# 2022 Clean Watersheds Needs Survey (CWNS)

# Cost Estimation Tool Methods

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## List of Acronyms and Abbreviations

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| **A2O** | anaerobic-anoxic-aerobic method |
| **AHS** | U.S. Census Bureau's American Housing Survey |
| **BLS** | Bureau of Labor Statistics |
| **BMP** | best management practice |
| **BNR** | biological nutrient removal |
| **$BOD_5$** | biochemical oxygen demand |
| **Capdet** | CapdetWorks |
| **CBR** | Clean Water Benefits Reporting |
| **CCI** | construction cost index |
| **CEAP** | Conservation Effects Assessment Project |
| **CET** | cost estimation tool |
| **CPI** | Consumer Price Index |
| **CSO** | combined sewer overflow |
| **CWA** | Clean Water Act |
| **CWNS** | Clean Watersheds Needs Survey |
| **CWSRF** | Clean Water State Revolving Fund |
| **DEP** | data entry portal |
| **DEQ** | Department of Environmental Quality |
| **EPA** | U.S. Environmental Protection Agency |
| **EQIP** | Environmental Quality Incentives Program |
| **FIA** | Forest Inventory and Analysis |
| **ft** | foot |
| **i-DST Green** | Green Integrated Decision Support Tool |
| **i-DST Grey** | Grey Integrated Decision Support Tool |
| **I/I** | infiltration and inflow |
| **IUP** | intended use plan |
| **LID** | low impact development |
| **MDE** | Maryland Department of the Environment |
| **MG** | million gallons |
| **MGD** | million gallons per day |
| **mg/L** | milligrams per liter |
| **MPCA** | Minnesota Pollution Control Agency |
| **NASF** | National Association of State Foresters |
| **NEP** | National Estuary Program |
| **NPS** | nonpoint source |
| **NRCS** | U.S. Department of Agriculture's Natural Resources Conservation Service |

| | |
|---|---|
| **OWTS** | on-site wastewater treatment system |
| **PVC** | polyvinyl chloride |
| **RBC** | rotating biological contactor |
| **SBR** | sequencing batch reactor |
| **SCM** | stormwater control measure |
| **SPU** | Seattle Public Utilities |
| **SSA** | state-specific approach |
| **SWC** | Stormwater Calculator |
| **TMDL** | total maximum daily load |
| **USDA** | U.S. Department of Agriculture |
| **USFS** | U.S. Forest Service |
| **UV** | ultraviolet radiation |
| **WERF** | Water Environment Research Foundation |
| **WIT** | Watershed Improvement Tracking System |
| **WRF** | Water Research Foundation |
| **WWTP** | wastewater treatment plant |

# Glossary

| | |
|---|---|
| **Capital costs** | Fixed, one-time expenses incurred on the purchase of land, buildings, construction, and equipment used in the production of goods or in the rendering of services. |
| **Change type** | Term and categorization to describe one or more planned projects to be accomplished at a CWNS ID within the survey period. |
| **Cost** | Estimated dollars needed to implement one or more projects. |
| **CWNS ID** | The unique 11-digit identification number, either assigned by the Data Entry Portal or edited by the state, to identify each facility or group of related facilities. The first two digits of the code are required to be the state's two-digit Federal Information Processing Standards code. This is the basic unit of organization and identifier for the survey and is used to refer to the facility or facilities with which it is associated. |
| **Decentralized wastewater treatment infrastructure** | A system relying on natural processes and/or mechanical components to collect, treat, and disperse or reclaim wastewater from a single dwelling or building *or* a wastewater collection and treatment system under some form of common ownership that collects wastewater from two or more dwellings or buildings and conveys it to a treatment and dispersal system on a suitable site near the dwellings or buildings. For the purposes of the CWNS, decentralized systems may be on-site (individual) or clustered. Clustered systems may include multifamily septic systems or package plants. |
| **Facility** | An infrastructure asset or program that addresses a current or projected water quality problem or public health problem related to water quality. |
| **Facility type** | Describes the infrastructure purpose, stormwater regulatory category, and water-quality-related action of the infrastructure asset or program (e.g., treatment, collection, stormwater categorization, nonpoint source control measure, decentralized treatment type). |
| **Greenfield** | New stormwater development on flat terrain with minimal complicating factors, such as existing pavement, utilities, buildings, or stormwater practices. |
| **Infrastructure type** | Used to categorize groups of facility types based on pollution mitigation measures. Infrastructure types are wastewater, stormwater, nonpoint source, and decentralized treatment. |
| **Need** | Currently unfunded project(s) (or portions thereof) and associated capital costs that address a water quality problem—or a public health problem related to water quality—existing as of January 1, 2022, or expected to occur within the next 20 years. |
| **Need category** | Categorization of capital investment project types that can be funded through the Clean Water State Revolving Fund and included in the CWNS. CWNS categories generally follow the Clean Water State Revolving Fund funding categories. |
| **Needs data** | Data collected for each CWNS ID that pertain to needs. These data include documented needs, areas related to needs, and cost model inputs. |
| **Nonpoint source control infrastructure** | Infrastructure used to manage and/or treat nonpoint source pollution. |

| | |
|---|---|
| **Nonpoint source pollution** | Any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act. Nonpoint source pollution is caused when rainfall or snowmelt, moving over and through the ground, picks up and carries natural and human-made pollutants, depositing them into lakes, rivers, wetlands, coastal waters, and groundwater. |
| **Project** | A capital investment in an asset or program that addresses a water quality problem or public health problem related to water quality. |
| **Redevelopment** | Development or installation of a stormwater practice on an already developed piece of land where the removal of existing infrastructure leads to a costlier installation. For the CWNS, used to describe both redevelopments and retrofits. |
| **Retrofit** | The installation of a stormwater practice within existing development that is either currently untreated or inadequately treated by existing stormwater practices. |
| **Stormwater infrastructure** | Infrastructure used to collect, convey, treat, or infiltrate stormwater. Stormwater is rainwater or melted snow that runs off streets, lawns, and other sites. See "Stormwater infrastructure (gray)" and "Stormwater infrastructure (green)" also. |
| **Stormwater infrastructure (gray)** | Infrastructure that collects and conveys stormwater from impervious surfaces, such as roadways, parking lots, and rooftops, into a series of pipes and ultimately discharges untreated stormwater into a local water body. |
| **Stormwater infrastructure (green)** | Infrastructure that uses plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvesting and reuse, or landscaping to store, infiltrate, or evapotranspire stormwater and reduce flows to sewer systems or to surface waters. |
| **Wastewater infrastructure** | A managed system consisting of collection sewers and a treatment plant used to collect and treat wastewater from a service area. When publicly owned, such a system has been called a publicly owned treatment works, as defined at Title 40 of the *Code of Federal Regulations*, section 122.2. |

# 1. Introduction

This document contains information for state coordinators to reference when using the practice or facility cost estimation tools (CETs) developed and provided by the U.S. Environmental Protection Agency (EPA) as part of the 2022 Clean Watersheds Needs Survey (CWNS). It also outlines the background, methods, and data sources associated with each CET and provides tool inputs and equations that are accessible via the small community form or the CWNS data entry portal (DEP).

This document should be used in conjunction with the 2022 CWNS State Coordinator Manual for context on the policies and procedures of the survey and for term definitions and usage. The terms category, facility, construction type, and practice type are used throughout this document to describe the types of projects for which the tools can estimate costs.

- **Category** describes the types of capital improvement projects that can be funded through the Clean Water State Revolving Fund (CWSRF) and be included in the CWNS. CETs can be used to estimate costs for some of these project types. The categories are listed and defined in Appendix A.
- **Facility** is an infrastructure asset or program that addresses a current or projected water quality problem or water quality related public health problem.
- **Construction type** describes the type of needed capital improvement project, such as process improvement, replacement of infrastructure (“replacement”), rehabilitation of infrastructure (“rehabilitation”), installation of new infrastructure (“new”), increased level of treatment, increased capacity, or combined sewer overflow (CSO) correction.
- **Practice type** describes the type of infrastructure used to manage wastewater or stormwater quantity and/or quality. In the context of the CETs, a practice may be a passive structure, such as a detection basin for stormwater management, or a type of facility, such as a secondary mechanical wastewater treatment plant.

## 1.1 Purpose

The EPA uses the CWNS to communicate to Congress estimates for the Clean Water Act (CWA)-related needs of the nation and each state. The information collected during these surveys includes infrastructure needs (projects and their related costs) for several types of wastewater treatment and conveyance, stormwater, decentralized wastewater treatment, and nonpoint source (NPS) control infrastructure. Where possible, states submit documentation of projects and their associated costs; such documentation is generally available for most projects included in the survey, especially those for larger utilities. However, such costs are not readily available for all projects. In past surveys, to reduce burden on states and encourage full reporting of needs, the EPA allowed states to submit projects for certain facility types without documented costs if there was documentation demonstrating a need for the project. States then used CETs (previously called cost models or cost curves) to assign a cost to the needed project.

For the 2022 CWNS, the EPA developed an updated set of CETs intended to capture needs primarily related to smaller communities, which are less likely to have documentation of their infrastructure projects and associated costs than larger communities.[1,2] Available CETs include the following:

- Wastewater treatment (Categories I and II)
- Wastewater conveyance (Categories III and IV)
- CSO correction (Category V)
- Stormwater (Category VI)
- NPS control (Category VII)
- Decentralized wastewater treatment (Category XII)

Applying consistent methodology to applicable projects helps reduce response burden on states and communities while encouraging a full reporting of needs and ensuring the integrity of the data reported to Congress. The goal of these CETs is not to be overly complex or precise, but to provide a simple, transparent, and accurate way for states to estimate an average cost of typical CWSRF-eligible infrastructure based on a small list of parameters.

## 1.2 Time and Place Conversions

Where applicable, the underlying data used to develop all CETs was converted from a location-specific cost to a national average cost and updated to reflect 2022 dollars. The EPA used the RSMeans city cost index to correct for location and the Bureau of Labor Statistics (BLS) Consumer Price Index (CPI)[3] to adjust older cost data to 2022 dollars. For location correction calculations, RSMeans provides a city cost index for 657 major cities and census-designated places across the United States in terms of material, labor, and total cost factors. The EPA translated city cost factors to the ZIP code and/or county scale for use in various CETs. For CETs that use ZIP code as the location input, the EPA assigned RSMeans cost factors to ZIP codes that were within an RSMeans city or census-designated place. For ZIP codes outside of an RSMeans city, the EPA assigned the state average cost factor, calculated as the average of factors for all RSMeans cities in a given state.[4] For county-specific cost factors, such as for the decentralized wastewater treatment CET, the EPA used a similar approach and assigned cost factors to counties as the

[1] For the purpose of this cost estimating effort, needs associated with smaller communities are referred to as “smaller facilities,” as opposed to “small communities,” which are specifically defined for the CWNS and other EPA programs as communities with a population less than 10,000 people.

[2] Although CETs are targeted to smaller communities, CETs are made available to all users/facilities, regardless of size, so long as the project in question meets the criteria of CET use described in this section; mainly, that a document exists to describe the project and demonstrate its need, that the project fits within any size or capacity constraints applicable to the specific CET, and that no documentation exists for the cost of the project.

[3] The EPA also considered using the Engineering News-Record Construction Cost Index (CCI) to adjust for changing costs in the construction industry. Comparing the CCI to CPI from 1990 to 2020, the indices are nearly identical, varying by only 0.2 percent to 1.7 percent each year. Because the CPI is used in other parts of the CWNS, CPI was used for CET time adjustments.

[4] A value of 100 was assumed for states with no RSMeans city.

average of cost factors from all overlapping RSMeans cities. For counties with no overlapping RSMeans cities, the EPA assigned the state average cost factor.

In summary, the EPA used Equation 1-1 to correct costs for time and place. Throughout this document, costs are presented in January 2022 dollars.

$$\textit{Equation 1-1.}\quad Cost_{NA,2022} = \frac{LF_{NA}}{LF_{City}} \times \frac{CPI_{2022}}{CPI_{Year}} \times Cost_{City,Year}$$

Where,

$Cost_{NA,2022}$ = Project cost translated to a national average value in 2022
$LF_{NA}$ = RSMeans national average location factor (100)
$LF_{City}$ = RSMeans location factor for a specific city or ZIP code. For ZIP codes or counties without an RSMeans location factor, the EPA used the state average (values range from 69–119)
$CPI_{2022}$ = BLS CPI for 2022
$CPI_{Year}$ = BLS CPI for the year that the cost data are from
$Cost_{City,Year}$ = Cost for a given city and a given year (i.e., base cost from underlying data)

# 2. Wastewater Treatment (Categories I & II)

## 2.1 Background

In past surveys, the EPA provided wastewater treatment cost curves for a range of system types and construction types. Cost curves were made available to facilities treating flows up to 5 million gallons per day (MGD) or serving populations of up to 15,000 people. A summary of those cost curves is provided in Table 2-1.

**Table 2-1. Summary of 2004, 2008 and 2012 CWNS Wastewater Treatment (Category I & II) Cost Curves**

| Category and Construction Type | Cost Model Type | Modeling Criteria | User Inputs for Cost Modeling |
|---|---|---|---|
| Process improvement | Disinfection only | Projected design flow must not exceed 5 MGD | • Primary county<br>• Disinfection or filtration process present (yes or no)<br>• Projected residential and non-residential populations<br>• Future effluent type (e.g., secondary, advanced) |
| Replacement | Replacement of treatment plant | | • Primary county |

| Category and Construction Type | Cost Model Type | Modeling Criteria | User Inputs for Cost Modeling |
|---|---|---|---|
| Increase level of treatment | Increase level of treatment | | • Projected and present treatment type (lagoon or mechanical)<br>• Disinfection or filtration process present (yes or no)<br>• Projected residential and non-residential populations<br>• Projected effluent type (e.g., secondary, advanced)<br>• Nutrient removal (yes or no) |
| Increase capacity | Increase flow capacity and level of treatment | | • Same as replacement construction type<br>• Projected municipal design flow rate |
| New | New treatment plant | | • Primary county<br>• Projected treatment type (lagoon or mechanical)<br>• Disinfection or filtration process present (yes or no)<br>• Projected residential and non-residential populations<br>• Projected effluent type (e.g., secondary, advanced)<br>• Nutrient removal (yes or no) |

Although the EPA was able to reconstruct some of the cost curves (curves for construction type "new" from 2004 and 2012 were reconstructed, as discussed in section 2.2), there was little documentation from past surveys to describe the cost curve development process and data sources. In addition, 2012 cost curves may have been carry-overs from prior surveys. Given the age of the data and the incomplete documentation, the EPA used these past cost curves as guides for 2022 CWNS CET development but not directly as data sources.

## 2.2 CET Development

The EPA developed wastewater treatment plant (WWTP) cost estimation tools using multiple approaches depending on construction type and data availability. For "new" or "replacement" construction types, the EPA primarily used Hydromantis CapdetWorks™ (Capdet), a model that performs planning-level design and cost estimation of wastewater treatment construction projects (Hydromantis, 2014), to estimate construction costs for broad categories of WWTPs. For the remaining construction types ("rehabilitation," "system expansion," "treatment upgrade," and "add disinfection"), the EPA reviewed similar cost models, including Missouri's Cost Analysis for Compliance (CAFCom) tool[5] and the Grey Integrated Decision Support Tool (i-DST Grey).[6] The EPA also compiled project cost data from several sources, including peer-reviewed literature, state intended use plans (IUPs), and documented costs from the 2022 CWNS. For state IUPs, the EPA generally reviewed 2019 and 2020 data from all states where sufficiently detailed data were available. In this case, "sufficiently detailed" means that the EPA could determine the following basic system attributes:

- System type (lagoon, aerated lagoon, secondary mechanical, advanced)
- System capacity (MGD)
- Construction type (new, replace, rehabilitation, system expansion, treatment upgrade, add disinfection)
- Location (city)
- Cost year

The EPA collected project cost data from the 2022 CWNS using similar criteria, though limited suitable data were identified because states were not required to, and thus typically did not, report the project attributes necessary for incorporation into CET equations. All costs were adjusted to a 2022 national average using Equation 1-1.

Supporting data can be found in Appendix B.

### 2.2.1 New and Replacement

For "new" or "replacement" construction types, the EPA used Capdet to develop cost curves for the major system types (lagoon, aerated lagoon, secondary mechanical, and advanced) by modeling systems at average capacities of less than 5 MGD[7] and generating a linear regression equation for the costs of each system type. The EPA used the default Capdet inputs to create the curves, including a maximum capacity of 2.5 times the average capacity and average influent wastewater composition from Metcalf and Eddy et al. (2014).

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[5] The Missouri Department of Natural Resources developed the CAFCom tool to estimate the potential cost for publicly owned treatment works to comply with new requirements in a permit. CAFCom is based on Capdet, but uses inputs targeted toward and validated with common wastewater treatment systems in Missouri.

[6] The Integrated Decision Support Tool is a cost estimate decision support tool for planners implementing gray, green, and hybrid stormwater control measures (SCMs). The Gray Infrastructure Module, a component of the tool, is based on a statistical survey of project costs from numerous literature sources to develop cost curves for a range of green and gray combined sewage management unit processes. As the EPA only has access to the user interface of i-DST Grey, and not the underlying data or curve equations, this document uses i-DST Grey for comparison purposes only. The Green module, which the EPA uses in section 5, is for other SCMs and is based on a standard construction line-item cost estimation approach.

[7] Models for the previous surveys were limited to plants with capacity up to 5 MGD; this condition was set in 2008 based on the sizes of the facilities that used cost curves in the 2004 survey and was grandfathered into the 2012 survey. This capacity limit is being retained for the current models for "new" or "replacement" construction types because new plants above 5 MGD are likely to have documented costs. Additionally, there are relatively few large new plants being built.

Because secondary and advanced system types can cover a broad range of treatment processes, the EPA modeled multiple subtypes of these major system types. Final cost curves were based on the average cost of system subtypes. This grouping reduced the level of detail required of the user and captured major cost differences between major system types. Major system types, subtypes, and unit process compositions are provided in Table 2-2.

### Table 2-2. Description of Capdet Models Used to Generate Cost Curves for "New" or "Replacement" Category I and II WWTPs

| Major System Type | System Subtype | Unit Processes Included | | | | | |
|---|---|---|---|---|---|---|---|
| | | Screening and Grit Removal | Primary | Secondary / Biological | Disinfection | Sludge Process[a] | Extra |
| Lagoon | | X | | | X | | |
| Aerated lagoon | | X | | | X | | |
| Secondary mechanical | Trickling filter | X | X | X | X | X | |
| | RBC[b] | X | X | X | X | X | |
| | Oxidation ditch | X | X | X | X | X | |
| | Complete mix | X | X | X | X | X | |
| | Plug flow | X | X | X | X | X | |
| | Step aeration | X | X | X | X | X | |
| | Extended aeration | X | X | X | X | X | |
| | High rate | X | X | X | X | X | |
| | Pure oxygen | X | X | X | X | X | |
| | Contact stabilization | X | X | X | X | X | |
| Advanced | SBR[c] | X | | X | X | X | Equalization tank |
| | BNR[d] 3 stage (A2O[e]) | X | X | X | X | X | |
| | BNR 5 stage (modified Bardenpho) | X | X | X | X | X | |

a Gravity thickener, aerobic reactor, belt filter press, landfill
b Rotating Biological Contactor
c Sequencing Batch Reactor
d Biological Nutrient Removal
e Anaerobic/anoxic/oxic

The EPA also compared the Capdet outputs to previous CWNS cost curves (2004 and 2012, adjusted to 2022 dollars using Equation 1-1), as well as project cost data from state IUPs and the 2022 CWNS. Cost data comparisons are illustrated in Figure 2-1.

Capdet curves for lagoons and aerated lagoons estimate higher costs than the only other points of comparison—a cost curve from the 2012 CWNS and a single project cost. Unfortunately, no documentation is available describing the 2012 lagoon cost curve methodology, making it difficult to explain the difference between the curves. Compared to secondary mechanical cost curves, lagoon and aerated lagoon capital costs are less expensive per MGD treated at a smaller size (i.e., less than 1 MGD).

At larger sizes, the cost of the lagoon approaches that of secondary mechanical, while the aerated lagoon exceeds the cost of secondary mechanical, mainly due to the cost of blowers. Based on project data collected for other construction types (see Figure 2-2[a]), lagoons larger than 2 MGD do not appear to be common.

Capdet curves for secondary mechanical also estimate greater costs than the 2004 and 2012 cost curves but are in closer agreement than the lagoon curves. The percent difference between Capdet and 2004/2012 curves is more pronounced for smaller systems, with Capdet potentially overestimating costs at smaller scales (i.e., less than 1 MGD). Because of the multiple project-level data points available at these smaller scales, the EPA split the secondary mechanical curve into two parts, with costs less than or equal to 0.6 MGD based on a regression of project cost data and costs greater than 0.6 MGD based on Capdet. The capacity associated with the split was based on the intersection of each individual curve, rounded to the nearest 0.1 MGD.

Capdet curves for advanced are in closest agreement with all major system types, but still deviate most at smaller scales (i.e., less than 1 MGD). Therefore, a similar two-part equation was composed for "new" and "replacement" advanced systems, with a split at 1.1 MGD.

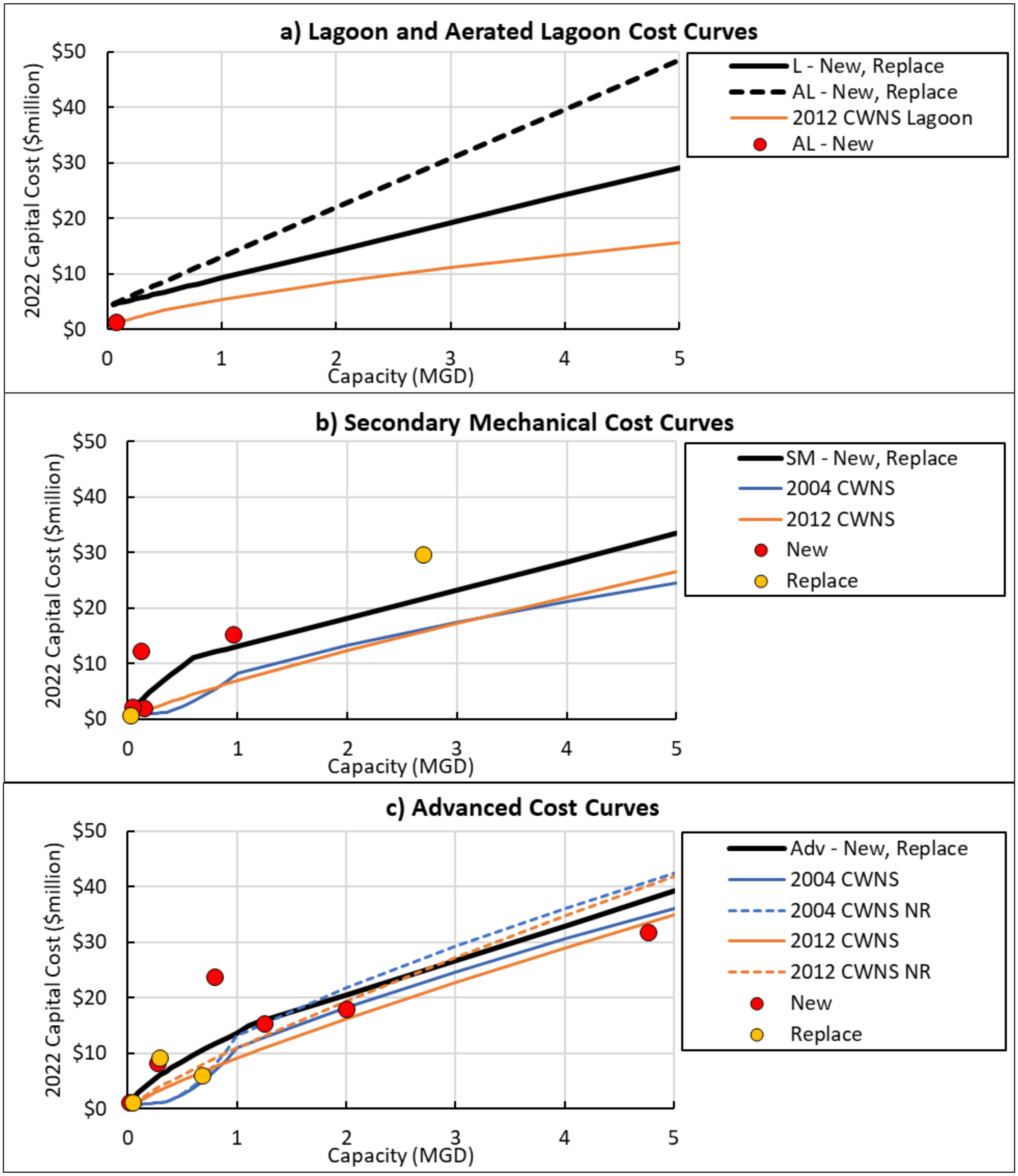


**Figure 2-1. Summary of "new" or "replacement" cost curves and project data for a) lagoon (L) and aerated lagoon (AL), b) secondary mechanical (SM), and c) advanced (Adv) treatment systems. NR= nutrient removal. Point data ("new" or "replacement") are from state IUPs or documented cost data from the 2022 CWNS. Final cost curves are shown in black lines and correspond to equations in Table 2-3.**

### 2.2.2 Rehabilitation, System Expansion, Treatment Upgrade

To develop cost curves for the “rehabilitation,” “system expansion,” and “treatment upgrade” construction types, the EPA relied on project cost data from state IUPs and documented costs from the 2022 CWNS, shown in Figure 2-2. Cost curve equations were determined by using the equation type (e.g., linear, logarithmic, power) that resulted in the highest R-squared value for a given group of data. The x-axis curve extents represent the range of project cost data that specific CET curves are based on. These ranges also correspond to the range of applicability for the specific practice type cost curve (Table 2-3).

Given the limited data available for lagoon and aerated lagoon construction types, all data were grouped by system type and used to generate “general rehabilitation” curves, which apply to all construction types. Due to limited available data for these system types, particularly for capacities greater than 0.5 MGD, a maximum capacity of 2.1 MGD was applied for all construction types.

For secondary mechanical systems, “system expansion” and “treatment upgrade” construction type costs appeared distinctly different from “rehabilitation,” and there were insufficient data available to distinguish between the first two types. Therefore, the EPA generated a single curve for both “system expansion” and “treatment upgrade” costs. For advanced systems, the EPA collected sufficient and distinct data for each construction type, and therefore generated three unique curves.

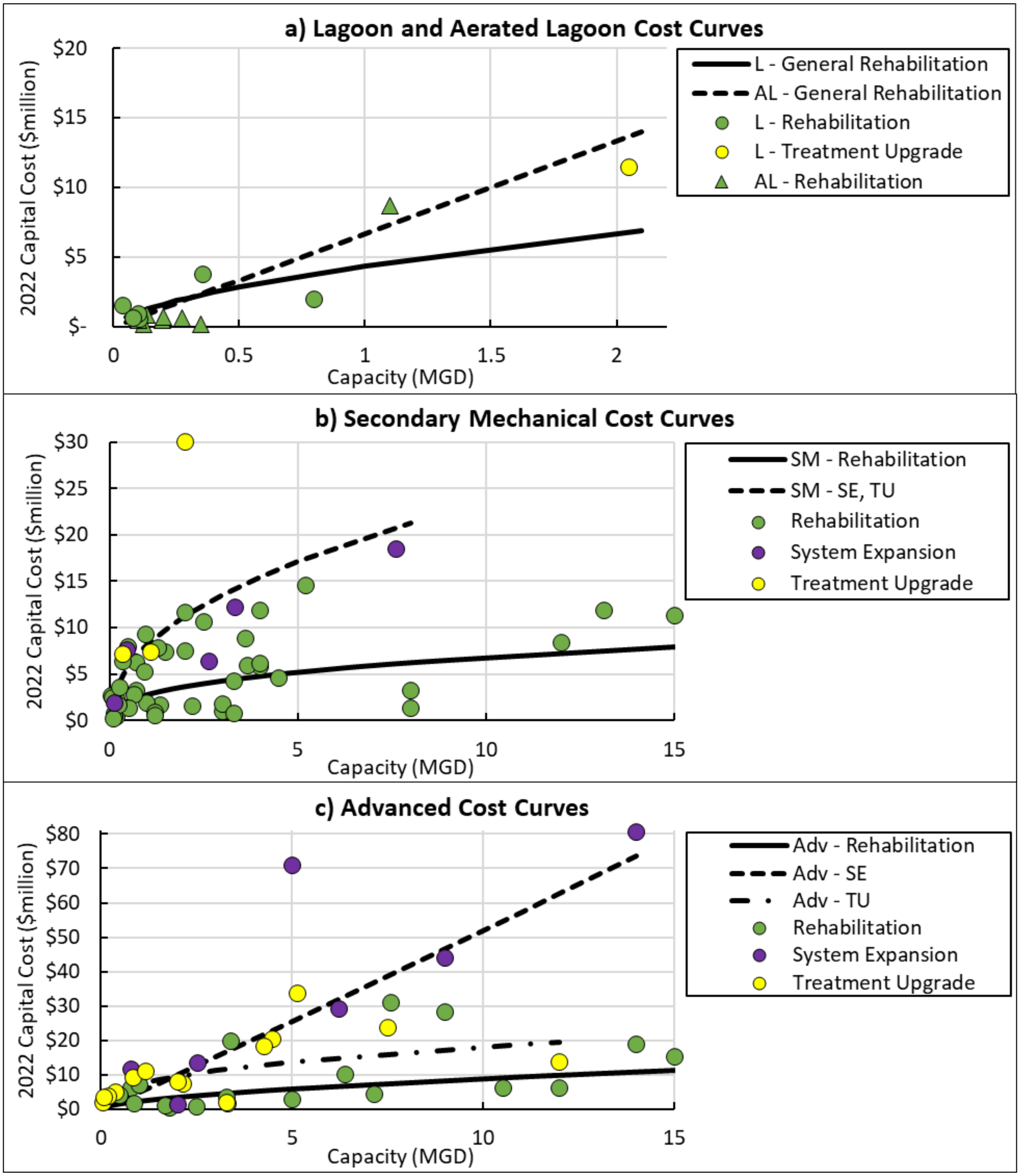


**Figure 2-2. Summary of "rehabilitation," "system expansion" (SE) and "treatment upgrade" (TU) project data and cost curves for a) lagoon (L) and aerated lagoon (AL), b) secondary mechanical (SM), and c) advanced treatment systems (Adv). Point data are from state IUPs or documented cost data from the 2022 CWNS. Final cost curves are shown in black lines and correspond to equations in Table 2-3.**

### 2.2.3 Add Disinfection

For the "add disinfection" construction type, the EPA compared cost estimates from Capdet, CAFCom, i-DST Grey, peer-reviewed literature, state IUPs, and documented costs from the 2022 CWNS (Figure 2-3). The EPA also compared these data to the single curve made available in 2012 for disinfection, though disinfection type—chlorine or ultraviolet radiation (UV)—was not specified in 2012. These costs represent only the costs of new disinfection unit processes.

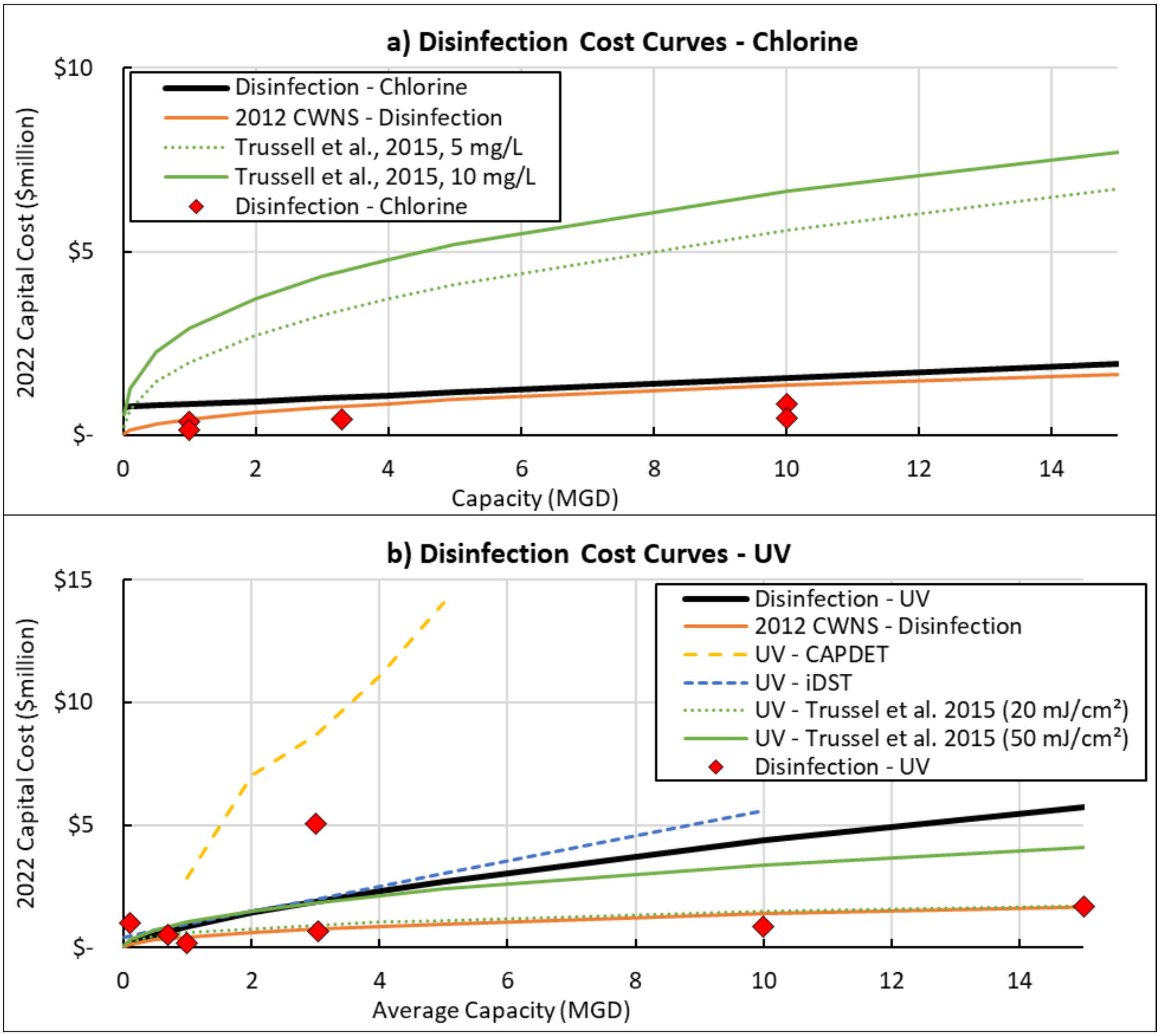


**Figure 2-3. Summary of "add disinfection" cost curves and project data for a) chlorine and b) UV. Final cost curves are shown as black lines and correspond to equations in Table 2-3.**

As expected, cost curve and project data suggest chlorine disinfection systems are generally less expensive than UV systems. The EPA based the chlorine disinfection curve on Capdet, as this model provided an intermediate and conservative cost estimate compared to the other models and project cost data available for comparison. The Capdet model is slightly higher than the 2012 disinfection curve and the five chlorine projects identified, but lower than planning-level cost models Trussell et al. (2015)

developed to support potable reuse treatment train design. Trussell et al. provide cost models for chlorine doses of 1 to 25 milligrams per liter (mg/L), but only 5 and 10 mg/L dosage models are shown here as these are more reflective of dosages commonly found at secondary and tertiary WWTPs (Great Lakes–Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers, 2014).

For UV systems, cost models and project data are also wide-ranging. The Capdet UV model is the highest, likely owing to default model inputs that assume relatively poor effluent water quality and corresponding high bulb quantities and/or wattage requirements. The planning level cost models from Trussell et al. (2015) for dosages typical of secondary and tertiary WWTPs (Health Research Inc., 2014) are at the lower end of the data range, possibly for opposite reasons; effluent produced for potable reuse is highly treated, with potentially lower bulb quantities and/or wattage requirements. The i-DST Grey UV model and CAFCom provide intermediate cost estimates. CAFCom is the model the EPA ultimately selected for UV disinfection due to the intermediate cost estimates and because it has been validated against actual project cost estimates in Missouri.

The few data points for larger systems, including an undefined (i.e., not confirmed to be chlorine versus UV) 22 MGD disinfection project, suggest that the i-DST Grey and Capdet cost curves may not be suitable for larger system sizes if extrapolated beyond 5 MGD. At a smaller scale (i.e., less than 5 MGD), the i-DST Grey curves capture most UV and undefined disinfection project costs.

### 2.2.4 Cost Curve Equations

Cost curves for each major system type/construction type combination associated with wastewater treatment are provided in Table 2-3. The EPA designed these equations to produce a national average cost in 2022 dollars based on system capacity (in MGD). Equation type (e.g., linear, power, logarithmic) is dictated by the underlying data; the EPA selected the type that produced the highest coefficient of determination and provided the most reasonable representation of observed trends.

### Table 2-3. Wastewater Treatment Cost Curve Equations by System and Construction Type

| Construction Type | Base Curve Equation | $r^2$ | Limit[a] (MGD) | Base Curve Equation Source |
|---|---|---|---|---|
| ***Lagoon*** | | | | |
| New or replacement | $4,978,405 \times C + 4,259,108$ | NA | 5 | Capdet—lagoon |
| Rehabilitation, system expansion, treatment upgrade | $4,334,434 \times C^{0.619}$ | 0.83 | 2.1 | PCD—rehabilitation, system expansion, treatment upgrade |
| ***Aerated Lagoon*** | | | | |
| New or replace | $8,871,326 \times C + 4,184,999$ | NA | 5 | Capdet—aerated lagoon |
| Rehabilitation, system expansion, treatment upgrade | $6,663,409 \times C$ | 0.87 | 2.1 | PCD—rehabilitation, system expansion, treatment upgrade |
| ***Secondary Mechanical*** | | | | |
| New or replacement, ≤0.6 MGD | $16,221,460 \times C^{0.749}$ | 0.89 | 5 | PCD—new, replace |
| New or replacement, >0.6 MGD | $5,062,323 \times C + 8,081,189$ | NA | 5 | Capdet—secondary mechanical |
| Rehabilitation | $2,824,125 \times C^{0.383}$ | 0.26 | 15 | PCD—rehabilitation |
| System expansion, treatment upgrade | $8,177,714 \times C^{0.459}$ | 0.29 | 8 | PCD—system expansion, treatment upgrade |
| ***Advanced*** | | | | |
| New or replacement, ≤1.1 MGD | $13,657,111 \times C^{0.678}$ | 0.79 | 5 | PCD—new, replace |
| New or replacement, >1.1 MGD | $6,193,944 \times C+8,141,130$ | NA | 5 | Capdet—advanced |
| Rehabilitation | $2,202,081 \times C^{0.605}$ | 0.28 | 15 | PCD—rehabilitation |
| System expansion | $4,854,422 \times C^{1.03}$ | 0.65 | 14 | PCD—system expansion |
| Treatment upgrade | $7,161,849 \times C^{0.400}$ | 0.47 | 12 | PCD—treatment upgrade |
| ***Add Disinfection*** | | | | |
| Add disinfection—UV | $870,933 \times C^{0.699}$ | NA | 30 | CAFCom |
| Add disinfection—chlorine | $78,178 \times C + 766,233$ | NA | 30 | Capdet |

[a] Cost curve limits are based on largest value of underlying project data or range of applicability for underlying model.

*C* = capacity in MGD; NA = not applicable; PCD = project cost data, including state IUPs, 2022 CWNS documented costs, and peer-reviewed literature.

## 2.3 Wastewater Treatment CET

The CETs for Categories I and II are based on the available data for the system type/construction type combinations presented in section 2.2. User inputs include major system type, construction type, and capacity. The DEP automatically adjusts the CET output for location using RSMeans location cost factors. CETs are only available for system capacities that are within the limits shown in Table 2-3.

The final equation used to calculate practice cost is as follows:

*Equation 2-1.* $$Cost = CPI \times LF_{ZIP\ Code} \times\ Base\ Cost\ Curve$$

Where,

*Cost* = total estimated capital cost
*CPI* = inflation adjustment based on BLS CPI
$LF_{ZIP\ Code}$ = ZIP code location factor (RSMeans, see section 1.2)
Base cost curve = from Table 2-3

# 3. Wastewater Conveyance (Categories III & IV)

## 3.1 Background

In past surveys, the EPA provided wastewater conveyance cost curves for Category III (conveyance system repairs) and Category IV (new conveyance systems) as a function of population served. These cost curves assumed that conveyance needs could be predicted based on the population served by a sewer system, accounting for a typical rate at which that conveyance system needed to be repaired, replaced, or constructed. The EPA provided Equation 3-1, which small communities could use to estimate this population:[8]

*Equation 3-1.* $$Population\ =\ (0.042) \times (Feet\ of\ Pipe) \times (\%\ Replacement\ or\ \%\ Rehabilitation)$$

Table 3-1 summarizes the conveyance cost curves provided in the past three surveys. Similar to wastewater treatment (Categories I and II), use of this cost curve was limited to facilities serving 15,000 persons or fewer. The EPA imposed this limit in 2008 to reduce the variability of cost estimates that were based only on population.

[8] From page 8-18 of the 2012 CWNS User Manual.

**Table 3-1. Summary of CWNS Wastewater Conveyance (Category III and IV) Cost Curves from Past Surveys**

| Category and Construction Type | Cost Model Type | CWNS Years | Modeling Criteria | User Inputs for Cost Modeling |
|---|---|---|---|---|
| Expansion | New/expand separate sewers—collector or interceptor | 2004<br>2008<br>2012 | Present population must not exceed 15,000 | Present and projected residential and non-residential population receiving collection |
| Rehabilitation or replacement | Separate sewer system rehabilitation/replacement | 2008<br>2012 | | |
| New | New/expand separate sewers—collector or interceptor | 2004<br>2008<br>2012 | | |

## 3.2 CET Development

### 3.2.1 Data Sources

For the 2022 CWNS, the EPA reviewed past cost curves and solicited feedback from states on the utility of population-based conveyance cost curves. Generally, all parties agreed that population is not the best predictor of conveyance needs. The amount of pipe serving a given community—particularly the portion requiring repair or replacement—depends on a multitude of factors, including population density, topography, age of the sewer system, and community growth rate.

Therefore, the EPA investigated other information sources to help estimate the cost of conveyance system installation, repair, or replacement. The EPA considered cost models such as Capdet and the Water Research Foundation's (WRF's) *Performance and Costs of Decentralized Unit Processes* (WERF, 2010),[9] i-DST Gray, unit costs from RSMeans, and typical project costs from state IUPs. While Capdet and WRF unit costs would likely provide a more precise estimation of project component costs, they would require users to input detailed specifications (e.g., pipe size, pipe material, construction method, design costs) that the EPA does not expect to be available. Rather, the EPA expects that CET users have minimal project details, with just a general idea of the overall size or scope of the project.

Given the general requirement that CETs should be easy to use with inputs that states or communities would have reasonable access to, the EPA decided to limit the required inputs and base the conveyance CET on IUP project costs for the following reasons:

- IUPs include project descriptions and costs of projects that have been submitted to state CWSRF programs; these are the same types of projects that the CWNS is designed to capture.

[9] The spreadsheet tool that accompanies the WRF's Performance and Costs of Decentralized Unit Processes provides estimated costs for a range of conveyance components, including pipe (as a function of length), material, and diameter. The spreadsheet is available for WRF members only.

- IUPs generally provide project descriptions that include important factors such as pipe length, pipe material, and project type (e.g., repair, replace).
- IUP project descriptions are a good indication of the level of detail that states and communities have access to in the planning stages of infrastructure projects.

Supporting project cost data can be found in Appendix C.

### 3.2.2 Use of Project Data in Cost Curves

To develop cost curves, the EPA compiled project cost data from 2019 and 2020 state IUPs and documented costs states submitted for the 2022 CWNS for Category III and IV projects (Appendix C). Project data include the following primary attributes:

- Need category (III or IV)
- Need subcategory (A or B)
- Pipe length (feet)
- Pump station quantity and capacity (in MGD, if applicable)
- Location (city)
- Cost year

EPA also collected the following secondary attributes, where possible, to evaluate whether more detailed cost curves could be developed (or if these attributes had a measurable effect on project costs):

- Sewer type (e.g., collector, force main, interceptor, lateral)
- Pipe material (e.g., polyvinyl chloride [PVC], concrete, cast iron)
- Pipe diameter (inches)
- Construction method (e.g., open cut, pipe bursting, cured-in-place)
- Presence or absence of appurtenances (e.g., manholes, inlets, valves)
- Number of grinder pumps
- Pump station type (e.g., vacuum, grinder, pressure)

The EPA used the RSMeans city cost index to translate location-specific costs into national averages, and used the BLS CPI to adjust older cost data to 2022 dollars using Equation 1-1.

### 3.2.3 Cost Curve Development—Category III

Prior to the 2022 CWNS, the EPA developed draft cost curves from 59 costs sourced from state IUPs, including 31 Category III-A projects and 28 Category III-B projects. The EPA used this preliminary dataset to develop a general costing approach by reviewing the primary and secondary attributes listed in section 3.2.2 to determine whether these attributes predicted project cost. Ultimately, secondary attributes were reported too inconsistently to provide any reliable predictive power.

Of the primary attributes collected, total pipe length was the most important variable for Category III projects. Additionally, curves fit through Category III-A data and Category III-B data were very similar (Figure 3-1). Given the similarity between Category III-A and III-B regressions, the EPA used a single cost curve for these categories within the conveyance CET.

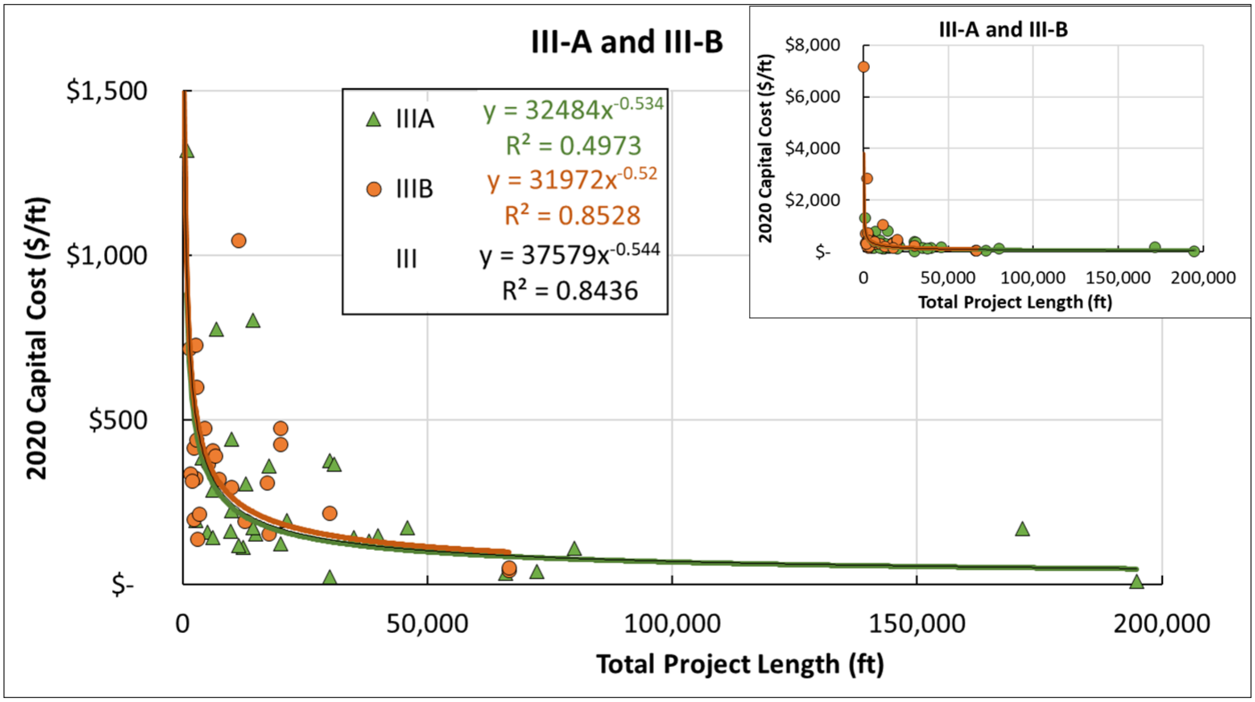


**Figure 3-1. Summary of initial Category III project costs plotted as cost per foot of pipe as a function of total pipe length. Data were collected prior to the 2022 CWNS from state IUPs and used to develop the draft Category III cost curve equation. Inset in upper right corner shows two projects ($2,826 per foot of pipe and $7,168 per foot of pipe) that are off the y-axis in the main plot.**

During the 2022 CWNS, the EPA collected an additional 13 III-A project costs and six III-B project costs. After removing an outlier (the $7,168/ft project in Figure 3-1), the total number of data points increased to 76. In general, these new project costs were slightly lower and more variable, causing estimated costs and the $r^2$ values of all curves to decrease (Figure 3-2). Although these new data also caused the III-A and III-B curves to diverge compared to the draft curves (Figure 3-1), the EPA decided to continue to use a single curve to represent Category III costs. First, the new data lead to greater variability (lower $r^2$) and therefore lower confidence in the individual curves. Second, although state coordinators designated individual project costs as either III-A or III-B, supporting documentation was often insufficient to confirm the exact nature of the rehabilitation project and the EPA did not confirm the subcategory during the review process.

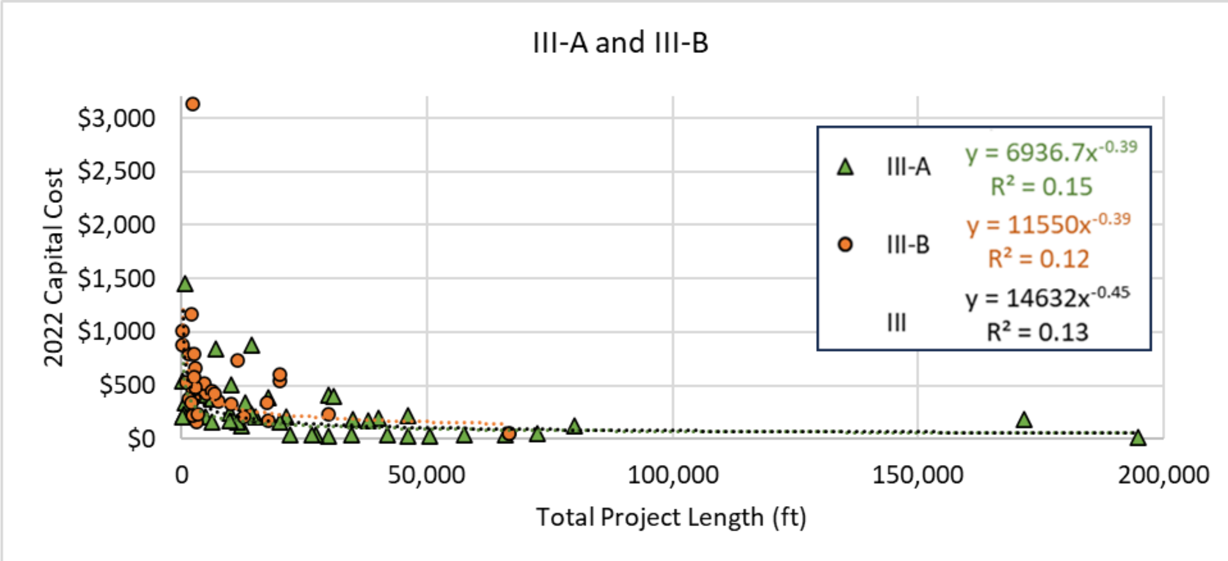


**Figure 3-2. Summary of all Category III project costs plotted as cost per foot of pipe as a function of total pipe length. Data include project costs from state IUPs and documented costs collected during the 2022 CWNS.**

### 3.2.4 Cost Curve Development—Category IV

The EPA compiled data from state IUPs and the 2022 CWNS for a total of 45 Category IV projects—37 Category IV-A and eight Category IV-B. Again, pipe length was determined to be the strongest predictor of project cost. Secondary attributes had little predictive power, with the exception of pump station presence.

For Category IV, pump stations were a common and significant component of overall project costs. Because there were insufficient data from IUPs to isolate the cost of pump stations, the EPA used the i-DST Grey[10] model to correct for pump station costs when developing the cost curve equation. The i-DST Grey model uses pump station capacity and quantity as inputs to a linear regression model (Equation 3-2). The EPA used this equation to subtract pump station costs from total project costs, then used the modified project cost data to generate the cost curve for the piping components of the project (discussed further in section 3.2.5).

$$\textit{Equation 3-2.}\quad Cost_{Pump\ Station} = n \times 423{,}184 \times C + 499{,}364$$

Where,

$Cost_{Pump\ Station}$ = total capital cost of a pump station in 2022 dollars
$n$ = number of pump stations
$C$ = pump station capacity, in MGD

Project costs for new interceptor systems (Category IV-B) were far more limited than those for new collector systems and appurtenances (Category IV-A), which is reasonable as interceptors tend to be larger and less common. However, given how few data points were available, the resultant IV-B model

[10] See footnote 6 in section 2 for an overview of the i-DST Grey model.

was not robust (see Figure 3-3). Whether the lack of correlation is due to the small number of projects or other reasons is hard to tell given the size of the dataset. Therefore, the EPA included both IV-A and IV-B projects in a single Category IV CET. This combined cost curve, which does not include pump station costs, is illustrated in Figure 3-4. Cost curve equations are provided in section 3.2.5.

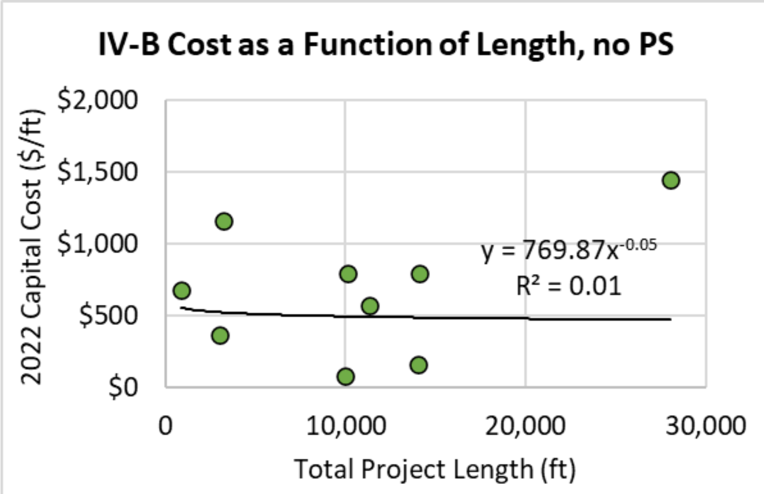


**Figure 3-3. Category IV-B cost per length as a function of total project length, where project cost reflects total project cost minus the estimated cost of the pump stations (PS).**

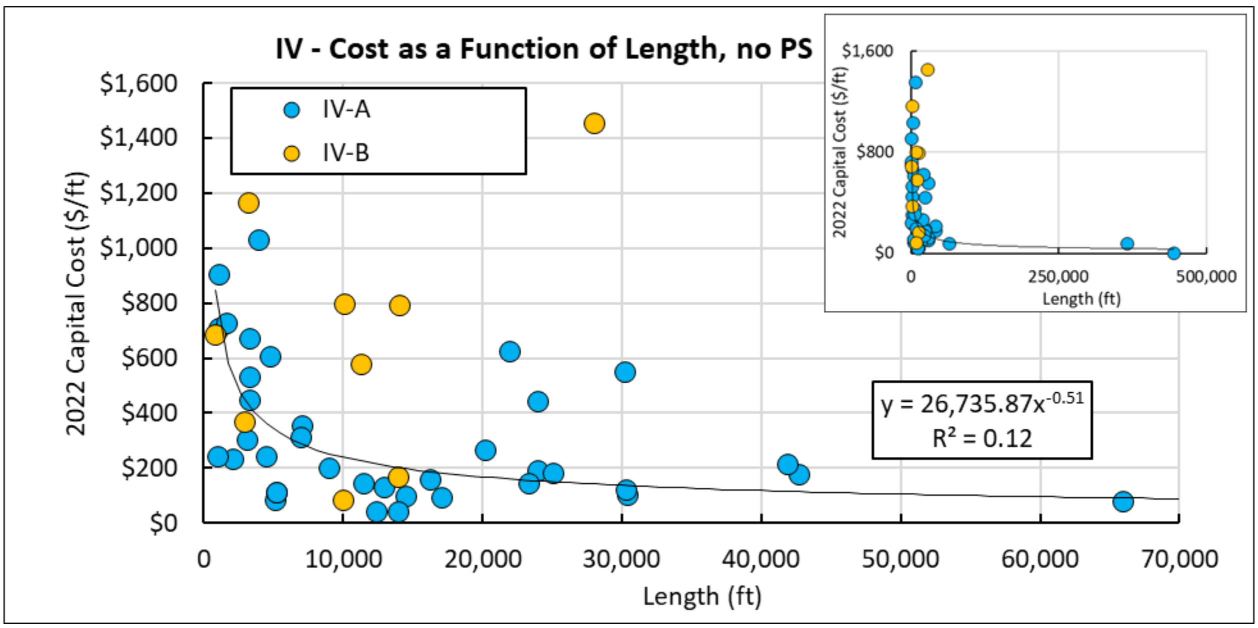


**Figure 3-4. Category IV cost per length as a function of total project length, where project cost reflects total project cost minus the estimated cost of pump stations (PS). Inset in upper right corner shows the full range of projects, which include two larger projects with total lengths of 367,000 and 445,000 feet of pipe.**

### 3.2.5 Initial Cost Curve Equations

Initial cost curve equations for Category III and IV projects are provided in

Table 3-2. For Category III projects, the EPA estimates total project cost as a function of total pipe length. For Category IV projects, the EPA estimates total project cost as the sum of pump stations and all other costs, where all other costs are a function of total pipe length.

**Table 3-2. Wastewater Treatment Cost Curve Equations by System and Construction Type**

| Category | Component | Base Curve Equation | $r^2$ | Limit[a] | Base Curve Equation Source |
|---|---|---|---|---|---|
| III | Total project | $L \times 14{,}632 \times L^{-0.45}$ | 0.14 | 195,000 ft | PCD III-A and III-B |
| IV | Pump stations | $n \times (423{,}184 \times C + 499{,}364)$ | NA | 10 MGD | i-DST Grey |
| IV | Total project without pump stations | $L \times 26{,}736 \times L^{-0.51}$ | 0.12 | 450,000 ft | PCD IV-A and IV-B |

[a] Cost curve limits based on largest value of underlying project data or range of applicability for underlying model.

*C* = capacity in MGD; *L* = total project length in feet; PCD = project cost data, including state IUPs and documented costs from 2022 CWNS; *n* = number of pump stations.

## 3.3 Wastewater Conveyance CET

The wastewater conveyance CET is based on user selections for need category, subcategory, total project pipe length, the total number of projects, and capacity of pump stations for Category IV projects. The DEP automatically adjusts the CET output for location using RSMeans location cost factors. CETs (

Table 3-2) are available for projects with total pipe lengths of less than 195,000 feet for Category III and less than 450,000 feet for Category IV, and pump stations smaller than 10 MGD.[11]

The final equations used to calculate practice cost are as follows.

$$\textit{Equation 3-3.}\quad Cost_{III} = CPI \times LF_{ZIP\ Code} \times L \times 14{,}632L^{-0.45}$$

$$\textit{Equation 3-4.}\quad Cost_{IV,Pipe} = CPI \times LF_{ZIP\ Code} \times L \times 26{,}736L^{-0.51}$$

$$\textit{Equation 3-5.}\quad Cost_{IV,Pump} = CPI \times LF_{ZIP\ Code} \times n \times (423{,}184C + 499{,}364)$$

Where,

$Cost_{III}$ = total estimated capital cost of Category III projects
$Cost_{IV,Pipe}$ = total estimated capital cost of pipe portion of Category IV projects
$Cost_{IV,Pump}$ = total estimated capital cost of pump station portion of Category IV projects, as applicable

[11] Although the i-DST Grey cost model is applicable to larger pump stations, the EPA expects facilities that have projects for new pump stations larger than 10 MGD will have cost documentation for those projects.

*L* = total length of all piping included in the project (ft)
*n* = number of pump stations
*C* = capacity of pump stations (MGD)
*CPI* = inflation adjustment based on BLS CPI
$LF_{ZIP\ Code}$ = ZIP code location factor (RSMeans, see section 1.2)

# 4. CSO Correction (Category V)

## 4.1 Background

In 2004 and 2008, the EPA provided CSO cost models where cost was calculated primarily as a function of population served. After the 2008 survey, states voiced concerns that the CSO cost curves produced estimates that were excessively high and based on outdated datasets. Therefore, the 2012 survey did not provide cost models to estimate costs for CSO Correction (Category V). The EPA expects that most CSO communities have long-term control plans that document projects and costs, making CSO modeling unnecessary. Additionally, many of the practices CSO communities might use to reduce wet-weather flows may be captured by the stormwater CET (section 5). Still, the EPA developed a CSO CET for storage facilities to provide some assistance to CSO communities. These are common, relatively simple practices that can be implemented throughout a sewershed or at a WWTP to reduce wet-weather peak flows and mitigate overflows. This section only discusses the CSO CET for storage facilities, but both the CSO CET and Stormwater CET (section 5) are available in the DEP for Category V needs.

## 4.2 CET Development

### 4.2.1 Data Sources

To generate a cost curve for a wet-weather storage facility, the EPA evaluated peer-reviewed and gray literature for project costs expressed as a function of storage volume (Appendix D). In addition, i-DST Grey[12] provides a cost curve for CSO storage basins, which the EPA used as an additional point of comparison. As shown in Figure 4-1, the project costs curve and the i-DST Grey cost curve are similar, which supports the development of a storage cost curve from the project cost data obtained by the EPA.

[12] See Footnote 6 for a description of i-DST Grey Model.

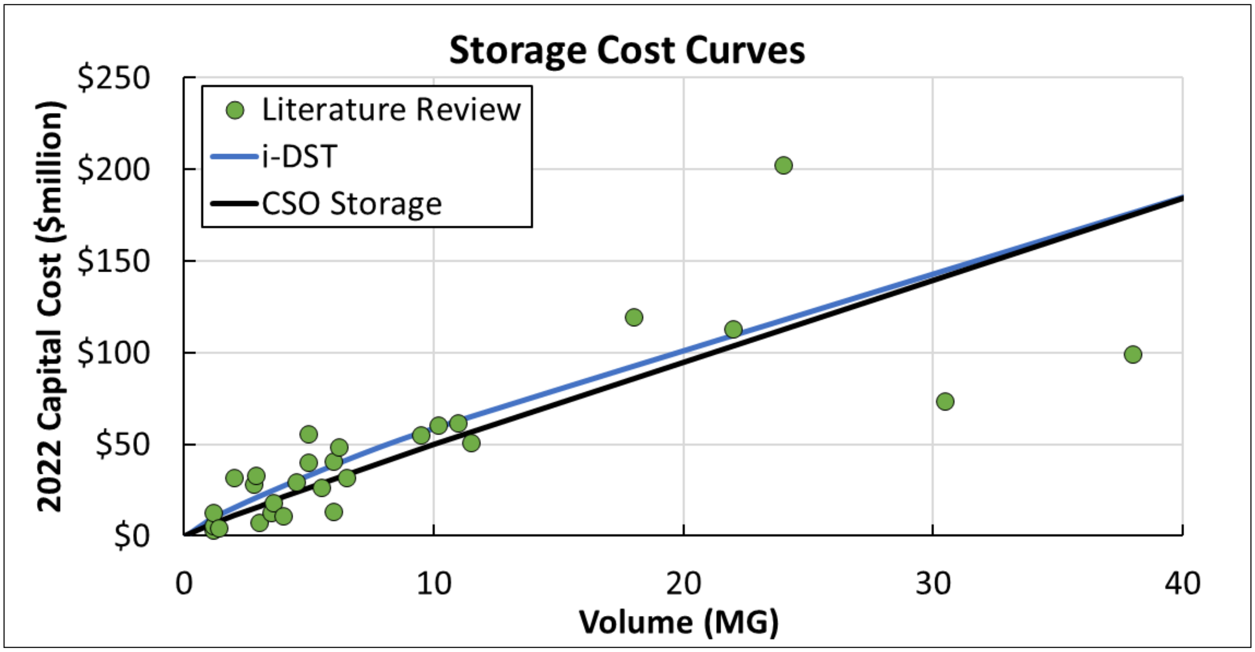


**Figure 4-1. Summary of storage project cost data from general literature review compared to i-DST Grey cost curve for CSO storage basin.**

### 4.2.2 Initial Cost Curve Equation

The initial cost curve equation for Category V is provided in Table 4-1, which calculates project cost as a function of storage volume, in million gallons (MG).

**Table 4-1. CSO Cost Curve Equation for Storage Basin**

| Category | Component | Base Curve Equation | $r^2$ | Limit (MG) | Base Curve Equation Source |
|---|---|---|---|---|---|
| V | Total project | $5{,}818{,}000 \times S^{0.94}$ | 0.61 | 38 | Literature review |

*S* = storage volume in MG

## 4.3 CSO CET

The CSO CET is based on user selections for system volume in MG. The CET automatically adjusts the CET output for location using RSMeans location cost factors. The cost curve is only available for project volumes that are less than 38 MG (Table 4-1).

The final equation used to calculate practice cost is as follows:

$$\textit{Equation 4-1.}\quad Cost = CPI \times LF_{ZIP\ Code} \times Base\ Cost\ Curve$$

Where,

*Cost* = total estimated capital cost
*CPI* = inflation adjustment based on BLS CPI
$LF_{ZIP\ Code}$ = ZIP code location factor (RSMeans, see section 1.2)
*Base Cost Curve* = from Table 4-1.

# 5. Stormwater (Category VI)

## 5.1 Background

The EPA has not provided stormwater CETs in past surveys, so states were previously limited to providing documented costs or developing their own approaches for estimating costs, also referred to as state-specific approaches (SSAs). In the 2008 CWNS, almost half of all stormwater needs were reported using SSAs. In 2012, the use of SSAs declined and only represented about 1 percent of stormwater needs. Participants of the 2012 CWNS end-of-survey meeting noted that stormwater needs should be better captured in future surveys.

The EPA closely reviewed the data submitted by states in past surveys to evaluate whether population, impervious area, urban land use area, jurisdictional area, or some combination thereof could be used as indicators of stormwater needs. The EPA did not identify any clear trends based on the available data, and thus concluded that the data were too variable to use as a basis for a formal CET at a national level. Specifically, the presence of impervious surface or runoff does not necessarily correlate with need—for example, even if there is impervious surface that generates stormwater, that stormwater may already be adequately treated or may be routed in such a way that does not necessitate treatment. Therefore, the EPA could not assign a need to an area without knowing what portion of that area requires stormwater treatment.

The EPA therefore shifted its effort to evaluating common cost models used by stormwater practitioners to see if any could be adapted for use in the 2022 CWNS. Based on this review, the EPA developed cost curves for 10 typical practice types based on simple, site-specific, and flexible inputs for each cost curve. Any community with a documented project could use the stormwater CET to estimate the cost of that project, as long as the project size was within the range of applicability for the specific practice type cost curve.

## 5.2 CET Development

### 5.2.1 Model Review

To develop a stormwater CET, the EPA first reviewed the following cost models:

- The EPA's Stormwater Calculator, Version 2.0.0.1 (SWC) (Rossman and Bernagros, 2019).
- The EPA's Opti-Tool (Tetra Tech, 2016).
- The Water Environment Research Foundation's (WERF's) Best Management Practice (BMP) and Low Impact Development (LID) Whole Life Cost Models: Version 2.0 (WERF, 2009).
- The Maryland Department of Environment (MDE) Cost Worksheet (King and Hagan, 2011).
- The Life Cycle Costing Module for Distributed Stormwater Control Measures for the integrated decision support tool (i-DST Green) (Grubert and Krieger, 2020).

All of these models except the i-DST Green are regression-based, where cost data as a function of a given parameter (e.g., practice volume, practice area, area treated) are collected from multiple case studies to create a model to predict costs. Regression-based models are popular but are often based on a limited number of sometimes highly variable example projects. Additionally, there is often limited information on the dimensions or design of the projects upon which those regressions are based.

The i-DST Green is a recently developed joint project between several organizations, including the EPA and the Georgia Institute of Technology, that allows for a standard line-item cost estimation approach. The model is detailed and customizable. It does not include soil factors, but a hydrologic module is under construction as part of the i-DST Green project. The i-DST Green user inputs include location, BMP type, BMP size, and a range of customization options for factors such as equipment use and internal or contracted labor. For additional information, refer to Gruber and Krieger (2020) and Krieger and Gruber (2021).

Based on a preliminary review of all models, the EPA decided to use i-DST Green as the basis for the stormwater CET for the following reasons:

- i-DST Green is based on a standard, line-item cost estimation approach that is more transparent than the other regression-based models.
- i-DST Green is based on the most current cost data, while the other regression-based models are based on case study data ranging from five to more than 15 years old.
- i-DST Green allows users to customize the design of each BMP, which would allow the EPA to customize design assumptions to reflect standard stormwater design practices.
- i-DST Green provides costs for the greatest number of practices, making it more widely applicable than other models.

The EPA compared the cost estimates that i-DST Green produces to those produced by the other models by modeling a range of practices across a range of sizes, using default inputs for each model. To translate between different approaches for sizing those practices, the EPA used a standard set of equations commonly used in stormwater design manuals and the EPA's SWC:

*Equation 5-1.* $$V = dA_P$$

*Equation 5-2.* $$R_v = 0.05 + 0.009(I)$$

*Equation 5-3.* $$V = PR_vA_d/12$$

Where,

$V$ = practice water quality volume ($ft^3$)
$d$ = depth of storage provided per unit area (ft)
$A_p$ = practice area ($ft^2$)
$R_v$ = volumetric runoff coefficient
$I$ = percent impervious cover of the drainage area
$A_d$ = practice drainage area ($ft^2$)
$P$ = precipitation depth (in)

For model comparisons, the EPA used a common scenario consisting of a drainage area impervious surface of 50 percent, a national average 85$^{th}$ percentile rainfall depth of 0.91 inches (Shrestha et al., 2013), and a varying practice size. Figure 5-1 shows the results of two rounds of comparisons.

The EPA first modeled the range of estimates produced by other cost models for every model/practice combination (some models did not cover all practices), except for underground detention or retention systems (the EPA did not identify any other cost models to compare these practices to). Most of the other models provide a way to account for difficult construction conditions or provide a "high," "medium," or "low" option to allow the user to access the range of costs that could be obtained from the models. These ranges are displayed as gray lines, solid for low and dashed for high. The EPA then modeled the same practice using i-DST Green, assuming design dimension defaults in i-DST Green (e.g., practice depth, media depth, presence of underdrain) and medium cost assumptions (i-DST Green allows for global toggling of "high," "medium," and "low" cost assumptions). Those preliminary cost estimates are shown in black in Figure 5-1. Cost estimates produced by i-DST Green using default inputs generally fall within ranges produced by other models reviewed.

The EPA then carefully reviewed the default inputs for each i-DST Green practice curve in the context of these ranges (except for underground detention or retention, for which the EPA used default inputs without adjustment). The EPA also compared default i-DST Green design inputs to typical design requirements common across several municipal and state stormwater design manuals. To ensure that the final cost curves used for the CWNS were representative of typical national average conditions, the EPA adjusted the i-DST Green curves if they appeared atypically high or low or if design assumptions differed from standard design practices.[13] Those adjustments are illustrated in red in Figure 5-1, and are as follows:

- Porous pavement: The default i-DST Green cost curve is high relative to other cost curves, due to accounting for existing pavement demolition and the cost of a 4-foot-thick reservoir layer with underdrain. To reflect greenfield construction for the base curve, the EPA removed the cost of pavement demolition. As underdrains are an optional component of porous pavement, the EPA reduced the thickness of the reservoir layer to 1 foot, which is approximately the minimum thickness required by design guidance (MDE, 2009; MPCA, 2013; SPU, 2017).
- Green roof: Although the default i-DST Green cost curve is high relative to other cost curves (approximately $60 to $80 per square foot), the cost is based on a typical design and is on the low end of the range of costs found in a green roof literature review of $40 to $500 per square foot (RTI International and Geosyntec Consultants, 2015). The EPA reduced the thickness of the growth media from 6 inches to 4 inches (typical thicknesses are 2 to 6 inches (MDE, 2009; North Carolina DEQ, 2020; SPU, 2017), though the resulting effect is minimal.
- Bioretention: The default i-DST Green cost curve is intermediate to somewhat high relative to other cost curves, but it includes a 3-foot-thick growing media layer, a 3-foot-thick underdrain reservoir, and no provision for temporary ponding in its calculation of storage volume. As 1- to 2-foot-thick underdrains are more common (if included at all) and ponding depths are typically included in storage volume calculations (MDE, 2009; SPU, 2017), the EPA decreased the underdrain reservoir depth from 3 feet to 1.5 feet and updated the capacity calculation to reflect 6 inches of ponding depth.
- Buffer strip: The default i-DST Green cost curve incorporates an underdrain, pea gravel diaphragm, and overflow berm, which is likely more complex than the typical buffer strip

[13] Default inputs for i-DST Green are intentionally comprehensive in terms of features that included (Grubert & Krieger, 2020), which can lead to a cost estimate that may be higher than average installations.

installation (e.g., the MDE Cost Worksheet, which produces the lowest cost estimate, only assumes vegetation planting is required). The EPA decreased the substrate depth from 4 feet to 1.5 feet.

- Infiltration trench: No change was made to default i-DST Green cost curve inputs.
- Vegetated swale: The default i-DST Green cost curve is high relative to other models, none of which include an underdrain. The default i-DST Green design includes an underdrain and filter media, making it similar to an infiltration trench and representing a more complex and costly version of the practice. The EPA removed the underdrain and filter media components to differentiate the vegetated swale from an infiltration trench.
- Constructed wetland: The default i-DST Green cost curve is high relative to other cost curves. The default i-DST Green inputs include a practice depth of 2 feet and a void ratio of 0.4, which is more representative of more costly subsurface flow systems. The EPA changed these values to a depth of 1.5 feet and a void ratio of 0.95 to be more representative of average depths and storage found in typical free-water surface (i.e., open water) wetlands (Kadlec and Wallace, 2008).
- Dry and wet ponds: The default i-DST Green cost curve is low relative to other cost curves, which may be more oriented toward smaller versions of the practice. This could result in overestimating costs for large systems when small system costs are extrapolated to larger systems. King and Hagan (2011) note that for the MDE Cost Worksheet, the cost is based on a system that treats a drainage area of 3 acres, and that there may be considerable economies of scale for larger systems, which are typical of this practice. For example, MDE requires that wet extended detention ponds, a version of the wet pond practice, have a minimum drainage area of 25 acres (MDE, 2009). To be more in line with other cost estimates while remaining conservative, the EPA used the "high" default costs for dry and wet pond cost curves, raising the estimated cost slightly but keeping it toward the lower end of the range.
- Underground detention or retention (not shown in Figure 5-1): No other cost curves for underground detention or retention were available for comparison. Due to the complex construction requirements, these practices tend to be on the order of three to four times more expensive than wet ponds on a volumetric basis. No adjustment was made to i-DST Green default assumptions.

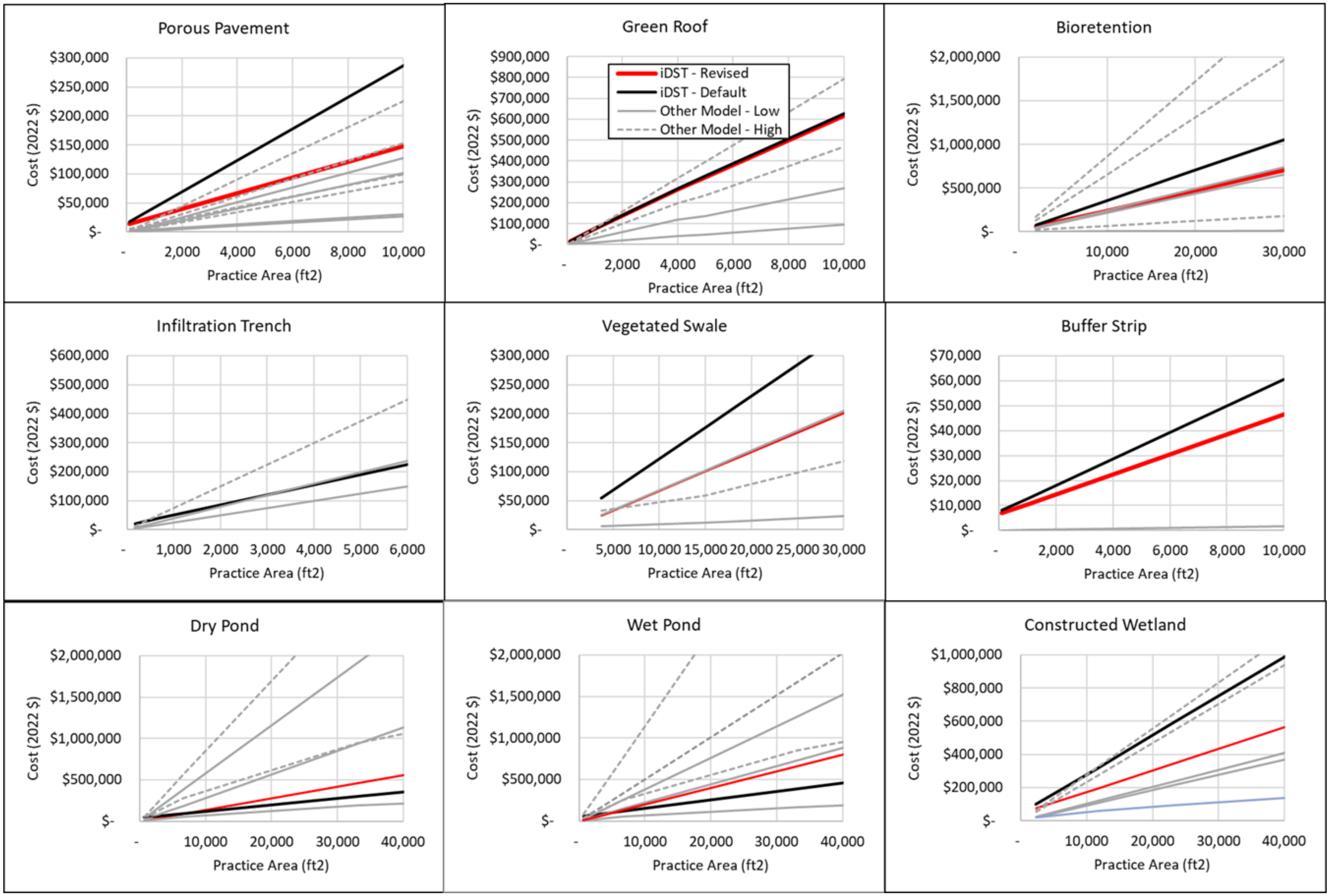


**Figure 5-1. Stormwater cost model comparisons for all practice cost curves except underground detention/retention (no other cost curves were available for comparison). Black lines represent i-DST Green cost curves using default inputs. Red lines represent i-DST Green cost curves using adjusted inputs. Gray lines represent all other models that provide cost curves for the practice.**

### 5.2.2 CWNS Cost Curves

The refined i-DST Green cost curves from the previous section form the basis of the practice cost curves provided in the CWNS. To account for the effects of location, inflation, development conditions, and pre-construction costs (e.g., design, permitting), the EPA developed separate cost factors.

### 5.2.3 Location

As stated previously, i-DST Green is based on a standard line-item cost estimation approach. In i-DST Green, individual unit costs can be adjusted for location using RSMeans location cost factors for material and installation costs (as opposed to the total cost factor used in Equation 1-1). However, these cost factors do not affect total practice costs uniformly, as each practice cost curve is based on a unique combination of line-item inputs. To simplify the number of calculations needed to estimate the net effect of location on practice cost, the EPA used an Excel macro to generate 200 cost estimates, where location and project size were randomly selected from a list of all available RSMeans locations and across a range of plausible practice sizes. For each location-specific cost, the EPA also generated a national average cost (Equation 5-4) so the ratio of the two costs (i.e., the stormwater location cost factor) could be calculated using the relationship shown in Equation 5-5.

*Equation 5-4.* $$Cost_{National\ Average} = aA_p + b$$

*Equation 5-5.* $$Cost_{Location\ i} = SLF \times Cost_{National\ Average}$$

Where,

$Cost_{National\ Average}$ = the national average practice cost as a function of practice area
$a$ = cost coefficient for national average cost curve
$A_p$ = practice area ($ft^2$)
$b$ = y-intercept for national average cost curve
$Cost_{Location\ i}$ = the practice cost for a randomly chosen location and the same practice area
$SLF$ = Stormwater location cost factor

Next, the EPA performed a multiple linear regression using material (*M*) and installation (*I*) cost factors for each location as independent variables and location factor (S*LF)* as the dependent variable, so that the influence of *M* and *I* on total cost could be captured using a single equation:

*Equation 5-6.* $$SLF = cI + dM + e$$

Where,

$I$ = RSMeans installation cost factor
$M$ = RSMeans material cost factor
$c$ = installation cost factor coefficient (see Table 5-1)
$d$ = material cost factor coefficient (Table 5-1)
$e$ = regression y-intercept

*SLF* regression coefficients, as well as national average cost curve coefficients, are provided in Table 5-1. Figure 5-2 shows an example of how accurate the EPA's location-specific cost curve is relative to the actual prediction from i-DST Green. The plots are for a bioretention system, but the conclusions are similar for other practices in that the percent error between the two approaches is generally 5 percent or less and decreases as practice size increases.

For the final stormwater CET, the *SLF* is calculated using ZIP code-based cost factors. *SLF* coefficients are anchored to 2020 costs, with Equation 1-1 used to adjust to 2022 dollars.

**Table 5-1. Summary of Base and Location Cost Curve Coefficients**

| Practice | $Cost_{National\ Average} = aA_p + b$ | | $SLF = cI + dM + e$ | | |
|---|---|---|---|---|---|
| | a | b | c | d | e |
| Porous pavement | 12.39 | 11,233 | 0.0017 | 0.0079 | 0.0364 |
| Green roof, < 2,000 ft$^2$ | 63.9 | 7,438 | 0.0016 | 0.0085 | -0.0007 |
| Green roof, > 2,000 ft$^2$ | 53.8 | 28,050 | 0.0011 | 0.0089 | 0.0007 |
| Bioretention | 21.12 | 10,943 | 0.0010 | 0.0088 | 0.0137 |
| Buffer strip | 3.68 | 5,985 | 0.0041 | 0.0068 | -0.0946 |
| Infiltration trench | 32.25 | 13,714 | 0.0015 | 0.0081 | 0.0436 |
| Vegetated swale | 6.15 | 12,547 | 0.0029 | 0.0065 | 0.0612 |
| Constructed wetland | 11.87 | 41,179 | 0.0031 | 0.0076 | -0.0663 |
| Dry pond | 12.8 | 66,120 | 0.0058 | 0.0031 | 0.1112 |
| Wet pond | 18.4 | 77,041 | 0.0066 | 0.0018 | 0.1438 |
| Underground detention/retention | 12.38 | 63,749 | 0.0012 | 0.0084 | 0.0358 |

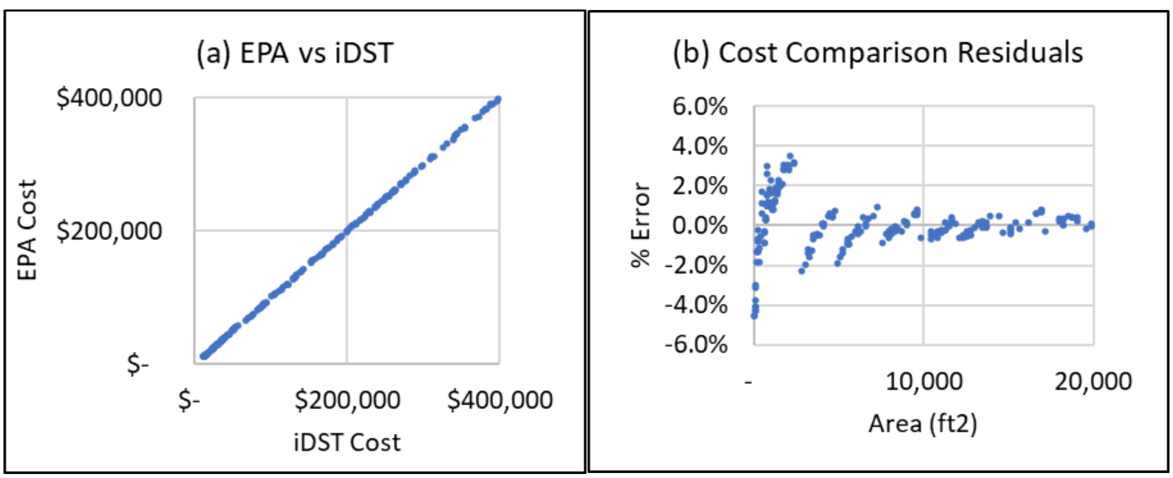


**Figure 5-2. a) Example comparison of the EPA cost-curve estimate and i-DST Green estimate for the cost of a bioretention system across a range of randomly selected locations and sizes and b) residual errors of the EPA cost-curve estimates as a function of practice size.**

### 5.2.4 Construction Type—Site or Construction Conditions

Stormwater cost models generally provide some way to account for difficult site or construction conditions compared to a typical, new-development installation. In the context of the CWNS, conditions that lead to a different or more costly version of the same practice are referred to as construction types. All stormwater cost models the EPA reviewed, except for the EPA's Opti-Tool, have some way of accounting for these conditions. Generally, the terms "redevelopment" and "retrofit" are used interchangeably in the context of stormwater cost models due to their overlapping meanings.[14] For the CWNS, EPA is adopting the term "redevelopment" for a stormwater practice construction type that accounts for difficult site or construction conditions.

While i-DST Green allows for the use of high-, medium-, or low-cost assumptions, it does not explicitly link cost assumptions to a particular set of site or construction conditions. Therefore, to allow cost estimates to be adjusted to reflect non-greenfield[15] conditions, the EPA summarized all available cost adjustment factors from other models for each practice. That summary, along with final factors, is shown in Table 5-2. For practices with multiple factors, an average value was calculated but limited to a maximum of 2.0 to limit the influence of extreme conditions. For practices without factors, the EPA assumed a value of 2.0, which is approximately the overall average value across all practices. For the new development construction type, the EPA assumed a cost factor of 1.0.

**Table 5-2. Summary of Redevelopment Cost Factors to Account for Difficult Site or Construction Factors**

| Practice | MDE Cost Worksheet: "Retrofit" | WERF Cost Model: "Retrofit" | EPA SWC: "Redevelopment" | Redevelopment Construction Type Cost Factor |
|---|---|---|---|---|
| Porous pavement | NA | NA | 1.3 | 1.3 |
| Green roof | NA | NA | 4.2 | 2.0 |
| Constructed wetland | 2.3 | NA | NA | 2.0 |
| Bioretention | 3.5 | 1.2 | 1.4 | 2.0 |
| Buffer strip | NA | NA | NA | 2.0 |
| Infiltration trench | NA | NA | 3 | 2.0 |
| Vegetated swale | NA | NA | NA | 2.0 |
| Dry pond | 1.5 | NA | 2 | 1.8 |
| Wet pond | 2.3 | NA | 1.4 | 1.9 |
| Underground detention or retention | NA | NA | 0.98 | 1.0 |

NA= not available

### 5.2.5 Pre-construction Costs

Pre-construction costs refer to design and planning costs required for stormwater practice construction. Typically, these costs are incorporated separately from the base practice cost model by applying a factor, which generally ranges from 10 to 30 percent, of construction costs for new development and a slightly higher factor for redevelopment. i-DST Green allows users to customize an estimate for pre-

[14] Redevelopment generally refers to development or installation of a stormwater practice on an already developed piece of land where the removal of existing infrastructure leads to a costlier installation. Retrofit generally refers to the installation of a stormwater practice within existing development that is either currently untreated or inadequately treated by existing stormwater practices.

[15] Greenfield is assumed here to mean new development on flat terrain with minimal complicating factors, such as existing pavement, utilities, buildings, or stormwater practices.

construction costs but does not prescribe input values. The EPA therefore reviewed pre-construction cost factors that other cost models recommended for new development and redevelopment of each practice. Again, the EPA used an average where multiple cost factors were available and assumed 30 percent for new development and 1.5 times the new development factor for redevelopment where no cost factors were available. These are both approximate averages across all practices that had data for pre-construction costs.

**Table 5-3. Summary of Pre-construction Cost Factors**

| Practice | MDE Cost Worksheet | | WERF Cost Model | EPA Opti-Tool | Pre-construction Cost Factor | |
|---|---|---|---|---|---|---|
| | New | Retrofit | New | New | New Development | Redevelopment |
| Porous pavement | 10% | NA | 10% | 35% | 18% | 28%[a] |
| Green roof | NA | NA | NA | NA | 30%[a] | 45%[a] |
| Constructed wetland | 30% | 50% | | 35% | 33% | 50% |
| Bioretention | 25% | 40% | 25% | 35% | 28% | 40% |
| Buffer strip | 10% | NA | NA | NA | 10% | 15%[a] |
| Infiltration trench | 40% | NA | NA | 35% | 38% | 56%[a] |
| Vegetated swale | 20% | NA | 25% | NA | 23% | 34%[a] |
| Dry pond | 30%[b] | 50%[b] | 25%[c] | 35% | 30% | 50% |
| Wet pond | 30% | 50% | 25% | 35% | 30% | 50% |
| Underground detention or retention | NA | NA | NA | 35% | 35% | 53%[a] |

[a] Average value, 30% for new development and 1.5 times new development for redevelopment where no other data are available.

[b] From dry extended detention ponds, assume similar for dry ponds.

[c] From retention pond, assume similar for dry ponds.

NA = not available

## 5.3 Stormwater CET

For the CET, the EPA collapsed the global inputs to simplify and standardize some of the details (see section 5.2), making the cost estimation a function of size, location, and construction type. Losing detail forfeits some accuracy in cost estimations but makes the CET easier for states to use.

The practice cost curves that form the foundation of the stormwater CET are based on practice area (Equation 5-4). However, depending on the practice, users have the option of sizing the practice by practice area or practice volume or drainage area impervious surface, which are automatically translated to practice area using Equation 5-1, Equation 5-2, and Equation 5-3.

The final equation used to calculate practice cost is as follows:

*Equation 5-7.* $$Cost = n \times CF_{Change\ Type} \times (1 + CF_{Pre-construction}) \times CPI \times SLF \times aA_p + b$$

Where,

*Cost* = total estimated capital cost
*n* = number of practices
$CF_{Construction\ Type}$ = construction type cost factor (Table 5-2)
$CF_{Pre\text{-}construction}$ = pre-construction cost factor (Table 5-3)
*CPI* = inflation adjustment based on BLS CPI
*SLF* = location factor (Equation 5-6)
*a* = cost coefficient for national average cost curve (Table 5-1)
$A_p$ = practice area ($ft^2$)
*b* = y-intercept for national average cost curve (Table 5-1)

Each cost curve developed for the stormwater CET considers economies of scale in practice construction cost. For example, 10 practices that are 1 acre each will cost more than one practice that is 10 acres in size. To ensure stormwater CETs are used appropriately, the EPA reviewed several stormwater design manuals to define limits for the size of an individual practice that states could estimate. For example, bioretention systems are generally not recommended for drainage areas larger than 5 acres. Where design guidelines or common practice assumptions were given in one unit of measure, the EPA used Equation 5-1, Equation 5-2, and Equation 5-3 to translate them to practice area, practice volume, and/or drainage area. Table 5-4 shows those limits for each practice. Within the DEP, limits are conveyed as hard warnings if users try to enter values above the maximum.

**Table 5-4. Stormwater Model Size Input Limits**

| Practice | Practice Area ($ft^2$) | Practice Volume ($ft^3$) | Drainage Area (Acres) |
|---|---|---|---|
| Permeable pavement | $A < 10,000$ | $V < 10,000$ | NA |
| Green roof | $A < 43,560$ | $V < 10,000$ | NA |
| Bioretention | $A < 15,000$ | $V < 26,000$ | < 5 |
| Buffer strip | $A < 440,000$ | $V < 260,000$ | NA |
| Infiltration trench | $A < 11,000$ | $V < 26,000$ | < 5 |
| Vegetated swale | $A < 29,000$ | $V < 26,000$ | < 5 |
| Constructed wetland | $6,000 < A < 100,000$ | $8,000 < V < 140,000$ | $5 < DA < 50$ |
| Wet pond | $2,000 < A < 50,000$ | $8,000 < V < 250,000$ | $5 < DA < 50$ |
| Dry pond | $A < 50,000$ | $V < 250,000$ | $DA < 50$ |
| Underground detention or retention | NA | $V < 250,000$ | $DA < 50$ |

# 6. Nonpoint Source—Agriculture (Category VII-A)

## 6.1 Background

The collection of NPS control data in the CWNS has been inconsistent across surveys, likely resulting in an under-reporting of the true national need. In the 2004, 2008, and 2012 surveys, NPS needs were not included in the total needs since they were not specifically identified in CWA section 516(b)(1)(B). Since that time, both the CWSRF eligibilities and CWNS data collection requirements have been amended in the CWA.

Since Category VII needs have been historically underrepresented, the EPA developed tools for the 2022 CWNS to help states develop reasonable estimates for their NPS needs. These tools estimate both acres of needs—termed "projects" for other infrastructure types—and costs associated with treating those acres with water-quality-related BMPs without putting the burden on states to gather project-by-project documentation or create their own models. The tools therefore needed to be based on publicly available, nationally applicable datasets; be easy to use; and provide reasonable estimates of state needs.

EPA prioritized NPS subcategories VII-A (Agriculture [Cropland]) and VII-C (Silviculture) for the development of CETs. Category VII-K (Hydromodification) was also identified as a priority NPS subcategory; however, the EPA was not able to identify a national data source that states could use to identify hydromodification needs. The EPA provided the resources listed in Appendix E to states so they could estimate the cost of planned hydromodification projects.

The following sections outline the methods and data sources that the EPA used to develop three tools:

- A tool to estimate the agricultural acres of need (the cropland acres tool).
- A CET to estimate the costs associated with treating agricultural acres of need.
- A CET to estimate the costs associated with treating silviculture acres of need (section 7).[16]

## 6.2 Cropland Agriculture Tools

The EPA evaluated available national, regional, and state data to anticipate how states are most likely to quantify cropland agriculture needs (i.e., acres of need and costs). Based on available datasets, the EPA determined that an estimation of cropland needs on a per-acre basis is likely to be the most broadly applicable. To help with that estimation, the EPA provided two tools to states:

- The cropland acres tool, which estimates the number of cropland acres that need conservation practices (acres of need) to address water quality concerns.
- The cropland CET, which applies a per-acre cost of practice implementation to the acres of need.

States could use both tools or use one in concert with another documentation method (e.g., SSA).

### 6.2.1 Cropland Acres Tool

The cropland acres tool requires the state coordinator to input the total number of acres of harvested cropland. The cropland acres tool then calculates the proportion of acres requiring BMPs.

[16] The EPA provides guidance regarding where to find data that could help states determine silviculture acres of need, but not a tool to estimate this.

#### 6.2.1.1 Acres of Need Data Sources

The EPA anticipates that states lacking state-specific information on cropland agriculture acres of need will use the following two sources of information from the U.S. Department of Agriculture (USDA) and the USDA's Natural Resources Conservation Service (NRCS):

- For total acres: the USDA's Census of Agriculture provides information on acres of harvested cropland[17] (at the national, state, and county level) and implementation of certain practices (conservation tillage and cover crops). This information is available for most of the United States.[18]
- For proportion of acres requiring conservation practices: the NRCS's Conservation Effects Assessment Project (CEAP) provides information on the extent of conservation practice implementation and need for additional practices on a regional basis for most agricultural areas of the country.

The NRCS's CEAP is a multi-agency, national effort to quantify the environmental effects of conservation practices and programs. CEAP cropland assessments, a subset of CEAP, are based on a sampling and modeling approach that uses data from representative crop fields (i.e., from the NRCS National Resources Inventory) to estimate the impacts of cropland-based conservation practices on the environment. Specifically, two goals of the CEAP cropland assessment are to:

1. Estimate the effects of current conservation practices on the landscape.
2. Estimate the need for conservation practices and the potential benefits of additional conservation treatment.

The results of the CEAP cropland assessments are provided in a series of 12 river basin reports, covering almost 96 percent of the cultivated cropland areas of the country.[19] Relevant to the development of a cropland CET, each river basin report provides an estimate of the total acres of cultivated cropland and the portion of those acres with a low, moderate, or high need for additional conservation practices. In the CEAP context, a high need refers to the most vulnerable acres with the least conservation treatment and the highest losses of sediment or nutrients. Although not directly linked to water quality, this classification scheme provides a basis for the estimation of additional conservation practices that would, presumably, have a positive effect on downstream water quality. Conversely, acres designated as having a low need for additional treatment are considered adequately treated. Table 6-1 shows the total

[17] Harvested cropland is specifically used instead of total cropland to indicate the area under active cultivation and potentially subject to NPS pollution export. The Census of Agriculture "harvested cropland" category appears to more closely correspond to the "cultivated cropland" addressed in the CEAP cropland assessments.

[18] Note that the EPA recommends this as a data source for number of acres harvested but the state coordinator is required to submit the USDA report or state report that supports the number that they ultimately enter into the tool.

[19] CEAP cropland assessments do not cover the Northeast (New England states, eastern New York, and northeastern New Jersey), the West (Arizona; most of California, Nevada, Utah, and New Mexico; southwest Wyoming; and western Colorado), Alaska, Hawaii, or the U.S. territories. Based on an overlay of CEAP basins with county cropland data from the 2017 USDA Census of Agriculture, 95.8 percent of U.S. cropland is located within a CEAP basin that has a corresponding cropland assessment.

cropland acres, and acres designated as having a high or moderate need, by basin from the 2003–2006 CEAP cropland assessments (CEAP-1).

**Table 6-1. CEAP Estimates of Cropland Needed Acres by Basin, 2003–2006**

| CEAP Basin | Cultivated Cropland (Million Acres) | Medium Need (Million Acres) | High Need (Million Acres) | Percent Medium and High |
|---|---|---|---|---|
| Upper Mississippi River Basin | 58 | 26 | 9.0 | 61% |
| Ohio-Tennessee River Basin | 25 | 12 | 6.0 | 70% |
| Missouri River Basin | 84 | 14 | 1.1 | 18% |
| Arkansas-White-Red Basin | 30 | 9.1 | 1.3 | 34% |
| Texas Gulf Basin | 18 | 10 | 7.6 | 97% |
| Lower Mississippi Basin | 19 | 10 | 6.3 | 86% |
| Great Lakes region | 15 | 5.0 | 2.8 | 53% |
| Souris-Red-Rainy Basin | 18 | 4.3 | - | 25% |
| South Atlantic Gulf Basin | 13 | 4.1 | 6.7 | 82% |
| Chesapeake Bay region | 4 | 1.7 | 0.8 | 59% |
| Delaware River Basin | 0.8 | 0.2 | 0.4 | 74% |
| Pacific Northwest Basin | 12 | 8.2 | 0.4 | 74% |

Although the CEAP-1 assessment represents the best available source of national needed acres data for cropland agriculture, the data are now almost 20 years old. A second CEAP survey (CEAP-2) was performed in 2015 and 2016 and would be preferable to CEAP-1; however, the results of CEAP-2 were not published in time to incorporate into this analysis (though a qualitative comparison is made in section 6.2.4). Therefore, to allow for the possibility that older data may be used for the cropland CET, the EPA reviewed several sources of information to determine if the CET should include an adjustment to account for changes in the level of BMP implementation that may have occurred since the CEAP-1 assessment.

The CEAP-1 cropland assessments provide qualitative discussion of various initiatives that were anticipated to increase conservation funding, and thus conservation practice implementation, across the country compared to 2003–2006 conditions. For example, the Texas Gulf Basin Report points to the 2008 Farm Bill, while the Great Lakes Region Report points to the 2010 Great Lakes Restoration Initiative.

The NRCS also performed a formal follow-up survey for the Chesapeake Bay region to determine the Impacts of Conservation Adoption on Cultivated Acres of Cropland from 2003–2006 to 2011. The 2011 study found that, due to an increase in conservation practice implementation, the number of acres considered to have a high or moderate conservation need decreased from 59 percent to 46 percent, a decrease of 22 percent over five to eight years.

Data from the 2012 and 2017 USDA Censuses of Agriculture also show an overall increase in the level of conservation practice implementation during that time. Data for cover crops and conservation tillage—annual practices that together fulfill all three important nutrient and sediment reduction functions of "avoid, control, and trap" that the NRCS advocates for across its conservation programs—show that the percentage of cropland acres treated with those practices increased an average of 40 percent and 25 percent, respectively, over the five years from 2012 to 2017.[20]

Given CEAP-2 data were not published in time to be incorporated into the 2022 CWNS Cropland CET, as well as the lack of any other state-specific data, the EPA recommends that states use CEAP-1 data as a measure of the percentage of cropland acres with a moderate or high need for additional conservation practices (column five from Table 6-1) and apply a reduction factor of 50 percent to account for likely increases in conservation practice implementation that have occurred over the past 20 years.

#### 6.2.1.2 Tool Development Process

To help states implement the method described above to estimate acres of need for cropland agriculture based on CEAP-1 data, the EPA provides a cropland acres tool in the DEP. The tool is available for states that 1) lack state-specific data on acres of need for cropland agriculture that require conservation practices and 2) are covered by one or more CEAP cropland assessments.

States could use the cropland acres tool on a statewide or county-level basis. First, states must enter the total number of harvested cropland acres from the 2017 USDA Census of Agriculture for their state or county. The cropland acres tool then assigns a percent need based on the CEAP basin in which those harvested cropland acres are located, corresponding to the last column of Table 6-1. For states that have harvested cropland within multiple CEAP basins, the cropland acres tool calculates a weighted average need. For states that are only partially covered by a CEAP basin (Colorado, Idaho, New Jersey, New York, Texas, and Wyoming), the weighted average need assumes 0 percent need for counties outside of the CEAP basins. The resulting output in acres of need, based on the weighted average need and total harvested cropland acres in the state, thus reflects only the total acres of need within CEAP basins, on a state level.

For counties with harvested cropland that falls within multiple CEAP basins, need is assigned based on which basin contains more of the county, by area.

The final equation used to calculate the number of acres of need is as follows:

*Equation 6-1.*
$$Acres\ of\ Need\ (Acres) = 50\% \times Percent\ Need \times Harvested\ Cropland\ (Acres)$$

Where,

*Acres of need* = total estimated acres of need
*50 percent* = reduction factor to account for increased practice implementation since CEAP-1
*Percent need* = based on the CEAP-1 assessment

As stated previously, several states are not included, or largely not included, in the CEAP cropland assessments. Those states—Alaska, Arizona, California, Connecticut, Hawaii, Maine, Massachusetts, Nevada, New Hampshire, Rhode Island, Utah, and the U.S. territories—represent 4.2 percent of U.S. harvested cropland. Of that portion, California represents over half (approximately 2.5 percent

[20] Censuses of Agriculture conducted prior to 2012 do not report cover crop and conservation tillage implementation data.

nationally) and the remaining states each represent less than 1 percent of the national total. For states with cropland that is not represented in the CEAP-1 assessments and that anticipate having significant needs associated with cropland agriculture, the EPA provides other methods to estimate acres of need based on available data.

### 6.2.2 Cropland CET

The cropland CET requires an input of acres of need at a state or county level, which can be obtained using the cropland acres tool or a state-specific method.

#### 6.2.2.1 Cost Data Sources

To provide up-to-date, geographically specific cost estimates, the NRCS maintains state payment schedules for conservation practices. The payment schedules represent the financial assistance that the NRCS provides for specific conservation practices, based on estimated costs for various implementation scenarios[21] for each practice. These practice scenario costs are likely the most comprehensive, nationally applicable source of agriculture NPS control unit costs available.

The NRCS also provides conservation program implementation data (available through the NRCS's Soil and Water Resources Conservation Act data viewer) which documents the implementation of conservation practices in terms of the acres and count of each practice funded each year, by state, to address various natural resource concerns. The EPA compiled 10 years of available data (2011 to 2020) on practices implemented to address water quality resource concerns for each state to use for various purposes.[22]

To develop practice unit costs, the EPA obtained state practice scenario cost data from the NRCS for fiscal year 2021 (final costs were adjusted to 2022 dollars). The data provide cost breakdowns for each practice in terms of the equipment installation, labor, materials, mobilization, and foregone income (foregone income was not included in this analysis due to CWSRF ineligibility) required to implement the practice, with individual quantities and rates tailored to each state. For each practice, cost data were provided for multiple "scenarios," which are different versions of the same practice. Costs for individual scenarios are provided in terms of a typical application (i.e., typical in terms of practice size, capacity, acres treated). Because CEAP modeling assumptions and NRCS implementation data are only provided at the practice level (not the scenario level) and neither specifies any measure of practice size, the EPA assumed that NRCS practice costs for scenarios were typical and calculated an average cost for each practice as the average cost of the scenarios for that practice.

In some cases, the cost for a single scenario was unusually high (i.e., approximately an order of magnitude or greater than the average of other scenario costs for that practice), often because it was a

[21]Implementation scenarios and associated costs are provided on each state's Payment Schedules page.

[22] The EPA recognizes that practices to address water quality impacts from cropland agriculture are not exclusively funded through NRCS conservation programs. However, based on discussion with the NRCS, the EPA believes that the practices most commonly funded through NRCS programs to address water quality are a reasonable proxy for the practices most likely to be implemented on cropland.

highly specific version of the practice. The EPA assumed those scenario costs were outliers and removed them from the practice group.

For practices that are implemented over the entire treated area (e.g., nutrient management) and for which the NRCS provides practice costs on a per-acre basis, the resulting cost unit is dollars per acre treated. For practices not costed in terms of acres treated, the EPA assumed NRCS practice costs reflect the cost of a single, typical installation, with units of dollars per practice. To convert from dollars per practice to dollars per acres treated, the EPA used conservation program implementation data to determine the average acres treated by single applications of the practice from 2011–2020.[23] The resulting cost per acre treated was calculated using Equation 6-2.

*Equation 6-2.* $$Cost_{Per\ Acre}\left(\frac{\$}{Acre}\right) = Cost_{Per\ Practice}\left(\frac{\$}{Practice}\right) \div Treament\left(\frac{Acres}{Practice}\right)$$

Next, to estimate the cost associated with implementing practices to address the acres of need for cropland agriculture, the EPA adopted the assumptions used in the CEAP cropland assessments. The studies identified a generic suite of practices that could be applied to an acre of harvested cropland with an NPS pollution need. The EPA utilized the same suite of practices as a proxy for the treatment of a typical acre of cropland need. The suite of practices is not intended to be prescriptive or site-specific but to be a functional proxy for structural and vegetative practices that could be implemented to slow runoff, capture contaminants, and enable more efficient nutrient application. Although some individual CEAP basin studies add slight variations to the suite, all suites are based on the same general core, which consists of one practice to address each of the following NPS pollution sources:

- In-field mitigation: Practices include terraces, contouring, or stripcropping, which are assumed surrogates for practices used to control overland flow.
- Edge-of-field mitigation: Practices include riparian buffers or filter strips, which are assumed surrogates for practices used to trap or treat pollutants to reduce edge-of-field contaminant loadings.
- Nutrient management: A single practice to ensure implementation of the "four Rs"—right rate, right form, right time, and right method—of nutrient application to avoid application of excess nutrients to cropland.

The EPA paired these assumptions with the previously developed NRCS practice unit costs to come up with the state-specific, per-acre cost of addressing cropland NPS need. Table 6-2 provides a summary of that approach, as well as national averages for practice costs and the full model cost. The full model cost represents the implementation of structural practices, as well as the implementation of five years of nutrient management (see section 6.2.3 for discussion of the planning horizon). On average, the approach estimates a cost of $408 per acre over five years to treat cropland acres of need identified by CEAP cropland assessments.

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[23] The EPA used the state-specific and national NRCS data for Land Unit Acres Receiving Conservation by Practice, Conservation Practices Related to Water Quality, Land Unit Acres Receiving Conservation by Practice (including practice count), and Fiscal Year. As reported by NRCS, the land unit acres in these data reflect the geographic extent of land treated with water quality conservation practices.

**Table 6-2. Summary of Agriculture-Cropland Unit Costs**

| BMP Function | NRCS Conservation Practices Used for Costing (Practice Standard Code No.) | BMP Cost ($/Acre)[a] | | |
|---|---|---|---|---|
| | | Min. | Average | Max. |
| In-field runoff mitigation | Average of:<br>Terrace (600)<br>Stripcropping (585)<br>Contour farming (330) | $10 | $42 | $114 |
| Edge-of-field loading mitigation | Average of:<br>Riparian forest buffer (391)<br>Filter strip (393) | $5 | $179 | $489 |
| Nutrient management[b] | Nutrient management (590) | $142 | $186 | $326 |
| | Total annualized unit cost[c] | $34 | $54 | $92 |
| | **Total unit cost[d,e]** | $188 | $408 | $747 |

[a] National average, based on average of NRCS scenario costs for each practice.
[b] Cost reflects implementation of practice for five years. See section 6.2.3 for discussion.
[c] Cost reflects annualized total, where practice total costs have been divided by their respective lifetimes (one year for nutrient management, five to 15 years for structural practices). For comparison purposes only.
[d] Total cost reflects five years of nutrient management implementation and installation of structural practices.
[e] Sum of components may not add up to total due to averaging methods and rounding.

The total cost in Table 6-2 reflects the per-acre cost of implementing practices for each of the BMP functions over five years. The practices that were used to estimate the cost have varying lifespans, or periods over which the practice is expected to function effectively. For example, because nutrient management has a lifespan of one year, the costs for that practice would be incurred every year. Riparian forest buffer, on the other hand, has a lifespan of 15 years. Except for nutrient management, the practices used to develop the per-acre cost in Table 6-2 have lifespans ranging from five to 15 years. Therefore, over a five-year planning horizon (see section 6.2.3), the EPA would expect five instances of the nutrient management per-acre cost, but only one instance of the cost for the other practices. The total annualized cost shown in Table 6-2 is calculated as the single-year cost of the same suite of practices, where the cost of structural practices has been divided by their respective lifetimes (this is why the annualized cost is not simply the total cost divided by five). Total annualized cost is shown for model validation purposes; this is discussed further in section 6.2.4.

#### 6.2.2.2 CET Development Process

States can use the proposed agriculture-cropland CET to determine a state-specific cost, at either a county or state level, for implementing conservation practices on harvested cropland acres that have a need for practice implementation. The following steps describe the calculations and inputs required to use the cropland CET:

1. On a county or state scale, determine the harvested cropland acres of need using a state-specific method or the cropland acres tool (see section 6.2.1; entered by state coordinator).
2. Multiply the acres of need by the state-specific unit cost to obtain an estimate of cropland need for that state or county (calculated by the cropland CET).

### 6.2.3 Acres of Need Planning Horizon

The goal of the CWNS is to capture water quality needs anticipated by states within the next 20 years. However, given the uncertainty in the data used as the basis for the cropland CET—in particular, the age of the CEAP-1 data and assumptions about changes in practice implementation over time—it is not reasonable to extrapolate cropland needed acres 20 years into the future based on the method outlined above. The EPA also recognizes that state-level NPS planning and farm-level planning often do not operate on a 20-year timeframe. Therefore, the EPA has established a five-year timeframe for cropland needed acres estimation. The EPA considered several planning horizons relevant to the data that states are likely to use when estimating needed acres, including the following:

- State nonpoint source management program plans: The EPA expects all states to review and, as appropriate, revise and update their NPS management programs every five years.
- Total maximum daily load (TMDL) implementation plans: There is no standard timeframe for implementing or reviewing TMDL implementation plans; however, some states (e.g., Oregon) require plans to be evaluated every five years.
- Census of Agriculture: The census is taken once every five years.
- NRCS conservation planning: There is no standard or recommended timeframe for implementing or evaluating farm-level or area-wide conservation plans. Implementation schedules are driven by the resource concerns addressed and practices included in the plan. The NRCS recommends that conservation plans be updated as needed to reflect changes in variables that drive planning decisions, such as markets, weather, and technology.
    - The Environmental Quality Incentives Program (EQIP), one of the major NRCS programs used to fund farm-level conservation practices, allows for contracts up to 10 years; however, a typical EQIP contract spans approximately three years.
    - The Farm Bill, which allocates mandatory spending for conservation programs, is reauthorized every five years.

### 6.2.4 Cropland Tools Data Validation

The proposed agriculture-cropland CET and cropland acres tool provide a simple way for states without full documentation of CWNS cropland agriculture needs to estimate their needs. To evaluate the reasonableness of the CET, the EPA compared it to several other datasets.

First, the EPA applied the proposed CET and cropland acres tool to all 2017 harvested acres located within a CEAP basin to approximate the total need that would result if each state implemented the tools. While the CEAP basins do not cover the entire country, they do represent about 96 percent of the 318 million acres of harvested cropland across all U.S. agricultural areas (as of 2017). Table 6-3 shows the results, including an estimated need of $30 billion to address cropland NPS needs over five years. If translated to an annualized basis (see discussion in section 6.2.2 and Table 6-2), the resulting total annual need would be $4 billion.

**Table 6-3. Estimate of Cropland Need Across all CEAP Basins Using the Proposed Tools**

| CEAP Basin | Harvested Cropland (Million Acres)[a] | Percent Need (Adjusted)[b] | Basin-Average Cost ($/Acre)[c] | Total 5-Year Need ($ Billion) |
|---|---|---|---|---|
| Upper Mississippi River Basin[d] | 59 | 30% | $478 | $8.0 |
| Ohio-Tennessee River Basin[d] | 32 | 35% | $469 | $5.2 |
| Missouri River Basin[d] | 85 | 9% | $433 | $3.1 |
| Arkansas-White-Red Basin[d] | 29 | 17% | $302 | $1.4 |
| Texas Gulf Basin | 13 | 49% | $202 | $1.2 |
| Lower Mississippi Basin[d] | 16 | 43% | $336 | $2.1 |
| Great Lakes region | 18 | 27% | $463 | $2.0 |
| Souris-Red-Rainy Basin | 19 | 12% | $364 | $0.81 |
| South Atlantic Gulf Basin | 14 | 41% | $410 | $2.2 |
| Chesapeake Bay region | 5.6 | 30% | $691 | $1.1 |
| Delaware River Basin | 1.4 | 37% | $747 | $0.37 |
| Pacific Northwest Basin | 12 | 37% | $500 | $2.0 |
| **Total** | **304** | | | **$30** |

[a] Harvested cropland from 2017 Census of Agriculture.
[b] Calculated by applying proposed 50% reduction factor to values in column five of Table 6-1.
[c] Area-weighted average cost across all counties within each CEAP basin.
[d] Part of Mississippi River Basin.

In comparison to the values presented in Table 6-3, as well as an annual equivalent need of $4 billion (based on the annual cost presented in Table 6-2), the total reported Category VII-A need from the 2008 CWNS was $1.8 billion ($2.4 billion adjusted to 2022 dollars[24]). However, 2008 NPS needs reporting was inconsistent, and an additional $5.4 billion ($7.2 billion adjusted to 2022 dollars) were reported as "unofficial cost estimates" that did not meet the definition of need and/or the documentation requirements outlined in the Report to Congress.

Additional comparisons can be made to similar studies in the Mississippi River Basin. Rabotyagov et al. (2014) used CEAP-1 data and methods to model the cropland conservation investments required in the Mississippi Basin (see Table 6-3 for applicable CEAP basins) to reduce the size of the Gulf of Mexico hypoxic zone to a national policy goal of 5,000 square kilometers. The study integrated a conceptual treatment model similar to one used in CEAP-1 studies (and proposed for use in this CET) with water quality and economic models and an optimization algorithm to determine the lowest cost for achieving the policy goal. The study estimated an average annual practice implementation cost of $62 per acre ($75 per acre in 2022 dollars), more than the annual average of $54 per acre calculated by the CET (Table 6-2). The study authors then applied that cost to the highest need acres from the CEAP-1 study and found that an annual investment of $2.7–$5.6 billion ($3.3–6.7 billion in 2022 dollars) in cropland conservation practices was required to achieve the measurable water quality goal, with the lower end of

[24] All inflation adjustments made using the Bureau of Labor Statistics CPI Inflation Calculator.

the range representing the most optimized approach to nutrient reduction. Xu et al. (2022) used a land use model to estimate the cost of reducing nitrogen loadings by 45 percent, which corresponds to the target of the 2008 Gulf Hypoxia Action Plan (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2008). They found an annual investment of $6 billion (2022 dollars) would be required. However, this result is associated with reducing annual nitrogen in runoff by 45 percent, compared to the more targeted reductions of spring nitrogen and phosphorus loads of 19 percent assumed by Rabotyagov et al. (2014).

Using an annualized version of the costs estimated by the cropland CET for Mississippi River basins (Table 6-3) would result in an annual cost of $2.6 billion—slightly less than the optimal $3.3 billion estimated by Rabotyagov et al. (2014) and about half as much as the $6 billion estimated by Xu et al. (2022). While neither Rabotyagov et al. (2014) or Xu et al. (2022) explicitly linked investment need to the CWA's water quality goals, a measurable water quality outcome like reducing the hypoxic zone size could be considered a proxy for achieving other water quality goals. These points of comparison suggest the CET could be underestimating the true need for cropland nonpoint source management.

As an additional point of comparison, the 2018 Farm Bill identifies approximately $33 billion (2022 dollars) in mandatory spending for conservation programs over five years. Not all Farm Bill conservation program funding is used for direct implementation of conservation practices (e.g., some of the funding is used to remove environmentally sensitive land from agricultural production, some is allocated to funding research for innovative conservation practices). In addition, practices that are implemented through the Farm Bill programs are not necessarily targeted to the acres that have a high or moderate need for additional practices. Conversely, not all cropland conservation practices are funded through NRCS programs. With those caveats, the allocation of Farm Bill funding at approximately $33 billion over five years for agricultural land conservation provides a point of comparison for the $30 billion over five years estimated using the cropland tools.

CEAP-2 results were published during the 2022 CWNS—too late for incorporation into the Cropland CET, but early enough to be qualitatively considered here. CEAP-2 surveys were performed from 2013 to 2016, representing an update to CEAP-1 surveys performed from 2003 to 2006. Over the intervening decade, total cropland increased very slightly while national acres in medium or high need categories remained similar despite regional differences. Of the regions that experienced reductions in the acres considered medium or high need, reductions ranged from 20 to 26 percent, which is considerably less than the conservative 50 percent reduction factor built into the CET. Farming practices also shifted due to changing climate and economic drivers. For example, in the northern and southern plains, there was a shift from wheat and other close-grown crops with lower nutrient needs to corn and soybean, which are generally higher yielding and have greater nutrient demands. Concurrently, implementation of structural practices and conservation tillage increased, resulting in reduced surface exports of sediment and nutrients. However, the increase in conservation tillage, which reduces the applied nutrients' ability to be incorporated into the soil, combined with more crops with higher nutrient demands and lower nutrient management implementation rates, resulted in an increase in subsurface nutrient losses. In total, the negligible net change in national acres of need, combined with increases in subsurface nutrient losses that are not adequately addressed by the current practice model, suggest that the Cropland CET remains conservative (i.e., low) in its estimate of Category VII-A needs.

# 7. Nonpoint Source—Silviculture (Category VII-C)

## 7.1 Background

For discussion of Category VII background information, see section 6.1.

## 7.2 Silviculture CET

The EPA evaluated available national, regional, and state data to anticipate how states are most likely to estimate needs for silviculture. Based on available datasets, the EPA determined that a CET that estimates silviculture need on a per-acre basis was the most broadly applicable.

Each state is required to input data for its total annual harvested acres and average BMP implementation rate. The silviculture CET estimates the cost of implementing forestry BMPs on the portion of annual harvested acres without adequate BMP implementation.

### 7.2.1 Acres of Need Data Sources

The EPA anticipates that states lacking state-specific information on silviculture acres of need will rely on the following two sources of information from the USDA and the National Association of State Foresters (NASF):

- For total acres: The USDA Forest Service Forest Inventory and Analysis Program (FIA) provides a range of forestry data. The program collects, analyzes, and reports information on the status and trends of U.S. forests. At a state level, the program provides results of ongoing surveys that include an average annual estimate of the acres of forest land that are treated by cutting (e.g., harvesting, thinning). In other words, it provides state-level estimates of the annual acres of forest land that are subject to activities that may result in nutrient or sediment export.
- For portion of acres requiring silviculture BMPs: The NASF is a nonprofit organization composed of directors of forestry agencies in the states, U.S. territories, and District of Columbia. It conducts periodic surveys of many state BMP programs to determine average adherence to BMP implementation on active harvest lands. The most recent survey, conducted in 2019, shows that BMPs are implemented 92 percent of the time across all surveyed states. The remaining 8 percent of harvested areas still require BMPs.

### 7.2.2 Cost Data Sources

To determine the cost of silviculture BMP implementation, the EPA met with federal, state, and industry experts, reviewed state publications (e.g., state forest action plans, TMDLs), and reviewed peer-reviewed literature. The EPA, with the assistance of forestry experts, identified several studies that estimated the per-acre costs of silviculture BMP implementation, which are listed in Table 7-1 and illustrated in Figure 7-1.

Lickwar et al. (1992) and Woodman and Cubbage (1994), the oldest studies in the group, performed desktop analyses of actual forestry operations to model harvest activities with and without BMPs. They found site conditions (e.g., topography, proximity to streams) to be the main drivers of BMP implementation costs. They also found that industrial sites were generally larger and had fewer water bodies and less topographic relief than nonindustrial private forests, resulting in lower implementation costs. Given the age of the studies, it is likely that BMP implementation requirements have since increased, which may explain the overall lower implementation costs seen in Table 7-1 and Figure 7-1 from these older studies.

Shaffer et al. (1998) surveyed 272 loggers, asking them to estimate the cost of typical forestry BMPs, including haul roads, broad-based dips, water turn-outs, waterbars, multiple types of stream crossings, streamside management zones, and log landings. Then, they applied those BMP unit costs to 46 randomly chosen harvest sites across Virginia, ranging in size from 12 to 207 acres, matching costs with observed installations of the BMPs. Their study resulted in the widest range of per-acre costs ($6 to $164 per acre), illustrating the variability of needed BMPs across harvest sites.

Sawyers et al. (2012) only evaluated the per-acre costs associated with skid trail closure techniques, so their results may underestimate the cost to implement a typical suite of BMPs. Still, they emphasize the importance of proper skid trail closure, citing Litschert and MacDonald (2009), who found that across 200 logging sites, 83 percent of erosion features connected to stream channels originated from skid trails. The range of values Sawyers et al. calculated reflects a design with a waterbar only at the low end and a waterbar with slash cover at the upper end. These values are based on actual charges from the skidding contractors.

Kelly et al. (2017) provided the most current and applicable estimate of forestry BMP costs. They developed a hypothetical, 100-acre harvest job designed to incorporate typical BMPs, including three stream crossings; reshaping, seeding, and mulching of crossing banks upon closeout; three wet sections of skid trail requiring corduroy; and installation of 50 waterbars. They surveyed 123 loggers from the Northeast and asked them to bid on the 100-acre job with and without BMPs; the difference between the two bids served as an estimate of the cost of BMP implementation. The authors found that, on average, the cost to implement water quality BMPs was $62 per acre ($72 per acre adjusted to 2022 dollars).

Although the estimate from Kelly et al. (2017) is the most robust and applicable to silviculture CET development, the authors provide no indication of the cost range submitted by survey respondents. To investigate the potential range, the EPA obtained unit costs for each BMP from Kelly et al.'s hypothetical 100-acre plot using practice scenario costs from NRCS State Payment Schedules (national averages), the U.S. Forest Service's (USFS) Watershed Improvement Tracking System (WIT),[25] and peer-reviewed literature. Using minimum and maximum cost values for each BMP, the resulting cost range is $74 to $296 per acre and is illustrated as the "Unit Cost Approach" in Figure 7-1. While the EPA did not directly use this range, it indicates that the value estimated by Kelly et al. (2017) of $72 per acre may be low. This could be due to the nature of the survey—since loggers were responding to a hypothetical bid, they likely responded in an economically competitive way. Also, central values tended to skew toward the lower end of the ranges for other studies when comparing the ranges with the typical or average value.

[25] USFS staff shared the USFS WIT database with the EPA. It provides a record of project costs implemented on USFS property and includes costs for many common forestry BMPs.

Lastly, the estimate from Kelly et al. does not include BMPs for road construction and maintenance (aside from stream crossings), which can be a significant source of silviculture NPS pollution (Binkley and Brown 1993; Cristan et al., 2016; Ice and Schilling, 2012). The EPA was not able to identify any national information source that would allow states to estimate the length of forest roads requiring BMPs; therefore, the silviculture CET does not allow states to estimate the length of roadways requiring BMP implementation. As a result, the silviculture CET may underestimate total silviculture needs.

**Table 7-1. Summary of Per-Acre Silviculture BMP Implementation Costs, Adjusted to January 2022 Dollars**

| Source | Year | States | Average | Min | Max |
|---|---|---|---|---|---|
| Lickwar et al., 1992 | 1987 | AL, FL, GA | $31 | $11 | $63 |
| Woodman and Cubbage, 1994 | 1994 | GA | $47 | $37 | $159 |
| Shaffer et al., 1998 | 1998 | VA | $33 | $6 | $164 |
| Sawyers et al., 2012 | 2009 | VA | $86 | $86 | $181 |
| Kelly et al., 2017 | 2017 | Northeast | $72 | | |

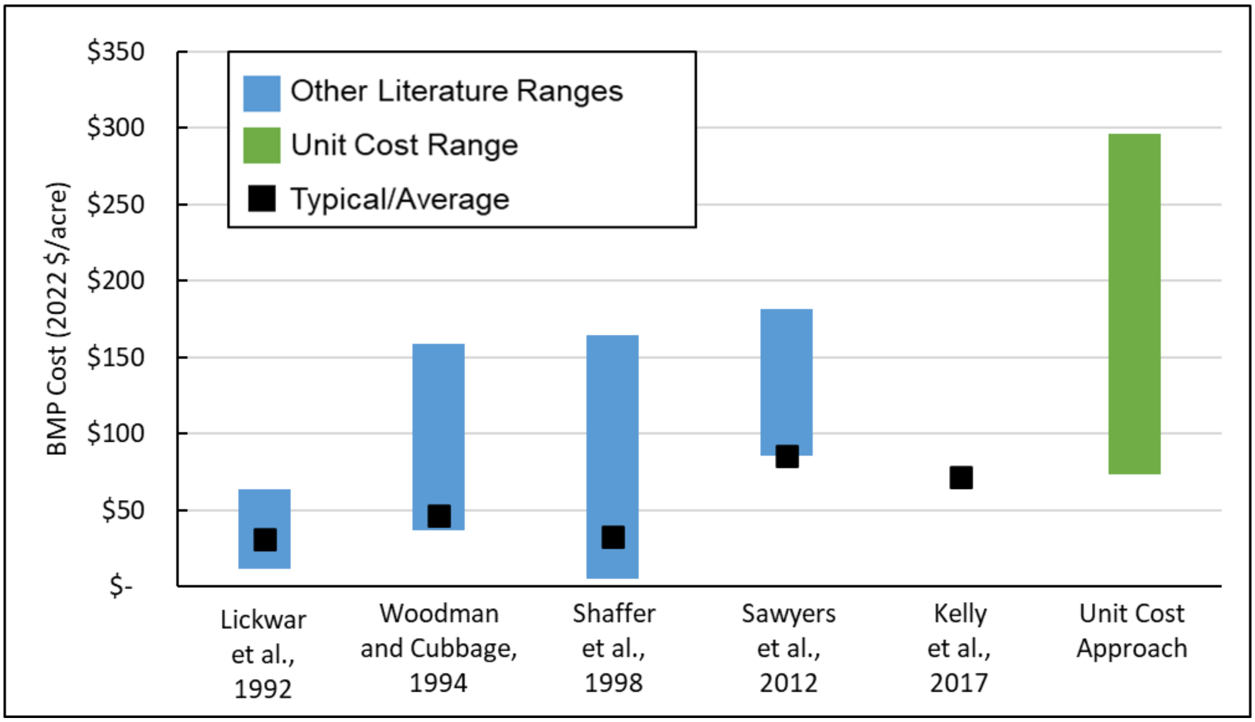


**Figure 7-1. Illustration of Per-Acre Silviculture BMP Implementation Costs.**

To obtain costs at a state level, the EPA adjusted Kelly et al.'s estimate for the per-acre cost using statewide average RSMeans location cost factors. The EPA first converted the base cost ($72 per acre) to a national average by dividing it by the average location cost factor for the states surveyed in the study (Maine, New Hampshire, New York, Vermont), or 97.9. The EPA then converted the national average ($74 per acre) to individual state values, which range from $51 per acre to $87 per acre.

### 7.2.3 CET Development Process

The proposed silviculture CET allows states to determine the annual number of active harvest acres that need additional water quality BMPs and the cost for implementing those practices. To do so, states could use the USFS FIA database (or another state-specific source of information) to determine the annual number of forest acres expected to undergo active harvest (harvest area). States for which these data are not reported in the FIA database (during the 2022 CWNS, the USFS FIA indicated that 10 states had pending results) were directed to use the regional average percent of total forest area (shown in Table 7-2) that the EPA calculated using available state data.

**Table 7-2. Percent of Forest Area Harvested Annually by NASF Region**

| NASF Forest Region | Average % of Forest Area Harvested Annually |
|---|---|
| Southeast | 2.3% |
| Western | 1.0% |
| Northeast–Midwest | 1.1% |

Using the most recent NASF BMP survey (or other state-specific source of information), states could determine the rate of BMP implementation. If the state is not included in the NASF BMP survey, they were directed to use the regional average (shown in Table 7-3) that EPA calculated using available state data.

**Table 7-3. BMP Implementation Rate by NASF Region**

| NASF Forest Region | Average BMP Implementation Rate |
|---|---|
| Southeast | 94% |
| Western | 91% |
| Northeast–Midwest | 93% |

The EPA then used Equation 7-1 to estimate the five-year expenditure (see section 7.2.4 for planning horizon discussion) needed for silviculture BMP implementation (calculated by silviculture CET):

*Equation 7-1.*
$$Need\ (\$/Year) = \big(1 - BMP\ Rate\ (\%)\big) \times Harvest\ Area\ \left(\frac{Acres}{Year}\right) \times Adjusted\ State\ Cost\ \left(\frac{\$}{Acre}\right)$$

Similar to the cropland CET, a state could use the silviculture CET to estimate only the acres of harvest area needing treatment or the cost to implement that treatment.

The EPA encouraged states to separately estimate needs associated with water quality BMPs for forest roads since the silviculture CET does not include this component due to a lack of national data that could be used to estimate the length of forest roads in need of water quality BMPs.

#### 7.2.4 Acres of Need Planning Horizon

The goal of the CWNS is to capture needs anticipated by states within the next 20 years. However, given the nature of the data used as the basis for the silviculture CET, it is not reasonable to project silviculture needs 20 years into the future. For example, data from the FIA on annual harvested area is estimated on a five-to-10-year timeframe. BMP practices and implementation rates also change over time (Conrad et al. 2018; Cristan et al. 2018), and BMP implementation rates have recently been estimated on a four-year basis (the most recent NASF BMP surveys in 2015 and 2019). Therefore, the EPA established a five-year timeframe for estimating silviculture NPS acres of need.

#### 7.2.5 CET Data Validation

In 2008, the reported need for Category VII-C was $332 million ($442 million in 2022). If each state were to use the silviculture CET, the resulting total five-year need would equal $257 million. This is likely an underestimation of total needs due to the omission of needs associated with forest road BMPs, which the EPA encouraged states to estimate using state-specific data.

# 8. Decentralized Wastewater Treatment (Category XII)

## 8.1 Background

In past surveys, decentralized wastewater treatment system cost curves were provided for on-site wastewater treatment systems (OWTS) and clustered systems for "new" and "rehabilitation" construction types. Very few clustered system needs were reported in the 2012 CWNS. Of the OWTS needs, costs were split relatively evenly between those modeled and documented. The 2012 decentralized cost models included the following equations (in 2022 dollars):

- New On-Site = $4,653 × Population × Locational Factor
- Rehab On-Site = $3,675 × Population × Locational Factor
- New Clustered = $5,873 × Population × Locational Factor
- Rehab Clustered = $4,640 × Population × Locational Factor

For the 2022 CWNS, the EPA reviewed multiple information sources to determine a current, representative cost for decentralized treatment systems for use in the decentralized CET. The EPA did not develop a separate CET for clustered systems, given the very low portion of overall need reflected in past surveys.

## 8.2 CET Development

To develop new unit costs for the decentralized CET (OWTS only), the EPA reviewed numerous data sources, including past survey data over 10 years old and current data submitted for the 2022 CWNS. While seemingly a simple task—estimating the average cost to install one of the most common and long-standing wastewater treatment processes in the United States—it became increasingly apparent that costs can vary tremendously. First, difficult construction conditions such as site access challenges, high groundwater tables, rocky geology, and steep topography can easily double the cost of a "standard" new system. Second, there is a recent but growing trend of states requiring more expensive advanced treatment, such as aerobic treatment systems, in environmentally sensitive locations. Combined, these factors can lead to project-level costs that span an order of magnitude in a single state. To develop a reasonable average, the EPA combined current cost estimates with U.S. Census data to weigh low-cost, "standard" systems with higher-cost systems indicative of difficult construction conditions or advanced treatment.

### 8.2.1 Cost Data

The EPA first reviewed data from past surveys and other governmental and online resources, including the EPA's Clean Water Benefits Reporting (CBR). Any cost originally expressed on a per-person basis was converted to a per-system basis using a national average of 2.5 persons per household, obtained from the 2022 Census (U.S. Census, 2022). A summary of those data is provided in Table 8-1.

**Table 8-1. Summary of Decentralized Treatment System Cost Data in 2022 Dollars**

| Source | Construction Type | Average Cost per Person | Average Cost per System |
|---|---|---|---|
| New | | | |
| 2012 cost curve | New | $4,653 | $11,632 |
| 2012 documented costs | New | $6,771 | $16,927 |
| Rehabilitation, Repair, or Replace | | | |
| 2012 cost curve | Rehabilitation | $3,675 | $9,188 |
| 2012 documented costs | Rehabilitation | $1,179 | $2,947 |
| 2012 documented costs | Replace | $2,222 | $5,554 |
| CBR | Repair or replace | $3,218 | $8,046 |

The data in Table 8-1 show a distinction between the cost to construct a new system ($11,600 to $17,000) and the cost to repair, rehabilitate, or replace a failing system (about $3,000 to $9,200). Unfortunately, the EPA found very little information to describe the type or range of projects captured by these costs. For example, CBR data were characterized as either "new," "repair," "replace," or "repair or replace," with little indication of the distinction between each. Only one "new" project was reported in CBR. It had an unusually low cost ($1,340 per person) compared to other data sources and was thus not included here.

The EPA then used Google to search online cost sources using the terms "septic system cost" and "decentralized unit process cost," as well as searching peer-reviewed literature (via Google Scholar) using the same search terms. Searches were intended to identify readily available data that could confirm or disprove values in Table 8-1 rather than compile an exhaustive list. General online searches yielded reviews of vendor data (e.g., Glover 2023; Thorsby 2023) showing costs ranging from roughly $4,000 to $25,000 per system. Although this is a wide range, it covers the values for new systems in Table 8-1 and suggests values across the country can be highly variable. Cost data identified in the peer-reviewed literature were generally too narrow in focus to be informative for this effort. The most thorough cost estimate the EPA found was WERF's Performance & Cost of Decentralized Unit Processes (WERF 2010). WERF found installation costs for single-family systems (e.g., septic tanks with gravity trench, low pressure distribution, subsurface drip irrigation dispersal systems) ranged from about $8,000 to $17,000 (WERF 2010, costs adjusted to 2022).

During the 2022 CWNS, the EPA leveraged state data submitted as part of the survey as well as cost data collected by other EPA staff that were conducting parallel cost data collection efforts. Cost data sources generally included historic loan data, contractor estimates or invoices, and email correspondence with technical experts. Ranges were wide for states with more than one cost estimate, similar to the cost ranges in Table 8-1. Table 8-2 summarizes the data by state, adjusted for time and location. Although only nine states are represented, they represent a mix of site conditions and treatment requirements across the United States.

**Table 8-2. Summary of Cost Data for "New" or "Replace" Systems from 2022 CWNS and EPA in 2022 Dollars**

| State | Source | n | Average | Range | | |
|---|---|---|---|---|---|---|
| Iowa | 2022 CWNS SSA | 958 | $14,606 | $3,517 | – | $56,387 |
| Minnesota | 2022 CWNS SSA | 12 | $23,774 | $12,315 | – | $46,607 |
| Ohio | 2022 CWNS SSA | 1 | $17,726 | $17,726 | – | $17,726 |
| Utah | 2022 CWNS SSA | 1 | $21,489 | $21,489 | – | $21,489 |
| Vermont | 2022 CWNS SSA | 53 | $29,594 | $10,008 | – | $53,294 |
| Washington | 2022 CWNS SSA | 23 | $22,389 | $13,967 | – | $29,545 |
| Alabama | EPA | 3 | $17,075 | $10,167 | – | $23,678 |
| Arkansas | EPA | 4 | $15,707 | $8,623 | – | $28,334 |
| North Carolina | EPA | 4 | $27,014 | $9,975 | – | $32,774 |
| | | **Average:** | **$21,042** | **$11,976** | **–** | **$34,426** |

The EPA's cost estimates for Alabama, Arkansas, and North Carolina include information such as system type and construction conditions, which were generally not available from 2022 CWNS SSA costs. The EPA's data reflect costs of standard systems with gravel drainfields, mounded systems with pumps needed for difficult sites, and advanced treatment systems. Costs for standard systems with typical site conditions were typically reported as $8,000 to $12,000. This lines up with WERF's estimate of standard system cost of about $8,000. It is also within the lower range of estimates from states that provided more than one cost estimate for their 2022 CWNS SSA (about $3,500 to $14,000). Upper end costs from Alabama, Arkansas, and North Carolina represent advanced or difficult construction system types, and range from about $24,000 to $33,000.

Supporting cost data is provided in Appendix F.

### 8.2.2 Cost Data Limitations

The average value for each state and the average of state averages shown in Table 8-2 is likely not a true average cost for the country. First, average values from Iowa, Minnesota, Vermont, and Washington come from historic loan data, which may include administrative or other unspecified cost markups that do not reflect typical costs incurred by homeowners. Second, average values from Alabama, Arkansas, and North Carolina represent the average of a range of two to four system types, with no consideration of the prevalence of each. For example, the average cost of a $10,000 system and a $30,000 system is $20,000, assuming equal prevalence of the two. However, if 90 percent of systems cost $10,000 and only 10 percent of systems cost $30,000, an "average cost" of $20,000 would be highly inflated relative to the appropriately weighted average of $12,000.

### 8.2.3 Prevalence Data

To estimate system prevalence, the EPA used results from the 2021 U.S. Census Bureau's American Housing Survey (AHS), which provides a breakdown of household wastewater system characteristics. Table 8-3 summarizes the composition of households with a septic tank or cesspool (alternative classifications are public sewer or other). As shown, only 6 percent of systems are characterized as non-standard, which includes both difficult construction conditions and advanced treatment types.

**Table 8-3. Summary of 2021 U.S. Census American Housing Survey Septic Tank Types (U.S. Census, 2021a)**

| Type of Sewage System | 2021 AHS Definition[a] | Number of Households | Percent of Households (%) |
|---|---|---|---|
| Standard septic tank and subsurface leach field | Considered a conventional system, the primary components are a standard septic tank and subsurface leach field. | 18,371,000 | 94 |
| Pump used to distribute wastewater | Often called a pressurized system, an on-site wastewater system uses a pump to distribute wastewater throughout a shallow leach field under pressure. | 633,000 | 3 |
| Elevated above natural soil surface | A "mound" pressurized wastewater system that is elevated above the natural soil surface using a mound of suitable fill material, such as quality sand media. | 291,000 | 1 |
| Applied treated wastewater | Often referred to as an irrigation system, this type of system applies to treated wastewater slowly and uniformly (by dripping) from a network of narrow plastic tubing placed at shallow depths of six to 12 inches in the plant root zone. | 66,000 | 0 |
| Other | Any type of septic tank or cesspool system not listed above. This would include systems such as aerobic treatment units, sand filters, peat filters, and constructed wetlands. | 128,000 | 1 |
| **Total** | | **19,489,000** | **100** |

[a] 2021 AHS Definitions (U.S. Census, 2021b)

### 8.2.4 Construction Type

Of the six states that included costs with their SSAs, all stated that their needs pertain to new system construction or the replacement of failing systems. In addition, most of the other states that used the EPA's decentralized CET stated that their needs were for the construction of new systems or the replacement of failing systems; very few indicated needing the partial repair or rehabilitation of existing systems. Given the nature of these stated needs, the EPA determined that a single cost for the construction of new systems or the replacement of a failing system is the most representative construction type.

### 8.2.5 National Average Cost

To determine a defensible national average cost of installation for a "new" or "replacement" septic system, the EPA weighted the data in Table 8-2 using the AHS data in Table 8-3. Although 2021 AHS data indicate that 6 percent of systems require more costly construction types, the EPA used an estimate of 10 percent to reflect the growing portion of new systems requiring advanced treatment (which may be undercounted by the AHS); this estimate incorporates technical input from EPA staff familiar with current on-site wastewater practices. Weights of 90 percent and 10 percent were applied to the average minimum and average maximum from Table 8-1, respectively. For reasons discussed above, using the average minimum value may underestimate the cost of a standard system in states that submitted a range of costs; however, this is balanced by using the single average cost from Ohio and Utah in the same calculation, which likely overestimates the cost of a standard system. "Minimum" costs from Alabama, Arkansas, and North Carolina actually represent those states' average estimates of a standard system (middle and high estimates from those states represent more advanced system types). At the other end of the range, the average maximum value likely overestimates the cost of systems with difficult construction or advanced treatment requirements. In total, these interpretation nuances suggest that the weighted average presented in Table 8-4 may, if anything, be an overestimate of the true national average.

**Table 8-4. Calculation of Average Septic System Cost for New or Full Replace**

| Parameter | Average Minimum | Average Maximum |
|---|---|---|
| Cost | $11,976 | $34,426 |
| Weight (%) | 90% | 10% |
| **Weighted average** | **$14,221** | |

## 8.3 Decentralized Wastewater Treatment CET

The EPA's decentralized wastewater treatment CET is based on a cost per system that can be adjusted to a per-person cost, as needed, based on U.S. Census data for average people per household. Given the small fraction of needs that were made up of clustered systems in 2012, as well as the similar cost curve for clustered systems and OWTS, the EPA based the clustered systems cost on the population they serve, as was done with OWTS.

The base costs per system the EPA used for the decentralized CET is $14,221, which applied to all construction types. The final equation used to calculate system cost is as follows:

*Equation 8-1.* $$Cost = CPI \times LF_{City} \times System\ Cost \times n$$

*Equation 8-2.* $$n = Population\ Served / People\ per\ Household$$

Where,

*Cost* = total estimated capital cost
*CPI* = inflation adjustment based on BLS CPI
$LF_{City}$ = city location factor (RSMeans, see section 1.2)
*System Cost* = $14,221

*n* = number of systems, entered directly or calculated using Equation 8-2
*Population Served* = population served by decentralized systems
*People per Household* = average, based on most recent U.S. Census data for the scale at which data are entered (county or state)

# 9. References


Binkley, D., & Brown, T. C. (1993). Forest practices as nonpoint sources of pollution in North America. *JAWRA Journal of the American Water Resources Association*, *29*(5), 729–740.

Conrad IV, J. L., Greene, W. D., & Hiesl, P. (2018). A review of changes in US logging businesses 1980s–present. *Journal of Forestry*, *116*(3), 291–303.

Cristan, R., Aust, W. M., Bolding, M. C., Barrett, S. M., Munsell, J. F., & Schilling, E. (2016). Effectiveness of forestry best management practices in the United States: Literature review. *Forest Ecology and Management*, *360*, 133–151.

Cristan, R., Aust, W. M., Bolding, M. C., Barrett, S. M., & Munsell, J. F. (2018). National status of state developed and implemented forestry best management practices for protecting water quality in the United States. *Forest Ecology and Management*, *418*, 73–84.

Glover, E. (2023, March). How much does septic tank installation cost in 2023? *Forbes Home*. https://www.forbes.com/home-improvement/plumbing/septic-tank-installation-cost/

Great Lakes–Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers. (2014). *Recommended standards for wastewater facilities: Policies for the design, review, and approval of plans and specifications for wastewater collection and treatment facilities*. Health Research, Inc. https://www.health.state.mn.us/communities/environment/water/docs/tenstates/tenstatestan2014.pdf

Grubert, E., & Krieger, J. (2020). *Integrated decision support tool (iDST) life cycle costing module for distributed stormwater control measures (SCMs)*. http://hdl.handle.net/1853/62873

Hydromantis. (2014). *CapdetWorks™* (Version 3.0). https://www.hydromantis.com/CapdetWorks.html

Ice, G. G., & Schilling, E. B. (2012). *Assessing the effectiveness of contemporary forestry best management practices (BMPs): Focus on roads* (Special report no. 12-01). National Council for Air and Stream Improvement. https://www.ncasi.org/wp-content/uploads/2019/02/sr12-01.pdf

Kadlec, R. H., & Wallace, S. (2008). *Treatment wetlands*. CRC Press.

Kelly, M. C., Germain, R. H., & Bick, S. (2017). Impacts of forestry best management practices on logging costs and productivity in the northeastern USA. *Journal of Forestry*, *115*(6), 503–512.

King, D., & Hagan, P. (2011). *Costs of stormwater management practices in Maryland counties* (Ref. No. [UMCES] CBL 11-043). Maryland Department of the Environment.

Krieger, J., & Grubert, E. (2021). Life-cycle costing for distributed stormwater control measures on the gray-green continuum: A planning-level tool. *Journal of Sustainable Water in the Built Environment*, *7*(1), 04020019.

Lickwar, P., Hickman, C., & Cubbage, F. W. (1992). Costs of protecting water quality during harvesting on private forestlands in the southeast. *Southern Journal of Applied Forestry*, *16*(1), 13–20.

Litschert, S. E., & MacDonald, L. H. (2009). Frequency and characteristics of sediment delivery pathways from forest harvest units to streams. *Forest Ecology and Management*, *259*(2), 143–150.

MDE (Maryland Department of the Environment). (2009). *2000 Maryland stormwater design manual*. https://mde.maryland.gov/programs/water/stormwatermanagementprogram/pages/stormwater_design.aspx.

Metcalf and Eddy, Inc., Tchobanoglous, G., Stensel, H., Tsuchihashi, R., & Burton, F. (2014). *Wastewater engineering: Treatment and resource recovery* (5th ed.) McGraw-Hill.

Mississippi River/Gulf of Mexico Watershed Nutrient Task Force. (2008). Gulf Hypoxia Action Plan 2008 for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico and Improving Water Quality in the Mississippi River Basin. Washington, DC.

MPCA (Minnesota Pollution Control Agency). (2013). *Minnesota stormwater manual*. https://stormwater.pca.state.mn.us/index.php.

North Carolina DEQ (Department of Environmental Quality). (2020). *Stormwater design manual*. https://deq.nc.gov/about/divisions/energy-mineral-and-land-resources/stormwater/stormwater-program/stormwater-design

Rabotyagov, S. S., Campbell, T. D., White, M., Arnold, J. G., Atwood, J., Norfleet, M. L., Kling, C. L., Gassman, P. W., Valcu, A., Richardson, J., Turner, R. E., & Rabalais, N. N. (2014). Cost-effective targeting of conservation investments to reduce the northern Gulf of Mexico hypoxic zone. *Proceedings of the National Academy of Sciences*, *111*(52), 18530–18535.

Rossman, L.A., & Bernagros, J.T. (2019). *National Stormwater Calculator user's guide—version 2.0.0.1*. EPA/600/R-13/085g. U.S. Environmental Protection Agency. https://www.epa.gov/sites/default/files/2019-04/documents/swc_users_guide_desktop_v1.2.0.3_april_2019.pdf

RTI International & Geosyntec Consultants. (2015). *Low impact development stormwater control cost estimation analysis*. U.S. Environmental Protection Agency. https://pasteur.epa.gov/uploads/10.23719/1510483/documents/LID%20Cost%20Analysis_Report_National%20SWC_2015.pdf

Sawyers, C., Aust, W. M., Bolding, M. C., & Lakel III, W. A. (2012). Effectiveness and costs of overland skid trail BMPs. In J. R. Butnor (Ed.), *Proceedings of the 16th Biennial Southern Silvicultural Research Conference* (pp. 283–289). U.S. Department of Agriculture. https://doi.org/10.2737/SRS-GTR-156

Shaffer, R. M., Haney, H. L., Worrell, E. G., & Aust, W. M. (1998). Forestry BMP implementation costs for Virginia. *Forest Products Journal, 48*(9), 27–29.

Shrestha, S., Fang, X., & Li, J. (2013). Mapping the 95th percentile daily rainfall in the contiguous US. In C. L. Patterson, S. D. Struck, & D. J. Murray (Eds.), *World Environmental and Water Resources Congress 2013: Showcasing the future* (pp. 219–229). https://doi.org/10.1061/9780784412947.021

SPU (Seattle Public Utilities). (2017). *City of Seattle stormwater manual*. http://www.seattle.gov/util/cs/groups/public/@spuweb/@policy/documents/webcontent/1_046871.pdf.

Tetra Tech, Inc. (2016). *Opti-Tool for stormwater and nutrient management: User's guide*. U.S. Environmental Protection Agency. https://www3.epa.gov/region1/npdes/stormwater/tools/opti-tool-user-guide.pdf

Thorsby, D. (2023, January 13). How much does a septic tank or septic system cost in 2023? *U.S. News & World Report.* https://realestate.usnews.com/real-estate/articles/how-much-do-septic-tanks-cost

Trussell, R. R., Trussell, R. S., Salveson, A., Steinle-Darling, E., He, Q., Snyder, S., & Gerrity, D. (2015). *Equivalency of advanced treatment trains for potable reuse: User manual for Treatment Train Toolbox*. WateReuse Research Foundation.

U.S. Census Bureau. (2021a). *2021 national—plumbing, water, and sewage disposal—all occupied units*. American Housing Survey. https://www.census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html

U.S. Census Bureau. (2021b). *Definitions, accuracy, historical changes, and questionnaires*. American Housing Survey. https://www.census.gov/programs-surveys/ahs/tech-documentation/def-errors-changes.2021.html

U.S. Census Bureau. (2022). *Table AVG1: Average number of people per household, by race and Hispanic origin, marital status, age, and education of householder: 2022*. America's Families and Living Arrangements: 2022. https://www.census.gov/data/tables/2022/demo/families/cps-2022.html

WERF (Water Environment Research Foundation). (2009). *User's guide to the BMP and LID whole life cost models* (Version 2.0).

WERF (Water Environment Research Foundation). (2010). *Performance and cost of decentralized unit processes* (Report #DEC2R08). https://www.waterrf.org/research/projects/performance-and-costs-decentralized-unit-processes

Woodman, J. N., & Cubbage, F. W. (1994). Potential costs of mandatory best management practices in Georgia. In D. H. Newman & M. E. Aronow (Eds.), *Proceedings of the 24th Annual Southern Forest Economics Workshop* (pp. 309–322). University of Georgia.

Xu, Y., Elbakidze, L., Yen, H., Arnold, J. G., Gassman, P. W., Hubbart, J., & Strager, M. P. (2022). Integrated assessment of nitrogen runoff to the Gulf of Mexico. *Resource and Energy Economics*, *67*, 101279.

# Appendices

# Appendix A. Need Categories

Table A-1 provides the full list of need categories and definitions.[26]

### Table A-1. Need Categories and Definitions

| 2022 Category Number | Category Name | Description |
|---|---|---|
| I | Secondary Wastewater Treatment | This category includes needs for meeting secondary treatment criteria. Secondary treatment typically requires a treatment level that produces an effluent quality of 30 milligrams per liter of both 5-day biochemical oxygen demand ($BOD_5$) and total suspended solids. (Secondary treatment levels required for some lagoon systems may be less stringent.) In addition, the secondary treatment must remove 85 percent of $BOD_5$ and total suspended solids from the influent wastewater.<br><br>This category also includes facilities granted waivers of secondary treatment for marine discharges under section 301(h) of the CWA and "honey bucket lagoons," though they do not provide secondary treatment. |
| II | Advanced Wastewater Treatment | This category includes needs for attaining or maintaining a level of treatment that is more stringent than secondary treatment or producing a significant reduction in nonconventional or toxic pollutants in the wastewater treated by a facility. A facility is considered to have advanced wastewater treatment if it achieves one or more of the following: $BOD_5$ less than 20 milligrams per liter, nitrogen removal, phosphorus removal, ammonia removal, metal removal, or synthetic organic removal. |
| III-A | Infiltration/Inflow (I/I) Correction | This category includes needs for correction of sewer system I/I problems. For infiltration, this includes controlling the penetration of water into a sanitary or combined sewer system from the ground through defective pipes or manholes. For inflow, it includes controlling the penetration of water into the system from drains, storm sewers, and other improper entries. It also includes costs for preliminary sewer system analysis and detailed sewer system evaluation surveys. |
| III-B | Sewer Replacement/ Rehabilitation | This category includes needs for the maintenance (above and beyond ongoing operations and maintenance), reinforcement, or reconstruction of structurally deteriorating sanitary or combined sewers. The corrective actions must be necessary to maintain the structural integrity of the system. |

[26] Note that Categories VIII, IX, XI, and XIII are no longer collected.

| 2022 Category Number | Category Name | Description |
|---|---|---|
| IV-A | New Collector Sewers and Appurtenances | This category includes needs for new pipes used to collect wastewater from a sanitary or industrial wastewater source and carry it to an interceptor sewer that will convey it to a treatment facility. |
| IV-B | New Interceptor Sewers and Appurtenances | This category includes needs for constructing new interceptor sewers and pumping stations to convey wastewater from collection sewer systems to a treatment facility or to another interceptor sewer. Needs for relief sewers are included in this category. |
| V | Combined Sewer Overflow (CSO) Correction | This category includes needs to prevent or control the periodic discharges of mixed stormwater and untreated wastewater (CSOs) that occur when the capacity of a sewer system is exceeded during a wet weather event. This category does not include needs for overflow control allocated to flood control, drainage improvement, or the treatment or control of stormwater in separate storm systems. |
| VI-A | Gray Infrastructure | This category includes needs for stormwater management program activities associated with the planning, design, and construction of stormwater conveyance structures (e.g., pipes, inlets, roadside ditches, and other similar mechanisms). This category also includes needs associated with the planning, design, and construction of structural BMPs that treat stormwater (e.g., wet ponds, dry ponds, manufactured devices). |
| VI-B | Green Infrastructure | This category includes needs for stormwater management program activities associated with the planning, design, and construction of low-impact development and green infrastructure (e.g., bioretention, constructed wetlands, permeable pavement, rain gardens, green roofs, cisterns, rain barrels, vegetated swales, restoration of riparian buffers and flood plains). |
| VI-C | General Stormwater Management | This category includes needs for activities associated with implementing a stormwater management program. These needs can include geographic information systems and tracking systems, equipment (e.g., street sweepers, vacuum trucks), stormwater education program startup costs (e.g., setting up a stormwater public education center, building a traveling stormwater education display), and stormwater management plan development. |

| 2022 Category Number | Category Name | Description |
|---|---|---|
| VII-A | NPS Control: Agriculture (Cropland) | This category includes costs to address NPS pollution control needs associated with agricultural activities related to croplands. These activities include plowing, pesticide spraying, irrigation, fertilizing, planting, and harvesting. Examples of BMPs used to address these needs are conservation tillage, nutrient management, and irrigation water management. |
| VII-B | NPS Control: Agriculture (Animals) | This category includes all costs that address NPS pollution control needs associated with agricultural activities related to animal production (e.g., confined animal facilities and grazing). Some typical BMPs used to address agriculture (animal) needs are animal waste storage facilities, animal waste nutrient management, composting facilities, and planned grazing. Any costs associated with facilities or measures that address point source pollution discharges are not reported in this category. |
| VII-C | NPS Control: Silviculture | This category includes all costs that address NPS pollution control needs associated with forestry activities, such as removal of streamside vegetation, road construction and use, timber harvesting, and mechanical preparation for tree planting. Some typical BMPs used to address silviculture needs are pre-harvest planning, streamside buffers, road management, revegetation of disturbed areas, structural practices (e.g., sediment control structure), and equipment (e.g., timber harvesting equipment). |
| VII-E | NPS Control: Groundwater Protection (Unknown Source) | This category includes all costs that address groundwater protection NPS pollution control needs, such as wellhead and recharge area protection activities. Any need that can be attributed to a specific cause of groundwater pollution, such as leaking storage tanks, soil contamination in a brownfield, or leachate from a sanitary landfill, is reported in the appropriate specific category. |
| VII-F | NPS Control: Marinas | This category includes all costs that address NPS pollution control needs associated with boating and marinas, such as poorly flushed waterways; boat maintenance activities; discharge of sewage from boats; and the physical alteration of shoreline, wetlands, and aquatic habitat during the construction and operation of marinas. Some typical BMPs used to address needs at marinas are bulk heading, pump-out systems, and oil containment booms. |

| 2022 Category Number | Category Name | Description |
|---|---|---|
| VII-G | NPS Control: Resource Extraction | This category includes all costs that address NPS pollution control needs associated with mining and quarrying activities. Some typical BMPs used to address resource extraction needs are detention berms, adit (mine entrance) closures, and seeding or revegetation. Any costs associated with facilities or measures that address point source discharges are not reported in this category. |
| VII-H | NPS Control: Brownfields/Superfund | This category includes all costs that address NPS pollution control needs associated with 1) abandoned industrial sites that might have residual contamination (brownfields) and 2) hazardous waste sites covered under the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund sites). All costs for work at brownfield or Superfund sites, regardless of the activity, should be included in this category. Some typical BMPs used to address needs at brownfield or Superfund sites are excavation, removal, and disposal of contaminated sediment/soil; cleanup of contaminated groundwater or surface water; and capping of wells to prevent stormwater infiltration. |
| VII-I | NPS Control: Storage Tanks | This category includes all costs that address NPS pollution control needs associated with tanks designed to hold gasoline, other petroleum products, or chemicals. The tanks may be above or below ground level. Some typical BMPs used to address storage tank needs are spill containment systems; in situ treatment of contaminated soils and groundwater; and upgrade, rehabilitation, or removal of petroleum/chemical storage tanks. If these facilities or measures are part of addressing NPS needs at brownfields, the costs go in Category VII-H, "NPS Control: Brownfields/Superfund." |
| VII-J | NPS Control: Sanitary Landfills | This category includes all costs that address NPS pollution control needs associated with sanitary landfills. Some typical BMPs used to address needs at landfills are leachate collection, on-site treatment, gas collection and control, capping, and closure. |

| 2022 Category Number | Category Name | Description |
|---|---|---|
| VII-K | NPS Control: Hydromodification | This category includes needs to address the degradation of water resources as a result of altering the hydrological characteristics of coastal and non-coastal waters. For a stream channel, hydromodification is the process of the stream bank being eroded by flowing water, typically resulting in the suspension of sediments in the watercourse. Examples of such hydromodification activities include channelization and channel modification, dams, and stream bank and shoreline erosion. Some typical BMPs used to address hydromodification needs are conservation easements, swales, filter strips, shore erosion control, wetland development or restoration, and bank or channel (grade) stabilization. This category includes any work involving wetland or riparian area protection or restoration. |
| VII-M | NPS Control: Other Estuary Management Activities | This category is only used for management activities in the study areas of the 28 National Estuary Programs (NEPs) designated under section 320 of the CWA. It includes costs associated with a limited number of estuary management activities that may not be appropriately included in other need categories. Some typical estuary BMPs are habitat protection for aquatic species; fishery, oyster bed, and shellfish restocking and restoration; fish ladders; rejuvenation of submerged aquatic vegetation; artificial reef establishment; control of invasive vegetative and aquatic species; and water control structures for flow regime and salinity. Point source technologies included in the NEP's Comprehensive Conservation and Management Plans should not be included in this category. |
| X | Water Reuse | This category includes needs associated with conveyance of treated wastewater that is being reused, including associated rehabilitation/replacement needs. Examples are pipes to convey treated water from the wastewater facility to the drinking water distribution system or the drinking water treatment facility and equipment for application of effluent on publicly owned land.<br><br>The needs associated with additional unit processes to increase the level of treatment to potable—or less than potable but greater than the level normally associated with surface discharge needs—are reported in Category II. |

| 2022 Category Number | Category Name | Description |
|---|---|---|
| XII | Decentralized Wastewater Treatment Systems | This category includes needs associated with the rehabilitation, replacement, or new installation of on-site wastewater treatment systems or clustered (community) systems. It also includes the treatment portion of other decentralized sewage disposal technologies. Costs related to the development and implementation of on-site management districts are included (but not the costs of ongoing operations of such districts). Costs could also include the limited collection systems associated with the decentralized system. Public ownership is not required for decentralized systems.<br>This category does not include the needs to change a service area from decentralized wastewater treatment to a publicly owned centralized treatment system. Needs to construct a publicly owned centralized collection and treatment system should be reported in Category I and/or Category II. Needs to install sewers to connect the service area to an existing collection system are reported in Category IV-A and Category IV-B. |
| XIV | Desalination | This category includes needs for treatment and disposal of brine, desalination of brackish water to augment water supply, aquifer recharge using desalinated sea water, and treatment/ reinjection of brackish groundwater. |

# Appendix B. Wastewater Treatment Cost Data

The Excel workbook containing the compilation of wastewater treatment project and model cost data can be found at the following link:

Appendix B: Wastewater Treatment Cost Data.xlsx

# Appendix C. Wastewater Conveyance Cost Data

The Excel workbook containing the compilation of wastewater conveyance project and model cost data can be found at the following link:

Appendix C: Wastewater Conveyance Cost Data.xlsx

# Appendix D. Combined Sewage Overflow Storage Cost Data

The Excel workbook containing the compilation of CSO storage project and model cost data can be found at the following link:

Appendix D: CSO Cost Data.xlsx

# Appendix E. Hydromodification Project Cost Estimation Resources

Hydromodification (Category VII-K) was identified as a priority NPS subcategory; however, the EPA was not able to identify a national data source that states could use to identify hydromodification needs. Additionally, hydromodification projects—and their costs—tend to be widely variable and highly dependent on geography and site conditions. Below, the EPA provided a short list of resources that states could use to estimate the cost of planned hydromodification projects.

***Hydromodification Project Cost Estimation Resources***

NRCS State Payment Schedules

Each year, the NRCS determines material and labor costs for common agriculture practices based on fair marketplace compensation for individual states. Detailed cost estimates for hundreds of practices are included in each state's payment schedule, including a number of hydromodification practices.

Chesapeake Bay CAST Cost Profiles

The Chesapeake Assessment Scenario Tool (CAST) was developed by the Chesapeake Bay Program to help Chesapeake Bay states evaluate the cost and effectiveness of nutrient reduction scenarios. CAST provides information, including costs, about a range of typical BMPs, including hydromodification practices.

Maryland's Waterways Construction Guidelines

The Maryland Department of the Environment developed Maryland's Waterway Construction Guidelines to provide recommended details for approaches frequently encountered in waterway construction. This guide includes cost information.

# Appendix F. Decentralized Wastewater Treatment Cost Data

The Excel workbook containing the compilation of decentralized wastewater treatment cost data can be found at the following link:

Appendix F: Decentralized Wastewater Treatment Cost Data.xlsx