United States
Environmental Protection
Agency

Office of Water
Washington, DC 20460

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December 13, 2023

Benefit Cost Analysis for Revisions to the Effluent Limitations Guidelines and Standards for the Meat and Poultry Products Point Source Category

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U.S. Environmental Protection Agency
Office of Water (4303T)
Engineering and Analysis Division
1200 Pennsylvania Avenue, NW
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Abbreviations

ACS	American Community Survey
BLS	Bureau of Labor Statistics
BNR	Biological nutrient removal
BOD	Biochemical oxygen demand
CBG	Census block group
CH4	Methane
CN	Curve number
CO2	Carbon dioxide
COPD	Chronic obstructive pulmonary disease
CPI	Consumer Price Index
CWA	Clean Water Act
DAF	Dissolved air flotation
DBP	Disinfection byproduct
DMR	Discharge monitoring report
DO	Dissolved oxygen
EA	Environmental Assessment
ECHO	Enforcement and Compliance History Online
ECS	Equilibrium climate sensitivity
eGRID	Emissions & Generation Resource Integrated Database
ELGs	Effluent Limitations Guidelines and Standards
ESA	Endangered Species Act
FC	Fecal coliform
FUND	Climate Framework for Uncertainty, Negotiation, and Distribution
FWS	United States Fish and Wildlife Service
GDP	Gross domestic product
GHG	Greenhouse gas
HAB	Harmful algal bloom
HAWQS	Hydrologic and Water Quality System
HTF	Hypoxia task force
HUC	Hydrologic unit code
IAM	Integrated assessment model
IBI	Index of biotic integrity
IPCC	Intergovernmental Panel on Climate Change
IWG	Interagency Working Group on the Social Cost of Greenhouse Gases
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
MOVES3	Motor Vehicle Emission Simulator (version 3)
MPP	Meat and Poultry Products
MRM	Meta-regression model
NSDWR	National Secondary Drinking Water Regulation
NHD	National hydrography dataset
NPDES	National Pollutant Discharge Elimination System

O3	Ozone
OMB	Office of management and budget
PM2.5	Particulate matter (fine inhalable particles with diameters 2.5 µm and smaller)
POTW	Publicly owned treatment work
PWS	Public water system
SBREFA	Small Business Regulatory Enforcement Fairness Act
RIA	Regulatory Impact Analysis
SC-CO2	Social cost of carbon
SC-CH4	Social cost of methane
SDWA	Safe Drinking Water Act
SDWIS	Safe Drinking Water Information System
SMCL	Secondary maximum contaminant level
SWAT	Soil and Water Assessment Tool
T&E	Threatened and endangered
TDD	Technical Development Document
TIP	Treatment in place
TN	Total nitrogen
TP	Total phosphorus
TPC	Typical pollutant concentration
TSD	Technical Support Document
TSS	Total suspended solids
TTHM	Total trihalomethanes
USDA	United States Department of Agriculture
WTP	Willingness to pay
WQI	Water quality index

Executive Summary

Background

The U.S. Environmental Protection Agency (EPA) is proposing revisions to the technology-based effluent limitations guidelines and standards (ELGs) for meat and poultry products (MPP) point source category, 40 Code of Federal Regulations (CFR) part 432, which EPA amended in 2004 (69 FR 54476). The proposed rule establishes (1) more stringent nitrogen effluent limitations based on better performing technologies, (2) new effluent limitations for phosphorus, and (3) pretreatment standards for MPP facilities that discharge to a Publicly Owned Treatment Work (POTW).

Regulatory Options

EPA analyzed three regulatory options, labeled Option 1 through Option 3 and summarized in Table ES-1. These options differ in the stringency of control technologies and resulting effluent limits, and the applicability of these limits to MPP facilities. Specifically, the regulatory options include more stringent effluent limitations on nitrogen, new effluent limitations on phosphorus, updated effluent limitations for other pollutants including ammonia, new pretreatment standards for indirect dischargers, and revised production thresholds for the subcategories in the existing rule. EPA is also requesting comment on potentially establishing effluent limitations on chlorides for high chloride waste streams, establishing effluent limitations for E. coli for direct dischargers, and including conditional limits for indirect dischargers that discharge to POTWs that remove nutrients.

Under these options, EPA expects the revised ELGs to reduce the amount of nutrients and other pollutants (*e.g.*, biochemical oxygen demand, total suspended solids, oil and grease, fecal coliform, chlorides) discharged to surface waters from the MPP industry, with consequent benefits including improvement in water quality and aquatic habitats, reduced human and ecological health risk, enhanced natural resources, and economic productivity benefits.

Table ES-1: Summary of Regulatory Options

	Direct Dischargers		Indirect Dischargers	
Option	**Technology Basis**[a]	**Applicable Facilities**	**Technology Basis**[a]	**Applicable Facilities**
1	Adds to existing ELG: • full denitrification • chemical phosphorus removal • filter	• meat further processors > 50 million lbs/yr of finished product • meat slaughtering > 50 million lbs/yr live weight killed • poultry slaughtering >100 million lbs/yr of live weight killed • poultry further processors >7 million lbs/yr of finished product produced • renderers >10 million lbs/yr of raw material processed	Conventional pollution limits based on: • screening/grit removal • dissolved air flotation (DAF), and dewatering/solids handling	• meat further processors > 50 million lbs/yr of finished product • meat slaughtering > 50 million lbs/yr live weight killed • poultry slaughtering >100 million lbs/yr of live weight killed • poultry further processors >7 million lbs/yr of finished product produced • renderers >10 million lbs/yr of raw material processed
2	Same technology as Option 1	Same facilities as Option 1	Option 1 technology plus: • anaerobic lagoon (BOD pretreatment) • activated sludge (nitrification and full denitrification) • chemical P removal • filter	Option 1 facilities plus: • slaughterhouses producing >200 million lbs/yr • renderers processing >350 million lbs/yr raw material
3	Same technology as Option 1	Phosphorus limits for: • all direct discharging facilities producing > 10 million lbs/yr plus Phosphorus and more stringent nitrogen limits for: • all facilities producing >20 million lbs/yr.	Same technology as Option 2	Conventional limits for: • facilities producing >5 million lbs/yr plus Nitrogen and phosphorus limits for • all facilities >30 million lbs/yr

a. See *TDD* for a description of these technologies (U.S. EPA, 2023m).

Source: U.S. EPA Analysis, 2023

Table ES-2 summarizes the loading changes estimated to result from the regulatory options for selected pollutants. The negative changes indicate reductions in pollutant loads to receiving waters. Implementation of wastewater treatment technologies to meet effluent limits under the regulatory options are also estimated to reduce loadings of other pollutants, including halogens (*e.g.,* bromide, fluoride), total organic carbon, sulfate, total dissolved solids, metals (*e.g.,* aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, selenium, silver, sodium, thallium, tin, titanium, vanadium, and zinc), and microbiological contaminants (*e.g.*, *E. coli*, enterococcus, and fecal coliform). See Section 3.1 for details.

Table ES-2: Summary of Changes to Annual Loadings of Selected Pollutants Compared to the Baseline

Option	Discharge Type	Changes in Annual Pollutant[a] Loadings (millions lbs/year)					
		TN	TP	TSS	BOD	Oil and Grease	Chlorides[b]
1	Direct	-8.87	-7.68	-42.62	-1.55	-14.84	-190.46
	Indirect	0	0	-11.78	-7.73	-1.59	-286.50
	Total	-8.87	-7.68	-54.39	-9.28	-16.44	-476.96
2	Direct	-8.87	-7.68	-42.62	-1.55	-14.84	-190.46
	Indirect	-35.95	-8.43	-39.19	-55.40	-13.88	-286.50
	Total	-44.82	-16.11	-81.81	-56.95	-28.72	-476.96
3	Direct	-8.99	-7.83	-44.45	-1.57	-16.02	-190.46
	Indirect	-67.18	-11.73	-48.86	-88.18	-27.36	-286.50
	Total	-76.18	-19.56	-93.31	-89.75	-43.38	-476.96

a. Technologies implemented under the options are also estimated to reduce loadings of other pollutants. See Section 3.1 for details.

b. Chlorides has the same removal under each option.

Source: U.S. EPA Analysis, 2023

Benefits of Regulatory Options

EPA estimated the potential social welfare effects of the regulatory options and, where possible, quantified and monetized the benefits (see Chapters 3 through 5 for details of the methodology and results). Table ES-3 summarizes the anticipated benefits of this rule, some of which EPA quantified but did not monetize and others that were analyzed only qualitatively. Table ES-4 summarizes the national benefits that EPA quantified and monetized using a 3 percent discount. The total use and nonuse values for water quality changes shown in Table ES-4 are based on benefits explicitly modeled for a subset of water resources regions, as well as results extrapolated to the remaining regions. The modeled and extrapolated benefits are summarized in Table ES-5. Chapter 2 presents additional information on welfare effects that EPA analyzed only qualitatively.

Table ES-3: Estimated Welfare Effects of Changes in Pollutant Discharges from Meat and Poultry Product Facilities

Benefit Category	Effect of Regulatory Options	Benefits Analysis	
		Quantified	Monetized
Human Health Benefits from Surface Water Quality Improvements			
Human health effects from exposure via recreational use	Reduced exposure to pathogens and HAB-related illnesses from primary contact recreation and recreationally caught and consumed fish and shellfish		
Human health effects from exposure via drinking water	Reduced exposure to high nitrate concentrations, *pathogens*, and DBPs (which may be generated indirectly due to nutrient enrichment and eutrophication) in drinking water		
Ecological Condition and Recreational Use Effects from Surface Water Quality Changes			
Aquatic and wildlife habitat[a]	Improved ambient water quality in receiving and downstream reaches	✓	✓
Water-based recreation[a]	Enhanced value of swimming, fishing, boating, and near-water activities from water quality changes		
Aesthetics[a]	Improved aesthetics from shifts in water clarity, color, odor, including nearby site amenities for residing, working, and traveling		
Nonuse values[a]	Improved existence, option, and bequest values from improved ecosystem health		
Protection of T&E species	Improved T&E species habitat and potential effects on T&E species populations	✓	
Market and Productivity Effects			
Drinking water treatment costs	Improved quality of source water used for drinking	✓	
Wastewater treatment costs	Reduced wastewater treatment costs at POTWs		
Agricultural water use	Improved quality of surface waters used for livestock watering		
Industrial water use	Reduced cost of industrial water treatment		
Commercial fisheries	Improved fisheries yield and harvest quality due to improved aquatic habitat	✓	
Subsistence Harvesting	Improved fisheries yield and harvest quality due to improved aquatic habitat; Reduced risk of consuming contaminated fish and shellfish		
Tourism industries	Changes in participation in water-based recreation		
Property values	Improved property values from changes in water quality		
Climate Change and Air Quality-Related Effects			
Air emissions of $PM_{2.5}$	Changes in mortality and morbidity from exposure to particulate matter ($PM_{2.5}$) emitted directly or linked to changes in NO_X and SO_2 emissions (precursors to $PM_{2.5}$ and ozone)	✓	✓
Air emissions of NO_X and SO_2	Changes in ecosystem effects; visibility impairment; and human health effects from direct exposure to NO_x, SO_2, and hazardous air pollutants.	✓	✓
Air emissions of greenhouse gases (GHG; CH_4 and CO_2)	Changes in climate change effects	✓	✓

a. These values are implicit in the total WTP for water quality improvements.

Source: U.S. EPA Analysis, 2023

Table ES-4: Summary of Total Annualized Benefits for Regulatory Options, Compared to Baseline, Discounted at 3 Percent (Millions of 2022$)

Benefit Category	Option 1	Option 2	Option 3
Use and nonuse values for water quality changes (total willingness to pay for water quality improvements)[a, b]	$95.6	$166.1	$208.4
Climate change effects from changes in GHG emissions	-$1.9	-$7.0	-$10.1
Human health effects from changes in NO_X, SO_2, and $PM_{2.5}$ emissions	-$3.5	-$12.9	-$18.6
Total monetized benefits	**$90.2**	**$146.2**	**$179.7**
Additional benefits	+	+	+

a. Values reflect both modeled and extrapolated results using Model 1, as shown in Table ES-4. EPA modeled benefits for a subset of water resources regions (*i.e.,* regions 02, 03, 05, 07, and 08) and extrapolated the results to other regions, accounting for the respective loading reductions and populations. See Section 4.4 for details.

b. EPA modeled benefits for options 1 and 3 and interpolated the results to estimate benefits for option 2.

+ Additional non-monetized health, ecological, market and economic productivity benefits (see Table ES-2 and Chapter 2)

Source: U.S. EPA Analysis, 2023

Table ES-5: Estimated Total Annualized Willingness-to-Pay for Water Quality Improvements under Regulatory Options, using Model 1 and a 3 Percent Discount Rate (Main Estimates)

Basis of Estimate	Total Annualized WTP (Millions 2022$)[a,b]		
	Option 1	Option 2	Option 3
Regions explicitly modeled[c]	$42.3	$78.6	$101.9
Extrapolated regions	$53.3	$87.5	$106.5
U.S. total[d]	**$95.6**	**$166.1**	**$208.4**

a. Estimates based on Model 1, which provides EPA's main estimate of non-market benefits.

b. Estimated benefits are regional-level rather than national-level since water quality modeling was limited to selected water resource regions (see Section 3 for details).

c. Sum of benefits estimated for explicitly modeled water resources regions (*i.e.,* regions 02, 03, 05, 07, and 08) and used to extrapolate to other regions. The modeled regions account for 22 percent to 52 percent of total loading reductions, depending on the option and water quality parameter, and approximately half of the total population within the conterminous United States.

d. Based on MPP facilities discharging (directly or indirectly) to waters within the conterminous United States.

Source: U.S. EPA Analysis, 2023

Social Costs of Regulatory Options

Table ES-6 presents the incremental social costs attributable to the regulatory options, calculated as the difference between each option and the baseline. The regulatory options generally result in additional costs across regulatory options and discount rates. Chapter 7 describes the social cost analysis. The compliance costs of the regulatory options are detailed in the Regulatory Impact Analysis (RIA; U.S. EPA, 2023j).

Table ES-6: Estimated Total Social Costs by Regulatory Option and Discharge Type Discounted at 3 Percent (Millions 2022$)

Regulatory Option	Direct	Indirect	Total
Option 1	$216.5	$15.3	$231.9
Option 2	$216.5	$426.3	$642.8

Table ES-6: Estimated Total Social Costs by Regulatory Option and Discharge Type Discounted at 3 Percent (Millions 2022$)

Regulatory Option	Direct	Indirect	Total
Option 3	$223.7	$853.6	$1,077.3

Source: U.S. EPA Analysis, 2023.

Comparison of Benefits and Social Costs of Regulatory Options

In accordance with the requirements of Executive Order 12866: Regulatory Planning and Review and Executive Order 13563: Improving Regulation and Regulatory Review, EPA compared the benefits and costs of each regulatory option. Table ES-7 presents the monetized benefits and social costs attributable to the regulatory options, at a 3 percent discount.

Table ES-7: Total Annualized Benefits and Social Costs by Regulatory Option, Discounted at 3 Percent (Millions of 2022$)

Regulatory Option	Total Benefits		Total Social Costs
	Monetized Benefits	Other Benefits	
Option 1	$90.2	+	$231.9
Option 2	$146.2	+	$642.8
Option 3	$179.7	+	$1,077.3

+ There are also additional non-monetized health, ecological, market and economic productivity benefits (see Table ES-2 and Chapter 2)

Source: U.S. EPA Analysis, 2023

1 Introduction

EPA is proposing to revise the technology-based effluent limitation guidelines (ELGs) that apply to wastewater discharges from meat and poultry products (MPP) facilities. The MPP industry has approximately 5,000 facilities across the country which engage in meat and/or poultry slaughter, further processing, and/or rendering. Available data shows that MPP facilities discharge pollutants such as nutrients (nitrogen and phosphorus), oil and grease, biochemical oxygen demand (BOD), chlorides, pathogens, solids, and other substances (U.S. EPA, 2023e; 2023m). Discharges of these pollutants to surface waters can affect aquatic ecosystems and human health. The current MPP ELGs, which were last revised in 2004, include limitations only for nitrogen (total nitrogen and ammonia) and only for about 150 large MPP facilities that discharge directly to surface waters. The majority of MPP facilities discharge their wastewater to a publicly owned treatment work (POTW),[1] where wastewater from MPP facilities can interfere with or pass through treatment.

In this proposed rule, EPA analyzed various regulatory options that would establish (1) more stringent nitrogen effluent limitations based on better performing technologies, (2) new effluent limitations for phosphorus, and (3) pretreatment standards for MPP facilities that discharge to a POTW. EPA is also requesting comments on potentially establishing chlorides limits for high chloride waste streams, *E. coli* limits for direct dischargers, and conditional limits for indirect dischargers that discharge to POTWs that remove nutrients. Under these options, EPA expects the revised ELGs to reduce the amount of nutrients and other pollutants (*e.g.*, BOD, total suspended solids (TSS), oil and grease, fecal coliform, chlorides) discharged to surface waters from the MPP industry, with consequent benefits including improvement in water quality and aquatic habitats, reduced human and ecological health risk, enhanced natural resources, and economic productivity benefits.

This document presents the Agency's analysis of the benefits and social costs of the regulatory options and complements other analyses detailed in separate documents:

- *Environmental Assessment for Proposed Revisions to the Meat and Poultry Products Effluent Guidelines and Standards* (EA; U.S. EPA, 2023e). The EA summarizes the potential environmental and human health impacts that are estimated to result from the proposed regulatory options, if implemented.
- *Technical Development Document for Proposed Revisions to the Meat and Poultry Products Effluent Guidelines and Standards* (TDD; U.S. EPA, 2023m). The TDD summarizes the technical and engineering analyses supporting the proposed rule, including technology assessment, treatment costs, pollutant removal estimates, and explanations for the calculation of the effluent limitations and standards.
- *Regulatory Impact Analysis for Proposed Revisions to the Meat and Poultry Products Effluent Guidelines and Standards* (RIA; U.S. EPA, 2023j). The RIA describes EPA's analysis of the costs and economic impacts of the regulatory options. This analysis provides the basis for social cost estimates presented in Chapter 7 of this document. The RIA also provides information pertinent to

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[1] POTWs are treatment works (*i.e.*, systems involved in the storage, treatment, and reclamation of liquid waste) that are owned by a state or municipality.

meeting several legislative and administrative requirements, including the Regulatory Flexibility Act of 1980 (as amended by the Small Business Regulatory Enforcement Fairness Act [SBREFA] of 1996), various Executive Orders, and other requirements.

The rest of this chapter discusses aspects of the regulatory options that are salient to EPA's analysis of the benefits and social costs of the proposed rule and summarizes key analytic inputs and assumptions.

1.1 Meat and Poultry Products Facility Dischargers

The MPP point source category includes facilities "engaged in the slaughtering, dressing and packing of meat and poultry products for human consumption and/or animal food and feeds. Meat and poultry products for human consumption include meat and poultry from cattle, hogs, sheep, chickens, turkeys, ducks and other fowl as well as sausages, luncheon meats and cured, smoked or canned or other prepared meat and poultry products from purchased carcasses and other materials. Meat and poultry products for animal food and feeds include animal oils, meat meal and facilities that render grease and tallow from animal fat, bones and meat scraps." (See 40 CFR 432.1).

EPA estimates there are 5,055 facilities in total in the MPP industry, of which 1,176 facilities (23 percent) do not discharge any wastewater to the environment (zero dischargers). The remaining 3,879 facilities (77 percent) discharge wastewater directly to surface waters (direct dischargers) or send their wastewaters to a POTW (indirect dischargers). The regulatory options EPA analyzed for this proposed rule applies to these direct or indirect dischargers. Direct dischargers are mostly located in the eastern United States, whereas indirect dischargers are distributed across the country. Table 1-1 summarizes the distribution of MPP facilities by process and discharge type.

Table 1-1: Number of Facilities in MPP Industry by Process and Discharge Type

	Number of Facilities			
Process	**Direct Dischargers**	**Indirect Dischargers**	**Zero Dischargers**	**Total**
Meat First	47	509	270	826
Meat Further	29	2,741	690	3,460
Poultry First	70	168	52	290
Poultry Further	6	169	119	294
Render	19	121	45	185
Total	**171**	**3,708**	**1,176**	**5,055**

Source: U.S. EPA Analysis, 2023

1.2 Baseline and Regulatory Options Analyzed

The baseline for this analysis reflects existing conditions and applicable requirements in the absence of the proposed rule, including applicable permit limits based on the 2004 ELGs and any treatment in place at MPP facilities.

EPA is considering three regulatory options in this rulemaking. These options differ in the stringency of control technologies and resulting effluent limits, and the applicability of these limits to MPP facilities. Specifically, the regulatory options include more stringent effluent limitations on nitrogen, new effluent limitations on phosphorus, updated effluent limitations for other pollutants including ammonia, new pretreatment standards for indirect dischargers, and revised production thresholds for the subcategories in the existing rule. EPA is also requesting comment on potentially establishing effluent limitations on chlorides for high chloride waste streams, establishing effluent limitations for *E. coli* for direct dischargers, and including conditional limits for indirect dischargers that discharge to POTWs that remove nutrients. Table 1-2 summarizes the technology basis and applicability of the revised ELGs for the three regulatory options EPA analyzed for this proposed rule. As described in the preamble for this action, EPA is proposing Option 1 as the preferred option.

Table 1-2: Summary of Regulatory Options

	Direct Dischargers		Indirect Dischargers	
Option	**Technology Basis[a]**	**Applicable Facilities**	**Technology Basis[a]**	**Applicable Facilities**
1	Adds to existing ELG: • full denitrification • chemical phosphorus removal • filter	• meat further processors > 50 million lbs/yr of finished product • meat slaughtering > 50 million lbs/yr live weight killed • poultry slaughtering >100 million lbs/yr of live weight killed • poultry further processors >7 million lbs/yr of finished product produced • renderers >10 million lbs/yr of raw material processed	Conventional pollution limits based on: • screening/grit removal • dissolved air flotation (DAF), and dewatering/solids handling	• meat further processors > 50 million lbs/yr of finished product • meat slaughtering > 50 million lbs/yr live weight killed • poultry slaughtering >100 million lbs/yr of live weight killed • poultry further processors >7 million lbs/yr of finished product produced • renderers >10 million lbs/yr of raw material processed
2	Same technology as Option 1	Same facilities as Option 1	Option 1 technology plus: • anaerobic lagoon (BOD pretreatment) • activated sludge (nitrification and full denitrification) • chemical P removal • filter	Option 1 facilities plus: • slaughterhouses producing >200 million lbs/yr • renderers processing >350 million lbs/yr raw material
3	Same technology as Option 1	Phosphorus limits for: • all direct discharging facilities producing > 10 million lbs/yr plus Phosphorus and more stringent nitrogen limits for: • all facilities producing >20 million lbs/yr.	Same technology as Option 2	Conventional limits for: • facilities producing >5 million lbs/yr plus Nitrogen and phosphorus limits for • all facilities >30 million lbs/yr

a. See *TDD* for a description of these technologies (U.S. EPA, 2023m).

Source: U.S. EPA Analysis, 2023

1.3 Analytic Framework

The analytic framework includes basic components used consistently throughout the analysis of benefits and social costs of the regulatory options.

1. All values are presented in 2022 dollars;
2. Technology installation and the resulting pollutant loading changes occur at the end of the estimated wastewater treatment technology implementation year;
3. Benefits and costs are analyzed over a 40-year period (2026 to 2065) which covers the years when facilities are projected to implement wastewater treatment technologies to meet the revised ELGs and the subsequent life of these technologies;
4. Future benefits and costs are discounted using rates of 3 percent and 7 percent back to 2025, which is the expected year for the final rule publication;[2]
5. Benefits and costs are annualized; and
6. Future values account for annual U.S. population and income growth, unless noted otherwise.

These components are discussed in the sections below.

1.3.1 Constant Prices

This BCA applies a year 2022 constant price level to all future monetary values of benefits and costs. Some monetary values of benefits and costs are based on actual past market price data for goods or services, while others are based on other measures of values, such as household willingness-to-pay (WTP) surveys used to monetize ecological changes resulting from surface water quality changes. Values are adjusted to year 2022 dollars using appropriate indexes. For example, this BCA updates the WTP for surface water quality improvements using the Consumer Price Index (CPI) and the values of the social cost of carbon dioxide using the gross domestic product (GDP) deflator.

1.3.2 Technology Implementation Year

Benefits are projected to begin accruing when each plant implements the control technologies needed to comply with any applicable best available technology economically achievable (BAT) effluent limitations or pretreatment standards. For the economic impact and benefit analysis, EPA generally estimates that MPP direct dischargers will implement control technologies to meet the applicable rule limitations and standards as their permits are renewed, with technology implementation staggered over time, and no later than 2030. EPA assumes that approximately 20 percent of MPP direct dischargers will comply each year, between 2026 and 2030. In contrast, MPP indirect dischargers would have up to three years (*i.e.*, until the end of 2028) to comply with the proposed regulations. For the benefits analysis, EPA assumes that loading reductions and other benefits of technology implementation will start in 2028 to correspond to the

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[2] One exception is discounting of the benefits of avoided greenhouse gas emissions for which EPA uses discount rates of 2.5 percent, 3 percent, and 5 percent.

midpoint of the technology implementation period for direct dischargers and implementation deadline for indirect dischargers.

1.3.3 Period of Analysis

As explained in the TDD, compliance technologies are assumed to have a useful life of either 20 years or 40 years. Hence, the period of analysis extends to 2065 to capture the estimated life of the longest lasting compliance technology, starting from the first year of technology implementation in 2026. For those compliance technologies with a useful life of 20 years, EPA assumes that facilities will incur replacement costs in year 21 (to extend their useful life by another 20 years).

1.3.4 Discount Rate and Year

This BCA estimates the annualized value of future benefits and social costs using a discount rate of 3 percent. This discount rate reflects society's valuation of differences in the timing of consumption (*i.e.*, the social rate of time preference), as recommended by the Office of Management and Budget (OMB) in Circular A-4 (OMB, 2003b; 2023).[3] For additional information, EPA also estimated annualized values of future benefits and social costs using a discount rate of 7 percent to be consistent with the rate EPA has historically presented based on OMB recommendations for evaluating regulation that would mainly displace or alter the use of capital in the private sector (OMB, 2003a). Results using the 7 percent discount rate are presented in Appendix D.

One exception to this practice is discounting of the benefits of avoided greenhouse gas emissions for which EPA uses values of the social cost of methane (SC-CH_4) and the social cost of carbon dioxide (SC-CO_2) developed by the Interagency Working Group on the Social Cost of Greenhouse Gases (IWG) using discount rates of 2.5 percent, 3 percent, and 5 percent. Because greenhouse gases are long-lived and subsequent damages of current emissions can occur over a long time, the approach to discounting greatly influences the present value of future damages. The IWG published four sets of values for each of the SC-CH_4 and SC-CO_2 for use in benefit-cost analyses (IWG, 2021): an average value resulting from integrated assessment model runs for each of three discount rates (2.5 percent, 3 percent, and 5 percent), plus a fourth value, selected as the 95th percentile of estimates based on a 3 percent discount rate. Chapter 5 provides additional details on climate change-related benefits estimated using these different discount rates. When summarizing total annualized benefits, EPA includes climate-related benefit values estimated using average SC-CO_2 discounted at 3 percent.

All future cost and benefit values are discounted back to 2025, the anticipated rule promulgation year.

1.3.5 Annualization of Future Costs and Benefits

Consistent with the timing of technology installation and loading reductions described above, EPA uses the following equation to annualize the future stream of costs and benefits, assuming that costs and benefits accrue at the end of each year in the analysis period:

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[3] On April 7, 2023, OMB published a draft of proposed revisions to Circular A-4 for public comment (88 FR 20915). Among the proposed revisions are changes to the recommended discount rates. Until the revisions are finalized, the 2003 version of Circular A-4 remains in effect.

Equation 1-1.

$$AV = PV\frac{r(1+r)^n}{(1+r)^n - 1}$$

Where AV is the annualized value, PV is the present value, r is the discount rate (*e.g.*, 3 percent), and n is the number of years (40 years).

1.3.6 Population and Income Growth

To account for future population growth or decline, EPA used 2021 National Aeronautics and Space Administration (NASA) Socioeconomic Data and Applications Center (SEDAC) population forecasts for the United States (Hauer & Center for International Earth Science Information Network - Columbia University, 2021).[4] EPA used the NASA SEDAC growth projections to adjust affected population estimates for future years (*i.e.*, from 2025 to 2063).

Because WTP is expected to increase as income increases, EPA accounted for income growth when estimating WTP for water quality improvements. EPA projected future income over the applicable analysis period year (*i.e.*, from 2026 to 2065) based on income in 2021 (2021 American Community Survey) and income growth rates obtained from historical and projected “real disposable personal income” estimates (Energy Information Administration, 2023). Estimated growth rates, which vary by year, are based on the ratio of the real disposable person income per person (*i.e.*, real disposable personal income / population) for a given year relative to the 2021 value. Since Energy Information Administration projections are only through 2050, EPA used linear regression to estimate values for years 2051-2065.

1.4 Report Organization

This BCA report presents EPA’s analysis of the benefits of the regulatory options, assessment of the total social costs, and comparison of the social costs and monetized benefits.

The remainder of this report is organized as follows:

- Chapter 2 provides an overview of the main benefits expected to result from the implementation of the regulatory options analyzed for this proposal, including benefits that EPA was only able to analyze qualitatively.
- Chapter 3 summarizes the estimated changes in pollutant loadings and instream pollutant concentrations anticipated under the regulatory options, including the description of the approach EPA used to model changes in water quality across regions and regulatory options.
- Chapter 4 discusses EPA’s analysis of nonmarket benefits of predicted changes in surface water quality.
- Chapter 5 describes EPA’s analysis of impacts associated with changes in emissions of air pollutants associated with energy use, transportation, and other non-water quality effects of the regulatory options.

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[4] These projections are based on Shared Socioeconomic Pathway 2 (SSP2) (Hauer & Center for International Earth Science Information Network - Columbia University, 2021). SSP2 is a “middle-of-the-road” projection, where social, economic, and technological trends do not shift markedly from historical patterns.

- Chapter 6 summarizes the monetized benefits across benefit categories.
- Chapter 7 summarizes the social costs of the regulatory options.
- Chapter 8 addresses the requirements of Executive Orders that EPA is required to satisfy for the final rule, notably analysis of the benefits and costs of regulatory actions, as per Executive Order 14094 of April 6, 2023 (Modernizing Regulatory Review), which supplemented and reaffirmed the principles governing regulatory review in Executive Order 12866 of September 30, 1993 (Regulatory Planning and Review), and Executive Order 13563 of January 18, 2011 (Improving Regulation and Regulatory Review).
- Chapter 9 provides references cited in the text.

Several appendices provide additional details on selected aspects of analyses described in the main text of the report.

2 Benefits Overview

This chapter provides an overview of the welfare effects that would result from changes in pollutant loadings due to implementation of the regulatory options analyzed for the proposed rule. EPA expects the regulatory options would reduce discharge loads of various categories of pollutants when fully implemented. The categories of pollutants affected by the proposed rule would include nutrients (total nitrogen [TN] and total phosphorus [TP]), conventional pollutants (*e.g.*, TSS, BOD, oil and grease) and chlorides. The rule may also reduce loadings of bacteria and pathogens (*e.g.*, fecal coliform bacteria, *Salmonella sp., Escherichia coli*). Table 2-1 summarizes estimated changes in annual pollutant loads under full implementation of the ELGs under each of the three regulatory options. The TDD provides further detail on the loading changes.

Table 2-1: Summary of Changes to Annual Pollutant Loadings Compared to the Baseline

Regulatory Option	Changes in Annual Pollutant Loadings (millions lbs/year)					
	TN	TP	TSS	BOD	Oil and Grease	Chlorides[1]
1	-8.87	-7.68	-54.39	-9.28	-16.44	-476.96
2	-44.82	-16.11	-81.81	-56.95	-28.72	-476.96
3	-76.18	-19.56	-93.31	-89.75	-43.38	-476.96

[1] Chlorides has the same removal under all options.

Source: U.S. EPA Analysis, 2023

Reductions in the discharge of pollutants from MPP facilities may result in numerous environmental changes, and, in turn, welfare effects to society. The schematic diagram in Figure 2-1 summarizes the potential effects of the regulatory options, the expected environmental changes, and categories of benefits, and EPA's approach to analyzing those welfare effects.

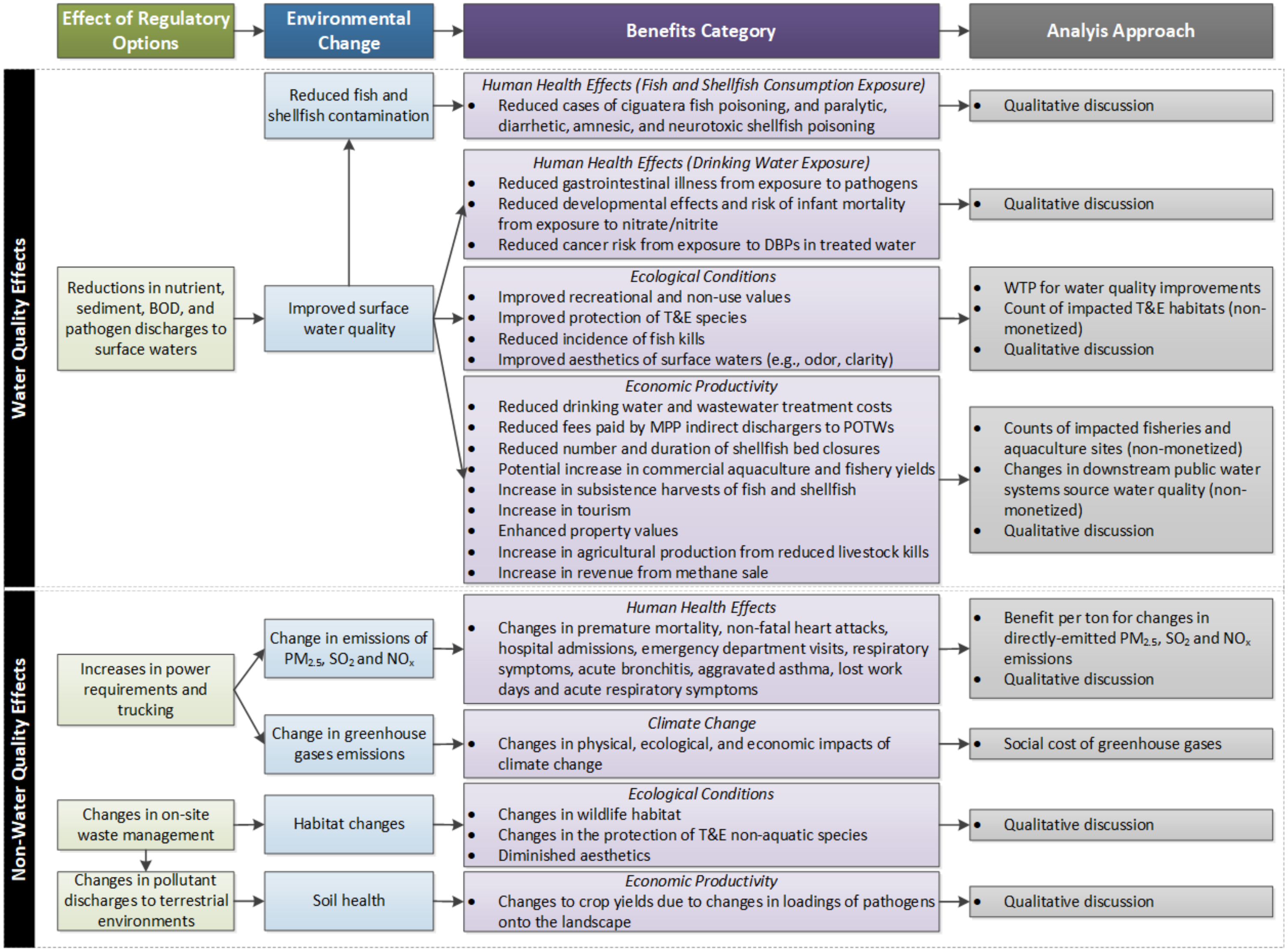
For example, the proposed rule is estimated to improve surface water quality by reducing excess nutrients, pathogens such as *E. coli*, and sediment discharges. Improved surface water quality may in turn provide (1) human health benefits via reduced exposure to contaminated waters used for primary contact recreation, contaminated drinking water, fish, and shellfish, and toxic harmful algal blooms [HABs] (either directly through skin contact, ingestion, or inhalation or indirectly through consumption of contaminated fish and shellfish), (2) recreational and nonuse benefits, (3) reductions in drinking and wastewater treatment costs, (4) reductions in fees paid by MPP indirect dischargers to POTWs, (5) productivity benefits to agriculture, (6) benefits to the commercial fishing and shellfishing industries, (7) benefits to subsistence fishers, (8) benefits to tourism, (9) improvements in property values.

In addition to water quality changes, the implementation of control technologies and other operational changes in MPP facilities, and indirectly by POTWs, also affects air quality through changes in direct emissions from wastewater treatment at MPP facilities and POTWs, or associated with changes in electricity and fuel used to power treatment technologies or to transport solid wastes from MPP facilities to landfills or land application areas. The negative impacts of these changes may be mitigated in part through increased methane capture and sale.

For a more detailed description of MPP facility pollutants, their fate, transport, and impacts on human health and the environment, see the EA.

EPA was not able to monetize or quantify all categories of benefits from reducing MPP facility discharges due to limitations of the available data and models to quantify the relationships between MPP facility discharges, surface water quality, ecosystem response and other environmental effects (*e.g.*, pollutant exposure, individual and population-level health effects, species abundance), and how society may value these effects. EPA was able to quantify and monetize some welfare effects, quantify but not monetize other welfare effects, and assess still other welfare effects only qualitatively (see section 2.5 for a summary of the benefits categories and how they are assessed). The remainder of this chapter provides a qualitative discussion of the benefits applicable to the proposed rule, including human health effects, ecological effects, economic productivity, and changes in air pollution. Some estimates of the monetary value of benefits changes presented in this document rely on models with a variety of limitations and uncertainties, as discussed in more detail in the respective chapters for the relevant benefit categories.

Figure 2-1: Summary of Benefits Resulting from the Regulatory Options



DBPs = disinfection byproducts; WTP = willingness to pay; T&E = threatened and endangered; POTWs = publicly owned treatment works

2.1 Human Health Impacts Associated with Changes in Surface Water Quality

Pollutants present in MPP wastewater discharges (*e.g.*, pathogenic *E. coli*, nitrogen, and phosphorus) can cause a variety of adverse human health effects. Table 2-2 summarizes the human health effects of selected pollutants present in MPP discharges. This summary is not exhaustive but instead highlights some of the primary ways MPP discharges may affect human health. Other pollutants present in MPP discharges, such as TSS, oil and grease, BOD, and halogens (*e.g.*, bromide), may also have potential human health effects indirectly by interfering with drinking water treatment or leading to the formation of harmful disinfection byproducts. The EA provides more detailed discussions of MPP pollutants and their health effects.

Table 2-2: Categories of Pollutants Present in MPP Discharges and Associated Health Effects

Pollutant Category	Human Health Effects
Pathogens	Exposure to *Streptococcus sp., E. coli*, fecal coliform and other pathogenic microorganisms through the ingestion of contaminated water during primary contact recreation, drinking water, or consumption of contaminated shellfish can lead to gastrointestinal illness (Oliveira *et al.*, 2011; U.S. EPA, 2009b; Wittman & Flick, 1995)
Nutrients (nitrogen and phosphorus)	Exposure to high levels of nitrogen in drinking water can lead to infant methemoglobinemia, colorectal cancer, thyroid disease, and neural tube defects (Ward *et al.*, 2018; U.S. EPA, 2000) Exposure to toxic HABs (whose development is influenced by excess nitrogen and phosphorus) can lead to skin rashes, liver and kidney damage, neurological issues, gastrointestinal symptoms or respiratory problems through ingestion or inhalation (Backer, 2002; World Health Organization, 2021). Exposure to contaminated shellfish from HAB toxins can lead to poisoning syndromes such as paralytic, diarrhetic, amnesic, or neurotoxic shellfish poisoning (Hoagland *et al.*, 2002; U.S. EPA, 2015d) Exposure to trihalomethane, which may be created as a disinfection by-product (DBP) in treated drinking water (due to eutrophication through nutrient enrichment and algae growth), can increase the risk of cancer (U.S. EPA, 2000)
Halogens (bromide)	Although the bromide ion has a low degree of toxicity (World Health Organization, 2009), it can contribute to the formation of brominated DBPs during drinking water disinfection processes, including chlorination, chloramination, and ozonation.

By reducing pollutant loads in MPP discharges, the regulatory options may reduce human exposure to MPP pollutants in surface water via three exposure pathways discussed further below: (1) primary contact recreation in waters affected by MPP discharges, (2) consumption of drinking water sourced from surface waters affected by MPP discharges, and (3) consumption of shellfish taken from waters affected by MPP discharges.

2.1.1 Primary Contact Recreation

Discharges from MPP facilities can affect the safety of recreational areas used for primary contact recreation such as swimming (Section 4.2.5 of the EA provides a list of potentially affected sites). Meat processing wastewater contains bacteria such as *Streptococcus sp., E. coli*, and fecal coliform (Mittal, 2004). Bacteria and pathogens enter the effluent stream from the blood, excrement, and offal of slaughtered livestock (The Environmental Integrity Project, 2018). Microorganisms may also be introduced from rinsing the hide and carcass, which could have retained bacteria from livestock housing areas, processing equipment and facility floor (Mittal, 2004). Additionally, the meat sludge byproduct in effluent can provide the nutrients needed for the long-term survival and proliferation of some microorganisms (Baskin-Graves *et al.*, 2019). Untreated bacteria and pathogens from MPP direct dischargers may affect the safety of surface water used for primary contact recreation. People exposed to pathogens associated with poultry and livestock (*i.e.*, *Salmonella*, enterococci, *E. coli*, *Campylobacter sp.*, and *Cryptosporidium sp.*) through ingestion during primary contact recreation may experience adverse health effects (U.S. EPA, 2009b). These pathogens can cause gastrointestinal illness and lead to symptoms such as diarrhea, abdominal pain, nausea, chills, and fever. The proposed rule would add *E. coli* as a new regulated pollutant (to be used as an indicator for proper disinfection) for MPP direct dischargers. This regulatory change may lead MPP direct dischargers to better disinfect their wastewater and reduce the risk of human exposure to *E. coli* and other pathogenic microorganisms; this, in turn, may lead to the avoidance of pathogen-related health effects.

Additionally, HABs, which can develop in response to excess nutrients, such as nitrogen and phosphorus discharges from MPP dischargers, may also be of concern. Exposure to harmful HAB toxins through primary and secondary contact recreation (*i.e.*, ingestion and inhalation) can cause skin rashes, liver and kidney damage, neurological issues, gastrointestinal symptoms or respiratory problems (Backer, 2002; World Health Organization, 2021).[5] Hoagland *et al.* (2009) estimated that the annual costs of respiratory emergency department visits between 2001 and 2006 associated with *Karenia brevis* algal blooms in Sarasota County, Florida ranged from \$0.03 to \$0.17 million (in 2022\$).[6] The regulatory options would lead to reductions in nutrients loadings from MPP facilities and, as a result, reduced occurrence of HABs and incidence of HAB-related illnesses.

2.1.2 Drinking Water

Pollutants discharged by MPP dischargers to surface waters affect the quality of the source water used by public water systems (PWS) that withdraw downstream from the facilities and may also affect the safety of treated drinking water delivered by the PWS. This can be due to the pollutants not being removed adequately during by the water treatment processes in place at drinking water treatment plants and/or the formation of DBPs from the interaction between constituents found in MPP discharges and chemicals used in drinking water treatment processes. For example, eutrophication (due to nutrient enrichment) and algal organic matter can lead to the formation of the DBPs trihalomethanes which are carcinogenic compounds that can pose a serious threat to human health if consumed (U.S. EPA, 2000). Bromide, another pollutant present in MPP discharges, can contribute to the formation of brominated DBPs during drinking water disinfection processes. Bromate, a regulated DBP under the Safe Drinking Water Act (SDWA), forms when bromine reacts directly with ozone. Chlorine reacts with bromide to produce hypobromite (BrO^-), which reacts with organic matter to form brominated and mixed chloro-bromo

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[5] Schaefer *et al.* (2020) also provide evidence that individuals may be exposed to toxins from HABs via inhalation when in close proximity to affected waters without any direct (primary or secondary) contact (*e.g.*, worked on land near the water, and visited a park or beach near affected waters).

[6] Costs were converted from \$0.02 to \$0.13 million in 2008\$ using the Bureau of Labor Statistic's Consumer Price Index for All Urban Consumers (Bureau of Labor Statistics, 2023).

DBPs, including three of the four regulated trihalomethanes[7] (THM4, also referred to as total trihalomethanes (TTHM) in this discussion) and two of the five regulated haloacetic acids[8] (HAA5). Additional unregulated brominated DBPs have been cited as an emerging class of water supply contaminants that can potentially pose health risks to humans (S. D. Richardson *et al.*, 2007; NTP, 2018; U.S. EPA, 2016b).

There is a substantial body of literature on trihalomethane precursor occurrence, trihalomethane formation mechanisms in drinking water treatment plants, and relationships between source water bromide levels and TTHM levels in treated drinking water. The formation of TTHM in a particular drinking water treatment plant is a function of several factors including chlorine, bromide, organic material, temperature, and pH levels as well as system residence times. There is also substantial evidence linking TTHM exposure to bladder cancer incidence (U.S. EPA, 2016b). Bromodichloromethane and bromoform are likely to be carcinogenic to humans by all exposure routes and there is evidence suggestive of dibromochloromethane's carcinogenicity (NTP, 2018; U.S. EPA, 2016b). The relationships between exposure to DBPs, specifically TTHMs and other halogenated compounds resulting from water chlorination, and bladder cancer are further discussed in U.S. EPA (2019a). The relationship has been the subject of multiple epidemiological studies (Cantor *et al.*, 2010; U.S. EPA, 2005; NTP, 2018), a meta-analysis (Villanueva *et al.*, 2003; Costet *et al.*, 2011), and pooled analysis (Villanueva *et al.*, 2004). Regli *et al.* (2015) conducted an analysis of potential bladder cancer risks associated with increased bromide levels in surface source water and showed that the overall pooled exposure-response relationship for TTHM is linear over a range of relevant doses. The linear relationship predicted an incremental lifetime cancer risk of 1 in ten thousand exposed individuals (10^{-4}) per 1 µg/L increase in TTHM.

Additionally, high nitrate concentrations in drinking water can lead to infant methemoglobinemia, colorectal cancer, thyroid disease, and neural tube defects (U.S. EPA, 2000; Ward *et al.*, 2018). Lastly, human exposure to *E. coli* through inadequate disinfection of drinking water can lead to adverse health effects such as abdominal cramps, vomiting, diarrhea, and fever (U.S. EPA, 2009b).

Public drinking water supplies are subject to legally enforceable health-based maximum contaminant levels (MCLs) established by EPA (U.S. EPA, 2023h). As the term implies, an MCL for drinking water specifies the highest level of a contaminant that is allowed in drinking water. The MCL is based on the MCL Goal (MCLG), which is the level of a contaminant in drinking water below which there is no known or expected risk to human health. EPA sets the MCL as close to the MCLG as possible, with consideration for the best available treatment technologies and costs. There may be adverse health effects from drinking water which contains contaminants exceeding the applicable MCL (*i.e.*, violations) or exceed a lower applicable MCLGs (even when no violation occurs). Table 2-3 shows the MCL and MCLG for selected constituents or constituent derivatives of MPP effluent. The health benefits of the proposed rule depend on whether reductions under the regulatory options will result in fewer PWS violations of the applicable MCLs or reduce contaminants levels between the MCLs and MCLGs. For example, reducing nitrate at public drinking water supplies that are in violation of the MCL to acceptable limits (at or below 10 mg/L) would help prevent infant methemoglobinemia, colorectal cancer, thyroid

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[7] The four regulated trihalomethanes are bromodichloromethane, bromoform, chloroform, and dibromochloromethane.

[8] The five regulated haloacetic acids are dibromoacetic acid, dichloroacetic acid, monobromoacetic acid, monochloroacetic acid, and trichloroacetic acid.

disease, and neural tube defects (U.S. EPA, 2000; Ward *et al.*, 2018). However, since the MCL is set to the MCLG there would be no additional health benefits from further reductions in nitrate at public drinking water supplies that are meeting the MCL. In contrast, there may be incremental health benefits for reductions in *E. coli* and certain trihalomethanes at public drinking water supplies that are meeting the MCLs but not the MCLGs. The MCLGs for total coliform bacteria, bromodichloromethane, and bromoform are set to zero and therefore any reduction is expected to provide benefits.

Table 2-3: Drinking Water Maximum Contaminant Levels and Goals for Selected Pollutants in MPP Discharges

Pollutant	MCL	MCLG
Total coliforms (including fecal coliform and *E. coli*)	5%[a]	0%
Nitrate-Nitrite as N	10 mg/L (Nitrate); 1 mg/L (Nitrite)	10 mg/L (Nitrate); 1 mg/L (Nitrite)
Total trihalomethanes (TTHM)	0.080 mg/L[b]	Not applicable[b]
bromodichloromethane	Not applicable	0 mg/L
bromoform	Not applicable	0 mg/L
dibromochloromethane	Not applicable	0.06 mg/L
chloroform	Not applicable	0.07 mg/L

a. Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal waste. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems. No more than 5.0% of samples can test total coliform-positive (TC-positive) in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.)

b. EPA has set the MCL for the total of four trihalomethanes. Although there is no collective MCLG for TTHM, there are individual MCLGs for individual contaminants.

Source: 40 CFR 141.53 as summarized in U.S. EPA (2023h): National Primary Drinking Water Regulation, EPA 816-F-09-004

Data and modeling limitations do not allow EPA to quantify the changes in contaminant levels in treated drinking water and the changes in the incidence of adverse health effects. However, as detailed in the EA, EPA identified at least 92 PWS affected by MPP discharges, based on the PWS that withdraw from source surface waters downstream from direct MPP dischargers.[9] Of these PWS, seven reported at least one violation of the applicable MCLs for total coliforms, nitrate-nitrite, or TTHM between 2004 and 2021. Eleven violations of the nitrates rule were first reported between 2004 and 2015. Four violations of the TTHM rule were reported between 2004 and 2005. Three violations of the Revised Total Coliform Rule, which went into effect in 2016, were reported between 2017 and 2021. The proposed MPP ELG revisions may provide health benefits by reducing levels of the contaminants in source waters that may contribute to PWS violations and the associated contaminant exposures through drinking water. This is in addition to potential benefits from avoided treatment costs discussed in Section 2.3.1. EPA will continue to assess potential methods for estimating human health benefits resulting from changes in source water quality and welcomes comments and data to help in this assessment.

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[9] An unknown number of additional PWS withdraw from source surface waters downstream from POTWs receiving effluent from indirect MPP dischargers or purchase treated waters from an affected PWS.

2.1.3 Shellfish Consumption

EPA conducted an initial screening analysis which revealed that 9 recreational and 26 commercial fishing/shellfishing areas are located downstream of MPP direct dischargers and may be affected by these discharges.[10] Section 4.2.2. of the EA provides detail on the potentially affected commercial fish species and location of the affected commercial and federally owned recreational fishing areas. Pollutants discharged by MPP facilities may affect human health through the consumption of contaminated shellfish and, to a potentially lesser degree, contaminated fish.[11] For example, phosphorus discharged by MPP facilities can stimulate survival and reproduction of fecal bacteria in aquatic ecosystems, which can pollute shellfish beds and lead to shellfish-borne diseases (Mallin & Cahoon, 2020; Oliveira *et al.*, 2011; Wittman & Flick, 1995). Additionally, some species of HABs produce potent toxins that can accumulate in fish and shellfish that feed on those algae, resulting in poisoning syndromes in human consumers (*e.g.*, paralytic, diarrhetic, amnesic, or neurotoxic shellfish poisoning) (Hoagland *et al.*, 2002; U.S. EPA, 2015d). The annual average public health cost of shellfish poisoning (which includes lost productivity due to sick days, costs of medical treatment and transportation, and costs associated with investigations into the cause of illness) between 1987 and 1992 was estimated to be $0.7 million (2022$) (Hoagland *et al.*, 2002).[12,13] Given a significant increasing trend in all HAB events from 1990 to 2019 (D. M. Anderson *et al.*, 2021), the current public health cost of adverse HAB effects is likely to be much larger.

Monitoring of commercial harvest areas and bed closures may limit exposure to contaminated shellfish and fish, with the exposure risk being relatively larger for recreational areas. Several studies have reported incidents of shellfish poisoning among subsistence fishers (Adams *et al.*, 2016; Kibler *et al.*, 2022; V. Trainer *et al.*, 2014). Subsistence fishers may be more susceptible to shellfish poisoning due to higher consumption rates of self-caught fish and shellfish. For example, subsistence harvesting of shellfish is common in coastal Alaska (Ouzinkie, Kodiak, and Old Harbor) despite paralytic shellfish poisoning risks due to recurrent toxic *Alexandrium* blooms (Kibler *et al.*, 2022). Several MPP facilities are located in coastal parts of Alaska and may contribute to HABs. Thus, EPA identified 7 MPP dischargers in coastal Alaska or the Anchorage Borough, including one direct discharger on Kodiak Island. Subsistence harvesters may also be less aware of shellfish bed closures and consumption advisories. For example, paralytic shellfish poisoning incidents was found to be three times higher for

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[10] The screening analysis examined intersections between commercial aquaculture sites and recreational shellfishing sites located in the immediate vicinities (within 200 meters) of MPP direct dischargers. EPA used data on aquaculture provided by the National Oceanic and Atmospheric Administration (NOAA) and recreational shellfishing sites provided by the U.S. Fish and Wildlife Service (National Oceanic and Atmospheric Administration [data set], 2022; U.S. Fish and Wildlife Service, 2022).

[11] Potential human exposure to contaminated fish through fish consumption, and associated illnesses such as ciguatera fish poisoning (Hoagland *et al.*, 2002), may be minimal since excess ammonia discharges and HABs can lead to fish kills (Cloern, 2001; Jordan, 2007). Therefore, EPA considers the primary route of exposure to be through shellfish consumption.

[12] Hoagland *et al.* (2002) obtained cost information from a literature review of the economic effects of HABs for events in the U.S. between 1987 and 1992. Cost estimates were based on the number of reported and unreported cases of shellfish poisoning, a $1,400 cost for reported illnesses and a $1,100 cost for unreported illnesses, and a $1 million cost for mortalities (Hoagland *et al.*, 2002).

[13] Costs were converted from $0.4 million in 2000$ using the Bureau of Labor Statistic's Consumer Price Index for All Urban Consumers (Bureau of Labor Statistics, 2023).

residents of Old Harbor compared to Kodiak due, in part, to differences in awareness to advisory information (Kibler *et al.*, 2022).

By reducing MPP nutrient discharges, the regulatory options may prevent human exposure to contaminated fish and shellfish and reduce the incidence of shellfish-related poisoning. EPA is unable to quantify these changes given the limitations of the available data and models necessary to link predicted changes in nutrient loads, to HABs, shellfish toxin levels, exposure, and adverse health effects.

2.2 Ecological and Recreational Impacts Associated with Changes in Surface Water Quality

Wastewater from MPP facilities contains pollutants such as nutrients (nitrogen and phosphorus), BOD, bacteria and pathogens, TSS, oil and grease, and chlorides. As detailed in the EA, discharges of these pollutants to surface water can have a variety of environmental effects, including fish kills,[14] reduction in the survival and growth of aquatic organisms, and degradation of aquatic habitat. The adverse effects associated with releases of MPP pollutants depend on many factors such as the chemical-specific properties of the effluent, the mechanism, medium, and timing of releases, and site-specific environmental conditions.

EPA expects pollution loading reductions under the regulatory options to improve habitat conditions for fresh- and saltwater plants, invertebrates, fish and amphibians, as well as terrestrial wildlife and birds that prey on aquatic organisms exposed to MPP facility pollutants. These changes have the potential to increase ecosystem productivity and the propagation and health of resident species, including fish and invertebrate populations, thus potentially enhancing commercial, recreational, and subsistence fisheries. Water quality improvements may also enhance other recreational activities such as swimming and boating, as well as nonuse values (*e.g.*, option, existence, and bequest values) of the waters that receive MPP facility discharges. The improvements could also contribute to the recovery of T&E species sensitive to water pollution Finally, the proposed rule has the potential to impact nonuse values (*e.g.*, option, existence, and bequest values) of the waters that receive MPP facility discharges.

2.2.1 Changes in Surface Water Quality

The regulatory options may affect the value of ecosystem services provided by surface waters impacted by MPP dischargers. Increases in ammonia and the presence of HABs can lead to odor and water clarity issues affecting the recreational and aesthetic value of the affected waters (Backer & McGillicuddy, 2006; Baskin-Graves *et al.*, 2019; U.S. EPA, 2000). Additionally, excessive amounts of phosphorus, ammonia, and other forms of nitrogen can lead to low dissolved oxygen (DO) levels (Mallin & Cahoon, 2020; U.S. EPA, 2001), which may, in turn, lead to the release of toxic metals from sediments and contamination of surface waters and aquatic habitats (Li *et al.*, 2013). The contamination of surface waters and aquatic habitats may also adversely affect fish propagation and survival. By reducing discharges of nitrogen and phosphorus pollutants to receiving reaches, the proposed regulatory options would reduce occurrence of HABs and the probability of toxic metals being released from waterbody sediments, improve surface water quality, and improve water clarity, odor, and DO levels.

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[14] For example, in 2019 discharges of partially treated wastewater from a MPP facility into the Mulberry Fork of the Black Warrior River in Alabama resulted in a large fish kill (Alabama Department of Environmental Management, 2021).

Society may value changes in ecosystem services resulting from the MPP regulatory options through a number of mechanisms, including increased use and utility derived from subsistence fishing and recreational activities (such as fishing, swimming, and boating). Individuals may also value the protection of habitats and species that reside in waters affected by MPP dischargers, even when those individuals do not use or anticipate future use of such waters for recreational or other purposes, resulting in nonuse values.

As detailed in the EA and in Chapter 3 of this document, EPA quantified potential environmental impacts from the regulatory options by estimating in-waterway concentrations of MPP facility pollutants and translating water quality estimates into a single numerical indicator, a water quality index (WQI). EPA used the estimated change in WQI as a quantitative estimate of ecological changes for this regulatory analysis. Section 3.3 of this report provides details on the parameters used in formulating the WQI and the WQI methodology and calculations.

A variety of primary methods exist for estimating recreational use values, including both revealed and stated preference methods (Freeman III, Herriges, & Kling, 2014). Where appropriate data are available or can be collected, revealed preference methods can be employed for estimating use values. Some people deem revealed preference methods more reliable because they rely on observed behavior to infer users' values for environmental goods and services. Examples of revealed preference methods include travel cost, hedonic pricing, and random utility (or site choice) models (Freeman III, Herriges, & Kling, 2014).

In contrast to direct use values, nonuse values are considered more difficult to estimate. Stated preference methods, or benefit transfer based on stated preference studies, are the generally accepted techniques for estimating these values (Johnston, Boyle*, et al.*, 2017; OMB, 2003a). Stated preference methods rely on carefully designed surveys, which either (1) ask people about their willingness to pay (WTP) for particular environmental improvements, such as increased protection of aquatic species or habitats with particular attributes, or (2) ask people to choose between competing hypothetical "packages" of environmental improvements and household cost (Bateman *et al.*, 2006; Johnston, Boyle*, et al.*, 2017). In either case, values are estimated by statistical analysis of survey responses.

Although the use of primary research to estimate values is generally preferred because it affords the opportunity for the valuation questions to closely match the policy scenario, the realities of the regulatory process often leave Agency analysts with benefit transfer as the only option for assessing certain types of non-market values (R.S. Rosenberger & Johnston, 2008; Johnston *et al.*, 2021). Benefit transfer is described as the "practice of taking and adapting value estimates from past research … and using them … to assess the value of a similar, but separate, change in a different resource" (V.K. Smith, G. Van Houtven, & S.K. Pattanayak, 2002, p. 134). It involves adapting research conducted for another purpose to estimate values within a particular policy context (Johnston *et al.*, 2021). Among benefit transfer methods, meta-analyses are often more accurate compared to other types of transfer approaches due to the data synthesis from multiple source studies (R.S. Rosenberger & Johnston, 2008; Johnston *et al.*, 2021). However, EPA acknowledges that there is still a potential for transfer errors (see Kaul *et al.*, 2013 for additional discussion on benefit transfer error) and no transfer method is always superior (Johnston *et al.*, 2021).

To quantify and monetize the benefits of revisions to the MPP ELGs, EPA followed the same methodology used in analyzing the proposed revisions to the technology-based ELGs for the steam electric generating point source category (U.S. EPA, 2023b). EPA relied on a benefit transfer approach based on a meta-analysis of 59 surface water valuation studies to estimate the use and nonuse benefits of improved surface water quality under the regulatory options. The valuation function includes explanatory variables to enable more accurate value predictions for the surface waters affected by MPP dischargers, linking these values to specific characteristics of affected water resources and households. This analysis is presented in Chapter 4.

2.2.2 Impacts on Threatened and Endangered Species

For T&E species, even minor changes to reproductive rates and small improvements in mortality levels may represent a substantial portion of annual population growth. By reducing discharges of MPP facility pollutants to T&E habitats, the regulatory options have the potential to impact the survivability of some T&E species living in these habitats. Section 9 of the Endangered Species Act (ESA) prohibits the take (hunting/trapping/collecting) of endangered species. Section 4(d) of the ESA affords threatened species similar protections with more flexibility on a case-by-case basis. As a result of not being legally hunted or collected, T&E species primarily derive value primarily from nonuse values, such as existence, bequest, and recreational values. In addition, pollutants from MPP dischargers may affect T&E species indirectly by causing damage to food webs and ecosystem stability. Reducing discharges of MPP facility pollutants to T&E habitats would benefit T&E species by improving species protection and survival.

EPA quantified but did not monetize the potential effects of the regulatory options on T&E species. As detailed in Section 4.2.3 of the EA, EPA constructed databases to determine which species have habitat ranges that intersect waters downstream from MPP direct dischargers and classified species according to their vulnerability to water pollution. Species deemed to have ‘higher’ vulnerability to water pollution from MPP discharges include species living in aquatic habitats for several life history stages and/or species that obtain a majority of their food from aquatic sources. See the *EA* for additional methodological details.

EPA identified 108 unique animal species with habitats that may be impacted by MPP direct dischargers. Of these 108 species, the majority (75) are classified as having a higher vulnerability to water quality impacts. Clams and fishes make up over half of the number of species potentially affected by the proposed rule and both groups have a higher vulnerability to water quality impacts. Examples of other affected species include the West Indian Manatee (mammal), Ozark Hellbender (amphibian), Slenderclaw crayfish (crustacean), bog turtle (reptile), and Painted rocksnail (snail). Table 2-4 provides a breakdown of the T&E species by group and vulnerability designation.

Table 2-4: Threatened and Endangered Species by Group and Vulnerability

Group	Lower	Moderate	Higher	Total Species Count
Amphibians	1	1	2	4
Birds	6	3	0	9
Clams	0	0	45	45
Crustaceans	0	0	3	3
Fishes	0	0	15	15
Insects	4	0	0	4
Mammals	7	1	1	9
Reptiles	10	0	6	16

Table 2-4: Threatened and Endangered Species by Group and Vulnerability

Group	Lower	Moderate	Higher	Total Species Count
Snails	0	0	3	3
Total	**28**	**5**	**75**	**108**

Note: 'Higher' vulnerability includes species living in aquatic habitats for several life history stages and/or species that obtain a majority of their food from aquatic sources. 'Moderate' vulnerability includes species living in aquatic habitats for one life history stage and/or species that obtain some of their food from aquatic sources. 'Lower' vulnerability includes species whose habitats overlap bodies of water, but whose life history traits and food sources are terrestrial.

EPA was unable to monetize the proposed rule's effects on T&E species due to a variety of challenges in quantifying the response of T&E populations to changes in water quality, including availability of life history and population dynamic data and the complex nature of aquatic ecosystems. Although a relatively large number of economic studies have estimated WTP for T&E protection, these studies focused on estimating WTP to avoid species loss/extinction, increase in the probability of survival, or an increase in species population levels (Subroy *et al.*, 2019; L. Richardson & Loomis, 2009). The studies summarized in Subroy et al. (2019) suggest that people attach non-trivial economic value to protection of T&E species. These values range from $16.74 per household (in 2022$) for Colorado pikeminnow to $165.03 (in 2022$) for lake sturgeon (both fish species).[15] Together, the results of these studies indicate that aggregate values for preservation of T&E species are likely to be significant. EPA is considering potential monetization approaches for estimating the value of improved T&E habitat for the final rule analysis. The agency solicits comments on the feasibility of quantifying the response of T&E populations to water quality improvements and potential valuation approaches.

2.3 Economic Productivity

The regulatory options may have economic productivity effects stemming from changes in the quality of waters used as sources of drinking water, for industrial processes, or for irrigation; changes in the quality of wastewater received by POTWs; changes in commercial and subsistence shellfish and fish harvests, tourism and property values; and changes in the generation, capture and sale of methane at MPP facilities and POTWs. These benefits are discussed qualitatively in the following sections.

2.3.1 Drinking Water Treatment Costs

The proposed regulatory options have the potential to reduce drinking water treatment costs for PWS affected by MPP dischargers by improving the quality of source waters. Treatment may be required to meet the health based MCLs discussed in Section 2.1.2, or for aesthetic considerations such as taste, odor, and color. EPA has established National Secondary Drinking Water Regulations (NSDWRs) that set non-mandatory water quality standards, referred to as secondary maximum contaminant levels (SMCLs), for 15 contaminants. These contaminants are not considered to present a risk to human health and EPA does not enforce the SMCLs.

Excess phosphorus in concentrations greater than 1.0 mg/L can interfere with the coagulation process in drinking water treatment plants and reduce treatment efficiency (Mallin & Cahoon, 2020). Excess chloride and TDS can corrode distribution system pipes and lead to the buildup of scale (a mineral

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[15] Costs were converted from 2016$ to 2022$ using the Bureau of Labor Statistic's Consumer Price Index for All Urban Consumers (Bureau of Labor Statistics, 2023).

deposit), reducing water flow (U.S. EPA, 2023k). Additionally, high algal biomass, as a result of eutrophication, can clog and corrode drinking water intake pipes, and increase the volume of chemicals needed to purify the water (Nordin, 1985). The presence of algal biomass and other organic matter may also contribute to higher treatment costs to avoid and control the formation of DBPs and their associated adverse health effects discussed in section 2.1.2. Algal blooms, chlorides, and high concentrations of total solids (TDS and TSS) may also impact the taste and smell of drinking water (Backer & McGillicuddy, 2006; U.S. EPA, 2012, 2023k), necessitating additional treatment.[16] The increased cost of treating drinking water due to excess nutrients and the presence of algal blooms can be substantial. For example, the City of Waco, Texas incurred an estimated $89.5 million in costs from 2002 to 2012 (in 2022$)[17] to address poor drinking water quality due to excess nutrients (U.S. EPA, 2015c). In addition, the City of Waco lost potentially up to $13.1 million (in 2022$)[18] in revenue due to taste and odor problems resulting in decreased water sales to neighboring communities prior to treatment plant upgrades (U.S. EPA, 2015c). In another example, the City of Celina, Ohio incurred $16.7 million in 2010 (in 2022$)[19] in increased drinking water treatment costs associated with a blue-green algae outbreak (U.S. EPA, 2015c).

Numerous studies have shown an unequivocal link between higher treatment costs and lower source water quality (see Heberling *et al.* (2022) for a non-exhaustive list of studies). Price and Heberling (2018), through a comprehensive review of the literature, developed average elasticities which relate percentage changes in drinking water treatment costs to a 1 percent change in source water quality (measured either in terms of pollutant concentrations or pollutant loadings). Using data from 15 U.S. studies, the authors developed elasticities for various water quality parameters, including nitrogen concentrations, phosphorus and sediment loadings, TOC, turbidity, and pH. The study found a 1 percent change in nitrogen (as nitrate) concentration to lead to a 0.06 percent change in drinking water treatment costs. Similarly, the study found a 1 percent change in phosphorus loads to lead to a 0.02 percent change in drinking water treatment costs ranging from 0.02 to 0.19 percent and a 1 percent change in sediment loads leads to a change in drinking water treatment costs ranging from 0.02 to 0.26 percent. Finally, a 1 percent reduction in TOC leads to a 0.10 to 0.55 percent decrease in drinking water treatment costs. As part of the water quality modeling described in Chapter 3, EPA identified estimated changes in pollutant concentration under the regulatory options for reaches with public water system surface water intakes. However, because of the limited data available on TIP and baseline operation and maintenance (O&M) costs for systems potentially affected by the proposed rule, EPA was not able to monetize changes in treatment

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[16] EPA has established National Secondary Drinking Water Regulations (NSDWRs) that set non-mandatory water quality standards or secondary maximum contaminant levels (SMCLs) for contaminants. The SMCLs serve as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor, and technical considerations such as damage to water equipment or reduced effectiveness of treatment for other contaminants. These contaminants are not considered to present a risk to human health at the SMCL. Chloride and TDS have SMCLs of 250 mg/L and 500 mg/L, respectively (U.S. EPA, 2023k).

[17] Costs were converted from $70.2 million in 2012$ using the Bureau of Labor Statistic's Consumer Price Index for All Urban Consumers (Bureau of Labor Statistics, 2023).

[18] Costs were converted from $10.3 million in 2012$ using the Bureau of Labor Statistic's Consumer Price Index for All Urban Consumers (Bureau of Labor Statistics, 2023).

[19] Costs were converted from $13.1 million in 2012$ using the Bureau of Labor Statistic's Consumer Price Index for All Urban Consumers (Bureau of Labor Statistics, 2023).

costs as a result of these changes. The Agency will continue to assess approaches to monetizing these benefits and welcomes comments on data to support these analyses.

Poor drinking water quality, actual or perceived, can also have economic impacts as consumers avert consuming tap water and turn to more expensive bottled water. Research documents a relationship between sales of bottled water and SDWA violations (Allaire et al, 2019).

Despite these findings, there are significant gaps in the literature that impede monetization of potential drinking water treatment cost reductions from reductions in nutrients and eutrophication levels. Among these gaps are limited information about how important water quality measures like nutrient concentrations, algae presence and HABs (as measured, for example, by cyanobacteria cell density) affect treatment costs,[20] and an insufficient understanding of how relationships between treatment costs and source water quality differ across treatment technologies (Heberling *et al.*, 2022). These gaps are only starting to be addressed. For example, a recent study by Heberling *et al.* (2022) assessed the avoided-treatment costs from improving surface water quality for a drinking water treatment plant in Ohio. The study found algal toxin to be a significant driver of treatment costs where the presence of a HAB toxin led to a 2.56 percent increase in daily costs.

Results from EPA's review of literature on the relationship between treatment costs and source water quality suggest that the regulatory options have the potential to reduce drinking water treatment cost at affected PWS. These cost savings may be the result of avoiding expensive treatment upgrades that may be necessary to meet applicable MCLs or may result from reduced costs to operate current treatment processes, such as reduced chemical use (alum) to treat solids. As detailed in the EA and summarized in Section 2.1.2, EPA identified 92 PWS that withdraw from surface waters downstream from MPP direct dischargers. Limited information is available on the treatment in place (TIP) at these PWS. However, they could potentially have to upgrade their existing treatment to meet applicable MCLs without the improvements in source water quality achieved under the regulatory options. Such upgrades can be very expensive. For example, Ribaudo et al. (2011) estimated the cost of nitrogen removal for individual community water systems to range from $19,500 to $815,000 per year, depending on system size.

EPA is continuing to evaluate the application of engineering models or treatment cost elasticity approach to quantify avoided treatment costs from improved source water quality and welcomes comments and additional information to help quantification of avoided drinking water treatment costs under the proposed rule. The agency also encourages comments on other measures of the benefits of improving source waters quality such as households WTP to reduce contaminant levels below SMCLs.

2.3.2 Wastewater Treatment Costs

The proposed regulatory options have the potential to transfer wastewater treatment costs at POTWs receiving MPP discharges to the MPPs. Reduced treatment costs for POTWs may result from reduced

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[20] As evidence of this limited information, the average elasticities developed in Price and Heberling (2018) for nitrogen and phosphorus loads were based on only one study each, when excluding studies that did not mitigate against potential omitted variable bias by (1) incorporating control variables consistent with economic theory in their models (*e.g.*, the volume of treated water, surface water or ground-water sourced water, among others) or (2) using a panel fixed effects estimator when panel data is employed. Only one additional study pertaining to treatment costs for phosphorus loads would be included when removing this restriction.

“pass through”[21] and “interference”[22] events, and improving the quality of biosolids. However, EPA also notes that any cost savings to the POTWs may be offset by reduced treatment fees paid by the MPP facilities to the POTWs. Because of a lack of data to estimate the changes, EPA is not quantifying these cost savings in this analysis but notes that savings at POTWs would reduce the net social costs attributable to this rule as discussed in Chapter 7. POTWs may conduct primary treatment, secondary treatment, and advanced treatment.[23] Conventional secondary biological treatment processes do not remove phosphorus and nitrogen to a substantial extent and their removal often requires advanced treatment such as biological nutrient removal (BNR) (U.S. EPA, 2004a).

Livestock slaughtering and cleaning can generate high TSS concentrations by introducing large amounts of blood and offal into the waste stream (Amorim & Moura, 2021). TSS can contribute to complications in wastewater treatment. Moreover, fats, oils, and grease are prone to float on top of effluent and can reduce efficiency of the treatment process (Mittal, 2004). Lastly, nutrients such as organic nitrogen and phosphorus have been found to be widespread in MPP wastewater, originating from bone, animal tissue, blood, manure, and cleaning compounds (U.S. EPA, 2004c; Ziara *et al.*, 2018). The cost of treating nutrients in wastewater depends on their concentrations, as well as other factors such as the type of technology utilized by the POTW (*e.g.*, BNR technologies, activated sludge, lagoons and oxidation ditches) and its size or treatment capacity (due to economies of scale) (U.S. EPA, 2015c). The regulatory options will lead to changes in pre-treatment or best management practices (BMPs) at MPP facilities which may result in reductions at POTWs of TSS, oil and grease, and nitrogen and phosphorus nutrient loads, and, as a result, potential reductions in treatment costs.

However, the regulatory options would also reduce the BOD concentration discharged by MPP indirect dischargers which may, in some cases, lead to increases in treatment costs at POTWs. This is because nitrogen removal almost always relies on biological treatment which requires some carbon source such as BOD (*i.e.*, bacteria must have oxygen to break down the sewage) (U.S. EPA, 2004a). A lack of BOD in the incoming wastewater may require a POTW to add a carbon source which can increase cost. This is dependent on the design of the facility and how much of the needed carbon comes from the MPP indirect discharger as opposed to other sources.

In addition, the regulatory options may also reduce the incidence of POTW pass through and interference related to MPP wastewater strength (*i.e.*, concentrations of BOD, TSS, oils and grease, and nitrogen) and, in turn, reduce the occurrence of associated fines. “Interference is costly to POTWs in terms of worker

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[21] “Pass through” is defined in 40 CFR Part 403.3(p) as “A discharge that exits the POTW into waters of the United States in quantities or concentrations that, alone or in conjunction with a discharge or discharges from other sources, is a cause of a violation of any requirement of the POTW's NPDES [National Pollutant Discharge Elimination System] permit (including an increase in the magnitude or duration of a violation).”

[22] “Interference” is defined in the General Pretreatment Regulations (40 CFR Part 403) in terms of a discharge which, alone or in combination with other discharges, inhibits or disrupts the POTW and causes it to violate its NPDES permit or applicable sludge use or disposal regulations (U.S. EPA, 1987).

[23] Primary treatment is the initial stage in the treatment of wastewater and involves the removal of coarse solids. Primary treatment is followed by secondary treatment that can remove up to 90 percent of the organic matter in wastewater by using biological treatment processes (the most common conventional methods are attached growth and suspended growth processes). Secondary treatment may be followed by advanced treatment which can be an extension of conventional secondary biological treatment (*e.g.*, to remove nitrogen or phosphorus) and may also involve physical-chemical separation techniques such as ion exchange and reverse osmosis (U.S. EPA, 2004a).

safety, physical plant integrity, effectiveness of operation, and liability for NPDES permit violations" (page 52, U.S. EPA (1987)). EPA studied a subset of POTWs that receive MPP wastewater discharges to inform consideration of the need for national pretreatment standards for MPP facilities. Many of the POTWs (approximately 73 percent) had violations for pollutants found in MPP wastewater, such as BOD, TSS, chlorides, nutrients, and oil and grease. The collected data thus indicate that POTWs are not adequately removing nutrients from MPP indirect dischargers and that MPP indirect dischargers are likely contributing to interference and pass through incidents. Moreover, the regulatory options may also reduce time and resource costs to POTWs related to the prevention measures (such as legal action) POTWs take to avoid interference from MPP indirect dischargers.

Lastly, the regulatory options may affect the quantity and quality of biosolids generated in the wastewater treatment process which may be sold and used in land applications (*e.g.*, as fertilizer for farmers). Biosolids are required to meet federal regulation (40 CFR Part 503) that set minimum requirements for land applications, including limits to pathogens such as fecal coliform and *Salmonella* (U.S. EPA, 2004a). 40 CFR Part 503.14 requires that biosolids must be applied to land at the appropriate agronomic rate which is the sludge application rate designed to provide the amount of nitrogen needed by the crop or vegetation grown on land. The regulatory options would affect biosolids generated by POTWs receiving MPP wastewater in two ways: (1) reduce the level of pathogens and thus potentially increase the quality of biosolids (2) reduce the amount of nitrogen and phosphorus may and therefore decrease biosolids effectiveness as a fertilizer (*i.e.*, increasing sludge application rates) and lower sales. Because POTWs are likely to receive discharges from multiple sources, the overall effect of the regulatory options on the quantity and quality of biosolids and revenue generated from their sale is likely to be small.

MPP facilities may also market recovered solids from their on-site wastewater treatment to offset some of their costs. Benefits depend on the uses for these industrial sludges. The same is true for recovered oil and grease, which can also be used as rendering feedstock. EPA is requesting input and available data to better define the market for these products to quantify the potential benefits.

2.3.3 Industrial and Agricultural Uses

MPP dischargers can affect the quality of water used for industrial and agricultural uses. Some industrial facilities treat water before use, and elevated sediment and turbidity levels resulting from MPP discharges may require additional treatment (Osterkamp et al. 1998) or use of filters to improve water quality or make a surface water source unusable. Even small amounts of suspended sediment can cause problems for industrial operations such as vegetable processing or cloth manufacture. Suspended sediment also increases the rate at which hydraulic equipment, pumps, and other equipment wear out, causing accelerated depreciation of capital equipment. In addition, HABs can lead to the clogging of industrial water intakes and cause problems for industrial facilities. As example of potential impacts on agricultural uses, nutrients can increase eutrophication and promote cyanobacteria blooms in surface waters used for livestock watering which can potentially kill livestock that drink from these waters (Backer, 2002; World Health Organization, 2021). EPA did not quantify or monetize effects of quality changes in industrial or agricultural water sources arising from the regulatory options due to the lack of data on direct MPP dischargers that affect source water for industrial processes or livestock watering.

2.3.4 Commercial Harvesting of Fish and Shellfish

Commercial harvest of fish and shellfish exists in salt waters and, to a certain extent, in the Great Lakes. Commercial fishing potentially affected by MPP discharges includes aquaculture leases for fish crustaceans, mollusks, and aquatic plants.[24] Specifically, potential impacts to commercial fishing and shellfishing exist along the Atlantic and Gulf Coasts with specific facilities discharging to the Albemarle Sound, Chesapeake Bay, Delaware Bay, and the Gulf of Mexico. Section 4.2.2. of the EA provides detail on the potentially affected commercial fish species and fishing areas located downstream from the MPP dischargers. Eutrophication and the formation of HABs stemming from MPP facility discharges of nutrients has the potential to negatively impact commercial harvest of fish and shellfish. HABs have occurred in the Great Lakes and coastal areas across the country (Hoagland *et al.*, 2002; Makarewicz *et al.*, 2006; Islam & Masaru, 2004; Jin, Thunberg, & Hoagland, 2008; V. L. Trainer *et al.*, 2007; U.S. EPA, 2015c). HABs can affect commercial fisheries by directly causing fish kills, causing habitat loss leading to lower ecosystem carrying capacity, forcing managers to establish closures, increasing the costs of processing harvested shellfish, and causing consumer demand to shrink due to the perception of risk (Hoagland *et al.*, 2002; Suddleson & Hoagland, 2021; U.S. EPA, 2015c). In some cases, excessive pollutant loadings due to toxic algal blooms can lead to the closure of shellfish beds, thereby reducing shellfish harvests and causing economic losses from reduced harvests (Jin, Thunberg, & Hoagland, 2008; V. L. Trainer *et al.*, 2007; Islam & Masaru, 2004; Suddleson & Hoagland, 2021). These economic losses may be significant. For example, Evans and Jones (2001) estimated the value of lost oyster harvests between September and December 2000 in Galveston Bay, Texas due to the closure of shellfish beds (which lasted 85 days) affected by a “red tide” event at $306,000 (in 2022$).[25] In another example, Jin, Thunberg, and Hoagland (2008) estimated the value of lost soft-shell crab and mussel harvests between April and August 2005 in Maine due to the closure of shellfish beds affected by a "red tide” event at $3.2 million and $586,000 (in 2022$), respectively.[26]

Improved water quality due to reduced discharges of pollutants from MPP dischargers would enhance aquatic life habitat and, as a result, contribute to reproduction and survival of commercially harvested species and larger fish and shellfish harvests, which in turn could lead to an increase in producer surplus.[27]

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[24] Commercial fishing areas were identified using two datasets: National Oceanic and Atmospheric Association’s (NOAA’s) aquaculture layer (National Oceanic and Atmospheric Administration [data set], 2022) and essential fish habitat (EFH) mapper (National Oceanic and Atmospheric Administration, 2021). The former includes the location of aquaculture leases within coastal and offshore waters. The areas covered include the Atlantic, Gulf, and Pacific coasts of the contiguous U.S. The latter includes information on the geospatial distribution of commercially caught fish species. To assess potential impacts from MPP direct dischargers, EPA identified commercial fishing areas that were within 200 meters of their 25-mile downstream flow path.

[25] Costs were converted from $240,000 in 2012$ using the Bureau of Labor Statistic’s Consumer Price Index for All Urban Consumers (Bureau of Labor Statistics, 2023).

[26] Costs were converted from $2.5 million and $460,000 in 2012$ using the Bureau of Labor Statistic’s Consumer Price Index for All Urban Consumers (Bureau of Labor Statistics, 2023).

[27] An increase in consumer surplus is unlikely since reduced discharges of pollutants from MPP dischargers would only affect the *local* commercial harvest of fish and shellfish species. Thus, improvements in harvest are unlikely to occur at a large enough scale to lead to subsequent price changes.

EPA did not monetize impacts to commercial fisheries from reducing pollutants from MPP dischargers under the regulatory options. Estimated increases in annual average pollutant loads under the regulatory options may affect commercial harvest by enhancing local fish populations (e.g., reducing fish kills) and reducing the number of days when shellfish beds are closed for harvest. The benefit to the economy from the regulatory options effects on commercially harvested fish shellfish species is determined by the sum of changes in both producer and consumer surplus. The change in producer surplus is a function of gross revenue change from the change in the commercial harvest due to improved water quality.[28] As shown by existing economic studies (U.S. EPA, 2004b; U.S. EPA, 2014), economic impacts on local producers are likely to be nontrivial. On the other hand, the overall effects to commercial fishery consumers arising from the regulatory options are likely to be negligible. Most species of fish have numerous close substitutes. The literature suggests that when there are plentiful substitute fish products, numerous fishers, and a strong ex-vessel market, individual fishers are generally price takers. Therefore, the measure of consumer welfare (consumer surplus) is unlikely to change because of small changes in fish and shellfish landings, such as changes EPA expects under the regulatory options.

2.3.5 Subsistence Harvesting of Fish and Shellfish

Discharges of pollutants may, for reasons similar to those described in Section 2.3.4 (*i.e.*, eutrophication and the formation of HABs), potentially impact subsistence harvesting of fish and shellfish through fish kills and fish and shellfish contamination. As shown in the EA, 50 unique MPP direct dischargers discharge within 50 miles of 44 unique tribal areas potentially affecting subsistence fishing areas on tribal lands (see Section 7 on the EA for detail on affected tribal lands and subsistence fishing areas).

Several studies have found losses of subsistence fishing due to HABs (U.S. EPA, V. L. Trainer *et al.*, 2007; 2015c). For example, subsistence fishers were heavily impacted after the closure of a recreational razor clam fishery in 2003 due to domoic acid from HABs throughout the Washington and Oregon coast (U.S. EPA, 2015c). Subsistence fishing may also be reduced due to bans on the harvesting of contaminated shellfish or concerns related to the risk of shellfish poisoning caused by fecal bacteria and HABs (see Section 2.1.3). The regulatory options would decrease discharges of nutrients from MPP facilities leading to potential reductions in the frequency of toxic HAB formation and, as a result, reductions in the risk of shellfish poisoning, thereby benefiting subsistence fishers.

2.3.6 Tourism

Discharges of pollutants may also affect the tourism and recreation industries (*e.g.*, boat rentals, sales at local restaurants and hotels) and, as a result, local economies in the areas surrounding affected waters due to changes in recreational opportunities (Mojica & Fletcher, 2020; Highfill & Franks, 2019). Approximately 87 percent of MPP direct dischargers discharge to an area with potential for recreation. Affected recreation area types include local parks, conservation easements, and state conservation areas (see Section 4.2.5 of the EA for detail). Although the average minimum distance from a discharger to a recreation area is 6.07 miles, quite a few recreational areas have MPP direct discharges less than a mile upstream. Given proximity of the dischargers to recreational areas, there is a potential of negative effects on water quality in recreational areas. For example, excess nutrients contained in MPP discharges may

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[28] Because normal profits are assumed to be a sufficient proxy for producer surplus, assessment of producer surplus is a relatively straightforward calculation in which the change in producer surplus is calculated as a species- and region-specific fraction of the change in gross revenue due to increased landings (U.S. EPA, 2004b; U.S. EPA, 2014).

result in HABs, which have been shown to negatively affect tourism (Donald M Anderson *et al.*, 2000; Bechard, 2020b; Hoagland *et al.*, 2002; Larkin & Adams, 2007; U.S. EPA, 2015c; Weir, Kourantidou, & Jin, 2022). For example, both Larkin and Adams (2007) and Bechard (2020b), found that the presence of HABs reduced monthly lodging sector sales and restaurant sector sales in the northwest and southwest coasts of Florida. In another example, a full season closure for recreational shellfishing due to the presence of HABs in Long Beach, Washington was estimated to cost $0.86 million (2022$). This estimate includes lost revenue for gas stations, food stores, accommodations, and food service places (Weir, Kourantidou, & Jin, 2022).[29, 30]

The effects of water quality on tourism are likely to be highly localized. Because few identified recreational sites are in close proximity to MPP direct discharge points, negative impacts on tourism-dependent local economies resulting from water quality effects on fishing and water-based recreation are unlikely. However, MPP discharges may still affect fish, swimming safety, and aesthetic value of water resources and thus recreational benefits, as described in Section 2.2.1EPA did not quantify or monetize the effects of water quality on tourism and local economies due to the lack of data on recreational behavior and visitation for the affected sites.

2.3.7 Property Values

Discharges of pollutants may affect the aesthetic quality of water resources by altering water clarity, color, and odor in the receiving and downstream reaches. For example, water clarity, color, and odor may be impacted by HABs and ammonia (Backer & McGillicuddy, 2006; Baskin-Graves *et al.*, 2019; U.S. EPA, 2000; U.S. EPA, 2015c). Studies suggest that properties are more desirable when located near unpolluted water (*e.g.*, Bin & Czajkowski, 2013; K.J. Boyle, Poor, & Taylor, 1999; Cassidy, Meeks, & Moore, 2023; Gibbs *et al.*, 2002; Kuwayama, Olmstead, & Zheng, 2022; Leggett & Bockstael, 2000; Liu, Opaluch, & Uchida, 2017; M. R. Moore *et al.*, 2020; Netusil, Kincaid, & Chang, 2014; Tang, Heintzelman, & Holsen, 2018; Walsh *et al.*, 2017; Wolf, Gopalakrishnan, & Klaiber, 2022). Moreover, properties have been shown to lose value when located near HABs and persistent blooms of "red tide" (Bechard, 2020a; Wolf, Gopalakrishnan, & Klaiber, 2022). Technologies implemented by MPP facilities to comply with the regulatory options remove nutrients to varying degrees and have varying effects on water eutrophication, algae production, water turbidity, and other surface water characteristics. Therefore, the regulatory options may lead to property value benefits with reductions in nutrient and sediment concentrations in adjacent surface waters.

EPA did not quantify or monetize the potential change in property values associated with the regulatory options. The magnitude of the effect on property values depends on many factors, including the number of housing units located in the vicinity of the affected waterbodies, community characteristics (*e.g.*, residential density), housing stock (*e.g.*, single family or multiple family), and the effects of MPP pollutants on the aesthetic quality of surface water. There are no well-established models to predict changes in the aesthetic quality of surface waters (*e.g.*, clarity and odor) that may result from the changes in pollutant concentrations under the regulatory options, and EPA therefore did not estimate impacts of

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[29] This estimate was based on an autoregressive distributed lag model of the change in foot traffic (using visitor foot traffic data from 2018 to 2021) during recreational clamming closures (Weir, Kourantidou, & Jin, 2022).

[30] Costs were converted from $0.8 million in 2021$ using the Bureau of Labor Statistic's Consumer Price Index for All Urban Consumers (Bureau of Labor Statistics, 2023).

the proposed rule on property values. In addition, there may be an overlap between shifts in property values and the estimated total WTP for surface water quality changes discussed in Section 2.2.1, and the Agency chose to avoid potential double-counting by not quantifying and monetizing this category.

2.3.8 Capture of Methane

As discussed later in Chapter 5, the regulatory options may lead to changes in methane (CH_4) emitted indirectly through changes in electricity consumption to power wastewater treatment processes.

Though there is no overall, net incremental change in CH_4 emissions associated with wastewater treatment technology, facilities may still have increased on-site emissions of CH_4 that can be captured[31] and used for on-site energy needs or marketed as renewable natural gas for electricity generation or transportation (Bracmort *et al.*, 2011). The regulatory options may provide additional incentives for MPP facilities to capture the CH_4 and use it beneficially (*e.g.*, for energy generation or heating), which has positive outcomes for MPP facilities and the environment. For example, the sale of captured CH_4 may provide MPP facilities additional revenue (see the RIA for additional details on potential revenue to MPP facilities). Because CH_4 is a potent greenhouse gas (GHG) its capture helps mitigate climate change impacts (see Chapter 5 for details on changes in CH_4 emissions). Generating energy and heat from captured CH_4 also potentially reduces use of non-renewable resources.

2.4 Changes in Air Pollution

The proposed rule has the potential to affect air pollution through two main mechanisms: (1) indirect changes in CH_4, CO_2, NO_x, and SO_2 emissions associated with changes in electricity consumed to power wastewater treatment processes at MPP facilities and POTWs, and (2) transportation-related air pollutant emissions (CH_4, CO_2, NO_x, and SO_2) due to changes in the trucking of solid waste for land application, landfilling, or composting.

CO_2 and CH_4 are greenhouse gases that EPA has determined endanger public health and welfare through their contribution to climate change. EPA used estimates of the social cost of carbon and methane (SC-CO_2 and SC-CH_4) to monetize the changes in emissions as a result of the proposed rule. SC-CO_2 and SC-CH_4 (collectively referred to as the social cost of greenhouse gases or SC-GHGs) are metrics that estimate the monetary value of projected impacts associated with marginal changes in emissions in a given year. They include a wide range of anticipated climate impacts, such as net changes in agricultural productivity and human health, property damage from increased flood risk, and changes in energy system costs, such as reduced costs for heating and increased costs for air conditioning. For this analysis, EPA applied the interim SC-GHG estimates recommended by the Interagency Working Group on the Social Cost of Greenhouse Gases (IWG) (Interagency Working Group on the Social Cost of Greenhouse Gases, 2021).[32] Chapter 5 details this analysis.

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[31] The capture of methane prevents its release as a greenhouse gas (GHG) into the atmosphere. Captured methane is generally flared (releasing CO_2, a less potent GHG into the atmosphere) or used for energy purposes (Bracmort *et al.*, 2011).

[32] EO 13990 directed the Interagency Working Group (IWG) to develop a comprehensive update of its SC-GHG estimates, recommendations regarding areas of decision-making to which SC-GHG should be applied, and a standardized review and updating process to ensure that he recommended estimates continue to be based on the best available economics and science going forward. The SC-GHG estimates used in this report are interim values until updated estimates of the impacts of

NO_X, and SO_2 are known precursors to $PM_{2.5}$, a criteria air pollutant that has been associated with a variety of adverse health effects, including premature mortality and hospitalization for cardiovascular and respiratory diseases (*e.g.*, asthma, chronic obstructive pulmonary disease [COPD], and shortness of breath).

EPA used benefit-per-ton estimates for stationary and mobile sources (which represent the total monetized human health benefits, including premature mortality and morbidity) to monetize human health related impacts from changes in these emissions (Wolfe *et al.*, 2019;U.S. EPA, 2023n). EPA estimated the changes in energy use by MPP facilities and POTWs to power treatment processes. For changes in electricity consumed, EPA used the Emissions & Generation Resource Integrated Database (eGRID) to estimate changes in the tons of NO_X and SO_2 emissions (U.S. EPA, 2023d).[33] Trucking emissions were estimated based on the increased mileage traveled and emission factors from EPA's MOVES3 Motor Vehicle Emission Simulator. The TSD provides additional details on the methodology. EPA then multiplied estimates of the changes in tons of NO_x and SO_2 emissions by the estimated benefits per ton of emissions reported in Wolfe *et al.*, 2019. See Chapter 5 for details of this analysis.

In addition to health effects from air emissions, air pollution (*e.g.,* $PM_{2.5}$) can create a haze that affects visibility. Reduced visibility could impact views in national parks by softening the textures, fading colors, and obscuring distant features and therefore reduce the value of recreational activities (*e.g.*, K. J. Boyle *et al.*, 2016; Poudyal, Paudel, & Green, 2013). A number of studies (*e.g.*, Bayer, Keohane, & Timmins, 2006; Beron, Murdoch, & Thayer, 2001; Chay & Greenstone, 1998) also found that reduced air quality and visibility can negatively affect residential property values. EPA did not quantify or monetize the effects of changes in air emissions on recreational opportunities and property values due to complexity of the relationship between visibility and the levels of predominant pollutants in the atmosphere.

2.5 Summary of Benefit Categories

Table 2-5 summarizes the potential benefits of the regulatory options analyzed for the proposed rule and the level of analysis applied to each category. As indicated in the table, only a subset of potential effects can be quantified and monetized. The monetized welfare effects include the use and nonuse values from surface water quality improvements, and changes in air emissions. Other welfare effect categories, including impacts on the habitats of T&E species, and commercial fisheries were quantified but not monetized. Finally, EPA was not able to quantify or monetize other welfare effects, including drinking and wastewater treatment cost reductions, impacts to subsistence harvesting, tourism, and property values,

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climate change can be developed (Interagency Working Group on the Social Cost of Greenhouse Gases, 2021). In December 2023, EPA published new SC-GHG estimates as a supplement to a rulemaking finalizing "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review." (U.S. Environmental Protection Agency, 2023l) These new estimates reflect recent advances in the scientific literature on climate change and its economic impacts and incorporate recommendations made by the National Academies. As these values were not finalized at the time EPA conducted this analysis, EPA did not use them in the main analysis. However, EPA is presenting disbenefits estimated using these values in Appendix F.

[33] eGRID is a comprehensive source of data from EPA's Clean Air Markets Division on the environmental characteristics of almost all electric power generated in the United States. The data includes emissions, emission rates, generation, heat input, resource mix, and many other attributes.

and some other human health risks. EPA evaluated these effects qualitatively as discussed above in Sections 2.1 through 2.4.

Table 2-5: Estimated Welfare Effects of Changes in Pollutant Discharges from Meat and Poultry Product Facilities

Category	Effect of Regulatory Options	Benefits Analysis		
		Quantified	Monetized	Methods (Report Chapter where Analysis is Detailed)
Human Health Benefits from Surface Water Quality Improvements				
Reduced incidence of adverse human health effects (*e.g.,* cases of gastrointestinal illness) from exposure to MPP pollutants via recreational use	Reduced exposure to pathogens and HAB-related illnesses from primary contact recreation and recreationally caught and consumed fish and shellfish			Qualitative discussion (Chapter 2)
Reduced incidence of adverse human health effects (*e.g.,* developmental effects, gastrointestinal illness, cancer) from exposure to MPP pollutants via drinking water	Reduced exposure to high nitrate concentrations, *pathogens*, and DBPs (which may be generated indirectly due to nutrient enrichment and eutrophication) in drinking water			Qualitative discussion (Chapter 2)
Ecological Condition and Recreational Use Effects from Surface Water Quality Changes				
Aquatic and wildlife habitat[a]	Improved ambient water quality in receiving and downstream reaches	✓	✓	Benefit transfer (Chapter 4); Qualitative discussion (Chapter 2)
Water-based recreation[a]	Enhanced value of swimming, fishing, boating, and near-water activities from water quality changes			
Aesthetics[a]	Improved aesthetics from shifts in water clarity, color, odor, including nearby site amenities for residing, working, and traveling			
Nonuse values[a]	Improved existence, option, and bequest values from improved ecosystem health			
Protection of T&E species	Improved T&E species habitat and potential effects on T&E species populations	✓		Qualitative discussion (Chapter 2) Quantitative analysis (EnvA)
Market and Productivity Effects				
Drinking water treatment costs	Improved quality of source water used for drinking	✓		Qualitative discussion (Chapter 2) Quantitative analysis (EnvA)
Wastewater treatment costs	Reduced wastewater treatment costs at POTWs			Qualitative discussion (Chapter 2)

Table 2-5: Estimated Welfare Effects of Changes in Pollutant Discharges from Meat and Poultry Product Facilities

Category	Effect of Regulatory Options	Benefits Analysis		
		Quantified	**Monetized**	**Methods (Report Chapter where Analysis is Detailed)**
Agricultural water use	Improved quality of surface waters used for livestock watering			Qualitative discussion (Chapter 2)
Industrial water use	Reduced cost of industrial water treatment.			Qualitative discussion (Chapter 2)
Commercial fisheries	Improved fisheries yield and harvest quality due to improved aquatic habitat	✓		Qualitative discussion (Chapter 2)
Subsistence Harvesting	Improved fisheries yield and harvest quality due to improved aquatic habitat; Reduced risk of consuming contaminated fish and shellfish			Qualitative discussion (Chapter 2)
Tourism industries	Changes in participation in water-based recreation			Qualitative discussion (Chapter 2)
Property values	Improved property values from changes in water quality			Qualitative discussion (Chapter 2)
Capture of CH_4	Reduction in emissions of CH_4 associated with wastewater treatment			Qualitative discussion (Chapter 2)
Climate Change and Air Quality-Related Effects				
Air emissions of $PM_{2.5}$	Changes in mortality and morbidity from exposure to particulate matter ($PM_{2.5}$) emitted directly or linked to changes in NO_X and SO_2 emissions (precursors to $PM_{2.5}$ and ozone)	✓	✓	Qualitative discussion (Chapter 2); Health benefits (Chapter 5)
Air emissions of NO_X and SO_2	Changes in ecosystem effects; visibility impairment; and human health effects from direct exposure to NO_x, SO_2, and hazardous air pollutants.	✓	✓	Qualitative discussion (Chapter 2); Health benefits (Chapter 5)
Air emissions of greenhouse gases (CH_4 and CO_2)	Changes in climate change effects	✓	✓	Qualitative discussion (Chapter 2); Social cost of GHG (Chapter 5)

a. These values are implicit in the total WTP for water quality improvements.

Source: U.S. EPA Analysis, 2023

3 Water Quality Effects of Regulatory Options

To evaluate the water quality effects of the regulatory options, EPA estimated the pollutant loading reductions that would result from implementation of treatment under each regulatory option, accounting for any existing treatment in place. EPA conducted this analysis for two MPP waste streams: 1) combined MPP process wastewater and 2) high chlorides wastewater (as a segregated waste stream). This section summarizes the changes in pollutant loads (refer to the TDD for details) and outlines the approach EPA used to evaluate the effects of these changes on receiving and downstream waters, based on modeling results. The resulting water quality changes inform the analysis of nonmarket benefits in Chapter 4.

3.1 Changes in Pollutant Loadings

EPA estimated pollutant loads for the three regulatory options EPA analyzed for this proposal, based on four wastewater treatment technology systems for the combined MPP process waste stream (see Table 1-2). EPA estimated pollutant loads based on evaporation technology for both direct and indirect dischargers with a high chlorides waste stream. EPA estimated baseline pollutant loadings using the facility flows and the effluent pollutant concentrations associated with the treatment in place (TIP). Wastewater treatment installed across the industry varies and some facilities already operate treatment consistent with one of the technology systems included in the proposed rule regulatory options. Target effluent concentrations were calculated for the pollutants of interest for each technology system, as well as any treatment currently in place at a facility.

Table 3-1 summarizes the total, industry-level changes to annual pollutant loadings for the specific pollutants of interest covered by the proposed rule under each regulatory option, compared to the baseline. As shown, annual pollutant loading reductions increase from Option 1 to Option 3 for nutrients and conventional pollutants (TSS, BOD, and oil and grease).

Table 3-1: Summary of Changes to Annual Loadings of Selected Pollutants Compared to the Baseline

Option	Discharge Type	Changes in Annual Pollutant[a] Loadings (millions lbs/year)					
		TN	TP	TSS	BOD	Oil and Grease	Chlorides[b]
1	Direct	-8.87	-7.68	-42.62	-1.55	-14.84	-190.46
	Indirect	0	0	-11.78	-7.73	-1.59	-286.50
	Total	-8.87	-7.68	-54.39	-9.28	-16.44	-476.96
2	Direct	-8.87	-7.68	-42.62	-1.55	-14.84	-190.46
	Indirect	-35.95	-8.43	-39.19	-55.40	-13.88	-286.50
	Total	-44.82	-16.11	-81.81	-56.95	-28.72	-476.96
3	Direct	-8.99	-7.83	-44.45	-1.57	-16.02	-190.46
	Indirect	-67.18	-11.73	-48.86	-88.18	-27.36	-286.50
	Total	-76.18	-19.56	-93.31	-89.75	-43.38	-476.96

a. Technologies implemented under the options are also estimated to reduce loadings of other pollutants. See Table 3-2 for details.

b. Chlorides has the same removal under each option.

Source: U.S. EPA Analysis, 2023

Implementation of wastewater treatment technologies to meet effluent limits under the regulatory options are also estimated to reduce loadings of other pollutants, including halogens (*e.g.,* bromide, fluoride), total organic carbon, sulfate, total dissolved solids, metals (*e.g.,* aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, selenium, silver, sodium, thallium, tin, titanium, vanadium, and zinc), and microbiological contaminants (*e.g.*, *E. coli*, enterococcus, and fecal coliform). Table 3-2 summarizes total loading reductions across the broader set of pollutants.

Table 3-2: Summary of Changes to Annual Loadings of Pollutants Compared to the Baseline

Option	Discharge Type	Changes in Annual Pollutant Loadings by Pollutant Group			
		Classical/Biologicals[a] (millions lbs/year)	Metals[b] (millions lbs/year)	Nutrients[c] (millions lbs/year)	Microbiological[d] (MPN/year)
1	Direct	-932	-4.15	-16.5	0
	Indirect	-33	0.00	0.0	0
	Total	-965	-4.15	-16.5	0
2	Direct	-932	-4.15	-16.5	0
	Indirect	-1,310	-1.33	-44.4	0
	Total	-2,242	-5.48	-60.9	0
3	Direct	-946	-4.20	-16.8	0
	Indirect	-2,080	-3.27	-78.9	0
	Total	-3,026	-7.47	-95.7	0

a. Classicals/biologicals include BOD, bromide, COD, chloride, fluoride, oil and grease, total organic carbon (TOC), sulfate, total dissolved solids (TDS), and TSS.

b. Metals include aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, selenium, silver, sodium, thallium, tin, titanium, vanadium, and zinc.

c. Nutrients include TN and TP.

d. Microbiologicals include E. coli, enterococcus, and fecal coliform.

Source: U.S. EPA Analysis, 2023

3.2 Waters Affected by Meat and Poultry Facility Discharges

EPA estimates the regulatory options potentially affect 3,879 MPP facilities. Some MPP discharge locations could not be identified with available data sources (Detailed and Census Questionnaires, ECHO database, and HAWQS point source database), which resulted in a smaller universe in this document than what is represented elsewhere in associated rulemaking documents.[34] EPA used the United States Geological Survey (USGS) medium-resolution National Hydrography Dataset (NHD) (U.S. Geological Survey, 2018) to represent and identify waters affected by MPP facility discharges, and used additional attributes provided in version 2 of the NHDPlus dataset (U.S. EPA, 2019) to characterize these waters. In the aggregate, the 3,879 MPP facilities discharge to 2,736 waterbodies (as categorized in NHDPlus), including lakes, rivers, and estuaries. Receiving reaches that lack NHD classification for both waterbody area type and stream order generally correspond to reaches that do not have valid flow paths[35] for analysis of the fate and transport of MPP facility discharges (see Section 3.3). EPA did not assess pollutant

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[34] The Agency was unable to determine locational information for two direct discharge facilities (one percent of all direct discharge facilities) and 378 indirect discharge facilities (a little over 10 percent of indirect discharge facilities).

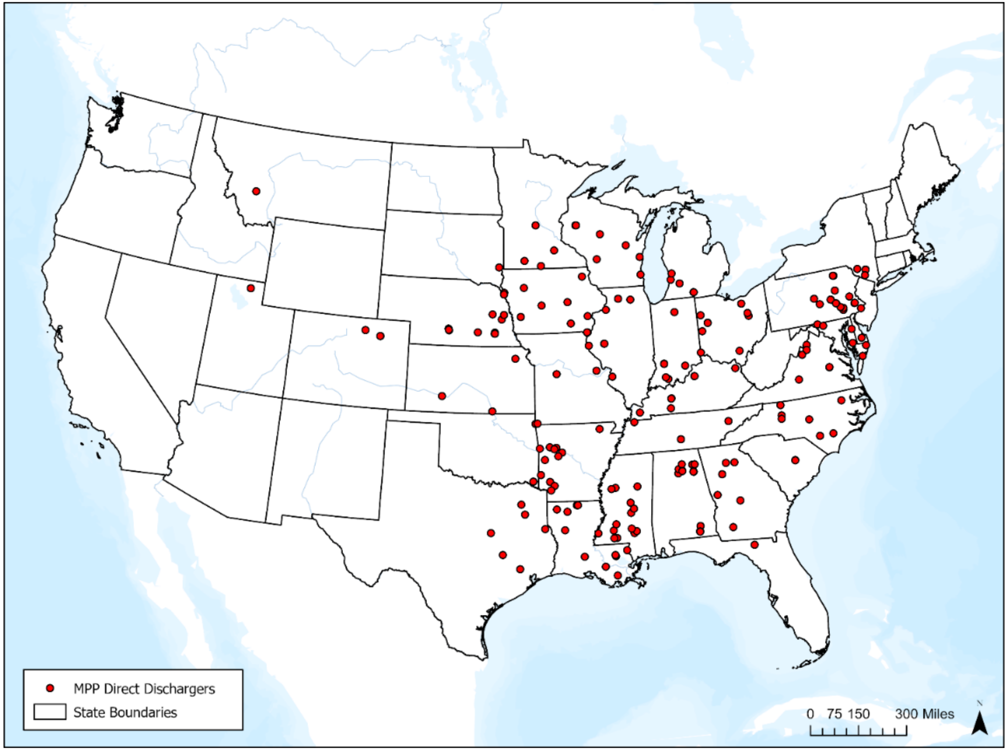
[35] In NHDPlus, the flow path represents the distance traveled as one moves downstream from the reach to the terminus of the stream network. An invalid flow path suggests that a reach is disconnected from the stream network.

loadings and water quality changes associated with these waterbodies because of the lack of a defined flow path in NHDPlus, the complexity of flow patterns, and the relatively small changes in concentrations expected. EPA did not quantify the water quality changes and resulting benefits to these systems.

3.2.1 Waters Affected by Direct Dischargers

EPA identified 169 unique MPP facilities affected by the regulatory options that discharge directly to a total of 188 unique waterbodies (as categorized in NHDPlus). EPA identified the discharge type of the direct dischargers based on the Detailed and Census Questionnaires. EPA determined the location of direct dischargers based on data from the Detailed and Census Questionnaires, available data on permitted point sources from the Hydrologic and Water Quality System (HAWQS), and EPA's Enforcement and Compliance History Online (ECHO) database. EPA was able to locate all MPP direct discharge locations with available data sources. The MPP direct discharge facilities are dispersed across the conterminous United States, with the vast majority of facilities located east of the Rocky Mountains. Figure 3-1 depicts the locations of the MPP direct discharge universe.

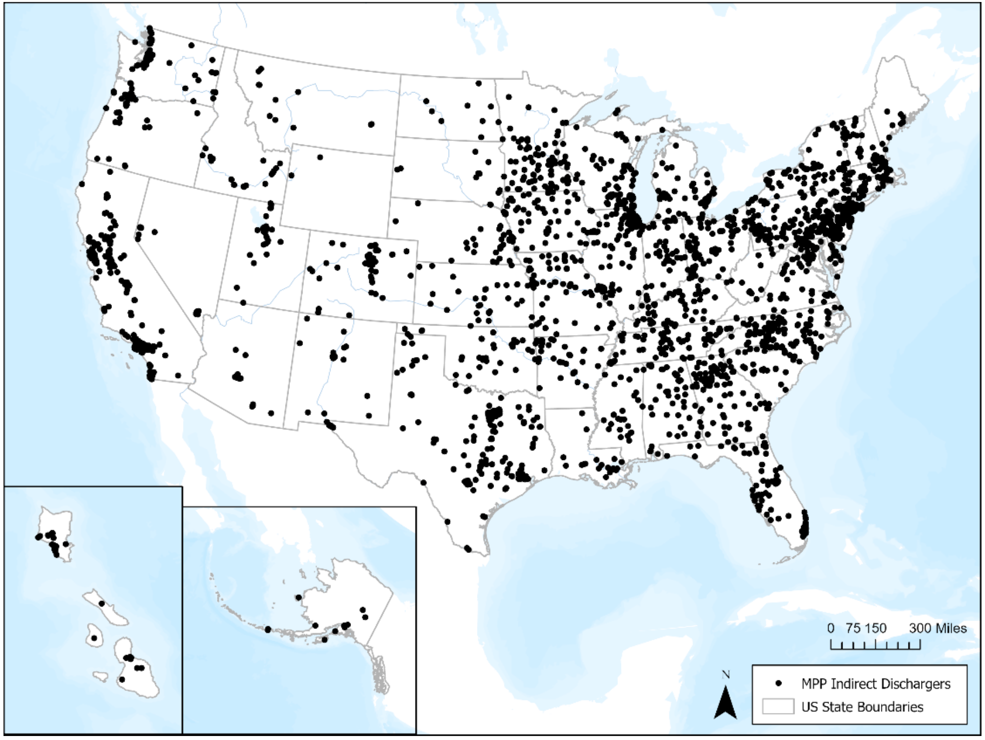
Figure 3-1: Map of the MPP direct discharge facility universe



3.2.2 Waters Affected by Indirect Dischargers

EPA identified 3,330 unique facilities discharging indirectly to a total of 2,554 unique waterbodies (as categorized in NHDPlus) via POTWs. EPA identified the discharge type of the indirect discharge facilities based on the Detailed and Census Questionnaires. EPA determined the location of indirect discharge facilities with data from the Detailed and Census Questionnaires, the HAWQS point source dataset, and the ECHO database. Of the 3,708 indirect discharge facilities identified in the Detailed and Census Questionnaires, 267 facilities did not have sufficient information in any dataset to determine a location. A further 111 facilities have location information but are located outside the boundaries of the conterminous United States. The final number of indirect discharge facilities included in the analyzed universe is 3,330. The MPP indirect discharge facilities are dispersed across the conterminous United States with higher concentrations of facilities along the west coast, Midwest, and the east coast.

Figure 3-2: Map of the MPP indirect discharge facility universe



3.3 Water Quality Changes Downstream from Meat and Poultry Facilities

To evaluate the potential water quality impacts of the proposed rule, EPA developed models for selected watersheds using HAWQS 2.0 and the Soil and Water Assessment Tool (SWAT; Neitsch *et al.*, 2011). The models delineate subbasins and reaches at the resolution of 12-digit Hydrologic Unit Codes (HUCs). The models predict changes in concentrations of TN, TP, TSS, BOD, and DO as a result of the regulatory options.[36] For analytic efficiency, EPA modeled a subset of level 2 Hydrologic Unit Code (HUC) water resource regions under selected regulatory scenarios to characterize the water quality changes due to the proposed ELG revisions. The results help inform understanding of the rule benefits on receiving and downstream waters.

EPA focused initial modeling efforts on five water resources regions and on the preferred regulatory option (Option 1) and the most stringent regulatory option (Option 3). The five modeled regions are Mid-Atlantic (region 02), South Atlantic-Gulf (03), Ohio (05), Upper Mississippi (07), and Lower Mississippi (08). These five regions account for varying shares of the total loading reductions estimated for the three regulatory options: approximately 51 percent of the total TN loading reductions, 44 to 47 percent of the total TP loading reductions, and 22 to 31 percent of the total TSS loading reductions. EPA aims to expand

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[36] EPA did not include MPP facilities located outside the conterminous United States due to a lack of available data for Alaska, Hawaii, and the U.S. Territories.

the scope of explicitly modeled regions to cover all affected regions and regulatory options for the final rule.[37] Appendix A provides details on model setup, including calibration results.

Following the approach EPA used in previous regulatory analyses (*e.g.*, see 2023 proposed Steam Electric ELG; U.S. EPA, 2023i), EPA used a water quality index (WQI) to translate water quality measurements for multiple parameters into a single numerical indicator (Corona *et al.*, 2020; Johnston, Besedin, & Holland, 2019; Walsh & Wheeler, 2013; Van Houtven *et al.*, 2014) and to quantify overall improvements under the regulatory options. Thus, the WQI link water quality changes from reduced nutrient, sediment, and biochemical oxygen demand discharges to effects on human uses and support for aquatic and terrestrial species habitat.

3.3.1 WQI Data Sources

The WQI includes six parameters: TN, TP, TSS, BOD, DO, and fecal coliform (FC). To calculate the WQI, EPA used modeled concentrations for TN, TP, TSS, BOD, and DO from the HAWQS/SWAT models. EPA obtained FC concentrations from the USGS National Water Information System (NWIS) for 2007-2022 and held these values constant between the baseline and regulatory options.[38] EPA averaged the FC data by adapting a common sequential averaging imputation technique which involves assigning the average of ambient FC concentrations within a smaller hydrologic unit to hydrologic units within the same larger hydrologic unit with missing data, and progressively expanding the geographical scope of the hydrologic unit (Hydrologic unit code (HUC10, HUC8, HUC6, HUC4, and HUC2) to fill in all missing data.[39] This approach is based on the assumption that reaches located in the same watershed generally share similar characteristics. This approach has not been peer reviewed, but it has been used by EPA for similar rules (U.S. EPA, 2023i) and subject to public review during the associated comment periods.

3.3.2 WQI Calculation

The WQI provides a link between specific pollutant levels, as reflected in individual index parameters (*e.g.,* dissolved oxygen), and the presence of aquatic species and suitability of the water for particular uses. The WQI used in this analysis uses the framework of the National Sanitation Foundation WQI (McClelland, 1974) and the Oregon WQI (Dunnette, 1979), with adjustments made by Cude (2001) to

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[37] There are 18 water resource regions in the conterminous United States. However, EPA estimates that nine of the regions would have small loading reductions (less than 2 percent) under the regulatory options because of the limited number of MPP dischargers and/or technology in place at the discharging facilities. Adding two more regions to the set of modeled regions (Missouri (10), and Arkansas-White-Red (11)) would increase the share of total loading reductions explicitly modeled to between 79 and 91 percent for TN, between 85 and 94 percent for TP, and between 86 and 90 percent for TSS, depending on the regulatory option.

[38] USGS's NWIS provides information on the occurrence, quantity, quality, distribution, and movement of surface and underground waters based on data collected at approximately 1.5 million sites in all 50 States, the District of Columbia, and U.S. territories. More information on NWIS can be found at http://waterdata.usgs.gov/nwis/.

[39] Hydrologic Unit Codes (HUCs) are cataloguing numbers that uniquely identify hydrologic features such as surface drainage basins. The HUCs consist of 8 to 14 digits, with each set of 2 digits giving more specific information about the hydrologic feature. The first pair of values designate the region (of which there are 22), the next pair the subregion (approximately 245), the third pair the basin or accounting unit (approximately 405), and the fourth pair the subbasin, or cataloguing unit (approximately 2,400) (U.S. Geological Survey, 2007, 2022). Digits after the first eight offer more detailed information at the watershed and subwatershed levels. In this discussion, a HUC level refers to a set of waters that have that number of HUC digits in common. For example, the HUC6 level includes all reaches for which the first six digits of their HUC are the same.

account for spatial and morphologic variability in the natural characteristics of streams. The WQI ranges from 10 to 100 with low values indicating poor quality and high values indicating good water quality.

Implementing the WQI methodology involves three key steps: (1) obtaining water quality levels for each of the six parameters included in the WQI – DO, TN, TP, BOD, FC, and TSS; (2) transforming parameter levels to subindex values expressed on a common scale; and (3) aggregating the individual parameter subindices to obtain an overall WQI value that reflects waterbody conditions across the six parameters.

These steps are used to calculate the WQI value for the baseline and for each analyzed regulatory option. The scope of the water quality modeling is the same as that for the analysis of nonmarket benefits of water quality improvements discussed in Chapter 40. See details of the calculations in Appendix B: WQI Calculation and Regional Subindices, including the subindex curves used to transform levels of individual parameters.

3.3.3 Baseline WQI

Based on the estimated WQI value under the baseline scenario (WQI-BL), EPA categorized each of the 3,036 HUC12 modeled reaches using five WQI ranges (WQI < 25, 25≤WQI<45, 45≤WQI<50, 50≤WQI<70, and 70≤WQI) (Table 3-3). WQI values of less than 25 indicate that water is not suitable for boating (the recreational use with the lowest associated WQI on the WQL), whereas WQI values greater than 70 indicate that waters are swimmable (the recreational use with the highest associated WQI on the WQL).

Table 3-3: Estimated Percentage of Potentially Affected Reaches in Modeled Watersheds by WQI Classification: Baseline Scenario

Water Quality Classification	Baseline WQ	Number of HUC12 Watersheds[a]	Percent of Affected HUC12 Watersheds[a]
Unusable	WQI<25	1,195	5.0%
Suitable for Boating	25≤WQI<45	18,789	79.0%
Suitable for Rough Fishing	45≤WQI<50	1,721	7.2%
Suitable for Game Fishing	50≤WQI<70	2,006	8.4%
Suitable for Swimming	70≤WQI	67	0.3%
Total		**23,778**	**100.0%**

a. SWAT estimates water quality in the main stream reach of each modeled HUC12 watersheds in water resources regions 02, 03, 05, 07, and 08.

Source: U.S. EPA Analysis, 2023

3.3.4 Estimated Changes in Water Quality from the Regulatory Options

To estimate the benefits of water quality improvements resulting from the regulatory options, EPA calculated the change in WQI for each analyzed regulatory option as compared to the baseline. This analysis was done for each 12-digit HUC watershed. EPA estimated changes in ambient concentrations of TN, TP, TSS, BOD, and DO using the HAWQS model. Although the regulatory options would also indirectly affect levels of other WQI parameters, such as bacteria, these other parameters were held constant in this analysis for all regulatory options, due to methodological and data limitations.

The difference in the WQI between baseline conditions and a given regulatory option (hereafter denoted as ΔWQI) is a measure of the change in water quality attributable to the regulatory option. Table 3-4 presents water quality change ranges for the analyzed regulatory options under each analysis period.

Table 3-4: Ranges of Estimated Water Quality Changes for Selected Water Resources Regions and Regulatory Options, Compared to Baseline

Region	Regulatory Option	25th Percentile[a] ΔWQI	Median[a] ΔWQI	75th Percentile[a] ΔWQI	ΔWQI Interquartile[a] Range	Maximum ΔWQI	Number of HUC12s with Non-Zero ΔWQI
02	Option 1	2.49E-05	7.89E-05	4.08E-04	3.83E-04	1.44E-01	44
	Option 3	2.43E-04	1.95E-03	1.41E-02	1.38E-02	9.83E+00	240
03	Option 1	3.91E-05	3.29E-04	3.58E-03	3.54E-03	2.67E+00	105
	Option 3	1.46E-04	1.93E-03	3.40E-02	3.39E-02	5.81E+00	542
05	Option 1	2.55E-05	2.17E-04	3.79E-03	3.77E-03	6.09E-01	66
	Option 3	4.83E-05	4.69E-04	7.81E-03	7.76E-03	1.58E+00	272
07	Option 1	1.01E-06	1.37E-04	2.42E-03	2.41E-03	1.38E+00	74
	Option 3	8.39E-05	1.73E-03	3.95E-02	3.94E-02	5.06E+00	387
08	Option 1	8.63E-06	5.11E-05	5.75E-03	5.74E-03	3.53E-01	30
	Option 3	1.74E-05	1.62E-04	1.87E-03	1.85E-03	4.22E-01	90

a. Quantiles are based on measurable changes in reaches downstream of MPP discharges.

Source: U.S. EPA Analysis, 2023

3.4 Limitations and Uncertainty

The methodologies and data used in the estimation of the water quality changes of the regulatory options involve limitations and uncertainties. Table 3-5 summarizes the associated limitations and uncertainties and indicates the direction of the potential bias. Regarding the uncertainties associated with estimated loads, see the TDD (U.S. EPA, 2023m).

Table 3-5: Limitations and Uncertainties in the Estimation of Water Quality Changes

Uncertainty/Limitation	Effect on Estimates	Notes
Limited data are available to validate water quality concentrations estimated by HAWQS/SWAT	Uncertain	While model estimates for flow have been calibrated against observed streamflow data, there was limited observed water quality data to calibrate model estimates for water quality.
Changes in WQI reflect only reductions in nutrient, suspended sediment, BOD, and DO concentrations	Underestimate	The estimated changes in WQI reflect only water quality changes resulting directly from reductions in nutrient, suspended sediment, BOD, and DO concentrations. They do not include changes in other water quality parameters (*e.g.*, fecal coliform) that are part of the WQI and for which EPA used constant values. Because the omitted water quality parameters are also likely to respond to changes in pollutant loads, the analysis underestimates the water quality changes.

Table 3-5: Limitations and Uncertainties in the Estimation of Water Quality Changes

Uncertainty/Limitation	Effect on Estimates	Notes
EPA used regional averages of monitoring data from 2007-2022 for fecal coliform, when location-specific data were not available	Uncertain	The monitoring values were averaged over progressively larger hydrologic units to fill in any missing data. As a result, WQI values may be limited in their temporal and spatial relevance. Note that the analysis keeps these parameters constant under both the baseline and regulatory options. Modeled changes due to the regulatory options are not affected by this uncertainty.
Use of nonlinear subindex curves	Uncertain	The methodology used to translate total suspended solids and nutrient concentrations into subindex scores (see Section 3.3.2 and Appendix B: WQI Calculation and Regional Subindices) employs nonlinear transformation curves. Water quality changes that fall outside of the sensitive part of the transformation curve (*i.e.,* above/below the upper/lower bounds, respectively) yield no change in the analysis and no benefits in the analysis described in Chapter 4.

4 Nonmarket Benefits from Water Quality Changes

As discussed in the EA, nutrients, bacteria and pathogens, conventional pollutants, and other pollutants discharged by MPP facilities can have a wide range of effects on water resources downstream from MPP facilities. These environmental changes affect environmental goods and services valued by humans, including recreation; commercial fishing; public and private property ownership; water supply and use; and existence services such as aquatic life, wildlife, and habitat designated uses. Some environmental goods and services (*e.g.*, commercially caught fish) are traded in markets, and thus their value can be directly observed. Other environmental goods and services (*e.g.*, recreation and support of aquatic life) cannot be bought or sold directly and thus do not have observable market values. This second type of environmental goods and services are classified as “nonmarket.” The estimated changes in the nonmarket values of the water resources affected by the regulatory options (hereafter nonmarket benefits) are additive to market values (*e.g.*, avoided costs of producing various market goods and services).

The analysis of the nonmarket value of water quality changes resulting from the regulatory options follows the same approach EPA used in the analysis of the Steam Electric ELGs (U.S. EPA, 2015a, 2020b; U.S. EPA, 2023a). As discussed in Section 3, initial water quality modeling is limited to five water resource regions (HUC 02, 03, 05, 07, and 08) and regulatory options 1 and 3.[40] Thus, the estimated benefits are for selected regions rather than national-level benefits. The analytical approach, which is briefly summarized below, involves:

- characterizing the change in water quality under the regulatory options relative to the baseline using a WQI and linking these changes to ecosystem services or potential uses that are valued by society (see Section 3.3.4), and
- monetizing changes in the nonmarket value of affected water resources under the regulatory options using a meta-analysis of surface water valuation studies that provide data on the public’s WTP for water quality changes (see Section 4.1).

The analysis accounts for improvements in water quality resulting from concentration changes in nutrients, bacteria and pathogens, conventional pollutants, and other pollutants in HUC12s potentially affected by MPP facility discharges. The assessment uses the U.S. Census Bureau’s Census Block Group[41] (CBG) as the geographic unit of analysis, assigning a radial distance of 100 miles from the CBG centroid. The choice of 100 miles is based on typical driving distance to recreational sites (*i.e.*, 2 hours or 100 miles; Viscusi, Huber, & Bell, 2008). EPA estimates that households residing in a given CBG value water quality changes in all modeled HUC12s within this range, with all unaffected HUC12s being viable substitutes for affected HUC12s within the 100-mile buffer around the CBG. In this analysis, affected HUC12s are restricted to (1) selected water resource regions for which water quality modeling was

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[40] EPA is continuing to model additional regions to inform understanding of benefits across the United States.

[41] CBGs “are statistical divisions of census tracts, are generally defined to contain between 600 and 3,000 people, and are used to present data and control block numbering.” (U.S. Census Bureau, 2022).

completed *and* (2) HUC12s that showed non-zero WQI changes under each option (see Section 3 for more details).[42]

4.1 Methods

EPA estimated economic values of water quality changes at the CBG level using results of a meta-analysis of 189 estimates of total WTP (including both use and nonuse values) for water quality improvements, provided by 59 original studies conducted between 1981 and 2017.[43] The estimated econometric model allows calculation of total WTP for changes in a variety of environmental services affected by water quality and valued by humans, including changes in recreational fishing opportunities, other water-based recreation, and existence services such as aquatic life, wildlife, and habitat designated uses. The model also allows EPA to adjust WTP values based on the core geospatial factors predicted by theory to influence WTP, including: scale (the size of affected resources or areas), market extent (the size of the market area over which WTP is estimated), and the availability of substitutes.

The meta-analysis regression is based on two models:

- **Model 1** provides EPA's main estimate of non-market benefits (Section 4.2) and assumes that households' WTP for a one-point improvement on the WQI (hereafter, one-point WTP) depends on the average level of water quality between the baseline and the policy scenario.[44] It does not depend on the magnitude of the water quality change specified in the surveys of studies included in the underlying meta-data. This restriction means that the meta-model satisfies the adding-up condition with respect to the scale of the water quality change, a theoretically desirable property.[45]
- **Model 2** includes an additional variable (*lnquality_ch*) and allows one-point WTP to depend not only on the average level of water quality but also on the magnitude of the water quality change specified in the surveys of studies included in the underlying meta-data. The model allows for the possibility that the WTP for a one-point improvement on the WQI depends on both the average level of water quality between the baseline and the policy scenario and the total water quality change that

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[42] When calculating geospatial variables included in the meta-regression model (*ln_ar_agr*, *ln_ar_ratio*, and *sub_proportion*; see Appendix D for details), EPA treated all HUC12s downstream from any MPP discharger as "affected HUC12s." This universe of HUC12s captures all HUC12s that could experience water quality changes under various technology control/regulatory options.

[43] Although the potential limitations and challenges of benefit transfer are well established (Desvousges, Smith, & Fisher, 1987), benefit transfers are a nearly universal component of benefit cost analyses conducted by and for government agencies. As noted by V. Kerry Smith, George Van Houtven, and Subhrendu K. Pattanayak (2002, p. 134) , "nearly all benefit cost analyses rely on benefit transfers, whether they acknowledge it or not."

[44] In this model, the average WTP per unit of water quality approximates marginal WTP per an additional one point improvement. This approximation is assumed to be valid at some point between WQI (baseline) and WQI (policy). Therefore, WTP per unit of WQI changes is approximated at the midpoint of the water quality change valued for that meta-data observation.

[45] The adding-up condition ensures that if the model were used to estimate WTP for the cumulative water quality change resulting from several CWA regulations, the benefits estimates would be equal to the sum of benefits from using the model to estimate WTP for water quality changes separately for each rule (Moeltner, 2019; Newbold *et al.*, 2018). However, with the decision to limit "affected HUC12s" to HUC12s with non-zero changes under *each* regulatory option, rather than a consistent set of waters across regulatory options, the adding-up condition does not hold across options. EPA use different set of "affected HUC12s" across regulatory options to avoid including waterbodies affected only by under Option 3 in the estimated average WQI change under Option 1and thus underestimating benefits for Option 1.

respondents were asked to value[46]. Since environmental quality is considered by economists to be a normal good,[47] one-point WTP is expected to decrease when the total WQI change increases according to the law of diminishing marginal utility. As indicated by a negative sign on the *lnquality_ch* coefficient, the estimated WTP for a one-point improvement on the WQI scale is larger when respondents were asked to value a 10-point improvement compared to a 20-point improvement. EPA used Model 2 to generate alternative estimates of non-market benefits. To satisfy the adding-up condition using this model, EPA treats the water quality change variable as a methodological variable, using WQI change (ΔWQI) values of 20 and 7 to develop low and high estimates, respectively. These values were based on the 75th and 25th percentile of water quality changes included in the meta-data (see Section 4.3 for Model 2 results).

Appendix C provides more details about the differences between Models 1 and 2, details on how EPA used the meta-analysis to predict household WTP for each CBG and year, and the estimated regression equation, intercept, and variable coefficients for the two models. The appendix also provides names and definitions of the independent variable and assigned values.

Based on the meta-analysis results, EPA multiplied the coefficient estimates for each variable (see Model 1 and Model 2 in Table C-3) by the variable levels calculated for each CBG or fixed at the levels indicated in the “Assigned Value” column in Table C-3. The sum of these products represents the predicted natural log of the one-point WTP (*ln_OWTP*) for a representative household in each CBG; taking the exponential results in the estimate of *OWTP*. Equation 4-1 provides the equation used to calculate household benefits for each CBG.

Equation 4-1.

$$HWTP_{Y,B} = OWTP_{Y,B} \times \Delta WQI_B$$

where:

$HWTP_{Y,B}$ = Average annual household WTP in 2022$ in year *Y* for households located in the CBG (*B*),

$OWTP_{Y,B}$ = WTP for a one-point improvement on the WQI (*i.e.*, one-point WTP) for a given year (*Y*) and the CBG (*B*), estimated by the meta-analysis function and evaluated at the midpoint of the range over which water quality is changed, and

ΔWQI_B = Estimated annual average water quality change for the CBG (*B*).

To estimate WTP for water quality improvements under the regulatory options, EPA first estimated annual average water quality improvements under the proposed rule and then applied the meta-regression model (MRM) to estimate per household WTP for water quality improvements in a given CBG and year. Monetary values of water quality improvements are estimated for all years from 2026 through 2065.

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[46] If the estimated WQI change is assigned to the *lnquality_ch* variable, Model 2 would not satisfy adding up conditions because WTP per one point improvement would be different for a one-step improvement (e.g., ΔWQI=10) versus a two-step improvement (i.e., the sum of WTP = *f* (ΔWQI=5) and WTP = *f* (ΔWQI=5) does not equal WTP= *f* (ΔWQI=10)).

[47] Environmental quality, including water quality, is a "normal" good because people want more of it as their real incomes increase.

Implementation of technology required to meet rule requirements will be based on a phased approach during the first five years of the analysis period (2026-2030). To account for phased technology implementation in the benefits analysis, EPA assumed that full benefits start in Year 3 of the analysis period, or 2028. This assumption underestimates benefits in 2026 and 2027 but overestimates benefits in 2028 and 2029 when technology upgrades are still ongoing. As summarized in Table 4-1, the estimated average annual household WTP, based on Model 1, is \$0.67 for Option 1 and \$1.27 for Option 3.

To estimate total WTP (TWTP) for water quality changes for each CBG, EPA multiplied the per-household average annual WTP values for the estimated annual average water quality change by the number of households within each CBG in a given year and calculated the present value (PV) of the stream of WTP over the 40 years in EPA's period of analysis. EPA then calculated annualized total WTP values for each CBG using 3 percent and 7 percent discount rates as shown in Equation 4-2.

Equation 4-2.

$$TWTP_B = \left(\sum_{T=2026}^{2065} \frac{HWTP_{Y,B} \times HH_{Y,B}}{(1+i)^{Y-2025}} \right) \times \left(\frac{i \times (1+i)^n}{(1+i)^{n+1} - 1} \right)$$

where:

$TWTP_B$ = Annualized total household WTP in 2022\$ for households located in the CBG (*B*),

$HWTP_{Y,B}$ = Average annual household WTP in 2022\$ for households located in the CBG (*B*) in year (*Y*),

$HH_{Y,B}$ = the number of households residing in the CBG (*B*) in year (*Y*),

T = Year when benefits are realized

i = Discount rate (3 or 7 percent)

n = Duration of the analysis (40 years)[48]

EPA generated annual household counts for each CBG through the period of analysis based on projected population growth following the method described in Section 1.3.6.

4.2 Main Results

Table 4-1 presents the main analysis results, based on Model 1, and water quality modeling results for five water resource regions (02, 03, 05, 07, and 08), and a 3 percent discount rate; results based on a 7 percent discount rate are presented in Appendix D. The total annualized value of water quality improvements from reducing nutrients, bacteria and pathogens, conventional pollutants, and other pollutants discharges from MPP facilities to affected HUC12s, for the preferred option (Option 1), is \$42.3 million.

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[48] See Section 1.3.3 for details on the period of analysis.

Table 4-1: Estimated Household and Total Annualized Willingness-to-Pay for Water Quality Improvements in Selected Regions under Regulatory Options 1 and 3, using Model 1 and a 3 Percent Discount Rate (Main Estimates)

Regulatory Option	Number of Affected Households (Millions)[a]	Average Annual WTP Per Household (2022$)[b]	Total Annualized WTP (Millions 2022$)[b,c]
Option 1	67.2	$0.67	$42.3
Option 3	85.5	$1.27	$101.9

a. The number of affected households varies across options because of differences in the number of HUC12s that have non-zero changes in water quality.

b. Estimates based on Model 1, which provides EPA's main estimate of non-market benefits.

c. Estimated benefits are regional-level rather than national-level since water quality modeling was limited to selected level 2 HUC water resource regions (see Section 3 for details).

Source: U.S. EPA Analysis, 2023

4.3 Alternative Model Results

Table 4-2 presents alternative benefit estimates based on Model 2 using a 3 percent discount rate and water quality modeling results for five water resource regions (02, 03, 05, 07, and 08). EPA used two settings of the ΔWQI variable (*lnquality_ch*) to generate low and high estimates using Model 2. As discussed in Section 4.1, one-point WTP is expected to decrease when the total WQI change increases. Thus, EPA used values of 20 units to develop low estimates and 7 units to develop high estimates. Average annual household WTP estimates for the preferred option (Option 1) range from $0.24 (low estimate) to $0.50 (high estimate). Total annualized values range from $16.1 million (low estimate) to $33.0 million (high estimate).

Table 4-2: Estimated Household and Total Annualized Willingness-to-Pay for Water Quality Improvements in Selected Regions under Regulatory Options 1 and 3, using Model 2 and a 3 Percent Discount Rate (Alternative Model Analysis)

Regulatory Option	Number of Affected Households (Millions)[a]	Average Annual WTP Per Household (2022$)[b]		Total Annualized WTP (Millions 2022$)[b,c]	
		Low	High	Low	High
Option 1	67.2	$0.24	$0.50	$16.1	$33.0
Option 3	85.5	$0.46	$0.94	$38.1	$78.0

a. The number of affected households varies across options because of differences in the number of HUC12s that have non-zero changes in water quality.

b. Estimates based on Model 2, an alternative model that includes the ΔWQI variable (*lnquality_ch*). For the ΔWQI variable setting in the Model 2-based analysis, EPA used values of 20 units to develop low estimates and 7 units to develop high estimates (see Appendix C for details).

c. Estimated benefits are regional-level rather than national-level since water quality modeling was limited to selected level 2 HUC resource regions (see Section 3 for details).

Source: U.S. EPA Analysis, 2023

4.4 Benefit Extrapolation

As described in Section 3.3 and above, for analytic efficiency, EPA modeled a subset of five water resource regions under selected regulatory scenarios to characterize the water quality changes due to the proposed ELG revisions. EPA focused initial modeling efforts on Mid-Atlantic (region 02), South Atlantic-Gulf (03), Ohio (05), Upper Mississippi (07), and Lower Mississippi (08) and on Option 1 and

Option 3. This section describes extrapolation of these results to Option 2 and to other water resources regions to provide insight into the potential magnitude of national benefits of the proposed rule. Appendix E provides additional details on the approach.

4.4.1 Benefits of Regulatory Option 2

Option 2 falls between regulatory Option 1 and Option 3 in terms of the stringency of the limits and the resulting loading reductions. Accordingly, EPA interpolated between the benefits obtained for the two options modeled explicitly to approximate probable benefits of Option 2. The interpolation accounts for the estimated reductions in TN, TP, and TSS loadings achieved under the three options, adjusted to account for the relative scale of the three parameters[49] and their relative influence on the overall WQI score. Appendix E provides additional details on the approach.

Specifically, EPA first calculated an aggregate loading reduction measure for each option as the weighted sum of TN, TP, and TSS loading reductions. EPA then interpolated the total WTP linearly between Options 1 and 3 using these aggregate loading reduction measures. Table 4-3 and Table 4-4 present the estimated total WTP for Option 2 based on Model 1 (main results) and Model 2 (alternative model results).

Table 4-3: Estimated Total Annualized Willingness-to-Pay for Water Quality Improvements in Selected Regions under Regulatory Options, using Model 1 and a 3 Percent Discount Rate (Main Estimates)

Regulatory Option	Total Annualized WTP (Millions 2022$)[a,b]
Option 1	$42.3
Option 2	$78.6
Option 3	$101.9

a. Estimates based on Model 1, which provides EPA's main estimate of non-market benefits.

b. Estimated benefits are regional-level rather than national-level since water quality modeling was limited to selected water resource regions (see Section 3 for details).

Source: U.S. EPA Analysis, 2023

Table 4-4: Estimated Total Annualized Willingness-to-Pay for Water Quality Improvements in Selected Regions under Regulatory Options, using Model 2 and a 3 Percent Discount Rate (Alternative Estimates)

Regulatory Option	Total Annualized WTP (Millions 2022$)[a,b]	
	Low	High
Option 1	$16.1	$33.0
Option 2	$29.5	$60.4
Option 3	$38.1	$78.0

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[49] Expressed in mg/L, concentrations of TSS tend to be approximately one order of magnitude (10 times) larger than TN concentrations (*e.g.*, 40 mg/L vs. 4 mg/L). TN concentrations in turn tend to be approximately one order of magnitude (10 times) larger than TP (*e.g.*, 4 mg/L vs. 0.4 mg/L).

Table 4-4: Estimated Total Annualized Willingness-to-Pay for Water Quality Improvements in Selected Regions under Regulatory Options, using Model 2 and a 3 Percent Discount Rate (Alternative Estimates)

Regulatory Option	Total Annualized WTP (Millions 2022$)[a,b]	
	Low	High

a. Estimates based on Model 2, an alternative model that includes the ΔWQI variable (*lnquality_ch*). For the ΔWQI variable setting in the Model 2-based analysis, EPA used values of 20 units to develop low estimates and 7 units to develop high estimates (see Appendix C for details).

b. Estimated benefits are regional-level rather than national-level since water quality modeling was limited to selected water resource regions (see Section 3 for details).

Source: U.S. EPA Analysis, 2023

4.4.2 Benefits Across Water Resources Regions

Loading reductions achieved under the regulatory options vary across regions based on the number and characteristics of the MPP facilities. Building on the approach described above to interpolate between Option 1 and Option 3, EPA extrapolated the results obtained for explicitly modeled regions to the other water resources regions based on the respective aggregate loading reductions for the two sets of regions and relative shares of the total population. Appendix E provides additional details on the approach.

EPA notes that this approach provides an approximate estimate of the potential national benefits of the proposed rule. This estimate is subject to uncertainty given the assumptions implicit in the extrapolation method, including assumptions regarding the characteristics of receiving waters in the different regions (*e.g.*, stream order, flow, baseline water quality) and populations (*e.g.*, income) among other factors. EPA expects the five explicitly modeled regions to capture a significant share of the total benefits of the proposed rule. Thus, the five explicitly modeled regions together account for 45 percent to 49 percent of the aggregate loading reductions across the conterminous United States, with the shares varying across regulatory options and parameters. For example, under Option 1 the five explicitly modeled regions account for 51 percent of total TN reductions, 44 percent of total TP reductions, and 22 percent of total TSS reductions. Additionally, approximately half of the total population of the conterminous United States in 2010 lived in the five explicitly modeled regions (U.S. EPA, 2017a).

Table 4-5: Estimated Total Annualized Willingness-to-Pay for Water Quality Improvements under Regulatory Options, using Model 1 and a 3 Percent Discount Rate (Main Estimates)

Basis of Estimate	Total Annualized WTP (Millions 2022$)[a,b]		
	Option 1	Option 2	Option 3
Regions explicitly modeled[c]	$42.3	$78.6	$101.9
Extrapolated regions	$53.3	$87.5	$106.5
U.S. total[d]	**$95.6**	**$166.1**	**$208.4**

a. Estimates based on Model 1, which provides EPA's main estimate of non-market benefits.

b. Estimated benefits are regional-level rather than national-level since water quality modeling was limited to selected water resource regions (see Section 3 for details).

c. Sum of benefits estimated for explicitly modeled water resources regions (*i.e.,* regions 02, 03, 05, 07, and 08) and used to extrapolate to other regions.

d. Based on MPP facilities discharging (directly or indirectly) to waters within the conterminous United States.

Source: U.S. EPA Analysis, 2023

Table 4-6: Estimated Total Annualized Willingness-to-Pay for Water Quality Improvements under Regulatory Options, using Model 2 and a 3 Percent Discount Rate (Main Estimates)

Basis of Estimate	Total Annualized WTP (Millions 2022$)[a,b]					
	Option 1		Option 2		Option 3	
	Low	High	Low	High	Low	High
Regions explicitly modeled[c]	$16.1	$33.0	$29.5	$60.4	$38.1	$78.0
Extrapolated regions	$20.3	$41.6	$32.9	$67.3	$39.8	$81.5
U.S. total[d]	**$36.4**	**$74.6**	**$62.3**	**$127.7**	**$77.9**	**$159.5**

a. Estimates based on Model 2, an alternative model that includes the ΔWQI variable (*lnquality_ch*). For the ΔWQI variable setting in the Model 2-based analysis, EPA used values of 20 units to develop low estimates and 7 units to develop high estimates (see Appendix C for details).

b. Estimated benefits are regional-level rather than national-level since water quality modeling was limited to selected water resource regions (see Section 3 for details).

c. Sum of benefits estimated for explicitly modeled water resources regions (*i.e.,* regions 02, 03, 05, 07, and 08) and used to extrapolate to other regions.

d. Based on MPP facilities discharging (directly or indirectly) to waters within the conterminous United States.

Source: U.S. EPA Analysis, 2023

4.5 Limitations and Uncertainty

Table 4-7 summarizes the limitations and uncertainties in the analysis of benefits associated with changes in surface water quality and indicates the direction of any potential bias.

Table 4-7: Limitations and Uncertainties in the Analysis of Nonmarket Water Quality Benefits

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
Water quality modeling limited to selected watersheds	Underestimate	EPA assessed water quality improvements resulting from the proposed rule in selected water resource regions for analytic efficiency (see Section 3 for details). Thus, the modeled nonmarket benefits from water quality changes are regional-level rather than national-level and are, thus, underestimated.
Interpolated Option 2 benefits	Uncertain	EPA interpolated benefits for Option 2 from the model results for Options 1 and 3, based on the aggregate load reductions. The interpolation assumes a linear relationship between loading reductions and total WTP. While the interpolation is applied to results for the same water resource region (*i.e.,* same affected waters and population), there is still uncertainty in the assumed relationship between loading reductions and total WTP owing to variations across the three options in the distribution of loading reductions spatially and across pollutants.

Table 4-7: Limitations and Uncertainties in the Analysis of Nonmarket Water Quality Benefits

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
Extrapolated national benefits	Uncertain	EPA extrapolated water quality improvement benefits modeled for selected water resources regions to other regions based on the estimated loading reductions and population. The approach assumes regions are similar in terms of the characteristics of affected waters (*e.g.,* flow, stream order, pollutant source contributions), populations (*e.g.,* income), and other factors. Additionally, the extrapolation is based on results representing a relatively small share of the overall loading reductions estimated nationwide. EPA plans to model additional water resources regions to increase the share of explicitly modeled versus extrapolated estimates to reduce the uncertainty.
Use of 100-mile buffer for calculating water quality benefits for each CBG	Underestimate	The distance between the surveyed households and the affected waterbodies is not well measured by any of the explanatory variables in the MRM. EPA would expect values for water quality changes to diminish with distance (all else equal) between the home and affected waterbody. The choice of 100 miles is based on typical driving distance to recreational sites (*i.e.*, 2 hours or 100 miles; Viscusi, Huber, & Bell, 2008). Therefore, EPA used 100 miles to approximate the distance decay effect on WTP values. However, there are limitations associated with the 100-mile assumption since 1) approximately 80 percent of day trips occur within this distance (*i.e.*, not 100 percent), 2) multi-day trips tend to involve greater distances than 100 miles, and 3) nonuse values likely extend beyond 100 miles, particularly for well-known waterbodies with which many U.S. households are familiar. The analysis underestimates WTP to the degree that people living farther than 100 miles place value on water quality improvements for these waterbodies. The literature shows that while WTP tends to decline with distance from the waterbody, people place value on the quality of waters outside their region.
Selection of the *lnquality_ch* variable value in Model 2 for estimating a range of WTP values (alternative model analysis)	Uncertain	One-point WTP is expected to decline as the magnitude of the water quality change increases. To account for variability in WTP due to the magnitude of the valued water quality changes, EPA estimated a range of values for one-point WTP using alternative settings for *lnquality_ch* (ΔWQI = 20 and 7 units, respectively). These values were based on the 25th and 75th percentile of water quality changes included in the meta-data. To ensure that the benefit transfer function satisfies the adding-up condition, this variable is treated as a methodological (fixed) variable. The negative coefficient for *lnquality_ch* implies that larger value settings produce smaller WTP estimates for a one-point WQI improvement, which is consistent with economic theory; smaller value settings produce larger WTP estimates for a one-point improvement. The selected values may bias the estimated WTP values either upward or downward (*i.e.*, higher values would result in lower one-point WTP estimates, lower values would result in higher one-point WTP estimates).

Table 4-7: Limitations and Uncertainties in the Analysis of Nonmarket Water Quality Benefits

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
Potential hypothetical bias in underlying stated preference results	Uncertain	Following standard benefit transfer approaches, this analysis proceeds under the assumption that each source study provides a valid, unbiased estimate of the welfare measure under consideration (cf. Moeltner, Boyle, & Paterson, 2007; Rosenberger and Phipps, 2007). To minimize potential hypothetical bias underlying stated preference studies included in meta-data, EPA set independent variable values to reflect best benefit transfer practices.
Use of different water quality measures in the underlying meta-data	Uncertain	The estimation of WTP may be sensitive to differences in the presentation of water quality changes across studies in the meta-data. Studies that did not use the WQI were mapped to the WQI, so a comparison could be made across studies. To account for potential effects of the use of a different water quality metric (*i.e.*, index of biotic integrity (IBI)) on WTP values for a one-point improvement on the WQI, EPA used a dummy variable in the MRM (see Appendix C for details). In benefit transfer applications, the IBI variable is set to zero, which is consistent with using the WQI.
Transfer error	Uncertain	Transfer error may occur when benefit estimates from a study site are adopted to forecast the benefits of a policy site. R.S. Rosenberger and Stanley (2006) define transfer error as the difference between the transferred and actual, generally unknown, value. Although meta-analyses are often more accurate compared to other types of transfer approaches due to the data synthesis from multiple source studies (Rosenberger and Phipps, 2007; Johnston *et al.*, 2021), there is still a potential for transfer errors (Shrestha, Rosenberger, & Loomis, 2007) and no transfer method is always superior (Johnston *et al.*, 2021).

5 Climate Change and Air Quality-Related Disbenefits

The regulatory options evaluated may affect air quality through three main mechanisms: (1) CH_4, CO_2, NO_x, and SO_2 emissions from changes in electricity consumption at MPP facilities and POTWs given changes in treatment processes; and (2) transportation-related CH_4, CO_2, NO_x, and SO_2 emissions due to changes in trucking of wastes from MPP facilities to landfills.

Because the changes in pollutant emissions are net increases, the effects on society are negative, *i.e.,* disbenefits. EPA thus estimated the climate-related disbenefits of changes in CO_2 and CH_4 emissions, as well as the human health disbenefits resulting from changes in fine particulate matter ($PM_{2.5}$) and ozone ambient exposure due to net changes in emissions of NO_x and SO_2.[50] $PM_{2.5}$ is a criteria air pollutant that has been associated with a variety of adverse health effects, including premature mortality and hospitalization for cardiovascular and respiratory diseases (*e.g.*, asthma, chronic obstructive pulmonary disease [COPD], and shortness of breath).

5.1 Changes in Air Emissions

EPA estimated changes in energy use, most notably electricity consumption (MWh), at MPP facilities and POTWs associated with changes in treatment processes. The approach is detailed in the TDD (U.S. EPA, 2023m) and briefly summarized below.

EPA used emission rates from its 2021 Emissions and Generation Resource Integrated Database (eGRID) to estimate emissions of CH_4, CO_2, NO_x, and SO_2. Table 5-1 presents pollutant emission rates from eGRID.

Table 5-1: Electricity eGRID U.S. Total Output Emission Rates

Pollutant	Emission Rate (lb/MWh)
CH_4	0.071
CO_2	852
NO_x	0.5
SO_2	0.5

Source: U.S. EPA, 2023c

EPA also estimated air emissions associated with the operation of transportation vehicles by multiplying the estimated distance traveled between MPP facilities and the off-site location for disposal of solid waste by pollutant-specific emission factors obtained from EPA's Motor Vehicle Emission Simulator (MOVES3; see Table 5-2).

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[50] Emissions of nitrogen oxides (NOx) lead to formation of both ozone and $PM_{2.5}$ while SO_2 emissions lead to formation of $PM_{2.5}$ only.

Table 5-2: Transportation Pollutant-Specific Emission Factors

Pollutant	Emission Factor (ton/mile)
CH_4	6.18×10^{-8}
CO_2	0.0020
NO_x	4.47×10^{-6}
SO_2	6.84×10^{-9}

Source: U.S. EPA, 2021, 2023g

Table 5-3 presents the estimated changes in air pollutant emissions for each regulatory option by category. The TDD details the methodology.

Table 5-3: Estimated Incremental Changes in Air Pollutant Emissions (Tons/Year)

Category	CH_4	CO_2	NO_x	SO_2
Option 1				
Energy use	2.2	26,600	15.7	16.6
Transportation	0.03	960	2.2	0.003
Option 2				
Energy use	8.2	98,400	57.7	61.2
Transportation	0.1	2,490	5.6	0.01
Option 3				
Energy use	11.8	142,000	83.4	88.2
Transportation	0.1	3,030	6.8	0.01

a. Positive values indicate a net increase in emissions.

Source: EPA Analysis, 2023

5.2 Climate Change Disbenefits

5.2.1 Data and Methodology

EPA estimated the climate disbenefits of the net CH_4 and CO_2 emission changes expected from the regulatory options using the estimates of the social cost of greenhouse gases (SC-GHG)[51], specifically using the social cost of methane (SC-CH_4) and social cost of carbon (SC-CO_2). SC-GHG estimates represent the monetary value of the net harm to society associated with a marginal increase in GHG emissions in a given year. SC-GHG estimates include the value of all climate change impacts (both negative and positive), including (but not limited to) changes in net agricultural productivity, human health effects, property damage from increased flood risk and natural disasters, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. The SC-GHGs therefore reflect the societal value of reducing emissions of the gas in question by one metric ton and is the theoretically appropriate value to use in conducting benefit-cost analyses of policies that affect CH_4 and CO_2 emissions. In practice, data and modeling limitations naturally restrain the ability of SC-GHG estimates to include all the important physical, ecological, and economic impacts of climate change, such that the estimates are a partial accounting of climate change impacts and will, therefore, tend to be

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[51] Estimates of the social cost of greenhouse gases are gas specific (*e.g.*, social cost of carbon (SC-CO_2), social cost of methane (SC-CH_4), social cost of nitrous oxide (SC-N_2O)), but collectively they are referred to as the social cost of greenhouse gases (SC-GHG).

underestimates of the marginal benefits of abatement. EPA and other Federal agencies began regularly incorporating SC-GHG estimates in their benefit-cost analyses conducted under EO 12866[52] since 2008, following a Ninth Circuit Court of Appeals remand of a rule for failing to monetize the benefits of reducing CO_2 emissions in that rulemaking process.

In 2017, the National Academies of Sciences, Engineering, and Medicine published a report that provides a roadmap for how to update SC-GHG estimates used in Federal analyses going forward to ensure that they reflect advances in the scientific literature (National Academies of Sciences, 2017b). The National Academies' report recommended specific criteria for future SC-GHG updates, a modeling framework to satisfy the specified criteria, and both near-term updates and longer-term research needs pertaining to various components of the estimation process. The research community has made considerable progress in developing new data and methods that help to advance various components of the SC-GHG estimation process in response to the National Academies' recommendations.

In a first-day executive order (EO 13990), Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis, President Biden called for a renewed focus on updating the SC-GHG estimates to reflect the latest science, noting that "it is essential that agencies capture the full benefits of reducing greenhouse gas emissions as accurately as possible." Important steps have been taken to begin to fulfill this directive of EO 13990. In February 2021, the IWG released a technical support document (hereinafter the "February 2021 TSD") that provided a set of IWG recommended SC-GHG estimates while work on a more comprehensive update is underway to reflect recent scientific advances relevant to SC-GHG estimation (IWG, 2021). In addition, as discussed further below, EPA has developed an updated SC-GHG methodology in the regulatory impact analysis of EPA's December 2023 final oil and gas standards, following an external peer review and a public comment process.[53] As these values were not finalized at the time EPA conducted this analysis, EPA did not use them in the main analysis to monetize the estimated climate disbenefits of this proposed rule. However, EPA is presenting disbenefits estimated using these values in Appendix F and requests comments on whether the Agency should proceed with using these values in the main analysis.

EPA has applied the IWG's recommended interim SC-GHG estimates in the Agency's regulatory benefit-cost analyses published since the release of the February 2021 TSD and is likewise using them in this BCA. EPA evaluated the SC-GHG estimates in the February 2021 TSD and determined that these estimates are appropriate for use in estimating the social disbenefits of GHG emissions expected to occur as a result of the proposed rule.

The SC-GHG estimates presented in the February 2021 SC-GHG TSD were developed over many years, using transparent process, peer-reviewed methodologies, the best science available at the time of that

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[52] Presidents since the 1970s have issued executive orders requiring agencies to conduct analysis of the economic consequences of regulations as part of the rulemaking development process. EO 12866, released in 1993 and still in effect today, requires that for all economically significant regulatory actions, an agency provide an assessment of the potential costs and benefits of the regulatory action, and that this assessment include a quantification of benefits and costs to the extent feasible. For purposes of this action, monetized climate disbenefits are presented for purposes of providing a complete benefit-cost analysis under EO 12866 and other relevant EOs. The estimates of change in GHG emissions and monetized disbenefits associated with those changes play no part in the record basis for this action.

[53] See https://www.epa.gov/environmental-economics/scghg

process, and with input from the public. Specifically, in 2009, an IWG that included EPA and other executive branch agencies and offices was established to ensure that agencies had access to the best available information when quantifying the benefits of reducing GHG emissions in benefit-cost analyses. The IWG published SC-CO_2 estimates in 2010 that were developed from an ensemble of three widely cited integrated assessment models (IAMs) that estimate climate damages using highly aggregated representations of climate processes and the global economy combined into a single modeling framework. The three IAMs were run using a common set of input assumptions in each model for future population, economic, and CO_2 emissions growth, as well as equilibrium climate sensitivity (ECS) — a measure of the globally averaged temperature response to increased atmospheric CO_2 concentrations. These estimates were updated in 2013 based on new versions of each IAM.[54] In August 2016 the IWG published estimates of SC-CH_4 and SC-N_2O using methodologies that are consistent with the methodology underlying the SC-CO_2 estimates. In 2015, as part of the response to public comments received to a 2013 solicitation for comments on the SC-CO_2 estimates, the IWG announced a National Academies of Sciences, Engineering, and Medicine review of the SC-CO_2 estimates to offer advice on how to approach future updates to ensure that the estimates continue to reflect the best available science and methodologies. In January 2017, the National Academies released their final report, Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide, and recommended specific criteria for future updates to the SC-CO_2 estimates, a modeling framework to satisfy the specified criteria, and both near-term updates and longer-term research needs pertaining to various components of the estimation process (National Academies of Sciences, 2017b). Shortly thereafter, in March 2017, President Trump issued EO 13783, which disbanded the IWG, withdrew the previous technical support documents, and directed agencies to "ensure" SC-GHG estimates used in regulatory analyses "are consistent with the guidance contained in OMB Circular A-4", "including with respect to the consideration of domestic versus international impacts and the consideration of appropriate discount rates" (EO 13783, Section 5(c)). Benefit-cost analyses following EO 13783 used SC-GHG estimates that attempted to focus on the specific share of climate change damages in the United States as captured by the models (which did not reflect many pathways by which climate impacts affect the welfare of U.S. citizens and residents) and were calculated using two default discount rates recommended by Circular A-4 (OMB, 2003a), 3 percent and 7 percent.[55] All other methodological decisions and model versions used in the SC-GHG calculations remained the same as those used by the IWG in 2010 and 2013, respectively.

On January 20, 2021, President Biden issued EO 13990, which re-established an IWG and directed the group to develop an update of the SC-GHG estimates that reflect the best available science and the recommendations of National Academies (86 FR 7037, January 25, 2021). In February 2021, the IWG recommended the interim use of the most recent SC-GHG estimates developed by the IWG prior to the

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[54] Dynamic Integrated Climate and Economy (DICE) 2010 (Nordhaus, 2010), Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) 3.8 (Anthoff & Tol, 2013a, 2013b), and Policy Analysis of the Greenhouse Gas Effect (PAGE) 2009 (Hope, 2012).

[55] EPA regulatory analyses under EO 13783 included sensitivity analyses based on global SC-GHG values and using a lower discount rate of 2.5 percent. OMB Circular A-4 (OMB, 2003a) recognizes that special considerations arise when applying discount rates if intergenerational effects are important. In the IWG's 2015 Response to Comments, OMB—as a co-chair of the IWG—made clear that "Circular A-4 is a living document," that "the use of 7 percent is not considered appropriate for intergenerational discounting," and that "[t]here is wide support for this view in the academic literature, and it is recognized in Circular A-4 itself." OMB, as part of the IWG, similarly repeatedly confirmed that "a focus on global SCC estimates in [regulatory impact analyses] is appropriate" (IWG, 2015).

group being disbanded in 2017, adjusted for inflation (IWG, 2021). As discussed in the February 2021 SC-GHG TSD, the IWG's selection of these interim estimates reflected the immediate need to have SC-GHG estimates available for agencies to use in regulatory benefit-cost analyses and other applications that were developed using a transparent process, peer reviewed methodologies, and the science available at the time of that process. The February 2021 update also recognized the limitations of the interim estimates and encouraged agencies to use their best judgment in, for example, considering sensitivity analyses using lower discount rates. The IWG published a Federal Register notice on May 7, 2021, soliciting comment on the February 2021 SC-GHG TSD and on how best to incorporate the latest peer-reviewed scientific literature in order to develop an updated set of SC-GHG estimates. The EPA has applied the IWG's interim SC-GHG estimates in regulatory analyses published since the release of the February 2021 SC-GHG TSD, and is likewise using them in the benefit-cost analysis calculations in this BCA.

As noted above, EPA participated in the IWG but has also independently evaluated the interim SC-CO_2 estimates published in the February 2021 TSD and determined they are appropriate to use to estimate climate benefits for this action. EPA has also evaluated the supporting rationale of the February 2021 TSD, including the studies and methodological issues discussed therein, and concludes that it agrees with the rationale for these estimates presented in the TSD and summarized below. The February 2021 SC-GHG TSD provides a complete discussion of the IWG's initial review conducted under EO 13990. In particular, the IWG found that the SC-GHG estimates used under EO 13783 fail to reflect the full impact of GHG emissions in multiple ways. First, the IWG concluded that those estimates fail to capture many climate impacts that can affect the welfare of U.S. citizens and residents. Examples of affected interests include direct effects on U.S. citizens and assets located abroad, international trade, and tourism, and spillover pathways such as economic and political destabilization and global migration that can lead to adverse impacts on U.S. national security, public health, and humanitarian concerns. Those impacts are better captured within global measures of the social cost of greenhouse gases.

In addition, assessing the benefits of U.S. GHG mitigation activities requires consideration of how those actions may affect mitigation activities by other countries, as those international mitigation actions will provide a benefit to U.S. citizens and residents by mitigating climate impacts that affect U.S. citizens and residents. A wide range of scientific and economic experts have emphasized the issue of reciprocity as support for considering global damages of GHG emissions. Using a global estimate of damages in U.S. analyses of regulatory actions allows the U.S. to continue to actively encourage other nations, including emerging major economies, to take significant steps to reduce emissions. The only way to achieve an efficient allocation of resources for emissions reduction on a global basis — and so benefit the United States and its citizens — is for all countries to base their policies on global estimates of damages.

As a member of the IWG involved in the development of the February 2021 SC-GHG TSD, EPA agrees with this assessment and, therefore, in this BCA EPA centers attention on a global measure of SC-CO_2. This approach is the same as that taken in EPA regulatory analyses over 2009 through 2016. A robust estimate of climate damages only to U.S. citizens and residents that accounts for the myriad of ways that global climate change reduces the net welfare of U.S. populations does not currently exist in the literature. As explained in the February 2021 TSD, existing estimates are both incomplete and an underestimate of total damages that accrue to the citizens and residents of the United States because they do not fully capture the regional interactions and spillovers discussed above, nor do they include all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature, as discussed further below. EPA, as a member of the IWG, will continue to review developments in the literature, including more robust methodologies for estimating the magnitude of the various damages to U.S. populations from climate impacts and reciprocal international mitigation activities, and explore ways to better inform the public of the full range of carbon impacts.

Second, the IWG concluded that the use of the social rate of return on capital (7 percent under OMB Circular A-4 guidance, as published in 2003; Circular A-4 was subsequently revised in 2023) to discount the future benefits of reducing GHG emissions inappropriately underestimates the impacts of climate change for the purposes of estimating the SC-GHG. Consistent with the findings of National Academies (2017a) and the economic literature, the IWG continued to conclude that the consumption rate of interest is the theoretically appropriate discount rate in an intergenerational context (Interagency Working Group on Social Cost of Carbon, 2013; Interagency Working Group on Social Cost of Carbon United States Government, 2010; IWG, 2016), and recommended that discount rate uncertainty and relevant aspects of intergenerational ethical considerations be accounted for in selecting future discount rates.[56] Furthermore, the damage estimates developed for use in the SC-GHG are estimated in consumption-equivalent terms, and so an application of OMB Circular A-4 (2003)'s guidance for regulatory analysis would then use the consumption discount rate to calculate the SC-GHG. As a member of the IWG involved in the development of the February 2021 SC-GHG TSD, EPA agrees with this assessment and will continue to follow developments in the literature pertaining to this issue. EPA also notes that while OMB Circular A-4, as published in 2003, recommends using 3 percent and 7 percent discount rates as "default" values, Circular A-4 also reminds agencies that "different regulations may call for different emphases in the analysis, depending on the nature and complexity of the regulatory issues and the sensitivity of the benefit and cost estimates to the key assumptions." On discounting, Circular A-4 (2003) recognizes that "special ethical considerations arise when comparing benefits and costs across generations," and Circular A-4 (2003) acknowledges that analyses may appropriately "discount future costs and consumption benefits…at a lower rate than for intragenerational analysis." In the 2015 Response to Comments on the Social Cost of Carbon for Regulatory Impact Analysis, OMB, EPA, and the other IWG members recognized that "Circular A-4 is a living document" and "the use of 7 percent is not considered appropriate for intergenerational discounting. There is wide support for this view in the academic literature, and it is recognized in Circular A-4 itself." Thus, EPA concludes that a 7 percent discount rate is not appropriate to apply to value the social cost of greenhouse gases in the analysis presented in this analysis. Furthermore, in the 2023 revisions to Circular A-4, OMB no longer recommends the use of a 7 percent discount rate (OMB, 2023). In this analysis, to calculate the present and annualized values of climate benefits, EPA uses the same discount rate as the rate used to discount the value of damages from future GHG emissions, for internal consistency. That approach to discounting follows the same approach that the February 2021 SC-GHG TSD recommends "to ensure internal consistency—*i.e.*, future damages from climate change using the SC-GHG at 2.5 percent should be discounted to the base year of the analysis using the same 2.5 percent rate." EPA has also consulted the National Academies' 2017

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[56] GHG emissions are stock pollutants, with damages associated with what has accumulated in the atmosphere over time, and they are long lived such that subsequent damages resulting from emissions today occur over many decades or centuries depending on the specific greenhouse gas under consideration. In calculating the SC-GHG, the stream of future damages to agriculture, human health, and other market and non-market sectors from an additional unit of emissions are estimated in terms of reduced consumption (or consumption equivalents). Then that stream of future damages is discounted to its present value in the year when the additional unit of emissions was released. Given the long time horizon over which the damages are expected to occur, the discount rate has a large influence on the present value of future damages.

recommendations on how SC-GHG estimates can "be combined in RIAs with other cost and benefits estimates that may use different discount rates." The National Academies reviewed "several options," including "presenting all discount rate combinations of other costs and benefits with [SC-GHG] estimates."

While the IWG works to assess how best to incorporate the latest, peer reviewed science to develop an updated set of SC-GHG estimates, it recommended the interim estimates to be the most recent estimates developed by the IWG prior to the group being disbanded in 2017. The estimates rely on the same models and harmonized inputs and are calculated using a range of discount rates. As explained in the February 2021 SC-GHG TSD, the IWG has concluded that it is appropriate for agencies to revert to the same set of four values drawn from the SC-GHG distributions based on three discount rates as were used in regulatory analyses between 2010 and 2016 and subject to public comment. For each discount rate, the IWG combined the distributions across models and socioeconomic emissions scenarios (applying equal weight to each) and then selected a set of four values for use in benefit-cost analyses: an average value resulting from the model runs for each of three discount rates (2.5 percent, 3 percent, and 5 percent), plus a fourth value, selected as the 95th percentile of estimates based on a 3 percent discount rate. The fourth value was included to provide information on potentially higher-than-expected economic impacts from climate change, conditional on the 3 percent estimate of the discount rate. As explained in the February 2021 SC-GHG TSD, and EPA agrees, this update reflects the immediate need to have an operational SC-GHG for use in regulatory benefit-cost analyses and other applications that was developed using a transparent process, peer-reviewed methodologies, and the science available at the time of that process. Those estimates were subject to public comment in the context of dozens of proposed rulemakings as well as in a dedicated public comment period in 2013.

Table 5-4 presents the interim SC-CH_4 and SC-CO_2 estimates across all the model runs for each discount rate for emissions occurring in 2024 to 2063. Values for 2024 through 2050 are reported in 2022 dollars but are otherwise identical to those presented in the IWG's 2016 TSD (IWG, 2016). Values for 2051 to 2063 were linearly extrapolated from values published through 2050. For purposes of capturing uncertainty around the SC-GHG estimates in analyses, the IWG's February 2021 TSD emphasizes the importance of considering all four of the SC-GHG values. The SC-GHG values increase over time within the models – *i.e.*, the societal harm from one metric ton emitted in 2030 is higher than the harm caused by one metric ton emitted in 2025 – because future emissions produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change, and because GDP is growing over time and many damage categories are modeled as proportional to GDP. EPA estimated the climate disbenefits of the estimated CH_4 and CO_2 emissions for each analysis year between 2024 and 2063 by applying the annual SC-CH_4 and SC-CO_2 estimates, shown in Table 5-4, to the estimated changes in CH_4 and CO_2 emissions in the corresponding year under the regulatory options. EPA then calculated the present value and annualized value of climate disbenefits as of the expected rule promulgation year of 2024 by discounting each year-specific value to the year 2024 using the same rate used to calculate the corresponding SC-GHG.

Table 5-4: Interim Estimates of the Social Cost of Methane and Social Cost of Carbon, 2025-2065

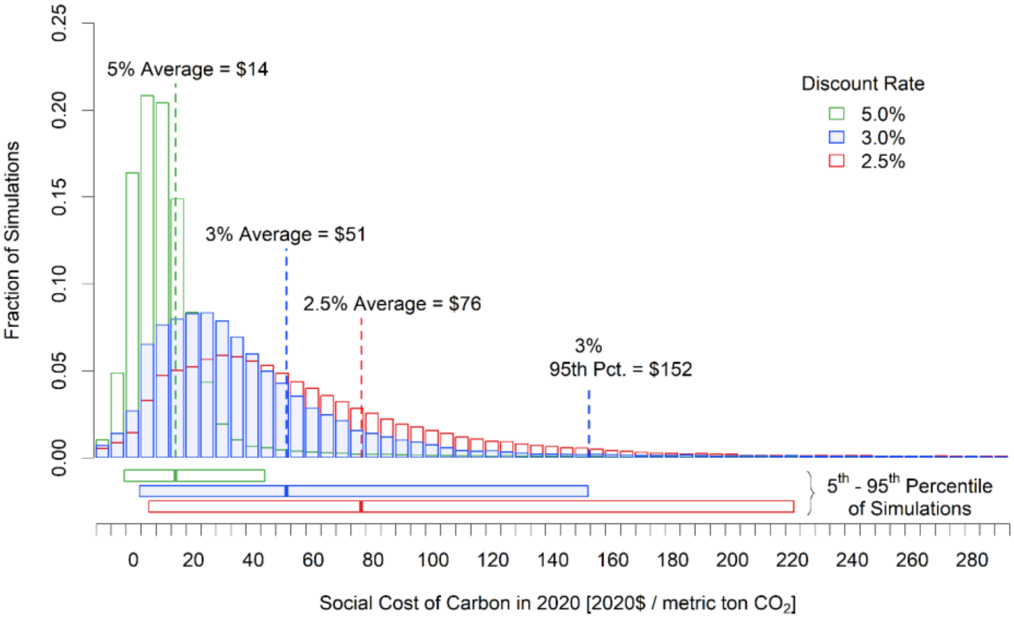
	Social Cost of Methane (2022$/Metric Tonne CH_4)				Social Cost of Carbon (2022$/Metric Tonne CO_2)			
Year	5% Average	3% Average	2.5% Average	3% 95th Percentile	5% Average	3% Average	2.5% Average	3% 95th Percentile
2025	$894	$1,901	$2,460	$5,032	$19	$63	$93	$189
2026	$928	$2,013	$2,572	$5,255	$19	$64	$94	$193
2027	$962	$2,013	$2,572	$5,367	$20	$65	$96	$197
2028	$984	$2,124	$2,683	$5,479	$21	$67	$97	$201
2029	$1,017	$2,124	$2,795	$5,702	$21	$68	$99	$205
2030	$1,051	$2,236	$2,795	$5,814	$22	$69	$100	$209
2031	$1,085	$2,236	$2,907	$5,926	$22	$70	$102	$213
2032	$1,118	$2,348	$2,907	$6,150	$23	$72	$103	$217
2033	$1,118	$2,348	$3,019	$6,373	$24	$73	$105	$222
2034	$1,230	$2,460	$3,131	$6,485	$24	$74	$106	$226
2035	$1,230	$2,460	$3,131	$6,709	$25	$75	$108	$230
2036	$1,230	$2,572	$3,243	$6,821	$26	$77	$109	$234
2037	$1,342	$2,572	$3,354	$7,044	$26	$78	$111	$239
2038	$1,342	$2,683	$3,354	$7,156	$27	$79	$112	$243
2039	$1,342	$2,795	$3,466	$7,380	$28	$81	$114	$247
2040	$1,454	$2,795	$3,466	$7,491	$28	$82	$115	$251
2041	$1,454	$2,907	$3,578	$7,715	$29	$83	$117	$255
2042	$1,565	$2,907	$3,690	$7,827	$30	$84	$118	$259
2043	$1,565	$3,019	$3,690	$8,050	$30	$86	$120	$263
2044	$1,565	$3,019	$3,802	$8,162	$31	$87	$121	$267
2045	$1,677	$3,131	$3,913	$8,386	$32	$88	$123	$271
2046	$1,677	$3,131	$3,913	$8,498	$33	$90	$124	$275
2047	$1,677	$3,243	$4,025	$8,610	$33	$91	$126	$279
2048	$1,789	$3,354	$4,137	$8,833	$34	$92	$127	$283
2049	$1,789	$3,354	$4,137	$8,945	$35	$93	$129	$287
2050	$1,901	$3,466	$4,249	$9,169	$35	$95	$130	$291
2051	$1,911	$3,533	$4,314	$9,300	$36	$96	$132	$295
2052	$1,960	$3,609	$4,389	$9,468	$37	$97	$133	$299
2053	$2,011	$3,687	$4,466	$9,638	$38	$99	$135	$303
2054	$2,062	$3,767	$4,544	$9,812	$39	$100	$137	$307
2055	$2,115	$3,849	$4,623	$9,989	$39	$102	$138	$312
2056	$2,169	$3,932	$4,704	$10,169	$40	$103	$140	$316
2057	$2,224	$4,017	$4,786	$10,353	$41	$104	$141	$320
2058	$2,281	$4,104	$4,869	$10,540	$42	$106	$143	$325
2059	$2,339	$4,193	$4,954	$10,730	$43	$107	$145	$329
2060	$2,399	$4,284	$5,041	$10,923	$44	$109	$147	$334
2061	$2,461	$4,377	$5,128	$11,120	$45	$110	$148	$339
2062	$2,524	$4,471	$5,218	$11,321	$46	$112	$150	$344
2063	$2,588	$4,568	$5,309	$11,525	$47	$114	$152	$348
2064	$2,654	$4,667	$5,402	$11,733	$48	$115	$154	$353
2065	$2,722	$4,768	$5,496	$11,945	$49	$117	$155	$358

Note: These values are identical to those reported in the February 2021 TSD (IWG, 2021), adjusted for inflation to 2022 dollars using the annual GDP Implicit Price Deflator values in the U.S. Bureau of Economic Analysis' (BEA) NIPA Table 1.1.9 (U.S. Bureau of Economic Analysis, 2023). Values are rounded to the nearest dollar and vary depending on the year of emissions. EPA extrapolated past 2050 assuming exponential growth based on the period 2045-2050.

Source: U.S. EPA Analysis, 2023, based on IWG (2021)

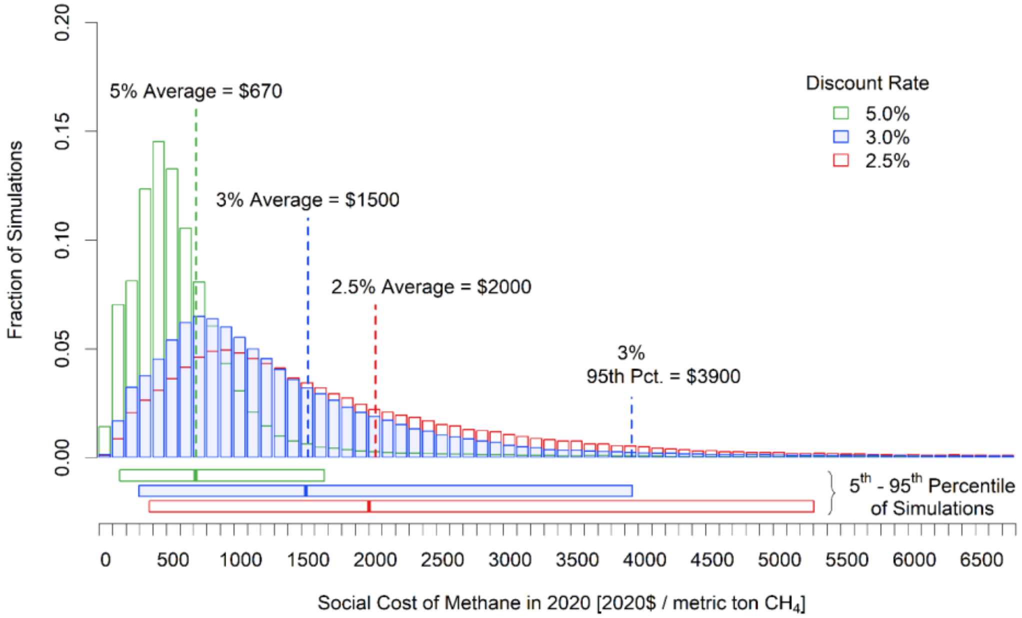
There are several limitations and uncertainties associated with the SC-GHG estimates presented in Table 5-4. Some uncertainties are captured within the analysis, while other areas of uncertainty have not yet been quantified in a way that can be modeled. Figure 5-1 and Figure 5-2 present the quantified sources of uncertainty in the form of frequency distributions for the SC-CH_4 and SC-CO_2 estimates for emissions in 2020 (in 2020 dollars). The distribution of SC-GHG estimates reflect uncertainty in key model parameters such as the equilibrium climate sensitivity, as well as uncertainty in other parameters set by the original model developers. To highlight the difference between the impact of the discount rate and other quantified sources of uncertainty, the bars below the frequency distributions provide a symmetric representation of quantified variability in the SC-GHG estimates for each discount rate. As illustrated by the figure, the assumed discount rate plays a critical role in the ultimate estimates of the SC-GHG. This is because GHG emissions today continue to impact society far out into the future, so with a higher discount rate, costs that accrue to future generations are weighted less, resulting in a lower estimate. As discussed in the February 2021 SC-GHG TSD, there are other sources of uncertainty that have not yet been quantified and are thus not reflected in these estimates.

Figure 5-1: Frequency Distribution of Interim SC-CO_2 Estimates for 2020 (in 2020$ per Metric Ton CO_2)



Source: 2021 TSD

Figure 5-2: Frequency Distribution of Interim SC-CH_4 Estimates for 2020 (in 2020$ per Metric Ton CH_4)



Source: 2021 TSD

The interim SC-GHG estimates presented in Table 5-4 have several limitations. First, the current scientific and economic understanding of discounting approaches suggests discount rates appropriate for intergenerational analysis in the context of climate change are likely to be less than 3 percent, near 2 percent or lower (IWG, 2021). Second, the IAMs used to produce these interim estimates do not include all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature and the science underlying their "damage functions" — *i.e.*, the core parts of the IAMs that map global mean temperature changes and other physical impacts of climate change into economic (both market and nonmarket) damages — lags behind the most recent research. For example, limitations include the incomplete treatment of catastrophic and non-catastrophic impacts in the integrated assessment models, their incomplete treatment of adaptation and technological change, the incomplete way in which inter-regional and intersectoral linkages are modeled, uncertainty in the extrapolation of damages to high temperatures, and inadequate representation of the relationship between the discount rate and uncertainty in economic growth over long time horizons. Likewise, the socioeconomic and emissions scenarios used as inputs to the models do not reflect new information from the last decade of scenario generation or the full range of projections.

The modeling limitations do not all work in the same direction in terms of their influence on the SC-GHG estimates. However, the IWG has recommended that, taken together, the limitations suggest that the interim SC-GHG estimates used in this proposed rule likely underestimate the damages from net CH_4 and CO_2 emissions. In particular, the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (IPCC, 2007), which was the most current IPCC assessment available at the time when the IWG decision over the ECS input was made, concluded that SC-CO_2 estimates "very likely…underestimate the damage costs" due to omitted impacts. Since then, the peer-reviewed literature has continued to support this conclusion, as noted in the IPCC's Fifth Assessment report (Intergovernmental Panel on Climate

Change, 2014) and other recent scientific assessments (*e.g.*, IPCC, 2018, 2019a, 2019b); U.S. Global Change Research Program (U.S. Global Change Research Program, 2016, 2018); and the National Academies of Sciences, Engineering, and Medicine (National Academies of Sciences, 2017a, 2019). These assessments confirm and strengthen the science, updating projections of future climate change and documenting and attributing ongoing changes. For example, sea level rise projections from the IPCC's Fourth Assessment report ranged from 18 to 59 centimeters by the 2090s relative to 1980-1999, while excluding any dynamic changes in ice sheets due to the limited understanding of those processes at the time (IPCC, 2007). A decade later, the Fourth National Climate Assessment projected a substantially larger sea level rise of 30 to 130 centimeters by the end of the century relative to 2000, while not ruling out even more extreme outcomes (U.S. Global Change Research Program, 2018). EPA has reviewed and considered the limitations of the models used to estimate the interim SC-GHG estimates, and concurs with the February 2021 SC-GHG TSD's assessment that, taken together, the limitations suggest that the interim SC-GHG estimates likely underestimate the damages from GHG emissions. The February 2021 SC-GHG TSD briefly previews some of the recent advances in the scientific and economic literature that the IWG is actively following and that could provide guidance on, or methodologies for, addressing some of the limitations with the interim SC-GHG estimates. The IWG is currently working on a comprehensive update of the SC-GHG estimates taking into consideration recommendations from the National Academies of Sciences, Engineering and Medicine, recent scientific literature, public comments received on the February 2021 TSD and other input from experts and diverse stakeholder groups (National Academies of Sciences, 2017a). While that process continues, EPA is continuously reviewing developments in the scientific literature on the SC-GHG, including more robust methodologies for estimating damages from emissions, and looking for opportunities to further improve SC-GHG estimation going forward. Most recently, EPA presented a set of updated SC-GHG estimates in the regulatory impact analysis of EPA's December 2023 final oil and gas standards that incorporates recent advances in the climate science and economics literature. Specifically, the updated methodology incorporates new literature and research consistent with the National Academies' near-term recommendations on socioeconomic and emissions inputs, climate modeling components, discounting approaches, and treatment of uncertainty, and an enhanced representation of how physical impacts of climate change translate to economic damages in the modeling framework based on the best and readily adaptable damage functions available in the peer reviewed literature. EPA solicited public comment on the draft technical report, which explains the methodology underlying the new set of estimates, in the docket for the proposed Oil and Gas rule. EPA also put the draft technical report through an external peer review. More information about this process and public comment opportunities is available on EPA's website.[57] EPA's technical report will be among the many technical inputs available to the IWG as it continues its work.

5.2.2 Results

Table 5-5 presents the undiscounted annual monetized climate disbenefits in selected years for each regulatory option. The disbenefits are calculated using the four sets of estimates of the SC-GHG from Table 5-4 (model average at 2.5 percent, 3 percent, and 5 percent discount rates; and 95th percentile at 3 percent discount rate). EPA multiplied estimated CH_4 and CO_2 emissions for each year within the period of analysis by the SC-CH_4 and SC-CO_2 estimates, respectively, for that year. The negative values

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[57] See https://www.epa.gov/environmental-economics/scghg

indicate that these are disbenefits due to the net increase in CH_4 and CO_2 emissions under the proposed rule.

Table 5-5: Estimated Undiscounted and Total Present Value of Climate Disbenefits from Incremental Changes in CH_4 and CO_2 Emissions under the Proposed Rule by Discount Rate (Millions of 2022$)

Regulatory Option	Year	Methane Benefits[a]				Carbon Dioxide Benefits[a]			
		5% Average	3% Average	2.5% Average	3% 95th percentile	5% Average	3% Average	2.5% Average	3% 95th percentile
1	2028	-$0.002	-$0.004	-$0.01	-$0.01	-$0.5	-$1.7	-$2.4	-$5.0
	2033	-$0.002	-$0.005	-$0.01	-$0.01	-$0.6	-$1.8	-$2.6	-$5.5
	2043	-$0.003	-$0.01	-$0.01	-$0.02	-$0.8	-$2.1	-$3.0	-$6.6
	2053	-$0.004	-$0.01	-$0.01	-$0.02	-$0.9	-$2.5	-$3.4	-$7.6
	2063	-$0.01	-$0.01	-$0.01	-$0.02	-$1.2	-$2.8	-$3.8	-$8.7
	TPV[b]	-$0.04	-$0.1	-$0.2	-$0.3	-$10.7	-$44.3	-$68.3	-$135.4
2	2028	-$0.01	-$0.02	-$0.02	-$0.04	-$1.9	-$6.1	-$8.9	-$18.4
	2033	-$0.01	-$0.02	-$0.02	-$0.05	-$2.2	-$6.7	-$9.6	-$20.3
	2043	-$0.01	-$0.02	-$0.03	-$0.1	-$2.8	-$7.8	-$11.0	-$24.1
	2053	-$0.02	-$0.03	-$0.03	-$0.1	-$3.5	-$9.0	-$12.3	-$27.7
	2063	-$0.02	-$0.03	-$0.04	-$0.1	-$4.3	-$10.4	-$13.9	-$31.9
	TPV[b]	-$0.2	-$0.5	-$0.6	-$1.2	-$39.1	-$162.0	-$250.0	-$495.7
3	2028	-$0.01	-$0.02	--$0.03	-$0.1	-$2.7	-$8.8	-$12.8	-$26.4
	2033	-$0.01	-$0.03	-$0.03	-$0.1	-$3.1	-$9.6	-$13.8	-$29.1
	2043	-$0.02	-$0.03	-$0.04	-$0.1	-$4.0	-$11.3	-$15.8	-$34.6
	2053	-$0.02	-$0.04	-$0.05	-$0.1	-$5.0	-$13.0	-$17.8	-$39.9
	2063	-$0.03	-$0.05	-$0.1	-$0.1	-$6.2	-$14.9	-$20.0	-$45.8
	TPV[b]	-$0.2	-$0.7	-$0.9	-$1.8	-$56.2	-$232.9	-$359.4	-$712.5

a. Values rounded to two significant figures. Negative values indicate disbenefits. Climate impacts are based on changes in CH_4 and CO_2 emissions and are calculated using four different estimates of the SC-CH_4 and SC-CO_2 (model average at 2.5 percent, 3 percent, and 5 percent discount rates; and 95th percentile at 3 percent discount rate). The IWG emphasized the importance and value of considering the benefits calculated using all four estimates. As discussed in the Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under EO 13990 (IWG, 2021), a consideration of climate benefits calculated using discount rates below 3 percent, including 2 percent and lower, are also warranted when discounting intergenerational impacts.

b. TPV represents the total present value from 2025-2065.

Source: U.S. EPA Analysis, 2023

Table 5-6 presents the annualized climate disbenefits associated with changes in GHG emissions over the 2025-2065 period under each discount rate by regulatory option and category of emissions. EPA annualized the climate disbenefits to enable consistent reporting across benefit categories (*e.g.*, benefits from improvement in water quality). All values are negative since net pollutant emissions increase under the proposed rule. Using the average SC-GHG values for the 3 percent discount rate and using a 3 percent discount rate to annualize the benefits yields annualized climate disbenefits for the preferred option of $10.0 million.

Table 5-6: Estimated Total Annualized Climate Disbenefits from Incremental Changes in CH_4 and CO_2 Emissions under the Proposed Rule by Discount Rate (Millions of 2022$)

Pollutant	Discount Rate	Regulatory Option		
		Option 1	Option 2	Option 3
Methane[a]	5% Average	-$0.003	-$0.01	-$0.01
	3% Average	-$0.01	-$0.02	-$0.03
	2.5% Average	-$0.01	-$0.03	-$0.04
	3% 95th percentile	-$0.01	-$0.05	-$0.08
Carbon dioxide[a]	5% Average	-$0.62	-$2.28	-$3.27
	3% Average	-$1.91	-$7.01	-$10.1
	2.5% Average	-$2.72	-$9.96	-$14.3
	3% 95th percentile	-$5.86	-$21.4	-$30.8
Total	5% Average	-$0.62	-$2.29	-$3.29
	3% Average	-$1.92	-$7.03	-$10.1
	2.5% Average	-$2.73	-$9.99	-$14.4
	3% 95th percentile	-$5.87	-$21.5	-$30.9

a. Values rounded to two significant figures. Negative values indicate disbenefits. Climate impacts are based on changes in CH_4 and CO_2 emissions and are calculated using four different estimates of the SC-CH_4 and SC-CO_2 (model average at 2.5 percent, 3 percent, and 5 percent discount rates; and 95th percentile at 3 percent discount rate). The IWG emphasized the importance and value of considering the benefits calculated using all four estimates. As discussed in the Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under EO 13990 (IWG, 2021), a consideration of climate benefits calculated using discount rates below 3 percent, including 2 percent and lower, are also warranted when discounting intergenerational impacts.

Source: U.S. EPA Analysis, 2023

As discussed above, the IWG is currently working on a comprehensive update of the SC-GHG estimates under EO 13990, taking into consideration recommendations from the National Academies of Sciences, Engineering, and Medicine, recent scientific literature, and public comments received on the February 2021 SC-GHG TSD. EPA is a member of the IWG and is participating in the IWG's review and updating process under EO 13990. In December 2023, EPA published new SC-GHG estimates as a supplement to a rulemaking finalizing "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review." (U.S. Environmental Protection Agency, 2023l) These new estimates reflect recent advances in the scientific literature on climate change and its economic impacts and incorporate recommendations made by the National Academies (National Academies of Sciences, 2017b). As these values were not finalized at the time EPA conducted this analysis, EPA did not use them in the main analysis presented in this section to monetize the estimated climate disbenefits of this proposed rule. However, EPA is presenting disbenefits estimated using these values in Appendix F and requests comments on whether the Agency should proceed with using these values in the main analysis.

5.3 Human Health Disbenefits

5.3.1 Data and Methodology

As summarized in Table 5-3, the regulatory options are estimated to result in small increases in the emissions of pollutants that adversely affect human health, including SO_2 and NO_x, which are both precursors to ambient $PM_{2.5}$. NO_x emissions are also a precursor to ambient ground-level ozone. The change in emissions alters the ambient concentrations, which in turn leads to changes in population exposure. EPA estimates the changes in the human health impacts associated with $PM_{2.5}$ and ozone.[58]

To estimate human health impacts and monetize the disbenefits of these changes in air emissions, EPA applied published benefit per ton estimates of changes in $PM_{2.5}$ and ozone precursors, to the estimates of SO_2 and NO_x emissions reported in Table 5-3. Table 5-7 presents benefit per ton estimates for 2025 through 2040 by emissions category using 3 percent discount rate (U.S. EPA, 2023n; Wolfe *et al.*, 2019). For transportation emissions, EPA applied the 2025 benefit per ton estimates to estimated emissions changes for each year in the period of analysis. For electricity usage, EPA applied the estimates available for 2025 to changes estimated in each year within 2025-2029, estimates available for 2030 to changes estimated in each year within 2030-2034, estimates available for 2035 to changes estimated in each year within 2035-2039, and estimates available for 2040 to the remainder of the analysis period 2040-2063.

Table 5-7: Benefit per Ton Values by Emission Category, 3 Percent Discount Rate ($2022)

Category	Year and Basis	Benefit per ton, SO_2 ($/ton)	Benefit per ton, NO_x ($/ton)	
			$PM_{2.5}$-related benefits	Ozone-related benefits
Electricity usage[a]	2025	$62,526	$8,461	$108,174
	2030	$70,568	$9,481	$142,722
	2035	$79,177	$10,614	$157,447
	2040	$86,539	$11,554	$169,907
Transportation[b]	2025; Krewski et al., 2009	$315,961	$7,413	
	2025; Lepeule et al., 2012	$716,988	$17,013	

a. Estimate of total dollar value of benefits (mortality and morbidity) for changes in emissions from electricity generating units. Updated from 2019 dollars to 2022 dollars using the GDP deflator (GDP deflator 2022 / GDP deflator 2019 = 1.333). [U.S. EPA, 2023n]

b. National average estimate of total dollar value of benefits (mortality and morbidity) for changes in emissions from on-road, heavy duty diesel vehicles in 2025. Updated from 2015 dollars using the GDP deflator (GDP deflator 2022 / GDP deflator 2015 = 1.215). [Wolfe *et al.*, 2019]

5.3.2 Results

Table 5-8 presents the undiscounted annual monetized human health disbenefits in selected years for each regulatory option, using a 3 percent discount rate. EPA multiplied estimated changes in SO_2 and NO_x emissions each year by the corresponding benefit per ton estimates for that year. Benefits are negative (*i.e.*, disbenefits) due to the net increase in SO_2 and NO_X emissions under the proposed rule.

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[58] Ambient concentrations of both SO_2 and NO_x also pose health risks independent of $PM_{2.5}$ and ozone, though EPA does not quantify these impacts in this analysis (U.S. EPA, 2016a;U.S. EPA, 2017b).

Table 5-8: Estimated Undiscounted and Total Present Value of Economic Value of Avoided Ozone and $PM_{2.5}$-Attributable Premature Mortality and Morbidity by Regulatory Option (Millions of 2022$, 3 Percent Discount Rate)

Regulatory Option	Year	SO_2		NO_x	
		Krewski et al. (2009)	2025; Lepeule et al., 2012	Krewski et al. (2009)	2025; Lepeule et al., 2012
1	2028	-$1.0	-$1.0	-$1.8	-$1.9
	2033	-$1.2	-$1.2	-$2.4	-$2.4
	2043	-$1.4	-$1.4	-$2.9	-$2.9
	2053	-$1.4	-$1.4	-$2.9	-$2.9
	2063	-$1.4	-$1.4	-$2.9	-$2.9
	TPV[a]	-$27.1	-$27.2	-$53.9	-$54.3
2	2028	-$3.8	-$3.8	-$6.8	-$6.8
	2033	-$4.3	-$4.3	-$8.8	-$8.9
	2043	-$5.3	-$5.3	-$10.5	-$10.6
	2053	-$5.3	-$5.3	-$10.5	-$10.6
	2063	-$5.3	-$5.3	-$10.5	-$10.6
	TPV[a]	-$100.0	-$100.1	-$197.7	-$198.7
3	2028	-$5.5	-$5.5	-$9.8	-$9.8
	2033	-$6.2	-$6.2	-$12.7	-$12.8
	2043	-$7.6	-$7.6	-$15.2	-$15.2
	2053	-$7.6	-$7.6	-$15.2	-$15.2
	2063	-$7.6	-$7.6	-$15.2	-$15.2
	TPV[a]	-$144.1	-$144.2	-$285.5	-$286.8

a. TPV represents the total present value from 2025-2065.

Source: U.S. EPA Analysis, 2023

5.4 Annualized Climate Change and Air Quality-Related Disbenefits of Regulatory Options

Table 5-9 presents the total annualized air quality-related disbenefits by regulatory option. For the climate change disbenefits, EPA used the same discount rate used to develop SC-GHG values. For the human health disbenefits, EPA used a 3 percent discount rate. Changes in air pollutant emissions under the preferred option (Option 1) result in annualized disbenefits of $5.4 million.

Table 5-9: Total Annualized Climate Change and Air Quality-Related Disbenefits by Regulatory Option and Discount Rate (Millions of 2022$)

Regulatory Option	SC-GHG Discount Rate	Climate Change	Human Health (at 3 Percent Discount Rate)		Total	
			Krewski et al. (2009)	2025; Lepeule et al., 2012	Krewski et al. (2009)	2025; Lepeule et al., 2012
1	3% (Average)	-$1.9	-$3.5	-$3.5	-$5.4	-$5.4
	5% (Average)	-$0.6	-$3.5	-$3.5	-$4.1	-$4.1
	2.5% (Average)	-$2.7	-$3.5	-$3.5	-$6.2	-$6.3
	3% (95th Percentile)	-$5.9	-$3.5	-$3.5	-$9.4	-$9.4
2	3% (Average)	-$7.0	-$12.9	-$12.9	-$19.9	-$20.0
	5% (Average)	-$2.3	-$12.9	-$12.9	-$15.2	-$15.2
	2.5% (Average)	-$10.0	-$12.9	-$12.9	-$22.9	-$22.9
	3% (95th Percentile)	-$21.5	-$12.9	-$12.9	-$34.4	-$34.4
3	3% (Average)	-$10.1	-$18.6	-$18.6	-$28.7	-$28.8
	5% (Average)	-$3.3	-$18.6	-$18.6	-$21.9	-$21.9
	2.5% (Average)	-$14.4	-$18.6	-$18.6	-$32.9	-$33.0
	3% (95th Percentile)	-$30.9	-$18.6	-$18.6	-$49.5	-$49.6

Source: U.S. EPA Analysis, 2023

5.5 Limitations and Uncertainty

Table 5-10 summarizes the limitations and uncertainties associated with the analysis of the climate change and air quality-related impacts.

Table 5-10: Limitations and Uncertainties in the Analysis of Climate Change and Air Quality-Related Disbenefits

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
EPA used emission factors from eGRID to estimate indirect emissions impacts from increased electricity consumption	Overestimate	The eGRID database provides emission factors based on historical electricity generation (observed or estimated using 2021 data). It is designed to be used to estimate the emissions footprint of marginal changes in electricity consumption, assuming a constant generation mix. eGRID provides static emission factors based on historical data and likely overstates emissions associated with the increased power consumption to operate MPP wastewater treatment systems since emission factors are expected to decline in the coming decades as the United States increasingly transitions to clean energy or expand carbon capture, utilization and storage using incentives in the 2022 Inflation Reduction Act Energy Infrastructure Reinvestment Program.
EPA used the industrial boilers sector as a proxy for the wastewater treatment sector.	Unknown	Benefit per ton values are not available for the wastewater treatment sector. EPA used the industrial sources it deemed most similar in terms of spatial distribution as wastewater treatment. However, differences in the distribution of wastewater emissions sources relative to the exposed populations, when compared to industrial boilers, may result in smaller or larger health impacts.

Table 5-10: Limitations and Uncertainties in the Analysis of Climate Change and Air Quality-Related Disbenefits

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
EPA did not analyze all benefits of changes in exposure to NO_X, SO_2 and other pollutants emitted by EGUs.	Underestimate	The analysis focused on adverse health effects related to $PM_{2.5}$ and ozone levels. There are additional benefits from changes in levels of NO_X, SO_2 and other air pollutants emitted by EGUs (*e.g.*, mercury, HCl). These include health benefits from changes in ambient NO_2 and SO_2 exposure, health benefits from changes in mercury deposition, ecosystem benefits associated with changes in emissions of NO_X, SO_2, PM, and mercury, and visibility impairment.
EPA did not analyze potential changes in greenhouse gases associated with changes in meat sales	Overestimate	Increases in meat prices may result in reduced sales in meat and poultry products. EPA did not estimate net changes in greenhouse gas emissions associated with the production of these products as compared to their substitutes.

6 Summary of Estimated Total Monetized Benefits

Table 6-1 summarizes the total annualized monetized benefits using a 3 percent discount rate. The monetized benefits do not account for all anticipated effects of the regulatory options, including human health (*e.g.*, avoided illnesses from exposure through recreational uses), ecological (*e.g.*, impacts of pollutant load changes on T&E species habitat), market and productivity benefits (*e.g.*, drinking water treatment cost savings). See Chapter 2 for a discussion of categories of benefits EPA did not monetize.

Table 6-1: Summary of Total Annualized Benefits for Regulatory Options, Compared to Baseline, at 3 Percent (Millions of 2022$)

Benefit Category	Option 1	Option 2	Option 3
Use and nonuse values for water quality changes	$95.6	$166.1	$208.4
Climate change effects from changes in GHG emissions	-$1.9	-$7.0	-$10.1
Human health effects from changes in NO_X, SO_2, and $PM_{2.5}$ emissions	-$3.5	-$12.9	-$18.6
Total monetized benefits	**$90.2**	**$146.2**	**$179.7**
Additional benefits	+	+	+

+ Additional non-monetized health, ecological, market and economic productivity benefits (see Table ES-2 and Chapter 2)

Source: U.S. EPA Analysis, 2023

7 Summary of Total Social Costs

This chapter discusses EPA's estimates of the costs to society under the regulatory options. Social costs include costs incurred by both private entities and the government (*e.g.*, in implementing the regulation). As described further in Chapter 9 of the RIA, EPA did not evaluate incremental baseline costs, and associated cost savings to state governments. To calculate social costs, EPA estimated technology implementation costs for MPP facilities and administrative costs to MPP facilities, states and POTWs, and the Agency.

7.1 Overview of Cost Analysis Framework

Chapter 3 of the RIA presents EPA's development of cost estimates for MPP facilities within the scope of the proposed rule. These costs, calculated on a pre-tax basis, are used in the social cost analysis.

For the analysis of social costs, EPA estimated a year-explicit schedule of technology implementation cost outlays over the period 2026-2065. EPA estimated that MPP dischargers will install treatment technologies based on a compliance schedule specific to discharge type. All direct dischargers will install treatment technologies over five years, with an estimated 20 percent doing so each year. Direct dischargers will also incur annual O&M costs on the same schedule. All indirect dischargers will implement technologies in year three and will begin incurring annual O&M costs beginning in that year. In addition, since EPA estimated that 70 percent of capital has a useful life of 20 years, direct dischargers will incur 100 percent of capital compliance costs when they first install the technology within years one through five and 70 percent of the capital compliance costs again within years 21 through 25 as some of the previously installed technology reaches its end of life. Indirect dischargers will incur 100 percent of capital compliance costs in year three and 70 percent in year 24.

EPA summed annual facility-level costs to develop estimates for the total costs of compliance in each year of the analysis period and calculated the present and annualized values of these costs using a 3 percent discount rate over the 40-year analysis period. EPA assumed that capital costs are incurred in the relevant compliance year for each facility, and annual O&M costs (operating labor, waste transport and disposal operation, etc.) are incurred each year after technology implementation. See Chapter 3 in the RIA for more details.

EPA used estimated costs to dischargers for labor, capital, and other resources necessary to ensure compliance with the regulatory options to assess costs to society. In this analysis, market prices for these resources are the opportunity cost to society. EPA assumed an inelastic supply of MPP products, meaning that the regulatory options do not affect the quantity of goods sold by the industry. This assumption is consistent with EPA's market impact analysis (Chapter 6 of the RIA) which shows that the regulatory options have a small impact on the production of MPP products and that demand is relatively inelastic with respect to price. As discussed in Section 2.3.2, POTWs receiving MPP discharges may incur lower wastewater treatment costs due to reductions in influent pollutant loads and improvements in the quality of biosolids. EPA did not estimate the cost savings at POTWs but to the extent that they offset some of the compliance costs incurred by indirect dischargers, the cost savings will reduce the total social costs attributable to this rule.

EPA also calculated the one-time and annual administrative costs of compliance. One-time administrative costs include the cost for facilities to read and comprehend the rule and the cost to Control Authorities and the Agency to review the ELGs and establish monitoring requirements. Control Authorities will incur annual costs to review direct dischargers' monitoring reports and take enforcement action as needed. The Agency will incur annual costs to review pollutant data from MPP dischargers for compliance. Annual costs are incurred in accordance with dischargers' compliance schedule.[59]

Control Authorities' annual costs are proportional to the percentage of direct dischargers in compliance each year. Therefore, their annual costs increase by 20 percent each year from years one through five, as direct dischargers come into compliance. After year five, Control Authorities incur 100 percent of total annual costs each year. The Agency's annual costs to review direct dischargers' data are incurred on the same schedule. The Agency also incurs annual costs to review indirect dischargers' data proportional to the percentage in compliance. Therefore, the Agency will not incur annual costs to review indirect dischargers' data until year 3, at which point the Agency will incur 100 percent of costs through year 40.

7.2 Key Findings for Regulatory Options

Table 7-1 presents annualized incremental costs for the regulatory options, as compared to the baseline, discounted at 3 percent. Appendix D presents annualized incremental costs discounted at 7 percent.

Table 7-1: Estimated Total Social Costs by Regulatory Option and Discharge Type Discounted at 3 Percent (Millions 2022$)

Regulatory Option	Direct	Indirect	Total
Option 1	$216.5	$15.3	$231.9
Option 2	$216.5	$426.3	$642.8
Option 3	$223.7	$853.6	$1,077.3
Option 1 with chlorides	$279.6	$109.9	$389.6
Option 2 with chlorides	$279.6	$520.9	$800.5
Option 3 with chlorides	$286.8	$948.2	$1,235.0

Source: U.S. EPA Analysis, 2023.

Table 7-2 provides additional details on the social cost calculations. For each regulatory option, the table presents the time profiles of incremental costs incurred compared to the baseline. The annualized costs, discounted at 3 percent, are presented as well. Estimated costs are highest in year three (2028), when 20 percent of direct and 100 percent of indirect dischargers incur capital costs, and year 24 (2049), when 20 percent of direct dischargers and 100 percent of indirect dischargers incur 70 percent of capital costs. Year three is also when Control Authorities and the Agency incur 60 percent of annual costs for direct dischargers and 100 percent of annual costs for indirect dischargers.

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[59] EPA estimated one-time administrative costs to read the rule for Options 1, 2, and 3, with and without chlorides, and annual administrative costs for Options 1 and 2, with and without chlorides.

Table 7-2: Time Profile of Costs to Society (Millions 2022$)

Year	Option 1	Option 2	Option 3	Option 1 with chlorides	Option 2 with chlorides	Option 3 with chlorides
2025	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2026	$191.9	$191.9	$198.1	$251.1	$251.1	$257.3
2027	$229.7	$229.7	$237.2	$300.2	$300.2	$307.7
2028	$353.1	$2,403.8	$4,942.3	$880.4	$2,931.1	$5,469.5
2029	$321.7	$682.8	$1,043.3	$499.6	$860.7	$1,221.2
2030	$361.3	$722.4	$1,084.2	$550.4	$911.5	$1,273.4
2031	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2032	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2033	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2034	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2035	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2036	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2037	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2038	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2039	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2040	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2041	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2042	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2043	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2044	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2045	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2046	$316.1	$677.2	$1,037.6	$490.9	$852.0	$1,212.3
2047	$316.1	$677.2	$1,037.6	$490.9	$852.0	$1,212.3
2048	$316.1	$677.2	$1,037.6	$490.9	$852.0	$1,212.3
2049	$365.6	$1,909.4	$3,795.0	$792.8	$2,336.6	$4,222.2
2050	$316.1	$677.2	$1,037.6	$490.9	$852.0	$1,212.3
2051	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2052	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2053	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2054	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2055	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2056	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2057	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2058	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2059	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2060	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2061	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2062	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2063	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2064	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
2065	$210.7	$571.8	$928.8	$351.9	$713.0	$1,070.0
PV, 3%	**$5,359.4**	**$14,858.2**	**$24,900.8**	**$9,004.5**	**$18,503.3**	**$28,545.9**
Annualized costs, 3%	**$231.9**	**$642.8**	**$1,077.3**	**$389.6**	**$800.5**	**$1,235.0**

Source: U.S. EPA Analysis, 2023.

8 Benefits and Social Costs

This chapter compares total monetized benefits and costs for the regulatory options. Benefits and costs are compared on two bases: (1) incrementally for each of the options analyzed as compared to the baseline and (2) incrementally across options. The comparison of benefits and costs also satisfies the requirements of Executive Order 12866: Regulatory Planning and Review and Executive Order 13563: Improving Regulation and Regulatory Review (see Chapter 9 in the RIA).

8.1 Comparison of Benefits and Costs by Option

Chapters 6 and 7 present estimates of the benefits and costs, respectively, for the regulatory options. Table 8-1 presents EPA's estimates of the annualized benefits and costs of the regulatory options.

Table 8-1: Total Estimated Annualized Benefits and Costs by Regulatory Option Compared to Baseline, at 3 Percent Discount (Millions of 2022$)

Regulatory Option	Total Benefits		Total Costs
	Monetized Benefits	Other Benefits	
Option 1	$90.2	+	$231.9
Option 2	$146.2	+	$642.8
Option 3	$179.7	+	$1,077.3

+ Additional non-monetized health, ecological, market and economic productivity benefits (see Table ES-2 and Chapter 2)

Source: U.S. EPA Analysis, 2023.

8.2 Analysis of Incremental Benefits and Costs

In addition to comparing estimated benefits and costs for each regulatory option relative to the baseline, as presented in the preceding section, EPA also estimated the benefits and costs of the options on an incremental basis. The comparison in the preceding section addresses the simple quantitative relationship between estimated benefits and costs for each option and determines whether costs or benefits are greater for a given option and by how much. In contrast, incremental analysis looks at the differential relationship of benefits and costs across options and poses a different question: as increasingly more costly options are considered, by what amount do benefits, costs, and net benefits (*i.e.*, benefits minus costs) change from option to option? Incremental net benefit analysis provides some insight into the net gain to society from imposing increasingly more costly requirements, but does not provide a full account for those gains given the share of the benefits that cannot be monetized. For example, the analysis omits important categories of benefits discussed further in Section 2 that include, but are not limited to, reduced incidence of adverse human health effects from exposure to MPP pollutants via recreational use or drinking water, water quality improvements in receiving and downstream reaches and the associated enhancement of swimming, fishing, boating, and near-water activities, aesthetic values from shifts in water clarity, color, or odor, improved ecosystem health, including benefits to T&E species habitat and populations, as well as various market benefits such as reduced drinking water and wastewater treatment costs, improved fisheries yield and harvest quality, and improved property values.

EPA conducted the incremental net benefit analysis by calculating the change in net benefits, from option to option, in moving from the least stringent option to successively more stringent options, where stringency is determined based on total pollutant loads.

Table 8-2: Analysis of Estimated Incremental Net Benefit of the Regulatory Options, Compared to Baseline and to Other Regulatory Options, at 3 Percent Discount (Millions of 2022$)

Regulatory Option	Net Annual Benefits[a]		Incremental Net Annual Monetized Benefits[b]
	Monetized Benefits	Other Benefits	
Option 1	-$141.7	+	N/A
Option 2	-$496.6	+	-$354.9
Option 3	-$897.6	+	-$401.0

+ Additional non-monetized health, ecological, market and economic productivity benefits (see Table ES-2 and Chapter 2)

a. Net annual other benefits were not quantified and therefore the net values shown are based on monetized benefits only. However, given generally increasing pollutant loading reductions as one moves from Option 1 to Option 2, and from Option 2 to Option 3, EPA anticipates the other benefits to also increase as one moves from Option 1 to Option 2, and from Option 2 to Option 3.

b. Net annual other benefits were not quantified and therefore the incremental net values shown are based on monetized benefits only.

Source: U.S. EPA Analysis, 2023.

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Appendix A: Water Quality Modeling

This section describes the methodology used to analyze the potential hydrologic and water quality effects in response to the proposed rule for the MPP industry.

SWAT Model Setup

EPA used HAWQS 2.0 to develop the initial SWAT models and extract data necessary to characterize the watersheds. HAWQS is a web-based interface that streamlines the development of SWAT watershed models by providing pre-loaded input data and modeling support capabilities for setting up models, running simulations, and processing outputs (2023). SWAT is a commonly used public domain semi-distributed mechanistic watershed model that is used to evaluate the effects of land management and agricultural practices on water, sediment, and chemical fluxes across a wide range of watershed sizes, land uses, and physiographic provinces (Neitsch *et al.*, 2011). HAWQS provides pre-loaded national input data necessary to develop SWAT watershed models at subbasin resolutions that range from the 14-digit HUC (HUC14) to the 8-digit HUC (HUC8).

For the water quality models described in Section 3.3, EPA developed watershed models with HUC12 subbasins using the HAWQS 2.0 interface. Table A-1 summarizes the pre-processed input datasets available within the HAWQS framework that were used in developing these models.

Table A-1: Case Study Models Input Dataset Summary

Input Dataset	Source	Specifications
Weather	Parameter-elevation Regressions on Independent Slopes Model (PRISM)	1981 – 2020 (gridded)
Soil	U.S. Department of Agriculture (USDA) National Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) Database	2018
	USDA NRCS State Soil Geographic (STATSGO) Database	2018
Land Use	National Land Cover Database (NLCD)	2016
	USDA National Agricultural Statistics Service (NASS) Cropland Data Layer (CDL)	2014-2017
	USDA NASS Fields	2006-2010
	U.S. Fish and Wildlife Service (FWI) National Wetlands Inventory (NWI)	2018
Aerial Deposition	National Atmospheric Deposition Program (NADP)	1980 – 2020 (monthly)
Watershed Boundaries	EPA NHDPlus v2	2019
Stream Networks	EPA NHDPlus v2	2019
Elevation	USGS National Elevation Dataset (NED)	2018 (10-meter DEM)
Point Sources	EPA Hypoxia Task Force (HTF)	2019
	EPA Integrated Compliance Information System National Pollutant Discharge Elimination System (ICIS-NPDES)	2019
Management Data	USDA NRCS crop management zone data	2010
Ponds, Potholes, and Reservoirs	U.S. Army Corps of Engineers (USACE) National Inventory of Dams (NID)	2018
	EPA NHDPlus v2	2019
Crop Data	USDA NASS CDL	2014 – 2017
Wetlands	U.S. Fish and Wildlife Service National Wetland Inventory (NWI)	2018
Water Use	USGS Water Use in the United States	2015

Source: U.S. EPA Analysis, 2023

SWAT also allows the user to choose among hydrology and water quality settings that determine how various SWAT processes are modeled. Table A-2 summarizes the relevant setting specifications used in HAWQS/SWAT models.

Table A-2: Summary of Relevant SWAT Hydrology and Water Quality Settings

SWAT Process	Associated SWAT File	Specifications
Potential evaporation	basins.bsn	Penman/Monteith method
Water routing	basins.bsn	Variable travel time
Curve number (CN) calculation	basins.bsn	Calculates daily CN value as a function of soil moisture
Instream sediment model	basins.bsn	Bagnold model

Source: U.S. EPA Analysis, 2023

Representation of Point Source Discharges from Direct and Indirect Facilities

HAWQS 2.0 includes default point source data to represent loadings not associated with land areas, such as permitted discharges from POTWs or industrial facilities, including MPP dischargers. The point source dataset used for the case study models includes data for flows, nitrogen, phosphorus, fecal coliform, *E. coli*, CBOD, and TSS by subbasin (HUC12). The parameters follow the standard SWAT model input data format for annual average discharges (reccnst.dat):

- Flow: (FLO) in cubic meters per day
- Nitrogen: nitrate (NO3), nitrite (NO2), ammonia (NH3), and organic nitrogen (ORGN), all in kilograms per day
- Phosphorus: mineral phosphorus (MINP) and organic phosphorus (ORGP) in kilograms per day
- Pathogens: E. coli (BACTP), and fecal coliform (BACTLP) in colony forming units (CFU) per 100 mL[60]
- Organic enrichment: CBOD (CBOD) in kilograms per day
- Sediment: TSS (SED) in metric tons (Mton) per day

Default point source data included in HAWQS 2.0 reflect 2019 annual average loadings from permitted point source dischargers. The scope includes discharges covered by NPDES individual permits from POTW and non-POTW facilities, whether they are classified as minor or major. Point source data for MPP direct dischargers were updated to reflect 2021 loadings from MPP permitted dischargers, whereas all other point source dischargers were left unchanged to their 2019 default values. All point source estimates were derived from the sources described below.

- EPA ICIS-NPDES Discharge Monitoring Reports (DMRs): ICIS-NPDES is an information management system that tracks permit compliance and enforcement status of facilities regulated by the NPDES permit program. DMRs are part of facilities' compliance verification process. These datasets include reported outfall flows and loadings or concentrations from NPDES-permitted facilities. In particular, the datasets include NPDES and outfall identifiers, geographic coordinates, parameters monitored, monitoring frequencies, statistical bases applied to report the values, and measured values in standardized units. The

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[60] *E. coli* was mapped to persistent bacteria and fecal coliform was mapped to less persistent bacteria based on review of the documentation of the pathogen modeling routines and past model applications.

DMR data are formatted as monthly measurements adjusted to DMR value standard units at each NPDES facility outfall.

- EPA ECHO Water Pollutant Loading Tool, Hypoxia Task Force (HTF) Nutrient Modeling Dataset: Total nutrient loads for all relevant NPDES-permitted point source facilities are summarized in a national dataset from EPA's ECHO Water Pollutant Loading Tool, Nutrient Modeling (HTF Search). This dataset reports annual total nitrogen (TN) and total phosphorus (TP) loads. The annual nutrient loading values include both 1) aggregated TN and TP loads from facilities reporting nutrient concentrations in DMRs and 2) modeled data where EPA imputed loads for facilities without DMR-reported nutrient data using Typical Pollutant Concentrations (TPCs) applied to facilities based on Standard Industrial Classification (SIC) code, flow class, and season. DMR data for 2019 and 2021 were extracted for nutrients, pathogens, BOD, TSS, and flows, where available.
- For select direct dischargers that were not reflected in the default point source dataset in HAWQS 2.0, EPA used the baseline loadings developed for this rulemaking analysis (described in Section 3.1).

The primary data source (HTF or DMR) determined the process by which the point source data were summarized. The HTF dataset served as the primary basis for annual nutrient loadings; for nutrients, DMR data were used secondarily to distribute total nutrient loadings across discharge outfalls and nutrient species. For pathogens (*E. coli* and fecal coliform), BOD, and TSS, the primary data source was DMR. The DMR data were used in combination with permit and facility characteristics to estimate total loadings and concentrations across discharge outfalls. External outfalls associated with NPDES-permitted dischargers were georeferenced to the HUC14s based on the outfall coordinates. The HAWQS 2.0 technical documentation has additional details on the development of the point source data (U.S. EPA, 2023f).

Model Calibration

SWAT parameters in initial models reflect default values from SWAT, as modified where applicable during HAWQS calibration (U.S. EPA, 2023f).

The SWAT calibration procedure involved four main steps:

1. Collect observed data within the case study modeling locations;
2. Run the model in "calibration mode" and iteratively adjust model parameters so that the predicted monthly streamflow and loadings time series approximate observed streamflow and loadings within the bounds of uncertainties of model inputs and estimates developed directly from observed data (using the USGS' Load Estimator [LOADEST]);
3. Run the statistical tests in SWAT's Calibration and Uncertainty Program (SWAT-CUP) to produce the calibration statistical metrics; and
4. Finalize the calibration parameters and update the project database and input files for further scenario analysis.

For the regions described in Section 3.3, flow calibration was completed for each HUC12 with sufficient observed data. HUC12s without sufficient observed flow data or HUC12s that did not result in a successful calibration were assigned calibration parameters from similar watersheds within the same HUC2 region, identified by a cluster analysis of watershed characteristics. There were insufficient observed water quality data to conduct calibration at the same scale, both spatially and temporally. Spatially, observed water quality data were available at far fewer locations than observed flow data. Temporally, continuous flow time series were often available for gage stations, but water quality data is more often collected as discrete grab samples. The frequency and duration of sampling affected which observed water quality data sites were appropriate for calibration, even with the use of USGS' LOADEST to estimate water quality time series from the discrete grab samples. The HAWQS 2.0 technical documentation has additional details on calibration procedures.

Appendix B: WQI Calculation and Regional Subindices

The first step in the implementation of the WQI involves obtaining water quality levels for each parameter, and for each waterbody, under both the baseline conditions and each regulatory option. Some parameter levels are field measurements while others are modeled values.

The second step involves transforming the parameter measurements into subindex values that express water quality conditions on a common scale of 10 to 100. EPA used the subindex transformation curves developed by Dunnette (Dunnette, 1979) and Cude (Cude, 2001a) for the Oregon WQI for BOD, DO, and FC. For TSS, TN, and TP concentrations, EPA adapted the approach developed by Cude (Cude, 2001a) to account for the wide range of natural or background nutrient and sediment concentrations that result from variability in geologic and other region-specific conditions, and to reflect the national context of the analysis. TSS, TN, and TP subindex curves were developed for each of the nine ecoregions used for the National Rivers and Streams Assessment (NRSA) using data from the 2013-2014 and 2018-2019 NRSAs.[61] For each of the nine ecoregions, EPA derived the transformation curves by assigning a score of 100 to the 10th percentile of the observations within each ecoregion (*i.e.,* using the 10th percentile as a proxy for “reference conditions”), and a score of 70 to the median concentration. An exponential equation was then fitted to the two concentration-score pairs for each ecoregion following the approach used in Cude (Cude, 2001b).

The final step in implementing the WQI involves combining the individual parameter subindices into a single WQI value that reflects the overall water quality across the parameters. Following McClelland’s approach, EPA calculated the overall WQI using a weighted geometric mean function.

Equation B-1 presents EPA’s calculation of the overall WQI score.

Equation B-1.

$$WQI_r = \prod_{i=1}^{n} Q_i^{Wi}$$

WQI_r = the multiplicative water quality index (from 10 to 100) for subbasin *r*

Q_i = the water quality subindex measure for parameter *i*

W_i = the weight of the *i*-th parameter

n = the number of parameters (*i.e.*, six)

The WQI parameter weights (Table B-1) are based on the parameter weights used in the WQI developed by Cude (Cude, 2001a) and updated for EPA’s C&D analysis (U.S. EPA, 2009a).[62]

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[61] The NRSA is a component of EPA’s National Aquatic Resources Survey (NARS). The NRSA provides information on the conditions of the nation’s rivers and streams and is conducted at regular intervals (2008-2009, 2013-2014, and 2018-2019) using a consistent approach. This enables comparison of stream conditions over time. The NRSA has several interesting features to support the development of a water quality index: it is based on a statistical representation of rivers and streams, it provides data for key indicators of biological, chemical and physical conditions, and includes both measured data and a categorical assessment of the conditions (poor, fair, good) for selected indicators. In particular, the 2013-2014 and 2018-2019 surveys provide categorical assessments of chemical conditions related to TN and TP.

[62] EPA (Schaafsma, 2015) revised the weights originally developed by McClelland (McClelland, 1974) by redistributing the weights to the six parameters retained in the EPA WQI (excluding temperature and pH) so that the ratio among the parameters is maintained and the weights sum to one.

Table B-1: WQI Parameter Weights

Parameter	Weight
Dissolved Oxygen	0.24
Fecal Coliform	0.22
Biochemical Oxygen Demand	0.15
Total Nitrogen	0.14
Total Phosphorus	0.14
Total Suspended Solids	0.11

Source: U.S. EPA Analysis, 2023, based on methodology in Schaafsma, 2015

Table B-2 presents parameter-specific functions used for transforming water quality data into water quality subindices for freshwater waterbodies for the six pollutants with individual subindices. The curves include threshold values below or above which the subindex score does not change in response to changes in parameter levels. For example, improving DO levels from 10.5 mg/L to 12 mg/L or from 2 mg/L to 3.3 mg/L would result in no change in the DO subindex score.

Table B-2: Freshwater Water Quality Subindices

Parameter	Concentrations	Concentration Unit	Subindex
Dissolved Oxygen (DO)			
DO saturation ≤100%			
DO	$DO \leq 3.3$	mg/L	10
DO	$3.3 < DO < 10.5$	mg/L	$-80.29+31.88 \times DO-1.401 \times DO^2$
DO	$DO \geq 10.5$	mg/L	100
100% < DO saturation ≤ 275%			
DO	NA	mg/L	$100 \times \exp((DOsat - 100) \times -1.197 \times 10^{-2})$
275% < DO saturation			
DO	NA	mg/L	10
Fecal Coliform (FC)			
FC	FC > 1,600	cfu/100 mL	10
FC	50 < FC ≤ 1,600	cfu/100 mL	$98 \times \exp((FC - 50) \times -9.9178 \times 10^{-4})$
FC	FC ≤ 50	cfu/100 mL	98
TN[a]			
TN	$TN > TN_{10}$	mg/L	10
TN	$TN_{100} < TN \leq TN_{10}$	mg/L	a × exp(TN×b); where a and b are ecoregion-specific values
TN	$TN \leq TN_{100}$	mg/L	100
TP[b]			
TP	$TP > TP_{10}$	mg/L	10
TP	$TP_{100} < TP \leq TP_{10}$	mg/L	a × exp(TP×b); where a and b are ecoregion-specific values
TP	$TP \leq TP_{100}$	mg/L	100
TSS[c]			
TSS	$TSS > TSS_{10}$	mg/L	10
TSS	$TSS_{100} < TSS \leq TSS_{10}$	mg/L	a × exp(TSS×b); where a and b are ecoregion-specific values
TSS	$TSS \leq TSS_{00}$	mg/L	100

Table B-2: Freshwater Water Quality Subindices

Parameter	Concentrations	Concentration Unit	Subindex
		Biochemical Oxygen Demand, 5-day (BOD)	
BOD	BOD > 8	mg/L	10
BOD	BOD ≤ 8	mg/L	100 × exp(BOD × -0.1993)

a. TN10 and TN100 are ecoregion-specific TN concentration values that correspond to subindex scores of 10 and 100, respectively. Use of 10 and 100 for the lower and upper bounds of the WQI subindex score follow the approach in Cude (2001a)

b. TP10 and TP100 are ecoregion-specific TP concentration values that correspond to subindex scores of 10 and 100, respectively. Use of 10 and 100 for the lower and upper bounds of the WQI subindex score follow the approach in Cude (2001a)

c. TSS10 and TSS100 are ecoregion-specific TSS concentration values that correspond to subindex scores of 10 and 100, respectively. Use of 10 and 100 for the lower and upper bounds of the WQI subindex score follow the approach in Cude (2001a)

Source: U.S. EPA Analysis, 2023, based on methodology in Cude (2001a).

The following tables provide the ecoregion-specific parameters used in estimating the TSS, TN, or TP water quality subindex, as follows:

- If [WQ Parameter] ≤ WQ Parameter 100 Subindex = 100
- If WQ Parameter 100 < [WQ Parameter] ≤ WQ Parameter 10 Subindex = a exp(b [WQ Parameter])
- If [WQ Parameter] > WQ Parameter 10 Subindex = 10

Where [WQ Parameter] is the measured concentration of either TSS, TN, or TP and WQ Parameter $_{10}$, WQ Parameter $_{100}$, a, and b are specified in Table B-3 for TSS, Table B-4 for TN, and Table B-5 for TP.

Table B-3: TSS Subindex Curve Parameters, by Ecoregion

Ecoregion	a	b	TSS_{100}	TSS_{10}
Coastal Plains	109.34	-0.015	5.86	156.84
Northern Appalachians	108.11	-0.061	1.29	39.27
Northern Plains	102.07	-0.001	18.10	2,049.20
Southern Appalachians	114.22	-0.012	10.88	199.43
Southern Plains	102.19	-0.001	15.53	1,667.06
Temperate Plains	114.02	-0.003	46.30	858.85
Upper Midwest	101.24	-0.021	0.59	111.70
Western Mountains	108.48	-0.018	4.51	131.95
Xeric	101.72	-0.003	6.53	887.38

Source: U.S. EPA Analysis, 2023

Table B-4: TN Subindex Curve Parameters, by Ecoregion

Ecoregion	a	b	TN_{100}	TN_{10}
Coastal Plains	148.67	-0.85	0.47	3.17
Northern Appalachians	128.25	-1.08	0.23	2.36
Northern Plains	124.98	-0.40	0.56	6.37
Southern Appalachians	178.79	-0.95	0.61	3.04
Southern Plains	113.00	-0.22	0.55	10.95
Temperate Plains	123.62	-0.13	1.57	18.65
Upper Midwest	119.92	-0.40	0.45	6.20
Western Mountains	121.28	-1.99	0.10	1.25
Xeric	130.03	-1.06	0.25	2.43

Source: U.S. EPA Analysis, 2023

Table B-5: TP Subindex Curve Parameters, by Ecoregion

Ecoregion	a	b	TP_{100}	TP_{10}
Coastal Plains	116.13	-5.33	0.03	0.46
Northern Appalachians	104.31	-5.75	0.01	0.41
Northern Plains	117.76	-13.58	0.01	0.18
Southern Appalachians	115.90	-1.02	0.15	2.41
Southern Plains	114.66	-4.37	0.03	0.56
Temperate Plains	103.46	-0.66	0.05	3.56
Upper Midwest	140.90	-1.58	0.22	1.67
Western Mountains	107.15	-3.89	0.02	0.61
Xeric	108.89	-9.72	0.01	0.25

Source: U.S. EPA Analysis, 2023

Appendix C: Methodology for Estimating WTP for Water Quality Changes

To estimate the nonmarket benefits of the water quality changes resulting from the regulatory options, EPA used updated results from a meta-analysis of stated preference studies described in detail in the 2015 Steam Electric rule BCA (U.S. EPA, 2015a; see Appendix H). To update results of the 2015 meta-analysis, EPA first conducted a literature review and identified ten new studies to augment the existing meta-data. EPA also performed quality assurance on the meta-data, identifying revisions that improved accuracy and consistency within the meta-data, and added or removed observations from existing studies, as appropriate. EPA then re-estimated the MRM and made additional improvements to the model by introducing explanatory variables to account for different survey methodologies, WTP estimation methodologies, payment mechanisms, and water quality metrics used in some of the added studies. A memorandum titled "Revisions to the Water Quality Meta-Data and Meta-Regression Models after the 2020 Steam Electric Analysis through December 2021" (ICF, 2022) details changes to the meta-data and MRMs following the 2020 Steam Electric ELG analysis (U.S. EPA, 2020c), summarizes how the studies and observations included in the meta-data have changed from 2015 to 2020 to present, and compares the latest MRM results with those from 2015 (U.S. EPA, 2015a) and 2020 (U.S. EPA, 2020c).

Table C-1 summarizes studies in the revised meta-data, including number of observations from each study, state-level study location, waterbody type, geographic scope, and household WTP summary statistics. In total, the revised meta-data includes 189 observations from 59 stated preference studies that estimated per household WTP (use plus nonuse) for water quality changes in U.S. waterbodies. The studies address various waterbody types including rivers, lakes, salt ponds/marshes, and estuaries. The ten studies added to the meta-data since 2015 are shaded in Table C-1.

Table C-1. Primary Studies Included in the Meta-data

Study	Obs. In Meta-data	State(s)	Waterbody Type(s)	Geographic Scope	WTP Per Household (2019$)		
					Mean	Min	Max
Aiken (1985)	1	CO	river/ stream and lake	Entire state	$238.19	$238.19	$238.19
G. D. Anderson and Edwards (1986)	1	RI	salt pond /marsh	Coastal salt ponds (South Kingstown, Charlestown, and Narragansett)	$222.82	$222.82	$222.82
Banzhaf *et al.* (2006)	2	NY	lake	Adirondack Park, New York State	$70.86	$66.69	$75.03
Banzhaf *et al.* (2016)	1	VA, WV, TN, NC, GA	river/ stream	Southern Appalachian Mountains region	$18.67	$18.67	$18.67
Bockstael, McConnell, and Strand (1989)	2	MD, DC, VA	estuary	Chesapeake Bay (Baltimore-Washington Metropolitan Area)	$137.31	$93.30	$181.32
Borisova *et al.* (2008)	2	VA/WV	river/ stream	Opequon Creek watershed	$42.54	$22.25	$62.83

Table C-1. Primary Studies Included in the Meta-data

Study	Obs. In Meta-data	State(s)	Waterbody Type(s)	Geographic Scope	WTP Per Household (2019$)		
					Mean	Min	Max
Cameron and Huppert (1989)	1	CA	estuary	San Francisco Bay	$61.07	$61.07	$61.07
Carson *et al.* (1994)	2	CA	estuary	Southern California Bight	$73.24	$50.81	$95.67
Choi and Ready (2019)	6	PA	river/ stream	Three creek watersheds: Spring, Mahantango, and Conewago	$4.56	$1.73	$10.40
Clonts and Malone (1990)	2	AL	river/ stream	15 free-flowing rivers, AL	$112.28	$96.56	$128.00
Collins and Rosenberger (2007)	1	WV	river/ stream	Cheat River Watershed	$22.43	$22.43	$22.43
Collins, Rosenberger, and Fletcher (2009)	1	WV	river/ stream	Deckers Creek Watershed	$229.82	$229.82	$229.82
Corrigan (2008)	1	IA	lake	Clear Lake	$152.03	$152.03	$152.03
Croke, Fabian, and Brenniman (1986-1987)	6	IL	river/ stream	Chicago metropolitan area river system	$90.25	$75.60	$107.18
De Zoysa (1995)	1	OH	river/ stream	Maumee River Basin	$86.53	$86.53	$86.53
Desvousges, Smith, and Fisher (1987)	12	PA	river/ stream	Monongahela River basin (PA portion)	$72.98	$24.46	$169.24
Downstream Strategies LLC (2008)	2	PA	river/ stream	West Branch Susquehanna River watershed	$15.70	$13.19	$18.21
Farber and Griner (2000)	6	PA	river/ stream	Loyalhanna Creek and Conemaugh River basins (western PA)	$93.91	$20.45	$183.21
Hayes, Tyrell, and Anderson (1992)	2	RI	estuary	Upper Narragansett Bay	$490.05	$481.71	$498.38
Herriges and Shogren (1996)	1	IA	lake	Storm Lake watershed	$76.09	$76.09	$76.09
Hite (2002)	2	MS	river/ stream	Entire state	$74.09	$71.81	$76.36
Holland and Johnston (2017)	6	ME	river/ stream	Merriland, Branch Brook and Little River Watershed	$13.90	$8.16	$21.27
Huang, Haab. T.C., and Whitehead (1997)	2	NC	estuary	Albemarle and Pamlico Sounds	$318.92	$314.43	$323.40

Table C-1. Primary Studies Included in the Meta-data

Study	Obs. In Meta-data	State(s)	Waterbody Type(s)	Geographic Scope	WTP Per Household (2019$)		
					Mean	Min	Max
Interis and Petrolia (2016)	10	AL/LA	estuary	Mobile Bay, AL; Barataria-Terrebonne estuary, LA	$87.91	$45.00	$140.47
Irvin, Haab, and Hitzhusen (2007)	4	OH	river/ stream and lake	Entire state	$26.72	$24.22	$28.64
Johnston and Ramachandran (2014)	3	RI	river/ stream	Pawtuxet watershed	$14.11	$7.05	$21.16
Johnston, Swallow, and Bauer (2002)	1	RI	river/ stream	Wood-Pawcatuck watershed	$48.08	$48.08	$48.08
R. J. Johnston et al. (2017)	3	RI	river/ stream	Pawtuxet watershed	$4.79	$2.40	$7.19
Kaoru (1993)	1	MA	salt pond /marsh	Martha's Vineyard	$269.56	$269.56	$269.56
Lant and Roberts (1990)	3	IA/IL	river/ stream	Des Moines, Skunk, English, Cedar, Wapsipinicon, Turkey; Illinois: Rock, Edwards, La Moine, Sangamon, Iroquois, and Vermillion River basins	$177.47	$152.94	$190.26
Lant and Tobin (1989)	9	IA/IL	river/ stream	Edwards River, Wapsipinicon River, and South Skunk drainage basins	$68.59	$50.04	$83.40
Lichtkoppler and Blaine (1999)	1	OH	river/ stream and lake	Ashtabula River and Ashtabula Harbor	$51.69	$51.69	$51.69
Lindsey (1994)	8	MD	estuary	Chesapeake Bay	$82.37	$41.18	$126.02
Lipton (2004)	1	MD	estuary	Chesapeake Bay Watershed	$78.88	$78.88	$78.88
Londoño Cadavid and Ando (2013)	2	IL	river/ stream	Cities of Champaign and Urbana	$47.70	$44.30	$51.10
Loomis (1996)	1	WA	river/ stream	Elwha River	$114.75	$114.75	$114.75
Lyke (1993)	2	WI	river/ stream and lake	Wisconsin Great Lakes	$97.10	$73.68	$120.52
Mathews, Homans, and Easter (1999)	1	MN	river/ stream	Minnesota River	$22.36	$22.36	$22.36

Table C-1. Primary Studies Included in the Meta-data

Study	Obs. In Meta-data	State(s)	Waterbody Type(s)	Geographic Scope	WTP Per Household (2019$)		
					Mean	Min	Max
C. Moore *et al.* (2018)	2	MD, VA, DC, DE, NY, PA, WV, CT, FL, GA, ME, MA, NH, NJ, NC, RI, SC, VT	lake	Chesapeake Bay Watershed	$131.21	$77.75	$184.67
N. M. Nelson *et al.* (2015)	2	UT	river/ stream and lake	Entire state	$259.70	$167.07	$352.33
Opaluch *et al.* (1998)	1	NY	estuary	Peconic Estuary System	$170.73	$170.73	$170.73
Roberts and Leitch (1997)	1	MN/SD	lake	Mud Lake	$10.30	$10.30	$10.30
Rowe *et al.* (1985)	1	CO	river/ stream	Eagle River	$165.95	$165.95	$165.95
Sanders, Walsh, and Loomis (1990)	4	CO	river/ stream	Cache la Poudre, Colorado, Conejos, Dollores, Elk, Encampment, Green, Gunnison, Los Pinos, Piedra, and Yampa rivers	$198.13	$99.89	$258.99
Schulze *et al.* (1995)	4	MT	river/ stream	Clark Fork River Basin	$75.19	$56.62	$95.54
Shrestha and Alavalapati (2004)	2	FL	river/ stream and lake	Lake Okeechobee watershed	$192.92	$170.12	$215.72
Stumborg, Baerenklau, and Bishop (2001)	2	WI	lake	Lake Mendota Watershed	$103.94	$82.28	$125.59
Sutherland and Walsh (1985)	1	MT	river/ stream and lake	Flathead River drainage system	$180.05	$180.05	$180.05
Takatsuka (2004)	4	TN	river/ stream	Clinch River watershed	$353.72	$224.28	$483.16
Van Houtven *et al.* (2014)	32	VA, NC, SC, AL, GA, KY, MS, TN	lake	Entire state (separate observations for each state)	$316.16	$260.91	$374.11
Wattage (1993)	2	IA	river/ stream	Bear Creek watershed	$53.68	$49.61	$57.76
Welle (1986)	4	MN	lake	Entire state	$175.44	$135.13	$227.59

Table C-1. Primary Studies Included in the Meta-data

Study	Obs. In Meta-data	State(s)	Waterbody Type(s)	Geographic Scope	WTP Per Household (2019$)		
					Mean	Min	Max
Welle and Hodgson (2011)	3	MN	lake	Lake Margaret and Sauk River Chain of Lakes watersheds	$178.91	$13.06	$351.48
Wey (1990)	1	RI	salt pond /marsh	Great Salt Pond (Block Island)	$78.85	$78.85	$78.85
Whitehead (2006)	3	NC	river/ stream	Neuse River watershed	$230.79	$33.93	$450.72
Whitehead and Groothuis (1992)	2	NC	river/ stream	Tar-Pamlico River	$43.08	$39.33	$46.82
Whitehead *et al.* (1995)	1	NC	estuary	Albermarle-Pamlico estuary system	$115.56	$115.56	$115.56
Whittington (1994)	1	TX	estuary	Galveston Bay estuary	$240.09	$240.09	$240.09
Zhao, Johnston, and Schultz (2013)	3	RI	river/ stream and lake	Pawtuxet watershed	$7.19	$3.59	$10.78

Similar to the 2015 MRM, the updated MRM satisfies the adding-up condition, a theoretically desirable property.[63] This condition ensures that if the model were used to estimate WTP for the cumulative water quality change resulting from several CWA regulations, the benefits estimates would be equal to the sum of benefits from using the model to estimate WTP for water quality changes separately for each rule (Moeltner, 2019; Newbold *et al.*, 2018).

The meta-analysis is based on 189 observations from 59 stated preference studies, published between 1985 and 2021. The variables in the meta-data fall into four general categories:

- *Study methodology and year variables* characterize such features as the year in which a study was conducted, payment mechanism and elicitation formats, and publication type. These variables are included to explain differences in WTP across studies but are not expected to vary across benefit transfer for different policy applications.
- *Region and surveyed populations* variables characterize such features as the geographical region within the United States in which the study was conducted, the average income of respondent households, and the representation of users and nonusers within the survey sample.
- *Sampled market and affected resource* variables characterize features such as the geospatial scale (or size) of affected waterbodies, the size of the market area over which populations were sampled, as well as land cover and the quantity of substitute waterbodies.

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[63] For a WTP function WTP (WQI_0, WQI_2, Y_0) to satisfy the adding-up property, it must meet the simple condition that $WTP(WQI_0, WQI_1, Y_0) + WTP(WQI_1, WQI_2, Y_0 - WTP(WQI_0, WQI_1, Y_0)) = WTP(WQI_0, WQI_2, Y_0)$ for all possible values of baseline water quality (WQI_0), potential future water quality levels (WQI_1 and WQI_2), and baseline income (Y_0).

- *Water quality (baseline and change)* variables characterize baseline conditions and the extent of the water quality change. To standardize the results across these studies, EPA expressed water quality (baseline and change) in each study using the 100-point WQI, if they did not already employ the WQI or WQL.

In the latest version of the MRM, EPA built upon published versions of the MRM (R. J. Johnston et al., 2017; Johnston, Besedin, & Holland, 2019; U.S. EPA, 2015b, 2020a), with revisions to better account for methodological differences in the underlying studies (see ICF (2022) for detail on changes in the meta-data and the explanatory variables used in the regression equation).

EPA also revised regional indicators to match the U.S. Census regions (U.S. Census Bureau, n.d.). To correct for heteroskedasticity, the model is estimated using weighted least squares with observations weighted by sample size and robust standard errors (J. P. Nelson & Kennedy, 2009). Detailed discussion of this approach can be found in Vedogbeton and Johnston (2020). A comprehensive review of these methods is provided by Stanley (2005).

Table C-2 provides definitions and presents descriptive statistics for variables included in the MRM, based on the meta-data studies.

Table C-2. Definition and Summary Statistics for Model Variables

Variable	Definition	Units	Mean	St. Dev.
Dependent Variable				
ln_OWTP	Natural log of WTP per unit of water quality improvement, per household.	Natural log of 2019$	1.873	1.391
OWTP[a]	WTP per unit of water quality improvement, per household.	2019$	15.931	23.595
Study Methodology and Year				
OneShotVal	Binary variable indicating that the study's survey only included one valuation question.	Binary (Value: 0 or 1)	0.534	0.500
tax_only[b]	Binary variable indicating that the payment mechanism used to elicit WTP is increased taxes.	Binary (Value: 0 or 1)	0.397	0.491
user_cost[b]	Binary variable indicating that the payment mechanism used to elicit WTP is increased user costs.	Binary (Value: 0 or 1)	0.021	0.144
volunt[b]	Binary variable indicating that WTP was estimated using a payment mechanism described as voluntary as opposed to, for example, property taxes.	Binary (Value: 0 or 1)	0.058	0.235
RUM	Binary variable indicating that the study used a Random Utility Model (RUM) to estimate WTP.	Binary (Value: 0 or 1)	0.566	0.497
IBI	Binary variable indicating that the study used the index of biotic integrity (IBI) as the water quality metric (rather than a WQI).	Binary (Value: 0 or 1)	0.079	0.271

Table C-2. Definition and Summary Statistics for Model Variables

Variable	Definition	Units	Mean	St. Dev.
lnyear	Natural log of the year in which the study was conducted (*i.e.*, data was collected), converted to an index by subtracting 1980.	Natural log of years (year ranges from 1981 to 2017).	2.629	0.979
non_reviewed	Binary variable indicating that the study was not published in a peer-reviewed journal.	Binary (Value: 0 or 1)	0.159	0.366
thesis	Binary variable indicating that the study is a thesis.	Binary (Value: 0 or 1)	0.079	0.271
lump_sum	Binary variable indicating that the study provided WTP as a one-time, lump sum or provided annual WTP values for a payment period of five years or less. This variable enables the policy analyst to estimate annual WTP values by setting *lump_sum*=0.	Binary (Value: 0 or 1)	0.180	0.385
Region and Surveyed Populations				
census_south[c]	Binary variable indicating that the affected waters are located entirely within the South Census region, which includes the following states: DE, MD, DC, WV, VA, NC, SC, GA, FL, KY, TN, MS, AL, AR, LA, OK, and TX.	Binary (Value: 0 or 1)	0.349	0.478
census_midwest[c]	Binary variable indicating that the affected waters are located entirely within the Midwest Census region, which includes the following states: OH, MI, IN, IL, WI, MN, IA, MO, ND, SD, NE, and KS.	Binary (Value: 0 or 1)	0.228	0.420
census_west[c]	Binary variable indicating that the affected waters are located entirely within the West Census region, which includes the following states: MT, WY, CO, NM, ID, UT, AZ, NV, WA, OR, and CA.	Binary (Value: 0 or 1)	0.090	0.287
nonusers_only	Binary variable indicating that the survey was implemented over a population of nonusers only (default category for this variable is a survey of any population that includes both users and nonusers).	Binary (Value: 0 or 1)	0.058	0.235
lnincome	Natural log of the median income (in 2019$) for the sample area of each study based on historical U.S. Census data. It was designed to provide a consistent income variable given differences in reporting of respondent income across studies in the meta-data (*i.e.*, mean vs. median). Also, some studies do not report respondent income. This variable was estimated for all studies in the	Natural log of income (2019$)	10.946	0.160

Table C-2. Definition and Summary Statistics for Model Variables

Variable	Definition	Units	Mean	St. Dev.
	meta-data regardless of whether the study reported summary statistics for respondent income.			
Sampled Market and Affected Resource				
swim_use	Binary variable indicating that the affected use(s) stated in the survey instrument include swimming.	Binary (Value: 0 or 1)	0.222	0.417
gamefish	Binary variable indicating that the affected use(s) stated in the survey instrument include game fishing.	Binary (Value: 0 or 1)	0.190	0.394
ln_ar_agr[d]	Natural log of the proportion of the affected resource area that is agricultural based on National Land Cover Database (NLCD), reflecting the nature of land use in the area surrounding the resource. The affected resource area is defined as all counties that intersect the affected resource(s).	Natural log of proportion (Proportion Range: 0 to 1; km^2/km^2)	-1.648	0.912
ln_ar_ratio	The ratio of the sampled area, in km^2, relative to the affected resource area. When not explicitly reported in the study, the affected resource area is measured as the total area of counties that intersect the affected resource(s), to create the variable *ar_total_area*. From here, *ln_ar_ratio* = log(*sa_area* / *ar_total_area*), where *sa_area* is the size of the sampled area in km^2.	Natural log of ratio (km^2/km^2)	-0.594	2.408
sub_proportion[e]	The water bodies affected by the water quality change, as a proportion of all water bodies of the same hydrological type in the sampled area. The affected resource appears in both the numerator and denominator when calculating *sub_proportion*. The value can range from 0 to 1.	Proportion (Range: 0 to 1; km/km or km^2/km^2)	0.351	0.401
Water Quality Baseline and Change				
ln_Q	Natural log of the mid-point of the baseline and policy water quality: Q = *(1/2)(WQI-BL + WQI-PC)*.	Natural log of WQI units	3.944	0.295
lnquality_ch	Natural log of the change in mean water quality (*quality_ch*), specified on the WQI.	Natural log of WQI units	2.552	0.801

a. Provided for informational purposes. Model uses the natural log version of the *OWTP* variable as the dependent variable.

b. The payment types collectively omitted from the payment type binary variables are: (1) increased prices, (2) increased prices and/or taxes, (3) multiple methods, (4) earmarked fund, and (5) not specified/unknown.

Table C-2. Definition and Summary Statistics for Model Variables				
Variable	Definition	Units	Mean	St. Dev.

c. The regions omitted from the regional binary variables are the Northeast Census region (ME, NH, VT, MA, RI, CT, NY, PA, and NJ) and the Chesapeake Bay (studies focused on the Chesapeake Bay or Chesapeake Bay Watershed since the Chesapeake Bay Watershed spans two Census regions).

d. In addition to the *ln_ar_agr* variable, EPA tested a variable for the proportion of the affected resource area that is developed, but it did not improve model fit.

e. The *sub_proportion* estimation method differs by waterbody type. For rivers, the calculation is the length of the affected river reaches as a proportion of all reaches of the same order. For lakes and ponds, the calculation is the area of the affected waterbody as a proportion of all water bodies of the same National Hydrography Dataset classification. For bays and estuaries, the calculation is the shoreline length of the waterbody as a proportion of all analogous (*e.g.*, coastal) shoreline lengths. To account for observations where multiple waterbody types are affected, the variable *sub_proportion* is defined as the maximum of separate substitute proportions for rivers, lakes, and estuaries/bays.

Using the updated meta-data, EPA developed MRMs that predict how WTP for a one-point improvement on the WQI (hereafter, one-point WTP) depends on a variety of methodological, population, resource, and water quality change characteristics. The estimated MRMs predict the one-point WTP values that would be generated by a stated preference survey with a particular set of characteristics chosen to represent the water quality changes and other specifics of the regulatory options where possible, and using best practices in economic literature (*e.g.*, excluding outlier responses from estimating WTP). As with the 2015 meta-analysis, EPA developed two MRMs (U.S. EPA, 2015a). Model 1 is used to provide EPA's main estimate of non-market benefits. Model 2 provides alternative estimates by including an additional variable (*lnquality_ch*), which accounts for the magnitude of WQI changes (*e.g.*, low or high) and the associated effect on estimated WTP values. The two models differ only in how they account for the magnitude of the water quality changes presented to respondents in the original stated preference studies:

- ***Model 1*** assumes that individuals' one-point WTP depends on the average level of water quality between the baseline and the policy. It does not depend on the magnitude of the water quality change specified in the surveys of studies included in the underlying meta-data. This restriction means that the meta-model satisfies the adding-up condition, a theoretically desirable property.
- ***Model 2*** allows one-point WTP to depend not only on the average level of water quality but also on the magnitude of the water quality change specified in the surveys of studies included in the underlying meta-data. The model allows for the possibility that the WTP for a one-point improvement on the WQI depends on both the average level of water quality between the baseline and the policy scenario and the total water quality change that respondents were asked to value. Since environmental quality is considered by economists to be a normal good,[64] one-point WTP is expected to decrease when the total WQI change increases according to the law of diminishing marginal utility. As indicated by a negative sign on the *lnquality_ch* coefficient, the estimated WTP for a one-point improvement on the WQI scale is larger when respondents were asked to value a 10-point improvement compared to a 20-point improvement. EPA used Model 2 to generate alternative estimates of non-market benefits. This model provides a better statistical fit to the meta-data, but it satisfies the adding-up condition only if the same magnitude of the water quality change is considered (*e.g.*, 10 points). To uniquely define the demand curve and satisfy the adding-up condition using this

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[64] Environmental quality, including water quality, is a "normal" good because people want more of it as their real incomes increase.

model, EPA treats the water quality change variable as a methodological variable and therefore must make an assumption about the size of the water quality change that would be appropriate to use in a stated preference survey designed to value water quality changes resulting from the regulatory options.

EPA used the two MRMs in a benefit transfer approach that follows standard methods described by Johnston *et al.* (2005), Shrestha, Rosenberger, and Loomis (2007), and R.S. Rosenberger & Phipps, 2007. Based on the benefit transfer literature (*e.g.*, Stapler & Johnston, 2009; K.J. Boyle & Wooldridge, 2018), methodological variables are assigned values that either reflect "best practices" associated with reducing measurement errors in primary studies or set to their mean values over the meta-data. The literature also recommends setting variables representing policy outcomes and policy context (*i.e.*, resource and population characteristics) at the levels that might be expected from a regulation. The benefit transfer approach uses CBGs as the geographic unit of analysis.[65] The transfer approach involved projecting benefits in each CBG and year, based on the following general benefit function:

Equation B-1.

$$\ln\left(OWTP_{Y,B}\right) = Intercept + \sum (coefficient_i) \times (independent\ variable\ value_i)$$

Where

$ln(OWTP_{Y,B})$ = The predicted natural log of household WTP for a one-point improvement in WQI score in a given year (*Y*) and CBG (*B*).

coefficient = A vector of variable coefficients from the meta-regression.

independent variable values = A vector of independent variable values. Variables include baseline water quality level ($WQI\text{-}BL_{Y,B}$) and expected water quality under the regulatory option ($WQI\text{-}PC_{Y,B}$) for a given year and CBG.

Here, $ln(OWTP_{Y,B})$ is the dependent variable in the meta-analysis—the natural log of an average WTP per one-point WQI score improvement per household, in a given CBG *B* for water quality in a given year *Y*.[66] The baseline water quality level ($WQI\text{-}BL_{Y,B}$) and expected water quality under the regulatory option ($WQI\text{-}PC_{Y,B}$) were based on water quality in waterbodies both within the selected water resource regions and within a 100-mile buffer of the centroid of each CBG. A buffer of 100 miles is consistent with Viscusi, Huber, and Bell (2008) and the finding that approximately 80 percent of recreational trips occur

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[65] A Census Block group is a group of Census Blocks (the smallest geographic unit for the Census) in a contiguous area that never crosses a State or county boundary. A block group typically contains a population between 600 and 3,000 individuals. There are 239,780 block groups in the United States based on the 2020 Census. See https://www.census.gov/geographies/reference-files/time-series/geo/tallies.html. http://www.census.gov/geo/maps-data/data/tallies/tractblock.html

[66] To satisfy the adding-up condition, as noted above, EPA normalized WTP values reported in the studies included in the meta-data so that the dependent variable is WTP for a one-point improvement on the WQI.

within a 2-hour drive from home.[67] Because one-point WTP is assumed to depend, according to Equation B-1, on both baseline water quality level ($WQI\text{-}BL_{Y,B}$) and expected water quality under the regulatory option ($WQI\text{-}PC_{Y,B}$), EPA estimated the one-point WTP for water quality changes resulting from the regulatory options at the mid-point of the range over which water quality was changed, $WQI_{Y,B} = (1/2)(WQI\text{-}BL_{Y,B} + WQI\text{-}PC_{Y,B})$.

In this analysis, EPA estimated WTP for the households in each CBG for waters within the selected water resource regions and within a 100-mile radius of that CBG's centroid. EPA chose the 100 mile-radius because households are likely to be most familiar with waterbodies and their qualities within the 100-mile distance. However, this assumption may be an underestimate of the distance within which households have familiarity with and WTP for waterbodies affected by MPP facility discharges and their quality. By focusing on a buffer around the CBG as a unit of analysis, rather than buffers around affected waterbodies, each household is included in the assessment exactly once, eliminating the potential for double-counting of households.[68] Total WTP is calculated as the sum of estimated CBG-level WTP across all CBGs that have at least one affected waterbody whose water quality is improved within the selected water resource regions and within 100 miles. Using this approach, EPA is unable to analyze the WTP for CBGs with no affected waters within 100 miles of the selected water resource regions even though households in those CBGs may value waters for use purposes farther than 100 miles from their home or are familiar with and have nonuse values for such waters.

In each CBG and year, predicted WTP per household is tailored by choosing appropriate input values for the meta-analysis parameters describing the resource(s) valued, the extent of resource changes (*i.e.*, $WQI\text{-}PC_{Y,B}$), the scale of resource changes relative to the size of the buffer and relative to available substitutes, the characteristics of surveyed populations (*e.g.*, users, nonusers), and other methodological variables. For example, EPA projected that household income (an independent variable) changes over time, resulting in household WTP values that vary by year.

Table C-3 provides details on how EPA used the meta-analysis to predict household WTP for each CBG and year. The table presents the estimated regression equation intercepts and variable coefficients ($coefficient_i$) for the two models, and the corresponding independent variables names and assigned values. The MRM allows the Agency to forecast WTP based on assigned values for model variables that are chosen to represent a resource change in the context of the regulatory options.

In this instance, EPA assigned six study and methodology variables, (*thesis, volunt, non_reviewed, lump_sum, user_cost*, *IBI*) a value of zero. Three methodological variables (*OneShotVal*, *tax_only*, *RUM*) were included with an assigned value of 1. For the study year variable *(lnyear)*, EPA gave the variable a value of 3.6109 (or the ln(2017-1980)), which is the maximum value in the meta-data. This value assignment reflects a time trend interpretation of the variable. Model 2 includes an additional variable, water quality change (*ln_quality_ch*), which allows the benefit transfer function to reflect differences in one-point WTP based on the magnitude of changes presented to survey respondents when eliciting WTP

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[67] According to Viscusi, Huber, and Bell (2008), the EPA National Center for Environmental Economics used data from the 1996 National Survey on Recreation and the Environment to calculate that 77.9 percent of boating visits, 78.1 percent of fishing visits, and 76.9 percent of swimming recreational visits are within a 100 mile radius of users' homes.

[68] Population double-counting issues can arise when using "distance to waterbody" to assess simultaneous improvements to many waterbodies.

values. To ensure that the benefit transfer function satisfies the adding-up condition, the *ln_quality_ch* variable was treated as a demand curve shifter, similar to the methodological control variables, and held fixed for the benefit calculations across all CBGs. To estimate low and high alternative analysis values of WTP for water quality changes resulting from the regulatory options, EPA estimated one-point WTP using two alternative settings of the *ln_quality_ch* variable: ΔWQI = 7 units and ΔWQI = 20 units. These two values represent the 25th percentile and 75th percentile values of the meta-data.

All but one of the region and surveyed population variables vary based on the characteristics of each CBG. EPA set the variable *nonusers_only* to zero for all CBGs because water quality changes are expected to enhance both use and nonuse values of the affected resources and thus benefit both users and nonusers (a nonuser value of 1 implies WTP values that are representative of nonusers only, whereas the default value of 0 indicates that both users and nonusers are included in the surveyed population). For median household income, EPA used CBG-level median household income data from the 2021 American Community Survey (5-year data) and accounted for projected income growth over the analysis period using the methodology described in Section 1.3.6.

Table C-3. Independent Variable Assignments for Surface Water Quality Meta-Analysis

Variable	Coefficient		Assigned Value	Explanation
	Model 1	Model 2		
Study Methodology and Year				
intercept	-2.823	-10.020		
OneShotVal	0.247	0.552	1	Binary variable indicating that the study's survey only included one valuation question. Set to one because one valuation scenario follows best practices for generating incentive-compatible WTP estimates (Carson, Groves, & List, 2014; Johnston, Boyle, *et al.*, 2017).
tax_only	-0.177	-0.478	1	Binary variable indicating that the payment mechanism used to elicit WTP is increased taxes. Set to one because using taxes as the payment mechanism generates incentive-compatible WTP estimates and is inclusive of both users and nonusers.
user_cost	-0.873	-1.199	0	Binary variable indicating that the payment mechanism used to elicit WTP is increased user cost. Set to zero because user cost payment mechanisms are less inclusive of nonusers than tax-based payment mechanisms.
volunt	-1.656	-1.870	0	Binary variable indicating that WTP was estimated using a payment mechanism described as voluntary as opposed to, for example, property taxes. Set to zero because hypothetical voluntary payment mechanisms are not incentive compatible (Johnston, Boyle, *et al.*, 2017).
RUM	0.901	0.680	1	Binary variable indicating that the study used a Random Utility Model (RUM) to estimate WTP. Set to one because use of a RUM to estimate WTP is a standard best practice in modern stated preference studies.
IBI	-2.355	-2.185	0	Binary variable indicating that the study used the IBI as the water quality metric. Set to zero because the meta-regression uses the WQI as the water quality metric, not the IBI.

Table C-3. Independent Variable Assignments for Surface Water Quality Meta-Analysis

Variable	Coefficient		Assigned Value	Explanation
	Model 1	Model 2		
lnyear	-0.135	-0.362	ln(2017-1980)	Natural log of the year in which the study was conducted (*i.e.*, data were collected), converted to an index by subtracting 1980. Set to the natural log of the maximum value from the meta-data (ln(2017-1980)) to reflect a time trend interpretation of the variable.
non_reviewed	-0.233	-0.247	0	Binary variable indicating that the study was not published in a peer-reviewed journal. Set to zero because studies published in peer-reviewed journals are preferred.
thesis	0.431	0.580	0	Binary variable indicating that the study is a thesis or dissertation. Set to zero because studies published in peer-reviewed journals are preferred.
lump_sum	0.534	0.518	0	Binary variable indicating that the study provided WTP as a one-time, lump sum or provided annual WTP values for a payment period of five years or less. Set to zero to reflect that the majority of studies from the meta-data estimated an annual WTP, and to produce an annual WTP prediction.
Region and Surveyed Population				
census_south	0.693	0.990	Varies	Binary variable indicating that the affected waters are located entirely within the South Census region, which includes the following states: DE, MD, DC, WV, VA, NC, SC, GA, FL, KY, TN, MS, AL, AR, LA, OK, and TX. Set based on the state in which the CBG is located.
census_midwest	0.667	0.945	Varies	Binary variable indicating that the affected waters are located entirely within the Midwest Census region, which includes the following states: OH, MI, IN, IL, WI, MN, IA, MO, ND, SD, NE, and KS. Set based on the state in which the CBG is located.
census_west	0.393	0.400	Varies	Binary variable indicating that the affected waters are located entirely within the West Census region, which includes the following states: MT, WY, CO, NM, ID, UT, AZ, NV, WA, OR, and CA. Set based on the state in which the CBG is located.
nonusers	-0.283	-0.380	0	Binary variable indicating that the sampled population included nonusers only; the alternative case includes all households. Set to zero to estimate the total value for water quality changes for all households, including users and nonusers.
lnincome	0.478	1.199	Varies	Natural log of median household income values assigned separately for each CBG. Varies by year based on the estimated income growth in future years.

Table C-3. Independent Variable Assignments for Surface Water Quality Meta-Analysis

Variable	Coefficient		Assigned Value	Explanation
	Model 1	Model 2		
Sampled Market and Affected Resource				
swim_use	0.300	0.361	0	Binary variables that identify studies in which swimming and gamefish uses are specifically identified. Set to zero, which corresponds to all recreational uses, since data on specific recreational uses of the reaches in HUC12s affected by MPP facility discharges are not available.
gamefish	0.871	0.531	0	
ln_ar	-0.572	-0.654	Varies	Natural log of the proportion of the affected resource area which is agricultural based on National Land Cover Database, reflecting the nature of development in the area surrounding the resource. Used Census county boundary layers to identify counties that intersect affected HUC12s (*i.e.,* HUC12s downstream from any MPP discharger) within the 100-mile buffer of each CBG. For intersecting counties, calculated the fraction of total land area that is agricultural using the National Land Cover Dataset (NLCD). The *ln_ar_agr* variable was coded in the meta-data to reflect the area surrounding the affected resources.
ln_ar_ratio	-0.157	-0.153	0.00846	The natural log of the ratio of the sampled area (*sa_area*) relative to the affected resource area (defined as the total area of counties that intersect the affected resource[s]) (*ar_total_area*). For the MPP scenario, *ln_ar_ratio* is calculated for each HUC12 within the scope of the analysis (*i.e.,* HUC12s downstream from any MPP discharger), and the final value is set to the mean value across all affected HUC12s. For each affected HUC12, *sa_area* is set based on the total area within the 100-mile buffer that intersects CBGs (*i.e.*, excludes portions of the buffer that intersect coastal areas), while *ar_total_area* is set based on the area of counties intersecting each affected HUC12.
sub_proportion	0.993	0.650	Varies	The size of the resources within the scope of the analysis relative to available substitutes. Calculated for each CBG as the ratio of reach miles within the 100-mile buffer *and* within affected HUC12s (*i.e.,* HUC12s downstream from any MPP discharger) to the total reach miles within the 100-mile buffer. Its value can range from 0 to 1.
Water Quality				
ln_Q	-0.666	-0.259	Varies	Because WTP for a one-point improvement on the WQI is assumed to depend on both baseline water quality and expected water quality under the regulatory option, this variable is set to the natural log of the mid-point of the range of water quality for the baseline and policy scenarios, $WQI_{Y,B} = (1/2)(WQI\text{-}BL_{Y,B} + WQI\text{-}PC_{Y,B})$. Calculated as the length-weighted average WQI score for all potentially affected HUC12s (*i.e.,* HUC12s with non-zero changes under each regulatory option) within the 100-mile buffer of each CBG.

Table C-3. Independent Variable Assignments for Surface Water Quality Meta-Analysis

Variable	Coefficient		Assigned Value	Explanation
	Model 1	Model 2		
lnquality_ch	NA	-0.683	ln(7) ln(20)	*ln_quality_ch* was set to the natural log of ΔWQI=7 or ΔWQI=20 for high and low estimates of one-point WTP, respectively.

Appendix D: Monetized Benefits and Social Costs using a 7 Percent Discount Rate

Nonmarket Benefits from Water Quality Changes

Sections 4.2 and 4.3 present main model and alternative model results, respectively, using a 3 percent discount rate and water quality modeling for five water resources regions (HUC regions 02, 03, 05, 07, and 08). This appendix presents nonmarket benefits from water quality changes using a 7 percent discount rate and water quality modeling for five water resources regions (HUC regions 02, 03, 05, 07, and 08). Table D-1 presents results based on Model 1, whereas Table D-2 presents alternative benefit estimates based on Model 2, using the same low and high *lnquality_ch* settings as described in Section 4.3.

Table D-1: Estimated Household and Total Annualized Willingness-to-Pay for Water Quality Improvements in Selected Regions under Regulatory Options, using Model 1 and 7 Percent Discount Rate (Main Estimates)

Regulatory Option	Number of Affected Households (Millions)[a]	Average Annual WTP Per Household (2022$)[b]	Total Annualized WTP (Millions 2022$)[b,c]
Option 1	67.2	$0.67	$39.4
Option 3	85.5	$1.27	$94.7

a. The number of affected households varies across options because of differences in the number of HUC12s that have non-zero changes in water quality.

b. Estimates based on Model 1, which provides EPA's main estimate of non-market benefits.

c. Estimated benefits are regional-level rather than national-level since water quality modeling was limited to selected level 2 HUC water resource regions (see Section 3 for details).

Source: U.S. EPA Analysis, 2023

Table D-2: Estimated Household and Total Annualized Willingness-to-Pay for Water Quality Improvements in Selected Regions under Regulatory Options, using Model 2 and 7 Percent Discount Rate (Alternative Model Analysis)

Regulatory Option	Number of Affected Households (Millions)[a]	Average Annual WTP Per Household (2022$)[b]		Total Annualized WTP (Millions 2022$)[b,c]	
		Low	High	Low	High
Option 1	67.2	$0.24	$0.50	$15.0	$30.7
Option 3	85.5	$0.46	$0.94	$35.3	$72.3

a. The number of affected households varies across options because of differences in the number of HUC12s that have non-zero changes in water quality.

b. Estimates based on Model 2, an alternative model that includes the DWQI variable (*lnquality_ch*). For the ΔWQI variable setting in the Model 2-based analysis, EPA used values of 20 units to develop low estimates and 7 units to develop high estimates (see Appendix C for details).

c. Estimated benefits are regional-level rather than national-level since water quality modeling was limited to selected level 2 HUC water resource regions (see Section 3 for details).

Source: U.S. EPA Analysis, 2023

Climate Change and Air Quality Benefits

Section 5.3 presents the monetized health effects from the changes in air emissions attributable to the proposed rule using a 3 percent discount rate. This section presents the estimated health effects using a

7 percent discount rate, based on the benefit per ton values in Table D-3. The results in Table D-4 also includes the estimated climate change benefits presented in Section 5.2.

Table D-3: Benefit per Ton Values by Emission Category, at 7 Percent Discount Rate ($2022)

Category	Year and Basis	Benefit per ton, SO_2 ($/ton)	Benefit per ton, NO_x ($/ton)	
			$PM_{2.5}$-related benefits	Ozone-related benefits
Electricity usage[a]	2025	$56,296	$7,601	$96,734
	2030	$63,432	$8,529	$127,997
	2035	$71,248	$9,537	$141,589
	2040	$77,817	$10,342	$152,916
Transportation[b]	2025; Krewski et al., 2009	$291,656	$6,805	
	2025; Lepeule et al., 2012	$656,226	$15,798	

a. Estimate of total dollar value of benefits (mortality and morbidity) for changes in emissions from electricity generating units. Updated from 2019 dollars to 2022 dollars using the GDP deflator (GDP deflator 2022 / GDP deflator 2019 = 1.333). [U.S. EPA, 2023n]

b. National average estimate of total dollar value of benefits (mortality and morbidity) for changes in emissions from on-road, heavy duty diesel vehicles in 2025. Updated from 2015 dollars using the GDP deflator (GDP deflator 2022 / GDP deflator 2015 = 1.215). [Wolfe *et al.*, 2019]

Table D-4: Total Annualized Climate Change and Air Quality-Related Benefits by Regulatory Option (Millions of 2022$)

Regulatory Option	SC-GHG Discount Rate	Climate Change Benefits	Human Health Benefits at 7 Percent Discount Rate		Total	
			Krewski et al. (2009)	2025; Lepeule et al., 2012	Krewski et al. (2009)	2025; Lepeule et al., 2012
1	3% (Average)	-$1.9	-$2.7	-$2.8	-$4.7	-$4.7
	5% (Average)	-$0.6	-$2.7	-$2.8	-$3.4	-$3.4
	2.5% (Average)	-$2.7	-$2.7	-$2.8	-$5.5	-$5.5
	3% (95th Percentile)	-$5.9	-$2.7	-$2.8	-$8.6	-$8.6
2	3% (Average)	-$7.0	-$10.1	-$10.1	-$17.1	-$17.1
	5% (Average)	-$2.3	-$10.1	-$10.1	-$12.4	-$12.4
	2.5% (Average)	-$10.0	-$10.1	-$10.1	-$20.1	-$20.1
	3% (95th Percentile)	-$21.5	-$10.1	-$10.1	-$31.6	-$31.6
3	3% (Average)	-$10.1	-$14.5	-$14.6	-$24.6	-$24.7
	5% (Average)	-$3.3	-$14.5	-$14.6	-$17.8	-$17.9
	2.5% (Average)	-$14.4	-$14.5	-$14.6	-$28.9	-$28.9
	3% (95th Percentile)	-$30.9	-$14.5	-$14.6	-$45.4	-$45.5

Source: U.S. EPA Analysis, 2023

Social Costs

Section 7.2 presented the total social costs discounted and annualized using a 3 percent discount rate. Table D-5 provides social costs discounted at 7 percent.

Table D-5: Estimated Total Social Costs by Regulatory Option and Discharge Type, 7 Percent Discount Rate (Million of 2022$)

Regulatory Option	Direct	Indirect	Total
Option 1	$211.7	$15.3	$227.0
Option 2	$211.7	$420.0	$631.7
Option 3	$218.7	$848.9	$1,067.5
Option 1 with chlorides	$273.7	$107.9	$381.7
Option 2 with chlorides	$273.7	$512.7	$786.4
Option 3 with chlorides	$280.7	$941.5	$1,222.2

Source: U.S. EPA Analysis, 2023.

Appendix E: Extrapolation of Nonmarket Benefits from Water Quality Changes

EPA is modeling water quality improvements using SWAT and estimating the total public WTP for these water quality improvements using a model that relates WQI values (see section 3.3 and Appendix B) to the characteristics of the affected resources, population, and other factors (see section 4.1 and Appendix C). As described in Section 3 and 4, due to data and modeling constraints,[69] EPA performed the detailed analysis for selected water resources regions and regulatory options.

To provide insight into the potential magnitude of total monetized benefits of the three regulatory options analyzed for the proposed rule, EPA extrapolated water quality benefits for the subset of explicitly modeled water resources regions and regulatory options to obtain national estimates across regulatory options. The extrapolation approach described in this Appendix was designed to be readily implemented using available information and to provide transparency, but relies on simplifying assumptions regarding the characteristics of affected resources and benefiting populations across the regions.

Model Scope

Figure E-1 shows the map of the level 2 Hydrologic Unit Code (HUC) water resource regions.

Figure E-1: Map of HUC2 water resources regions (source: USGS)

Table E-1 provides the number of MPP facilities and share of total industry load reductions across the regions, by pollutant and regulatory option. As shown in the table, a subset of the 18 water resources regions accounts for a disproportionate share of total pollutant load reductions across the regulatory

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[69] At the time of this report, flow calibration was completed for eight of the 18 regions in the conterminous United States and additional time would be needed to calibrate and complete model set up for additional regions, before calculating the required MRM geospatial variables, completing model runs, and analyzing the results.

options. Thus, for the preferred Option (Option 1), regions 02 (Mid Atlantic), 03 (South Atlantic-Gulf), 05 (Ohio), 07 (Upper Mississippi), and 08 (Lower Mississippi) together capture 51.0 percent of the total TN load reductions, 43.6 percent of total TP load reductions, and 21.5 percent of total TSS load reductions. Together, regions 10 (Missouri) and 11 (Arkansas-White-Red) account for an additional 40.4 percent of TN, 50.4 percent of TP, and 68.8 percent of TSS total load reductions, but calibration had not yet been completed for these two regions at the time of this report, therefore limiting EPA's ability to account for these additional reductions through explicit modeling.

In general, the greater the share of total load reductions explicitly modeled, the less consequential is extrapolation uncertainty when scaling the results to the rest of the conterminous United States. Thus, if EPA modeled the seven regions noted above (*i.e.,* 02, 03, 05, 07, 08, 10, and 11), then the benefits associated with over 90 percent of the total loading reductions estimated under Option 1 would have been modeled explicitly, leaving less than 10 percent of the total loading reductions as needing to have their associated benefits estimated by extrapolation.

Table E-1: Number of MPP Facilities and Share of Loading Reductions by Water Resource Region, Pollutant, and Regulatory Option

Water resource region	Number of MPP Facilities		TN			TP			TSS		
	Direct	Indirect	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
01: New England	0	137	0.0%	0.0%	0.3%	0.0%	0.0%	0.2%	0.0%	0.0%	0.1%
02: Mid Atlantic	26	529	0.9%	8.0%	9.4%	0.7%	4.6%	6.1%	5.6%	6.9%	7.9%
03: South Atlantic-Gulf	31	459	32.3%	23.3%	18.7%	24.2%	21.4%	20.4%	9.6%	9.6%	9.9%
04: Great Lakes	9	224	1.5%	1.9%	4.4%	0.7%	2.0%	2.6%	1.7%	2.4%	2.8%
05: Ohio	12	254	3.1%	5.9%	6.8%	3.1%	5.5%	5.3%	3.6%	4.3%	4.4%
06: Tennessee	3	67	2.4%	2.6%	2.0%	2.1%	2.0%	1.9%	3.7%	2.7%	2.5%
07: Upper Mississippi	18	405	10.5%	11.5%	15.3%	12.8%	12.7%	13.5%	1.4%	6.3%	7.7%
08: Lower Mississippi	11	49	4.2%	2.0%	1.8%	2.8%	1.9%	1.9%	1.2%	1.1%	1.2%
09: Souris-Red-Rainy	0	10	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
10: Missouri	14	219	22.8%	13.0%	11.5%	31.4%	22.1%	19.9%	62.3%	47.1%	43.3%
11: Arkansas-White-Red	22	145	17.6%	18.7%	15.7%	19.0%	19.5%	18.1%	6.6%	11.6%	11.2%
12: Texas-Gulf	8	179	4.7%	6.6%	6.0%	3.1%	4.8%	4.9%	0.7%	3.0%	3.2%
13: Rio Grande	0	31	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
14: Upper Colorado	0	12	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
15: Lower Colorado	0	39	0.0%	0.4%	0.2%	0.0%	0.2%	0.2%	0.0%	0.2%	0.2%
16: Great Basin	1	48	0.0%	1.7%	1.4%	0.0%	1.0%	1.1%	0.0%	1.0%	1.0%
17: Pacific Northwest	2	135	0.0%	0.4%	1.0%	0.0%	0.2%	0.5%	0.0%	0.1%	0.3%
18: California	0	415	0.0%	4.0%	5.4%	0.0%	2.1%	3.5%	3.6%	3.7%	4.3%
Total[a]	**157**	**3,357**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Regions 02+03+05+07+08	*98*	*1,696*	*51.0%*	*50.7%*	*51.9%*	*43.6%*	*46.1%*	*47.2%*	*21.5%*	*28.2%*	*31.1%*
Regions 10+11	*36*	*364*	*40.4%*	*31.7%*	*27.1%*	*50.4%*	*41.5%*	*38.0%*	*68.8%*	*58.7%*	*54.5%*
Other Regions	*23*	*1,297*	*8.6%*	*17.6%*	*20.9%*	*6.0%*	*12.4%*	*14.9%*	*9.7%*	*13.0%*	*14.4%*

a. An additional 14 direct dischargers and 351 indirect dischargers could not be assigned to a region due to missing location information.

Source: U.S. EPA Analysis, 2023.

Extrapolation Approach

EPA extrapolates modeled total WTP for the explicitly modeled regions to the rest of the conterminous United States based on the relative loading reductions under each option. The approach rests on the relationships between reductions in the point source loadings of individual pollutants, changes in-stream concentrations in receiving and downstream waters, WQI changes, the estimated WTP for water quality improvements, and populations who value these improvements. Implicit in this approach is the assumption that the affected waters in non-modeled regions are similar to those in the explicitly modeled regions with respect to hydrography (*e.g.,* flow, stream order), contributions of pollutant sources within the watersheds, and substitute reaches. The approach also implicitly assumes that populations valuing these improvements are similar with respect to socioeconomic characteristics (*e.g.,* income), proximity to improving waters, and other factors.

The extrapolation first divides the annualized WTP for modeled regions by an aggregate measure of pollutant load reductions to obtain a unit benefit value for each option (in dollars per pounds). This unit benefit value is then applied to the remaining regions to estimate benefits of loading reductions in these regions, accounting for differences in the size of the respective populations. Specifically, to estimate total WTP for the unmodeled regions under each option, EPA multiplies the unit benefit value by the aggregate load reductions in unmodeled regions and the ratio of the respective populations in the two sets of regions:

$$\$TWTP_{unmodeled,Option} = \mathit{\Delta} Load_{unmodeled,Option} \times \frac{\$TWTP_{modeled,option}}{\mathit{\Delta} Load_{modeled,Option}} \times \frac{Population_{unmodeled}}{Population_{modeled}}$$

The aggregate load measure reflects the estimated reductions in MPP loads of TN, TP, and TSS[70] in each region, adjusted to account for the relative influence of the three pollutants on the changes in WQI scores. The load adjustment is done because instream TP concentrations are generally an order of magnitude smaller than TN concentrations, which are in turn much smaller than TSS concentrations. Furthermore, in the WQI, the TN and TP subindex scores each have a higher influence on the overall WQI than the TSS subindex score. Thus, EPA calculated the weighted sum of loading reductions for TN, TP and TSS, where the weights reflect the relative magnitude of instream pollutant concentrations, as well as the pollutants' relative weights in the WQI score. See Table E-2 for details.

The relative magnitude of instream pollutant concentrations is based on the midpoint of concentrations corresponding to scores of 10 and 100 for the WQI subindex curves presented in Appendix B, benchmarked to the midpoint of TP concentrations. On average, the midpoint TN concentrations across the nine ecoregions is 0.2 times the corresponding midpoint TP concentrations. On average, the midpoint TSS concentrations across the nine ecoregions is 0.006 times the corresponding midpoint TP concentrations.

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[70] ICF is also modeling changes in biochemical oxygen demand and using dissolved oxygen modeled in SWAT.

Table E-2: Adjustment factors used to calculate the aggregate load reductions

Parameter	WQI weight (see Table B-2)	WQI relative weight for TN, TP, and TSS [a]	Relative magnitude of concentrations [b]	Overall weight applied to load reductions [a] x [b]
Dissolved Oxygen	0.24			
Fecal Coliform	0.22			
Biochemical Oxygen Demand	0.15			
Total Nitrogen	0.14	0.36	0.2	0.084
Total Phosphorus	0.14	0.36	1.0	0.359
Total Suspended Solids	0.11	0.28	0.006	0.002

Source: U.S. EPA Analysis, 2023.

The aggregate load changes are thus calculated using the following equation where $\Delta Load$, ΔTN, ΔTP and ΔTSS are load changes in kg.

$$\Delta Load = 0.084 \times \Delta TN + 0.359 \times \Delta TP + 0.002 \times \Delta TSS$$

Table E-3 summarizes pollutant loading reductions across water resources regions and regulatory options, including the aggregate pollutant load reductions used as basis for calculating the extrapolation scaling factor.

EPA calculated the population adjustment based on the 2010 population in each of the water resources regions (U.S. EPA, 2017a). The population in the explicitly modeled regions is 152.2 million people, compared to 154.3 million people in the remaining regions, resulting in an adjustment factor of 1.01.

Interpolation of Option 2 Benefits

EPA interpolates Option 2 results based on modeled total WTP for Option 1 and Option 3, assuming that the total WTP is proportional to the loading reductions for the three options. Thus, the aggregate loading reductions for Option 2 (4.4 million kg for the explicitly modeled water resources regions) fall between those of Option 1 (1.6 million kg) and Option 3 (6.0 million kg), so EPA interpolated the total WTP estimates linearly:

$$\begin{aligned}\$TWTP_{modeled,Option\ 2} \\ &= \$TWTP_{modeled,option1} \\ &+ \left(\Delta Load_{modeled,Option2} - \Delta Load_{modeled,Option1}\right) \\ &\times \frac{\left(\$TWTP_{modeled,option3} - \$TWTP_{modeled,option1}\right)}{\left(\Delta Load_{modeled,Option3} - \Delta Load_{modeled,Option1}\right)}\end{aligned}$$

Limitations and Uncertainty

The extrapolation approach rests on assumptions that factors determining the WTP are similar across regions, such as the characteristics of receiving waters (*e.g.*, stream order, flow, baseline water quality) and populations (*e.g.*, income), and differences in WTP across regions is then mostly determined by the magnitude of loading reductions and populations.

The uncertainty in the total national benefits is driven primarily by the share of the benefits that was estimated based on extrapolation, as opposed to modeled explicitly. The five explicitly modeled regions together account for 45 percent to 49 percent of the aggregate loading reductions across the conterminous United States, with the shares varying across regulatory options and parameters. For example, under Option 1 the five explicitly modeled regions account for 51 percent of total TN reductions, 44 percent of total TP reductions, and 22 percent of total TSS reductions. Additionally, approximately half of the total population of the conterminous United States in 2010 lived in the five explicitly modeled regions (U.S. EPA, 2017a). Accordingly, almost half of the total benefits extrapolated based on these two primary factors were explicitly modeled (44 percent of total Option 1 benefits, 49 percent of the total Option 3 benefits), with the explicitly modeled benefits providing lower bounds of the total benefit estimates for these two options.

Table E-3: Loading Reductions by Water Resource Region, Pollutant, and Regulatory Option

Water resource region	**TN Load Reduction (million kg)**			**TP Load Reduction (million kg)**			**TSS Load Reduction (million kg)**			**Aggregate Load Reduction (million kg)**		
	Option 1	**Option 2**	**Option 3**	**Option 1**	**Option 2**	**Option 3**	**Option 1**	**Option 2**	**Option 3**	**Option 1**	**Option 2**	**Option 3**
01: New England	-	-	0.110	-	-	0.015	-	-	0.053	-	-	0.015
02: Mid Atlantic	0.035	1.620	3.193	0.024	0.334	0.523	1.378	2.574	3.237	0.014	0.260	0.461
03: South Atlantic-Gulf	1.276	4.728	6.321	0.831	1.552	1.761	2.365	3.544	4.078	0.409	0.959	1.169
04: Great Lakes	0.058	0.384	1.503	0.025	0.147	0.223	0.415	0.874	1.136	0.014	0.087	0.208
05: Ohio	0.122	1.188	2.293	0.105	0.398	0.458	0.897	1.574	1.808	0.049	0.245	0.360
06: Tennessee	0.096	0.528	0.692	0.074	0.147	0.163	0.912	0.987	1.013	0.036	0.099	0.118
07: Upper Mississippi	0.416	2.335	5.165	0.438	0.918	1.167	0.346	2.345	3.182	0.193	0.529	0.857
08: Lower Mississippi	0.167	0.404	0.606	0.097	0.141	0.164	0.304	0.425	0.493	0.049	0.085	0.110
09: Souris-Red-Rainy	-	-	0.022	-	-	0.004	-	-	0.004	-	-	0.003
10: Missouri	0.901	2.624	3.885	1.079	1.602	1.719	15.320	17.452	17.809	0.488	0.823	0.972
11: Arkansas-White-Red	0.695	3.791	5.297	0.652	1.411	1.560	1.615	4.305	4.626	0.295	0.832	1.012
12: Texas-Gulf	0.188	1.343	2.024	0.106	0.346	0.422	0.166	1.115	1.328	0.054	0.239	0.323
13: Rio Grande	-	-	-	-	-	-	-	-	0.001	-	-	0.000
14: Upper Colorado	-	-	0.006	-	-	0.000	0.000	0.000	0.001	0.000	0.000	0.001
15: Lower Colorado	-	0.080	0.084	-	0.017	0.019	-	0.086	0.090	-	0.013	0.014
16: Great Basin	-	0.343	0.485	-	0.073	0.097	-	0.368	0.416	-	0.056	0.076
17: Pacific Northwest	0.000	0.087	0.331	0.000	0.015	0.041	0.000	0.019	0.131	0.000	0.013	0.043
18: California	-	0.807	1.823	-	0.153	0.300	0.888	1.372	1.756	0.001	0.125	0.263
Total[a]	**3.954**	**20.260**	**33.838**	**3.431**	**7.255**	**8.636**	**24.605**	**37.040**	**41.162**	**1.603**	**4.364**	**6.005**
Explicitly modeled regions (02+03+05+07+08)	-2.017	-10.275	-17.577	-1.496	-3.344	-4.072	-5.289	-10.462	-12.797	-0.715	-2.079	-2.957
Other regions	-1.937	-9.986	-16.262	-1.935	-3.912	-4.563	-19.316	-26.578	-28.364	-0.888	-2.285	-3.048

- No loading reduction.

Source: U.S. EPA Analysis, 2023.

Appendix F: Climate Change Disbenefits with Updated Social Cost of Greenhouse Gases

As discussed in Section 5.2, in December 2023, EPA published new estimates of the social cost of greenhouse gases (U.S. Environmental Protection Agency, 2023l). These estimates reflect recent advances in the scientific literature on climate change and its economic impacts and incorporate recommendations made by the National Academies of Science, Engineering, and Medicine (National Academies of Sciences, 2017b). As the values were still draft at the time this analysis was conducted, EPA did not use them in the main analysis but is presenting results based on these estimates in this Appendix for additional information.

For a complete discussion of the methodology underlying these updated SC-GHG estimates, see EPA (2023l) and the final RIA for the Oil and Gas final rule. Public comments and responses to public comments received on these estimates, and complete information about the external peer review of these estimates, can be found in the docket for the Oil and Gas rule. All replication instructions and computer code for the estimates, a link to the public comments, and all files related to the peer review process, including EPA's response to the peer reviewer recommendations are also available on EPA's website: https://www.epa.gov/environmental-economics/scghg.

Table F-1: Estimates of the Social Cost of Methane and Social Cost of Carbon by Near-term Ramsey Discount Rate, 2025-2065

	Social Cost of Methane (2022$/Metric Tonne CH_4)			Social Cost of Carbon (2022$/Metric Tonne CO_2)		
Year	**2.5%**	**2.0%**	**1.5%**	**2.5%**	**2.0%**	**1.5%**
2025	$1,800	$2,300	$3,100	$150	$240	$400
2026	$1,900	$2,300	$3,200	$150	$240	$410
2027	$1,900	$2,400	$3,300	$150	$250	$410
2028	$2,000	$2,500	$3,400	$160	$250	$420
2029	$2,100	$2,600	$3,400	$160	$250	$430
2030	$2,200	$2,700	$3,500	$160	$260	$430
2031	$2,200	$2,800	$3,700	$160	$260	$440
2032	$2,300	$2,900	$3,800	$170	$270	$440
2033	$2,400	$3,000	$3,900	$170	$270	$450
2034	$2,500	$3,100	$4,000	$170	$270	$450
2035	$2,600	$3,200	$4,100	$180	$280	$460
2036	$2,700	$3,300	$4,200	$180	$280	$460
2037	$2,800	$3,400	$4,300	$180	$290	$470
2038	$2,800	$3,500	$4,400	$190	$290	$470
2039	$2,900	$3,600	$4,600	$190	$290	$480
2040	$3,000	$3,700	$4,700	$190	$300	$480
2041	$3,100	$3,800	$4,800	$200	$300	$490
2042	$3,200	$3,900	$4,900	$200	$310	$490
2043	$3,300	$4,000	$5,000	$200	$310	$500
2044	$3,400	$4,100	$5,200	$210	$320	$500

Table F-1: Estimates of the Social Cost of Methane and Social Cost of Carbon by Near-term Ramsey Discount Rate, 2025-2065

	Social Cost of Methane (2022$/Metric Tonne CH_4)			Social Cost of Carbon (2022$/Metric Tonne CO_2)		
Year	**2.5%**	**2.0%**	**1.5%**	**2.5%**	**2.0%**	**1.5%**
2045	$3,500	$4,200	$5,300	$210	$320	$510
2046	$3,600	$4,300	$5,400	$220	$330	$520
2047	$3,700	$4,400	$5,500	$220	$330	$520
2048	$3,800	$4,500	$5,600	$220	$340	$530
2049	$3,900	$4,600	$5,800	$230	$340	$530
2050	$4,000	$4,700	$5,900	$230	$340	$540
2051	$4,100	$4,800	$6,000	$230	$350	$550
2052	$4,100	$4,900	$6,100	$240	$350	$550
2053	$4,200	$5,000	$6,200	$240	$360	$560
2054	$4,300	$5,100	$6,300	$240	$360	$560
2055	$4,400	$5,200	$6,500	$250	$370	$570
2056	$4,500	$5,300	$6,600	$250	$370	$570
2057	$4,600	$5,400	$6,700	$250	$370	$580
2058	$4,700	$5,500	$6,800	$260	$380	$580
2059	$4,700	$5,600	$6,900	$260	$380	$590
2060	$4,800	$5,700	$7,000	$260	$390	$590
2061	$4,900	$5,800	$7,100	$260	$390	$600
2062	$5,000	$5,900	$7,200	$270	$390	$600
2063	$5,100	$6,000	$7,400	$270	$400	$600
2064	$5,100	$6,100	$7,500	$270	$400	$610
2065	$5,200	$6,200	$7,600	$280	$400	$610

Note: These values are identical to those reported in U.S. EPA (2022, Table A.5.1), adjusted for inflation to 2022 dollars using the annual GDP Implicit Price Deflator values (127.224 / 113.784 = 1.118) in the U.S. Bureau of Economic Analysis' (BEA) NIPA Table 1.1.9 (U.S. Bureau of Economic Analysis, 2023). This table displays the values rounded to two significant figures. The annual unrounded values used in the calculations in this RIA are available in Appendix A.5 of U.S. EPA (2023l) and at: www.epa.gov/environmental-economics/scghg.

Source: U.S. EPA Analysis, 2023, based on Table A.5.1 in U.S. Environmental Protection Agency, 2023l.

Table F-2 presents the undiscounted annual monetized climate disbenefits in selected years for each regulatory option. The disbenefits are calculated using the three sets of SC-GHG estimates of the draft SC-GHG from Table F-1 (based on near-term Ramsey discount rate of 2.5 percent, 2 percent, and 1.5 percent). EPA multiplied estimated CH_4 and CO_2 emissions for each year within the period of analysis by the SC-CH_4 and SC-CO_2 estimates, respectively, for that year. The negative values indicate that these are disbenefits due to the net increase in CH_4 and CO_2 emissions under the proposed rule.

Table F-2: Estimated Undiscounted and Total Present Value of Climate Disbenefits from Incremental Changes in CH_4 and CO_2 Emissions under the Proposed Rule by Discount Rate (Millions of 2022$)

Regulatory Option	Year	Methane Benefits[a]			Carbon Dioxide Benefits[a]		
		2.5%	**2.0%**	**1.5%**	**2.5%**	**2.0%**	**1.5%**
1	2028	-$0.004	-$0.005	-$0.01	-$3.9	-$6.2	-$10.5
	2033	-$0.005	-$0.006	-$0.01	-$4.3	-$6.7	-$11.1
	2043	-$0.007	-$0.008	-$0.01	-$5.1	-$7.8	-$12.5
	2053	-$0.009	-$0.010	-$0.01	-$6.0	-$8.9	-$13.9
	2063	-$0.010	-$0.012	-$0.02	-$6.7	-$9.9	-$15.1
	TPV[b]	-$0.16	-$0.2	-$0.3	-$116.6	-$197.7	-$350.1
2	2028	-$0.02	-$0.02	-$0.03	-$14.2	-$22.8	-$38.4
	2033	-$0.02	-$0.02	-$0.03	-$15.7	-$24.7	-$40.7
	2043	-$0.02	-$0.03	-$0.04	-$18.6	-$28.6	-$45.6
	2053	-$0.03	-$0.04	-$0.05	-$21.9	-$32.6	-$50.8
	2063	-$0.04	-$0.05	-$0.06	-$24.7	-$36.2	-$55.2
	TPV[b]	-$0.6	-$0.8	-$1.1	-$426.9	-$723.7	-$1,281.6
3	2028	-$0.02	-$0.03	-$0.04	-$20.4	-$32.8	-$55.2
	2033	-$0.03	-$0.03	-$0.04	-$22.5	-$35.5	-$58.5
	2043	-$0.04	-$0.04	-$0.05	-$26.8	-$41.0	-$65.6
	2053	-$0.05	-$0.05	-$0.07	-$31.5	-$46.9	-$73.0
	2063	-$0.05	-$0.06	-$0.08	-$35.5	-$52.1	-$79.3
	TPV[b]	-$0.8	-$1.1	-$1.6	-$613.6	-$1,040.3	-$1,842.3

a. Values rounded to two significant figures. Negative values indicate disbenefits. Climate impacts are based on changes in CH_4 and CO_2 emissions and are calculated using three different estimates of the SC-CH_4 and SC-CO_2.
b. TPV represents the total present value from 2025-2065.

Source: U.S. EPA Analysis, 2023

Table F-3 presents the annualized climate disbenefits associated with changes in GHG emissions over the 2025-2065 period under each discount rate by regulatory option and category of emissions.

Table F-3: Estimated Total Annualized Climate Disbenefits from Incremental Changes in CH_4 and CO_2 Emissions under the Proposed Rule by Discount Rate (Millions of 2022$)

Pollutant	Discount Rate	Regulatory Option		
		Option 1	**Option 2**	**Option 3**
Methane[a]	2.5%	-$0.006	-$0.02	-$0.03
	2.0%	-$0.01	-$0.03	-$0.04
	1.5%	-$0.01	-$0.04	-$0.05
Carbon dioxide[a]	2.5%	-$4.65	-$17.0	-$24.4
	2.0%	-$7.23	-$26.5	-$38.0
	1.5%	-$11.7	-$42.8	-$61.6
Total	**2.5%**	**-$4.65**	**-$17.0**	**-$24.5**
	2.0%	**-$7.23**	**-$26.5**	**-$38.1**
	1.5%	**-$11.7**	**-$42.9**	**-$61.6**

a. Values rounded to two significant figures. Negative values indicate disbenefits. Climate impacts are based on changes in CH_4 and CO_2 emissions and are calculated using three different estimates of the SC-CH_4 and SC-CO_2.

Source: U.S. EPA Analysis, 2023