table 2 shows total costs of \$126, 750,847 for FY09 for Corps civil works activities, and Table 3 shows the total Corps costs for the years FY09 through FY12.

¹ Natural resource personnel, Wappapello Lake, MO (first identification of Emerald Ash Borer on Corps lands).

² Personal communication, Wen Chang, U.S. Army Engineer Institute for Water Resources, Alexandria, VA.

Fiscal Year	Invasive Species Costs
Fiscal Year 2009	\$126,750,847
Fiscal Year 2010	\$115,382,200
Fiscal Year 2011	\$159,210,421
Fiscal Year 2012	\$138,036,596

Using the “Methods” described above, costs were estimated for the business lines and budget items included in the Corps’ FY2009 – FY2012 budgets (DA 2008, 2009, 2010, 2011). The total costs are shown in Table 3.

Using the allocation of Corps costs to the NISC cost categories as described in the “Methods,” Table 4 shows the Corps’ costs allocated to the seven cost categories for FY09 through FY12.

	FY09	FY10	FY11	FY12
Prevention	\$15,628,980	\$14,186,768	\$22,768,255	\$23,538,108
ED&RR	\$8,529,248	\$8,850,212	\$11,870,812	\$11,229,782
Control	\$83,629,351	\$76,806,259	\$83,219,082	\$73,598,102
Research	\$4,490,000	\$6,236,000	\$6,541,232	\$1,749,600
Restoration	\$10,550,200	\$5,111,250	\$29,826,460	\$23,080,244
Ed & Public Awareness	\$2,577,068	\$2,746,711	\$3,508,579	\$3,355,460
Leadership/Int. Cooperation	\$1,346,000	\$1,445,000	\$1,476,000	\$1,485,300
TOTALS	\$126,750,847	\$115,382,200	\$159,210,421	\$138,036,596

DISCUSSION

The spread of invasive species and their effects on Corps missions and outcomes cannot be considered without recognition of the associated economic costs. As noted, Corps efforts and actions affecting invasives are developed under budget processes which can diminish — if not mask — the presence and impact of invasives. Costs for prevention and early detection are harder to identify than costs for control; though prevention and early detection could result in avoiding the need for control.

The cost-estimating procedures developed provide a tractable approach to documenting invasive costs for potential use in project and program planning and evaluation. The estimates of invasives costs serve to connect what the Corps does – outputs – with the natural resources impacted by those outputs.

As with much economic information, it is important to understand the derivation of the estimates, as documented here, and to identify where to use the estimates in the established budgetary and planning processes. As procedures to estimate costs — developed over the 2009 to 2011 period — are improved, refined and better information is received, the estimates and their use in budgetary and planning processes will improve correspondingly.

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