GREENHOUSE GAS EMISSIONS AND CLIMATE CHANGE ANALYSIS

JANUARY 2026

Maryland
Transportation
Authority

GREENHOUSE GAS EMISSIONS AND CLIMATE CHANGE ANALYSIS

of the

CHESAPEAKE BAY CROSSING STUDY ALTERNATIVES RETAINED for DETAILED STUDY

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ABBREVIATIONS AND ACRONYMS

ARDS	Alternatives Retained for Detailed Study
CAA	Clean Air Act
CCVV	Climate Change Vulnerability Viewer
CDC	Centers for Disease Control and Prevention
CH_4	Methane
CMIP6	Coupled Model Intercomparison Project
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CSNA	Climate Solutions Now Act
D2	Severe Drought
D3	Extreme Drought
D4	Exceptional Drought
EIS	Environmental Impact Statement
EJ	Environmental Justice
EPA	Environmental Protection Agency
EV	Electric Vehicle
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
GGRA	Greenhouse Gas Reduction Act
GHG	Greenhouse Gas
GIS	Geographic Information System
GWP	Global Warming Potential

H_2O	Water Vapor (as a greenhouse gas)
HFCs	Hydrofluorocarbons
ICE	Infrastructure Carbon Estimator
IPCC	Intergovernmental Panel on Climate Change
ITS	Intelligent Transportation Systems
LCCA	Life Cycle Cost Analysis
LOD	Limit of Disturbance
MCCC	Maryland Commission on Climate Change
MD	Maryland
MDE	Maryland Department of the Environment
MDNR	Maryland Department of Natural Resources
MDOT	Maryland Department of Transportation
MDP	Maryland Department of Planning
MDTA	Maryland Transportation Authority
MEPA	Maryland Environmental Policy Act
Mg C	Megagrams of Carbon
MOVES4	Motor Vehicle Emission Simulator
MSAR	Maryland State Agency Report
MT	Metric Ton
MT CO_2e	Metric Tons of Carbon Dioxide Equivalent
MTA	Maryland Transit Administration
N_2O	Nitrous Oxide
N.D.	No Date
NETR	Natural Environmental Technical Report
NF_3	Nitrogen Trifluoride
NOAA	National Oceanic and Atmospheric Administration
O_3	Ozone
O&M	Operations and Maintenance
O-Ds	Origins and Destinations
PCAP	Priority Climate Action Plan
PFCs	Perfluorocarbons
PTSU	Part-Time Shoulder Use
RCA	Resource Conservation Area
SAV	Submerged Aquatic Vegetation
SC-CH_4	Social Cost of Methane
SC-CO_2	Social Cost of Carbon Dioxide
SC-GHG	Social Cost of Greenhouse Gas
SC-N_2O	Social Cost of Nitrous Oxide
SF_6	Sulfur Hexafluoride
SHA	State Highway Administration
SSPRA	Sensitive Species Project Review Area
SUP	Shared Use Path
SWM	Stormwater Management
TSM/TDM	Transportation Systems Management / Transportation Demand Management
TSMO	Transportation Systems Management and Operations
TWIS	Truck Weigh and Inspection Stations
U.S.	United States
VMT	Vehicle Miles Traveled
WSDOT	Washington State DOT

1 INTRODUCTION

The Chesapeake Bay Crossing Study (Bay Crossing Study, or Study) is an engineering and environmental study being advanced by the Maryland Transportation Authority (MDTA) to address existing and future transportation issues at the William Preston Lane, Jr. Memorial Bridge (Bay Bridge) and its approaches along U.S. 50/301. The Bay Crossing Study includes engineering and analysis to describe potential significant environmental effects and inform the evaluation of alternatives.

The Maryland Environmental Policy Act (MEPA) requires State agencies to evaluate proposed actions that may impact the environment. This Greenhouse Gas (GHG) Emissions and Climate Change Analysis of the Bay Crossing Study Alternatives Retained for Detailed Study (ARDS) is being completed in consideration of MEPA requirements as well as general public and State agency comments received during the Bay Crossing Study. This analysis serves as a separate review of ARDS based on the MEPA framework and is not included as part of the Bay Crossing Study Environmental Impact Statement (EIS) prepared pursuant to the National Environmental Policy Act.

This GHG Emissions and Climate Change Analysis details 1) the potential effects of the Bay Crossing Study ARDS on climate change, and 2) the effects of climate change on the ARDS and its environmental impacts. The potential effects focus on GHG emissions and climate-related impacts associated with the ARDS. GHGs are defined as gases that trap heat in the atmosphere and drive climate change. The primary GHGs, independent of source, include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases (United States Environmental Protection Agency [EPA], 2025a). Some GHGs, such as CH_4, occur naturally and are emitted to the atmosphere through natural processes and human activities, while other GHGs, such as fluorinated gases, are created and emitted solely through human activities. This GHG Emissions and Climate Change Analysis enables State agencies to evaluate reasonable alternatives and mitigation measures that could avoid or reduce potential climate change-related effects.

This analysis begins with a description of the Bay Crossing Study, including the analysis area and objectives. **Section 3** details the Bay Crossing Study ARDS evaluated. **Section 4** provides an overview of the state statutes, regulations, and guidance and policy statements. **Section 5** details the methodology for the two main analyses: the GHG emissions analysis, detailing the potential effects of the ARDS on climate change, and the climate change analysis, focusing on the potential impacts of climate change on the ARDS. **Section 6** presents the existing conditions and environmental consequences of the ARDS. **Section 7** summarizes the results of each of the analyses.

2 BACKGROUND

2.1 Bay Crossing Study Area

The Chesapeake Bay is one of Maryland's most important natural, economic, and cultural resources and is the largest estuary in the United States. The Bay Bridge is a two-span structure that crosses the Chesapeake Bay from Anne Arundel County on the Western Shore to Queen Anne's County on the Eastern Shore. The original span was built in 1952, and a parallel span directly north of the original Bay Bridge was opened in 1973. Today, the two-lane original span typically carries eastbound traffic, and the three-lane second span typically carries westbound traffic. However, lanes on the bridge can be reversed to accommodate periods of heavy traffic. The approaches along U.S. 50/301 on each shore include six lanes (three lanes for each travel direction).

2.2 Greenhouse Gas Emissions and Climate Change Analysis Area

The MDTA analyzed traffic volumes along U.S. 50/301 and its interchanges to determine an appropriate analysis area. Based on traffic analyses along the Western Shore and Eastern Shore of the Chesapeake Bay, the western Study limit has been identified as the MD 2/MD 450 interchange just east of the Severn River Bridge, and the eastern Study limit has been identified as the U.S. 50/301 split.

GHG emissions are quantified for emissions sources within the analysis area resulting from construction and maintenance activities associated with the ARDS. GHGs are distributed over a large region, beyond the initial location of the emission source. Additionally, climate is characterized on global and regional scales, not by a specific boundary or localized area. Consequently, the overall potential effects on climatic change attributable to GHGs are evaluated over large regional or global scales, rather than in a project-specific area.

The scope of analysis for the effects of climate change on the ARDS is discussed within the context of observed and projected climate trends on a regional scale. These trends are then evaluated for assets and infrastructure within the analysis area to identify the potential effects of climate change on the ARDS and environmental resources within the analysis area.

2.3 Study Objectives

The Bay Crossing Study is moving forward to address transportation needs and access across the Chesapeake Bay and at the Chesapeake Bay approaches along the U.S. 50/301 corridor. Study objectives include environmental and financial responsibility, recognizing the importance of these issues given the sensitivity of the Chesapeake Bay as an environmental resource and the need to make responsible budgetary decisions regarding a costly proposed action. The Study needs include:

- adequate capacity and reliable travel times,
- mobility,
- roadway deficiencies,
- existing and future maintenance, and
- navigation.

3 ALTERNATIVES

The MDTA identified the ARDS, which are the range of reasonable alternatives for evaluation in the Tier 2 Study. The ARDS include the No-Build Alternative and six build alternatives (**Figure 3-1**). Each build alternative includes removing the existing eastbound and westbound Bay Bridge spans and replacing them with two new bridge spans constructed near the location of the existing Bay Bridge. The ARDS are differentiated by the number of lanes provided across the new bridge and on the approaches as well as the bridge location and consist of:

- **Alternative A - No-Build**: retains the existing Bay Bridge, the U.S. 50/301 alignment, and the existing number of lanes: 6 lanes along U.S. 50/301 on the Western Shore, 5 lanes across the Chesapeake Bay on the existing Bay Bridge, and 6 lanes along U.S. 50/301 on the Eastern Shore;

- **Alternative B - 6-8-6 North**: 6 lanes along U.S. 50/301 on the Western Shore, 8 lanes across the Chesapeake Bay on a new bridge with one span to the north of the existing spans and one span in-between the existing spans, and 6 lanes along U.S. 50/301 on the Eastern Shore;

- **Alternative C - 6-8-6 South**: 6 lanes along U.S. 50/301 on the Western Shore, 8 lanes across the Chesapeake Bay on a new bridge with one span to the south of the existing spans and one span in-between the existing spans, and 6 lanes along U.S. 50/301 on the Eastern Shore;

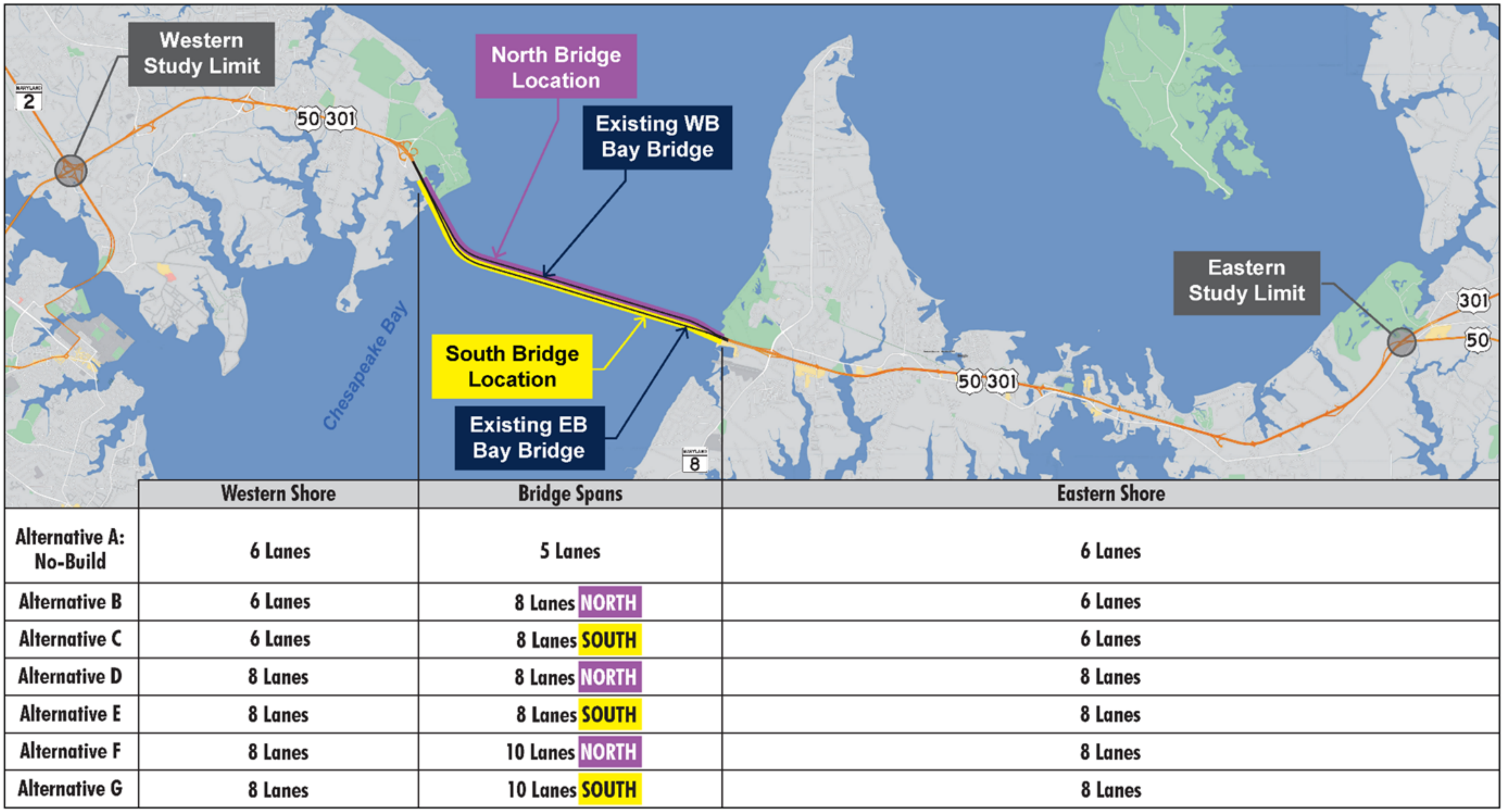
- **Alternative D - 8-8-8 North**: 8 lanes along U.S. 50/301 on the Western Shore, 8 lanes across the Chesapeake Bay on a new bridge with one span to the north of the existing spans and one span in-between the existing spans, 8 lanes along U.S. 50/301 on the Eastern Shore;

- **Alternative E - 8-8-8 South**: 8 lanes along U.S. 50/301 on the Western Shore, 8 lanes across the Chesapeake Bay on a new bridge with one span to the south of the existing spans and one span in-between the existing spans, 8 lanes along U.S. 50/301 on the Eastern Shore;

- **Alternative F - 8-10-8 North**: 8 lanes along U.S. 50/301 on the Western Shore, 10 lanes across the Chesapeake Bay on a new bridge with one span to the north of the existing spans and one span in-between the existing spans, 8 lanes along U.S. 50/301 on the Eastern Shore and

- **Alternative G - 8-10-8 South**: 8 lanes along U.S. 50/301 on the Western Shore, 10 lanes across the Chesapeake Bay on a new bridge with one span to the south of the existing spans and one span in-between the existing spans, 8 lanes along U.S. 50/301 on the Eastern Shore.

Figure 3-1: Alternatives Summary



	Western Shore	Bridge Spans	Eastern Shore
Alternative A: No-Build	6 Lanes	5 Lanes	6 Lanes
Alternative B	6 Lanes	8 Lanes NORTH	6 Lanes
Alternative C	6 Lanes	8 Lanes SOUTH	6 Lanes
Alternative D	8 Lanes	8 Lanes NORTH	8 Lanes
Alternative E	8 Lanes	8 Lanes SOUTH	8 Lanes
Alternative F	8 Lanes	10 Lanes NORTH	8 Lanes
Alternative G	8 Lanes	10 Lanes SOUTH	8 Lanes

Each of the build alternatives will also include an optional pedestrian/bicycle shared-use path (SUP), tolling, transit-related improvements, Transportation Systems Management (TSM)/Transportation Demand Management (TDM), stormwater management, utilities, and truck weigh and inspection stations. These common items, in addition to the improvements associated with each build alternative, informed the development of the limit of disturbance (LOD) for each build alternative. Additional detail on the ARDS can be found in the Tier 2 Study DEIS.

3.1 Alternative A: No-Build

Alternative A (6-5-6), the No-Build Alternative, would retain the existing Bay Bridge, the U.S. 50/301 alignment, and the existing number of lanes. This alternative would retain six lanes on the approaches on the Eastern and Western Shores and five lanes on the two-span Bay Bridge. The No-Build Alternative would include regular maintenance of the Bay Bridge and U.S. 50/301, but no capital improvements other than currently planned and programmed projects.

3.2 Alternative B: 6-8-6 North

Alternative B (6-8-6 North) would replace the existing Bay Bridge with two new bridge spans and would consist of six lanes along U.S. 50/301 on the Western Shore (three per direction), eight lanes on a new bridge (four per direction), and six lanes along U.S. 50/301 on the Eastern Shore (three per direction). The two new bridge spans would include one span to the north and one span in-between the location of the existing bridge spans. The approach roadways would remain on the existing roadway alignment, except where necessary to connect to the new bridge spans. Thus, with Alternative B, the five existing bridge lanes would be increased to eight bridge lanes; however, the number of lanes on the Western Shore and Eastern Shore would not change and would remain at six total travel lanes beyond the immediate tie-ins to the new bridge spans.

3.3 Alternative C: 6-8-6 South

Alternative C (6-8-6 South) would replace the existing Bay Bridge spans with two new bridge spans and would consist of six lanes along U.S. 50/301 on the Western Shore (three per direction), eight lanes on a new bridge (four per direction), and six lanes along U.S. 50/301 on the Eastern Shore (three per direction). The two new bridge spans would include one span to the south and one span in between the location of the existing bridge spans. The approach roadways would remain on the existing roadway alignment, except where necessary to connect to the new bridge spans. Thus, with Alternative C, the five existing bridge lanes would be increased to eight bridge lanes; however, the number of lanes on the Western Shore and Eastern Shore would not change and would remain at six total travel lanes beyond the immediate tie-ins to the new bridge spans.

3.4 Alternative D: 8-8-8 North

Alternative D (8-8-8 North) would replace the existing Bay Bridge spans with two new bridge spans and would consist of eight lanes along U.S. 50/301 on the Western Shore (four per direction), eight lanes on a new bridge (four per direction), and eight lanes along U.S. 50/301 on the Eastern Shore (four per direction). The two new bridge spans would include one span to the north and one span in-between the location of the existing bridge spans. Alternative D would increase the number of lanes along the U.S. 50/301 approaches to eight lanes from the MD 2/450 interchange on the Western Shore to the U.S. 50/301 split on the Eastern Shore and would generally remain on the existing roadway alignment except where necessary to connect to the new bridge spans. Thus, with Alternative D, the five existing bridge lanes would be increased to eight bridge lanes and the number of lanes on the Western Shore and Eastern Shore would increase from six total travel lanes to eight total travel lanes.

3.5 Alternative E: 8-8-8 South

Alternative E (8-8-8 South) would replace the existing Bay Bridge spans with two new bridge spans and would consist of eight lanes along U.S. 50/301 on the Western Shore (four per direction), eight lanes on a new bridge (four per direction), and eight lanes along U.S. 50/301 on the Eastern Shore (four per direction). The two new bridge spans would include one span to the south and one span in-between the location of the existing bridge spans. Alternative E would increase the number of lanes along the U.S. 50/301 roadway approaches to eight lanes from the MD 2/450 interchange on the Western Shore to the U.S. 50/301 split on the Eastern Shore and would generally remain on the existing roadway alignment except where necessary to connect to the new bridge spans. Thus, with Alternative E, the five existing bridge lanes would be increased to eight bridge lanes and the number of lanes on the Western Shore and Eastern Shore would increase from six total travel lanes to eight total travel lanes.

3.6 Alternative F: 8-10-8 North

Alternative F (8-10-8 North) would replace the existing Bay Bridge spans with two new bridge spans and would consist of eight lanes along U.S. 50/301 on the Western Shore (four per direction), ten lanes on a new bridge (five per direction), and eight lanes along U.S. 50/301 on the Eastern Shore (four per direction). The two new bridge spans would include one span to the north and one span in-between the location of the existing bridge spans. Alternative F would increase the number of lanes along the U.S. 50/301 approach roadway to eight lanes from the MD 2/450 interchange on the Western Shore to the U.S. 50/301 split on the Eastern Shore and would generally remain on the existing roadway alignment except where necessary to connect to the new bridge spans. Thus, with Alternative F, the five existing bridge lanes would be increased to ten bridge lanes and the number of lanes on the Western Shore and Eastern Shore would increase from six total travel lanes to eight total travel lanes.

3.7 Alternative G: 8-10-8 South

Alternative G (8-10-8 North) would replace the existing Bay Bridge spans with two new bridge spans and would consist of eight lanes along U.S. 50/301 on the Western Shore (four per direction), ten lanes on a new bridge (five per direction), and eight lanes along U.S. 50/301 on the Eastern Shore (four per direction). The two new bridge spans would include one span to the south and one span in-between the location of the existing bridge spans. Alternative G would increase the number of lanes along the U.S. 50/301 roadway approached to eight lanes from the MD 2/450 interchange on the Western Shore to the U.S. 50/301 split on the Eastern Shore and would generally remain on the existing roadway alignment except where necessary to connect to the new bridge spans. Thus, with Alternative G, the five existing bridge lanes would be increased to ten bridge lanes and the number of lanes on the Western Shore and Eastern Shore would increase from six total travel lanes to eight total travel lanes.

3.8 Other Components of the Build Alternatives

In addition to the number of lanes and location of the build alternatives described in the prior section, there are other components that will be included or not included in all of the build alternatives. These components will differ based on the needs of the individual build alternative (i.e., amount of SWM needed will depend on the amount of new impervious pavement), but they would be applied as part of each alternative. The components include an optional pedestrian / bicycle SUP, tolling, transit-related improvements, TSM/TDM, SWM, utilities, truck weigh and inspection station, and limit of disturbance.

3.8.1 Optional Pedestrian / Bicycle Shared-Use Path

All proposed build alternatives include the option for the safe inclusion of a pedestrian/bicycle shared-use path (SUP) along a new Bay Bridge. The MDTA has identified connections to existing and proposed trails and recreational facilities on the Eastern Shore and Western Shore.

3.8.2 Tolling

The MDTA owns and operates the Bay Bridge and uses tolls from its eight facilities to maintain and operate all their facilities. The Bay Bridge will continue to be a tolled facility and the MDTA will continue to manage it and the toll to address the current and future traffic and the associated congestion.

3.8.3 Transit-Related Improvements

Transit-related improvements would be made through a financial commitment from the MDTA that would focus on providing a one-time investment for local transit agencies near the Bay Bridge. The same commitment would be made for all alternatives and would not be used to differentiate between alternatives.

All potential transit-related opportunities would be determined in the future, closer to the time of construction. The MDTA would coordinate with the Maryland Transit Administration (MTA), local governments, and local transit agencies to help determine the opportunities. However, these agencies would determine the transit-related improvements that would be most beneficial for them at that time, and they would be separate and distinct projects from the Bay Crossing.

3.8.4 TSM/TDM Considerations

Two TSM/TDM improvements were considered with the retained build alternatives for potential future implementation: congestion pricing and part-time shoulder use (PTSU) lanes.

The Bay Bridge will continue to be a tolled facility. If a build alternative is selected, congestion pricing could be used in the future to provide flexibility for toll management strategies that the MDTA could use to further reduce congestion and achieve transportation goals.

The shoulders on the bridge would be full width (12 feet wide) to accommodate future maintenance needs and incident management; therefore, they would also be wide enough to accommodate a PTSU lane. Although the build alternatives have been developed to accommodate PTSU, the operation of PTSU lanes is not being included as part of the alternatives. Future implementation of PTSU is not precluded.

3.8.5 Stormwater Management

A planning-level, conceptual stormwater management (SWM) analysis was completed that identified the stormwater needs and potential treatment locations throughout the study area for each build alternative.

3.8.6 Utilities

The study area along U.S. 50/301 contains public utilities including: potable water, sanitary sewer, natural gas, electric power/distribution, communications, and cable television. The build alternatives would impact some of these utilities that are in close proximity to U.S. 50/301, and the impacts to these utilities and associated replacements have been included in the build alternatives.

3.8.7 Truck Weigh and Inspection Station

There are two existing Truck Weigh and Inspection Stations (TWIS) along U.S. 50/301 between Oceanic Drive and the Bay Bridge, one in each direction. As part of the build alternatives, these facilities would be upgraded and relocated where necessary.

3.8.8 Limits of Disturbance (LOD)

The LOD is the proposed boundary that would include all construction, erosion and sediment control, SWM, and right-of-way offsets. The LODs for the build alternatives were developed from the proposed horizontal and vertical geometry, typical sections, roadside design, and proposed interchange modifications. The LODs associated with each build alternative were used to calculate the environmental impacts.

4 REGULATORY CONTEXT

Maryland has been active for more than 15 years in establishing goals and implementing regulations to reduce GHG emissions in the State. The Maryland Commission on Climate Change (MCCC) was established in 2007 and codified in law in the MCCC Act of 2015 (Maryland Environment Code Title 2 Subtitle 13). The MCCC is charged with advising the Governor and General Assembly on ways to mitigate the causes of and prepare for and adapt to the impacts of climate change (MCCC, n.d.). Beginning with the Greenhouse Gas Reduction Act (GGRA) of 2009 and continuing with the Maryland Climate Solutions Now Act (CSNA) of 2022, Maryland set goals to reduce GHG emissions by 60 percent by 2031 (compared to a 2006 baseline) and to reach net zero emissions by 2045. The Maryland Department of the Environment (MDE) implemented the Climate Pollution Reduction Plan in 2023 to reach this goal.

The MCCC Act requires the MCCC and its participating agencies, including the Maryland Department of Transportation (MDOT), to maintain a comprehensive action plan with five-year benchmarks to achieve science-based reductions in Maryland's GHG emissions. MDOT takes a comprehensive approach to reducing emissions in the transportation sector, which is supported by four pillars of emission reductions:

- Transportation Technology,
- Vehicle Miles Traveled (VMT) Reduction,
- Congestion Mitigation, and
- Sustainable Design, Materials, and Practices.

These pillars lead to the identification, selection, and implementation of a range of strategies to reduce GHG emissions through adopting transportation technologies, improving system resiliency and efficiency, reducing VMT, mitigating congestion, and through sustainable design, infrastructure, and practices. The execution of these strategies will ensure that transportation infrastructure is resilient to the impacts of a changing climate and actively contributes to GHG emissions reduction objectives.

4.1 Relevant Regulations, Policies, and Guidelines

Major regulations and guidance that apply to the potential GHG emissions and climate change impacts of transportation projects include legislation for reducing GHG emissions and building infrastructure resilience. This GHG Emissions and Climate Change Analysis is aligned with the statutes, regulations, guidance, and policy statements outlined in Table 4-1.

Table 4-1: Relevant Regulations, Policies, and Guidelines

Regulation, Policy, Guidance	Jurisdiction	Description / Relevance to Study
Clean Air Act (CAA); United States Code Title 42 Chapter 85	Federal	The CAA defines the U.S. Environmental Protection Agency's (EPA) responsibilities for protecting and improving air quality and the ozone layer, including the regulation of GHGs.
MEPA Maryland Natural Resources Code Title 1, Subtitle 3.	State	Establishes a public priority to protect, preserve, and enhance the State's environment and requires State agencies to be stewards of the air, land, water, living, and historic resources, protecting the environment for the use and enjoyment of existing and future generations.
MCCC Act, Maryland Environment Code § 2-1305	State	Requires each State agency to review its planning, regulatory, and fiscal programs in consideration of Maryland's GHG reduction goal and the impacts of climate change. Each State agency shall identify and recommend specific policy, planning, regulatory, and fiscal changes to existing programs that do not currently support the State's GHG reduction efforts or address climate change. Agencies must report annually on the status of programs that support the State's GHG reduction efforts or address climate change, in accordance with § 2–1257 of the State Government Article, to the Commission and the Governor. Additionally, when conducting long–term planning, developing policy, and drafting regulations, each State agency shall take into consideration: (1) The likely climate impact of the agency's decisions relative to Maryland's GHG emissions reduction goals; and (2) the likely impact of the agency's decisions on disproportionately affected communities identified according to the methodology adopted by the Department under Environment Code § 1–702.
GGRA of 2009, Maryland Environment Code Title 2, Subtitle 12	State	Provides guidelines for agencies to develop plans, adopt regulations, and implement programs that reduce statewide GHG emissions. Required the State to reduce GHG emissions by 25% from a 2006 baseline by 2020. Amended in 2016 to incorporate additional reporting and interim goals, as well as set a new benchmark requiring a 40% reduction of emissions from 2006 levels by 2030 ("40 by 30"). Updated in March 2022 through the Maryland CSNA – see below.
CSNA of 2022; SB0528	State	Establishes goals to reduce GHG emissions by 60% by 2031 compared to a 2006 baseline and reaching carbon neutral emissions by 2045.
Coast Smart Council – Maryland Department of Natural Resources (MDNR), Maryland Natural Resources Code Titles 3 and 8	State	Establishes the Council and associated design criteria for capital projects reviewed by the Council to minimize future impacts associated with coastal flooding and sea level rise and establishes guidelines and requirements for capital project planning to address sea level rise and coastal flood impacts. Includes House Bills 615 (2015), 1350 (2018), and 1427 (2019).

Regulation, Policy, Guidance	Jurisdiction	Description / Relevance to Study
MDTA Environmental Policy Statement	State	The MDTA is committed to sustainable development; environmental compliance; stewardship; continuous improvement in environmental performance; and effective interaction with its employees, other government agencies, and the community. Through policies that foster environmental protection and stewardship, the MDTA reinforces practices that are essential to its overall operations.

4.2 State Plans and Goals

The State of Maryland has developed a robust set of plans and goals for addressing climate action and reducing GHG emissions, as well as adaptation strategies to build infrastructure resilience within the region. **Table 4-2** Table provides a summary of these State- and county-level efforts.

Table 4-2: Bay Crossing Study Climate-Related State Plans and Goals

State Plans and Goals	Description
Maryland's 2030 GGRA Plan (MDE, 2021)	The GGRA required the Maryland Department of Environment (MDE) to submit a plan for achieving the GHG reduction targets set as part of the GGRA. MDOT's GGRA Plan identifies four pillars to aid in achieving their "40 by 30" goal: investment in vehicle fuel economy, travel choice expansion, decongestion of roadways for travel efficiency, and more resilient infrastructure design that utilizes clean energy.
Maryland's Climate Pollution Reduction Plan (MDE, 2023a)	In alignment with the GGRA, the State plans to transition the light-duty vehicle fleet toward zero emission vehicles and increase the use of public transit and micro-mobility options by 2031. The plan emphasizes promoting sustainable growth and other transit and mobility-oriented development.
Priority Climate Action Plan (PCAP), State of Maryland (MDE, 2024)	The State's PCAP was developed to meet the requirements of the State of Maryland Climate Pollution Reduction Grant. The PCAP includes measures to decarbonize the transportation sector in Maryland through initiatives, such as advancing clean vehicle technologies, electrifying fleets, and developing plans to advance the reduction of GHG emissions from the transportation sector.
MDOT Carbon Reduction Strategy (MDOT, 2023a)	MDOT's strategy for carbon reduction is largely guided by MDE's 2030 GGRA Plan, developed in accordance with the State's GGRA. MDOT has identified five key categories of transportation activities that support carbon reduction: technological advances, reductions in VMT, congestion mitigation, infrastructure design improvements, and innovative solutions. Funds to implement these key categories will come through the State's Carbon Reduction Program and will be distributed through Metropolitan Planning Organizations.
MDOT Agency Climate Implementation Plan (MDOT, 2024b)	This document aims to fully integrate the considerations of Maryland's GHG reduction goals and the impacts of climate change into transportation policy, planning, and programming. MDOT's annual attainment report tracks and recommends strategies for climate action. This includes, but is not limited to, the safety of walking and biking, the percent reduction of lane miles at flood risk, improving access to transit, tracking VMT per capita, fleet conversion, and charging infrastructure.

State Plans and Goals	Description
MDOT Climate Action Status Report (MDOT, 2023b)	This report was required under the MCCC Act. The report provides a status update of MDOT's annual climate-related reports and provides a review of recent, ongoing, and planned activities that support GHG reduction efforts across policy, programs, and data implementation.
Maryland's Climate Pathway Report (MDE, 2023b)	The report provides an analysis of actions the State can take to achieve its GHG emissions reduction goals. This includes actions to reduce passenger vehicle use and shift vehicle fleets to zero emissions vehicles.
2050 Maryland Transportation Plan (MDOT, 2023c)	The plan outlines Maryland's vision to provide safe, reliable, accessible, equitable, and sustainable transportation options to Marylanders across the State. It emphasizes per capita VMT reduction, aiming for a 20% reduction by 2050 by investing in alternative forms of transportation and Transit-Oriented Development.
MDOT Transportation Resilience Improvement Plan (MDOT, 2024c)	The plan was developed to guide strategic investments in critical infrastructure, proactively identify and address actions, and align adaptation and mitigation efforts with MDOT's resilience objectives.
Maryland Climate Adaptation and Resilience Framework (MCCC, 2021)	The framework was created to establish the vision, goals, strategies, and activities that will guide the next decade of adaptation implementation across the State. It includes a goal of protecting critical infrastructure by creating a decision support toolbox to inform critical infrastructure planning and operations, updating plans to reflect top infrastructure resilience priorities, and implementing priority critical infrastructure projects.
Maryland Next Generation (NextGen) Adaptation Plan (MDE, 2023c)	The plan is a ten-year roadmap to increase climate change resilience in Maryland. The priorities and milestones in the NextGen Plan build on the Climate Adaptation and Resilience Framework released in 2021, including the goals surrounding protection of critical infrastructure.
Maryland State Hazard Mitigation Plan (Maryland Emergency Management Agency, 2021)	The plan includes identification of natural, technological, and human-caused hazards, as well as an assessment of the vulnerabilities and risks presented by those hazards. Goals include protecting State assets, infrastructure, and critical facilities from hazard events, as well as reducing flood hazard impacts and flood-related losses.
MDOT Maryland State Freight Plan (MDOT, 2022)	The Maryland State Freight plan outlines MDOT's commitment to carrying out actions that encourage GHG emissions reduction, such as replacing heavy-duty vehicles with more fuel-efficient models. It also recognizes that infrastructure resilience and environmental protection are key components of Maryland's transportation goals. Freight-specific objectives associated with these goals focus on network resilience, environmental protection, and conservation through project lifecycles and reduction in fossil fuel consumption in freight activities.
MDOT Strategic Asset Management Plan (MDOT, 2025)	The Strategic Asset Management Plan encompasses all MDOT fleets and infrastructure. While the plan is not primarily focused on sustainability, it does consider resilience in all project work and oversees tactical programs that contribute to climate goals, such as fleet electrification. The plan's main goal is to monitor, maintain, and improve the assets of MDOT, which indirectly will contribute to climate goals as MDOT invests in vehicles with better fuel economy or invests in more sustainable modes of transportation.

State Plans and Goals	Description
Queen Anne's County Comprehensive Plan 2022 (Queen Anne's County, 2022)	The Queen Anne's County Comprehensive Plan, influenced by MDOT and State of Maryland transportation and climate policies, reflects guiding principles of creating a sustainable future by strengthening principles for planning and growth management. The County advocates for environmentally friendly transportation policies, decreasing traffic congestion, increasing active transportation (i.e., human-powered modes of travel such as walking and cycling), and developing innovative local and regional transit options. The plan also calls for further environmental protection, with an emphasis on the Chesapeake Bay in Vision 9.
Anne Arundel Green Infrastructure Master Plan (Anne Arundel County, 2022)	The Green Infrastructure Master Plan guides the conservation of Anne Arundel County's significant natural lands through voluntary actions. The Green Infrastructure Network protects water and air quality, provides habitats, offers recreational opportunities, and supports climate change mitigation and adaptation. It aligns with the County's General Development Plan by prioritizing natural resource conservation, open space, and maintaining rural character.
Plan2040 (Anne Arundel County, 2021)	Plan2040, Anne Arundel County's General Development Plan, establishes a long-term framework for guiding land use, development, and public services over the next 20 years. Developed through extensive public engagement and interagency collaboration, the plan emphasizes protecting the natural environment, shaping the built environment, and fostering healthy communities and a resilient economy. It promotes a future that is green, smart, and equitable, and includes nine Region Plans to ensure localized planning and community input.
Resilience Authority | Annapolis and Anne Arundel County (Resilience Authority | Annapolis and Anne Arundel County, 2024)	The Resilience Authority of Annapolis and Anne Arundel County advances climate adaptation through infrastructure investments that reduce environmental and economic risks. Projects focus on restoring natural systems, improving stormwater management, and protecting vulnerable communities. By integrating equity and resilience, the Authority supports long-term sustainability and regional climate preparedness.

5 METHODOLOGY

The transportation system in Maryland faces increasing risks from climate-related extreme weather. The coast of Maryland is highly vulnerable to climate hazards, such as hurricanes, heavy precipitation, flooding, and erosion, which can lead to roadway damage and closures. This GHG Emissions and Climate Change Analysis evaluates the Bay Crossing Study ARDS in alignment with State law, such as MEPA framework, Maryland State Environmental Codes, and the agency guidance documents discussed in **Table 4-2** above. This analysis evaluates 1) the potential effects of the Bay Crossing Study ARDS on climate change through the calculation of GHG emissions, as well as 2) the effects of climate change on the ARDS and its associated environmental impacts. This analysis provides a separate review of ARDS and is not included as part of the Bay Crossing Study EIS.

Due to the nature of the Bay Crossing Study and potential emissions sources, such as those associated with mobile combustion of fossil fuel sources, the GHGs analyzed include CO2, CH4, and N2O. Maryland has not established criteria for identifying impacts from GHG emissions, but the MDTA is considering potential GHG emissions from the ARDS and placing those emissions in context to understand their potential effects on climate change. The extent of GHG effects will be determined through a comparison of GHG emissions between the ARDS.

The climate change analysis evaluates the historic and projected trends for chronic and acute climate variables. This includes average annual temperatures and precipitation trends and high tide flooding associated with sea level rise (chronic), as well as extreme temperatures and precipitation, hurricanes, severe storms and floods, drought, and wildfire (acute). The potential impacts of these trends on critical assets, infrastructure, and environmental resources within the analysis area are evaluated for the ARDS.

Table 5-1 includes key definitions for terminology used throughout the analysis. These definitions were derived from State and federal guidance and international climate science literature and have been adapted for the purposes of this analysis.

Table 5-1: Definitions of Terminology

Terminology	Definitions
GHG emissions	Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of radiation emitted by the Earth's surface, the atmosphere itself, and clouds. GHG emissions include CO_2, CH_4, N_2O, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), chlorofluorocarbons, nitrogen trifluoride (NF_3), sulfur hexafluoride (SF_6), water vapor (H_2O), and ozone (O_3) (Intergovernmental Panel on Climate Change [IPCC], 2021).
Climate Change	A long-term change in the average weather patterns that have come to define Earth's local, regional, and global climates. These changes have a broad range of observed effects (MDNR, n.d.).
Extreme Weather Event	An event that is rare at a particular place and time of year, typically as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations. The characteristics of what defines extreme weather may vary from place to place in an absolute sense and can include significant anomalies in temperature, precipitation, and winds that can manifest as heavy precipitation and flooding, heatwaves, drought, wildfires, and windstorms (including tornadoes and tropical storms). When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g., drought or heavy rainfall over a season). Consequences of extreme weather events can include safety concerns, damage, destruction, and/or economic loss (IPCC, 2021).
Resilience	The ability of communities to adapt to the challenges of changing conditions and disasters – including human-caused and natural hazards – and to build, advance, and maintain capacities related to quality of life, health and well-being, durable systems, economic vitality, human-made and nature-based infrastructure, and sustainable environmental systems (Maryland Office of Resilience, n.d.).
Climate Vulnerability	The susceptibility of an asset or system to adverse impacts from extreme weather and climate change, which is a function of exposure, sensitivity, and adaptive capacity. ○ **Exposure:** Whether an asset or system is located in an area experiencing direct climate impacts. ○ **Sensitivity:** How an asset or system responds to, or is affected by, exposure to climate hazards and extreme events. ○ **Adaptive Capacity:** The ability of an asset or system to adjust to or cope with existing extreme weather and climate variability or future climate impacts (IPCC, 2021).
Risk	The potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, livelihoods, health and well-being, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species. Risk is often represented as probability or likelihood of the occurrence of hazardous events or trends multiplied by the potential impacts if these events or trends were to occur (IPCC, 2021).

Terminology	Definitions
Climate Adaptation	Proactive investment to reduce the risks and vulnerabilities of the transportation network to extreme weather events and other disruptions (MDNR, n.d.).
Adaptive Capacity	The asset or system's ability to adjust/repair, or its flexibility to respond to damage caused by extreme weather events or changing environmental conditions (MDNR, n.d.).
Mitigation	Climate change mitigation or GHG mitigation is the reduction in GHG emissions that drive climate change.
	Hazard mitigation is the investment in physical or operational strategies to reduce known vulnerabilities and risks (MDNR, n.d.).
Hazard	An event or physical condition that has the potential to cause fatalities, injuries, property damage, infrastructure damage, agricultural loss, damage to the environment, interruption of business, or other types of harm or loss (MDNR, n.d.).

5.1 Greenhouse Gas Emissions Analysis

Transportation projects contribute to climate change due to the GHG emissions from the construction, maintenance, and operations of the transportation system. Vehicles with internal combustion engines are a significant source of GHG emissions in the transportation sector. The primary GHGs produced by the transportation sector are CO_2, CH_4, and N_2O. CO_2 emissions are a product of gasoline or diesel fuel combustion in internal combustion engines, along with relatively small amounts of CH_4 and N_2O. As such, the GHG emissions analysis focuses on these three primary GHGs.

A GHG emissions inventory estimates the amount of GHGs discharged into the atmosphere by specific sources over a period of time. Tracking annual GHG emissions allows countries, states, and smaller jurisdictions to understand how emissions are changing and what actions may be needed to attain emission reduction goals. The Infrastructure Carbon Estimator (ICE) tool was used to calculate lifecycle GHG emissions for the roadway construction and maintenance emissions of the ARDS (FHWA, 2025). Traffic data and the Motor Vehicle Emission Simulator (MOVES) MOVES4 emission model were used to calculate the construction-related emissions for each build alternative through design year 2045 (the year construction is projected to be complete) and operational emissions for the No-Build Alternative and build alternatives (collectively, ARDS) through 2060 (the furthest out the models could predict) (EPA, 2024a).

The IPCC, which is the United Nations body for assessing the science related to climate change, developed the global warming potential (GWP) concept to compare the ability of a GHG to trap heat in the atmosphere relative to CO_2. CO_2 is the principal anthropogenic GHG and is the reference gas against which other GHGs are measured, using a metric called "carbon dioxide equivalent" (CO_2e). CO_2e is the universal unit for comparing emissions of different GHGs, expressed in terms of the GWP of one unit of CO_2. The ICE tool uses the following GWP values from IPCC's Fourth Assessment Report over a 100-year time horizon: CO_2: 1, CH_4: 25, N_2O: 298 (IPCC, 2007).

GHG emissions were calculated for existing conditions, using a base year of 2022. The year 2022 was selected as the base year for representing existing conditions because traffic data generated for the Bay Crossing Study utilized 2022 as the reference year. As part of this process, traffic engineers generated existing (2022) summer weekend traffic, average daily traffic and diurnal curves from the MDTA data, which were then interpolated to align with annual average daily traffic volumes. Construction for the build alternatives is anticipated to occur between 2032 and 2045. The analysis considers the lifecycle roadway GHG emissions from the build alternatives, associated ecosystem carbon impacts, long-term emissions from vehicles during operations, and annualized GHG emissions from the product and construction stage of a bridge lifecycle. The GHG emissions were also considered in terms of GHG equivalencies and social costs to contextualize the potential impacts for a broader audience. GHG emissions related to construction of the build alternatives were modeled based on construction information for each alternative and design options, including the lifecycle emissions from the following infrastructure and activities:

- Capital carbon emissions of the material, manufacturing, and construction stage of each bridge of the build alternatives (Collings, 2021)
- Operational emissions from the roadway improvements of the build alternatives

5.1.1 *Lifecycle GHG Emissions*

The lifecycle GHG emissions analysis associated with the build alternatives evaluates and reports the full lifecycle GHG emissions related to the roadway design of the build alternatives. The analysis uses ICE Version 2.2.8 (ICE 2.2.8) for roadway components, while pre-use phase lifecycle emissions of the bridge structures are estimated according to capital carbon emission (in metric tons of CO_2e [MT CO_2e]) using a carbon intensity factor derived from benchmarked data based on material quantities, manufacturing processes, and typical construction practices (Collings, 2021).

The analysis encompasses three primary emission categories for both roadway and bridge components:

- Material: Includes the upstream emissions associated with materials extraction, production, chemical reaction, and raw material transportation.
- Transportation: Includes upstream emissions associated with fuel used in the transportation of materials to the site.
- Construction: Includes the emissions from energy and fuel used in construction equipment.

All lifecycle GHG emissions are presented in MT CO_2e. Emissions of each relevant GHG are calculated separately and then converted to MT CO_2e based on their respective GWPs. For the purposes of determining the lifecycle emissions of the roadway and bridge structures, construction of the build alternatives is assumed to occur between 2032 and 2045.

GHG emissions associated with construction and maintenance of the roadways of the build alternatives were modeled using ICE 2.2.8 based on construction information for each of the build alternatives and design options. ICE 2.2.8 inputs for roadway activities, including material, transportation, and construction, were based on anticipated construction activity and scale for the build alternatives.

To evaluate and compare the GHG emissions associated with each build alternative, this analysis applies a methodology of calculating capital carbon emissions, using bridge deck area as a proxy for material and construction-related carbon intensity. This methodology is specifically suitable for the early design phase, pre-use phase of the bridges since detailed bill-of-materials data are not yet available. The capital carbon footprint (in MT CO_2e) is estimated using the equation:

Capital Carbon = Bridge Deck Area (square meters [m^2]) × Carbon Intensity Factor (MT CO_2e/m^2)

The carbon intensity factor reflects average embodied emissions from the extraction, processing, manufacturing, transportation, and installation of materials, as well as construction-stage activities such as temporary works and waste. Based on benchmarking data presented in *The Carbon Footprint of Bridges*, normalized capital carbon values typically range from 1.0 to 7.0 MT CO_2e/m^2, with long-span highway structures averaging between 3.0 and 4.0 MT CO_2e/m^2 (Collings, 2021).

The lifecycle emissions of the bridge structures presented in this analysis only account for pre-use phase emissions, and do not account for emissions associated with future maintenance, repair, or rehabilitation activities of the bridge structure. This exclusion is due to the preliminary stage of Study development, where the full design details and material quantities of the build alternatives are not yet defined, making it infeasible to model these emissions accurately. Additionally, there are currently no industry-standard methods or models that reliably quantify long-term maintenance emissions for large bridge structures. The latest version of ICE (version 2.2.8) includes a bridge module; however, it is applicable only for structures under 1,000 feet in length. This limitation makes the ICE model unsuitable for large bridge projects, which exhibit significantly different material compositions, structural demands, and construction methods. For example, long-span bridges, especially those crossing deep water or requiring substantial vertical clearance, may involve extensive use of high-strength materials, deep foundations, or complex staging, all of which introduce carbon impacts beyond what ICE can represent. As such, until more accurate data and modeling techniques become available for this project type, maintenance-phase emissions of the bridge structures are not quantified for this analysis.

5.1.2 Ecosystem Carbon Impacts

In addition to the lifecycle and operational emissions associated with transportation infrastructure, natural systems store substantial quantities of carbon in both biomass and soils. Human land-use activities can release these carbon stores through vegetation removal and soil disturbance. This section quantifies the carbon stocks contained in forests, wetlands, and SAV that are likely to be affected by construction of the build alternatives.

Natural systems in the analysis area, including tidal and non-tidal wetlands, forested uplands, scrub shrub habitat, and managed open spaces, vary in both their carbon density and sequestration rates. Forested areas typically contain the greatest stocks of above-ground biomass carbon, while wetlands and deep organic soils store substantial below-ground carbon accumulated over centuries. These functions are recognized by the EPA and IPCC as foundational components of natural climate solutions and contributors to long-term climate resilience (EPA, 2023a; IPCC, 2022).

Disturbance or conversion of these ecosystems can release previously stored carbon and eliminate their long-term sequestration potential. Each build alternative would require varying amounts of vegetation clearing, ground disturbance, and fill placement to construct new bridge and roadway components. These activities can result in loss of stored carbon in affected habitats, fragmentation of natural systems with indirect effects on carbon cycling, and reduction of future sequestration potential, as permanently converted lands no longer accumulate carbon at natural rates.

MDNR spatial datasets of forest and wetland carbon storage were overlaid with maps of impacted areas to estimate carbon stocks subject to disturbance. The Zonal Statistics tool in ArcGIS Pro was used to calculate the mean pixel value within each disturbed area; this value was then multiplied by the total affected area of each ecosystem type. Forest and wetland carbon data represent aboveground forest biomass and belowground wetland carbon storage (Hurtt et al., 2023; Hurtt et al., 2024; Uhran, 2021). Belowground forest carbon was assumed to be 40% of aboveground biomass, based on average ratios (Hoover and Smith, 2021). Because most impacted wetlands were forested, aboveground wetland biomass was excluded, and wetland acreage was removed from forested area estimates to avoid double counting belowground carbon stocks.

This analysis also estimates forest carbon sequestration through 2060 using sequestration rates from the Maryland Climate Pollution Reduction Plan Forestry and Land-Use Appendix (MDE, 2023d). Annual sequestration rates for wetlands and SAV were not included, as methane emissions offset net carbon uptake in the analyzed portion of the Chesapeake Bay. The resulting estimates represent total ecosystem carbon stocks, though in practice not all carbon, particularly soil carbon, would be released under partial or surficial disturbance.

5.1.3 Operational GHG Emissions for the Bay Crossing Study ARDS

The overall well-to-wheel GHG emissions are defined as the sum of the direct tailpipe (pump-to-wheel) emissions and the indirect upstream (well-to-pump) emissions model estimates. Long-term GHG emissions from vehicle operations were analyzed for the existing conditions in 2022, as well as for the No-Build Alternative and build alternatives of design year 2045. These were calculated using MOVES4 and projected traffic volumes for the horizon year of 2060, which was determined using the embedded growth rate of VMT in the MOVES4 model for Anne Arundel and Queen Anne’s counties. MOVES4 input data defines the scale, methods, and parameters used for the analysis. These details are described in **Table 5-2**.

Table 5-2: MOVES4 Input Options Used in the Analysis

MOVES4 Tab	Model Selections
Scale	Default
Time Span	All hours, days, months, for the years 2022 to 2060
Geographic Bounds	Anne Arundel County and Queen Anne’s County
Vehicles/ Equipment	All MOVES4 vehicle and fuel type combinations
Output	The running exhaust all Greenhouse gases and their prerequisites
Time Aggregation	Annual

The radiative efficiencies and GWPs of GHGs, relative to CO_2, vary over time. To appropriately characterize their long-term climate impacts, GHG emissions from the ARDS are expressed using a 100-year GWP time horizon, consistent with EPA and IPCC guidance (IPCC, 2023). The operational emissions analysis quantifies annual vehicle operation-related GHG emissions on the ARDS from 2022 through 2060, using factors such as annual average daily traffic and average vehicle speed for existing, design, and future conditions. Although 2060 represents the final analysis year for estimating emissions, each year's emissions are expressed in terms of their 100-year GWP to reflect the long-term climate effect of those emissions. This distinction is important: the 2060 endpoint defines the emissions analysis period, whereas the 100-year time horizon defines the impact characterization of each year's emissions.

The operational GHG emission analysis estimated the annual emissions of the GHG based on VMT and emission rate of CO_2, CH_4, and N_2O within the analysis area. The vehicle emissions were computed using the MOVES4 model and represent the direct tailpipe emissions for each year of the analysis from 2045 to 2060. The analysis of ARDS emissions ends at the year 2060 because it is the furthest date predicted by the MOVES4 model. Well-to-pump emissions were calculated by multiplying the vehicle direct tailpipe emissions by a factor of 1.27 (to account for 27 percent growth) (Washington State Department of Transportation (WSDOT), 2018) to estimate the upstream indirect GHG emissions associated with fuel extraction, production, and transportation. This approach captures the well-to-wheel emissions, which include both the direct tailpipe (pump-to-wheel) emissions and the indirect upstream (well-to-pump) emissions, providing a more complete picture of the full lifecycle GHG impact from vehicle operation. The 1.27 factor reflects the typical upstream contribution to total GHG emissions from conventional fuels, based on lifecycle analysis data indicating that fuel extraction, refining, and distribution processes add approximately 27 percent to direct tailpipe emissions.

5.1.3.1 Annualized Operational GHG Emissions for the Bay Crossing Study ARDS

Annual GHG emissions of vehicle operations for each of the ARDS were calculated from 2045 traffic data using the MOVES4 model. Operational emissions vary among the ARDS due to differences in vehicle miles traveled, which depend on capacity, fleet size, and travel distances. The MOVES4 model also accounts for the phase-in of federal emissions standards over time; meaning that as newer, cleaner vehicles enter the fleet, the overall emissions from the vehicle population decrease year-to-year. It should be noted that this analysis is based on federal emissions standards in effect at the time of modeling, and future changes to these standards could significantly affect projected emission levels. The actual GHG emissions in future years may differ from these projections depending on the implementation of revised or more stringent federal vehicle emissions regulations. This analysis quantifies emissions for different model years within a project's lifecycle to represent this variation. The analysis of annualized operational emissions for the No-Build Alternative is formed by the assumption of linear growth between traffic provided for the existing (2022) and design year (2045). Future year emissions for each of the build alternatives between the design year and the horizon year (2060) are determined by annual activity growth rate accounted for in the MOVES4 model for Anne Arundel and Queen Anne's counties.

5.1.4 GHG Equivalency

Accessible comparisons or equivalents are provided for the public and decision-makers to understand GHG emissions in more familiar terms, such as representing GHG emissions as household emissions per year, average emissions from a certain number of cars on the road, or amount of fuel burned. Based on the GHG emission results, GHG equivalency values for the build alternatives were derived using the GHG Equivalencies Calculator (EPA, 2025b).

5.1.5 Social Cost of GHG (SC-GHG)

To provide additional context for the GHG emissions analysis, the social costs of GHGs (SC-GHG) associated with the lifecycle GHG emissions of the build alternatives were estimated. The SC-GHG translates the climate impacts of emissions into a dollar-value metric, enabling decision-makers and the public to compare alternatives, assess the significance of climate-related effects, and better understand the trade-offs associated with the ARDS.

The SC-GHG represents the estimated monetary value of damages associated with an incremental increase in GHG emissions in a given year. Conversely, it reflects the economic benefit of avoiding such emissions. The SC-GHG accounts for a range of climate-related damages, including changes in agricultural productivity, human health impacts, property damages from increased flood risk, and shifts in energy system costs (such as reduced heating costs and increased air conditioning costs). However, due to current limitations in modeling capabilities and scientific data, not all potential climate damages are captured. The integrated assessment models used to develop SC-GHG estimates inherently lag behind the latest scientific research and exclude some physical, ecological, and economic impacts. Despite these limitations, SC-GHG remains a useful tool for evaluating the potential climate consequences of GHG emission changes.

Discount rates play a critical role in determining SC-GHG values, as a significant portion of climate damages are projected to occur many decades in the future. The discount rate reflects the relative value placed on future versus present costs and benefits. A higher discount rate reduces the present value of future damages, while a lower discount rate gives greater weight to future effects. SC-GHG estimates were evaluated using three discount rates: 2.5 percent, 3 percent, and 5 percent, along with the 95th percentile at the 3 percent discount rate, to present the full range of potential outcomes. The 3 percent rate serves as the central estimate and is commonly used in regulatory analysis, striking a balance between present and future values. The 2.5 percent rate places a higher value on long-term climate impacts, emphasizing intergenerational equity by assigning greater importance to damages affecting future generations. In contrast, the 5 percent rate heavily discounts future harms, illustrating a scenario where society prioritizes near-term costs and benefits. Additionally, EPA includes a 95th-percentile estimate at the 3 percent discount rate to represent a high-impact, low-probability outcome—capturing the potential for catastrophic climate risks that fall in the extreme tail of the damage distribution (EPA, 2023a).

The SC-GHG values include the social costs of carbon dioxide (SC-CO_2), methane (SC-CH_4), and nitrous oxide (SC-N_2O). Emissions of CO_2, CH_4, and N_2O were estimated for the 2045 analysis year for the build alternatives, accounting for both construction-phase and operational emissions. The annualized SC-GHG associated with each build alternative was calculated by multiplying the estimated emissions of CO_2, CH_4, and N_2O by their respective social cost factors (expressed in 2020 dollars per metric ton of CO_2e), using EPA-provided values at 2.5 percent, 3 percent, and 5 percent discount rates, as well as the 95th percentile at 3 percent" (EPA, 2023a).

Additionally, cumulative SC-GHG impacts associated with the operational GHG emissions for the ARDS were estimated for the period from 2045 to 2060. These estimates were derived by a linear interpolation of both the SC-GHG cost factors and the projected operational GHG emissions between 2045 and 2060 for each of the build alternatives. Lifecycle GHG emissions for the bridge structure for the No-Build Alternative and use/post-use phases of the build alternatives are excluded from this analysis because modeling tools for large bridge structures are not available.

Although capital cost can serve as a proxy for certain infrastructure types, no reliable methodology exists for estimating bridge emissions at this preliminary design stage

5.2 Climate Change Analysis

The methodology for analyzing climate change describes the potential for climate change to impact the existing conditions of the analysis area as well as the ARDS. The analysis summarizes the existing critical assets and transportation inventory, as well as environmental resources and communities experiencing climate-related impacts within the analysis area. A summary of climate hazards currently impacting existing critical infrastructure, natural resources, and communities serves as the existing conditions discussion. The most recent and publicly available climate change science and an overview of observed and projected regional climate change trends are discussed. Climate change data used in this analysis are sourced from existing state, regional, or national datasets, which do not provide localized data within the analysis area.

5.2.1 Existing Climate Hazards

The following climate hazards are discussed in the climate change analysis:

Chronic Climate Hazards

- Average annual temperatures,
- Average annual precipitation, and
- High tide flooding and sea level rise.

Acute Climate Hazards

- Extreme temperatures (heat and cold),
- Extreme precipitation,
- Flooding events,
- Severe storms (thunderstorms, tornadoes, high winds, winter storms [blizzards, ice storms], hail),
- Wildfire, and
- Drought.

Pertinent land use information from the Bay Crossing Study Socioeconomic and Land Use Technical Report and the Natural Environment Technical Report (NETR) was incorporated to provide context for current climate conditions within the analysis area.

Records from MDOT State Highway Administration (SHA) were obtained to analyze existing conditions and documented impacts from past climate events. These records include documentation of key historical extreme weather events within the analysis area and associated road closures, detours, or other impacts associated with these events. The location and description of the road closures are included to help determine the scale of impact from past damaging events. Information such as the date of specific events and duration of closure are included, where available. No projects were identified that reflect climate-related maintenance work and emergency repairs or that proactively address flooding and other extreme weather concerns (SHA, 2025).

5.2.2 Climate Change Trends and Projections

Climate science is constantly evolving and being updated based on how climate and environmental conditions develop and how key drivers of change, such as future emissions, population, energy, transportation patterns, and land use impact those conditions (Basile et al., 2023). Climate projections are tools used to consider different climate scenarios or descriptions of how climate and environmental conditions may develop over time based on clear assumptions about key drivers of change (e.g., one scenario is typically referred to as "business as usual" and assumes current patterns of GHG emissions will continue). The Bay Crossing Study climate change projections reflect available regional and local data.

5.2.3 Critical Assets and Transportation Features

The inventory of existing critical assets and transportation features follows the organizational structure of the MDOT Strategic Asset Management Plan (2025), which lists seven categories of critical assets: pavement, structures, facilities, tunnels, rail, vehicle fleet and equipment, and major information technology systems.

Emergency services and other essential resources are also considered critical assets. The critical assets and transportation inventory for this analysis include the estimated quantities and elevation of existing roadway and pavement, drainage outfalls, number of outfalls in need of restoration or that could be improved by connecting the channels to more stable tie-in locations, structures, slopes and embankments, and traffic signals. A discussion of opportunities for hazard mitigation, adaptation, redundancy benefits of new potential alignments, and general resilience enhancements within the analysis area are included in **Section 6.2.3**.

The climate change analysis uses MDOT SHA's Climate Change Vulnerability Viewer (CCVV) tool (MDOT, 2025b) to aid in identifying sea level change and the predicted effects on roads and roadway infrastructure in Maryland. The geospatial application provides a means of visually depicting the extent of flooding and roadway inundation based on current conditions (modeled from 2015 conditions) and projected storm event scenarios for the years 2050 and 2100 (MDOT, 2025b).

5.2.4 Natural Resources

Environmental resources within the analysis area, identified in the Bay Crossing Study NETR, are impacted by a changing climate. Natural habitats reduce damage from coastal hazards through the processes of wave attenuation, increased infiltration, and sediment stabilization (The Nature Conservancy, 2016). The analysis of climate change on environmental resources focuses on tidal wetlands (marshes), aquatic habitat (submerged aquatic vegetation [SAV] and historic oyster beds), and terrestrial habitat (forest). These habitat groupings were selected to align with the Maryland Coastal Resiliency Assessment (The Nature Conservancy, 2016). These natural resources provide critical food and habitat for aquatic biota, improve water quality, reduce wave action and erosional forces near shorelines, capture and anchor suspended sediment, and absorb excess nutrients like phosphorus and nitrogen from the water column. The analysis of climate change also qualitatively addresses potential impacts to rare, threatened, and endangered species, as described in the NETR.

This analysis uses the MDOT CCVV tool to overlay sea level change with natural resource layers to determine flooding and inundation based on current conditions (modeled from 2015 conditions) and projected storm event scenarios for the years 2050 and 2100. This analysis focuses on the natural resources listed above located within Targeted Ecological Areas, a GIS layer identified by the MDNR identifying lands and watersheds of high ecological value that have been recognized as conservation priorities for important ecosystem services, such as biodiversity, cleaning air and water, storing nutrients, and protecting adjacent areas against storm and flood damage. This analysis also evaluates MDNR Sensitive Species Project Review Areas (SSPRA) and Resource Conservation Areas (RCAs) located within the analysis area. SSPRAs incorporate various types of ecologically significant resource areas, including Natural Heritage Areas, State and/or federally listed species, locally significant habitat areas, colonial waterbird sites, nontidal Wetlands of Special State Concern, and geographic areas of particular concern. An RCA is one of three Chesapeake Bay Critical Area land classifications and includes areas where natural resources and habitats are preserved and development is strictly regulated.

5.2.5 Communities

Communities within the analysis area, identified in the Bay Crossing Study Socioeconomic and Land Use (SELU) Technical Report, are also impacted by a changing climate. The analysis of climate change impacts on communities considers historically observed and projected conditions for chronic and acute climate variables such as sea level rise, increases in average annual temperatures, flooding, and severe storm events, such as tropical storms and hurricanes, derechos, thunderstorms, blizzards and ice storms, and Nor'easter (coastal storm) events. It includes an assessment of how these climate hazards have the potential to impact land use, residences, businesses, access to these residences and businesses, and human health and safety. The analysis includes the communities and census block groups identified in the SELU and a discussion on how climate change disproportionately affects underserved populations.

6 GHG EMISSIONS AND CLIMATE CHANGE ANALYSIS

The existing two spans of the Bay Bridge, which carry U.S. 50/301 between Anne Arundel and Queen Anne's counties across the Chesapeake Bay are operating at or near capacity and cannot accommodate increasing traffic demand. Congestion from high regional travel demand, and weekday commuter and summer weekend recreation trips, is expected to worsen by 2045 due to anticipated population and employment growth. Increasing traffic volumes and congestion on the Bay Bridge and its approaches contribute to GHG emissions. Conversely, changing climate conditions have the potential to impact this key transportation corridor.

Congestion on the Bay Bridge and its approaches limits mobility for all travel modes, affecting the movement of people, goods, and services across the Chesapeake Bay and in adjacent communities. Increased traffic congestion and vehicle idling lead to higher GHG emissions due to additional fuel use and reduced engine efficiency at low speeds. Additionally, changing climate conditions can exacerbate impacts to aging infrastructure and the health and safety of workers and the public.

MDOT uses an integrated approach to congestion mitigation under the Transportation Systems Management and Operations (TSMO) umbrella of programs at SHA. The TSMO strategies leverage technology to optimize capacity limited by congestion, reducing delays, and thereby reducing GHG emissions. Programs like the Coordinated Highways Action Response Team utilize Intelligent Transportation Systems (ITS) technologies to enhance travel and address capacity inefficiencies, further reducing GHG emissions.

6.1 Greenhouse Gas Emissions Analysis

The Paris Agreement, developed as part of the United Nations Climate Change Conference in Paris, France (COP21), set goals aimed at limiting global warming to well below 2 degrees Celsius (°C) above pre-industrial levels, with a more stringent target of limiting warming to 1.5°C to minimize the most severe impacts of climate change (United Nations, 2015). The IPCC reported in its Sixth Assessment Report publication, *Climate Change 2021: The Physical Science Basis*, that unless there are extensive reductions in GHG emissions in the coming decades, global warming of 1.5°C and 2°C above pre-industrial levels will be exceeded during the 21st Century (IPCC, 2021).

6.1.1 Affected Environment

Existing GHG emissions sources within the analysis area come primarily in the form of mobile emissions from regional travel, as well as bridge and roadway maintenance activities. This section contextualizes these emission sources and discusses existing GHG emissions estimates for the transportation industry and within Maryland.

6.1.1.1 Travel Patterns and Transit Services

Regional travel primarily contributes to GHG emissions within the analysis area. The Bay Bridge supports both local trips (e.g., work-related and discretionary trips) with origins and destinations (O-D) close to the Chesapeake Bay and regional trips (e.g., commerce, recreation) with O-Ds throughout and beyond Maryland. On typical weekdays, about 48 percent of Bay Bridge trips connect to Queen Anne's County and 47-48 percent to Anne Arundel County. During summer weekends, these percentages shift—only 22-30 percent connect to Queen Anne's County and

28-34 percent to Anne Arundel County, with more trips extending to distant counties. Worcester County (home to Ocean City) trip connections increase from 5-6 percent on weekdays to 19-24 percent on summer weekends. Further details regarding O-D patterns for traffic traveling across the Bay Bridge are provided in the Bay Crossing Study Traffic Analysis Technical Report.

Transit service across the Bay Bridge and within the analysis area is operated by four agencies, various local organizations, and private operators, which include: the MDOT Maryland Transit Administration (MTA), Annapolis Transit, Anne Arundel County Transit, and Queen Anne's County Ride. Further details about transit services across or adjacent to the Bay Bridge are provided in the Bay Crossing Study Purpose and Need Report. There are no existing ferries or passenger rail routes across the Bay and the Bay Bridge does not accommodate pedestrian or bicycle travel.

6.1.1.2 Maintenance and Emissions

The MDTA completed the *William Preston Lane Jr. Memorial (Bay) Bridge Life Cycle Cost Analysis (LCCA) Study* in 2015 to evaluate traffic operations and structural conditions of the Bay Bridge and to understand the costs and time frame for future improvements. The LCCA Study also considered complementary improvements needed if new structures are built, including mainline U.S. 50/301 improvements.

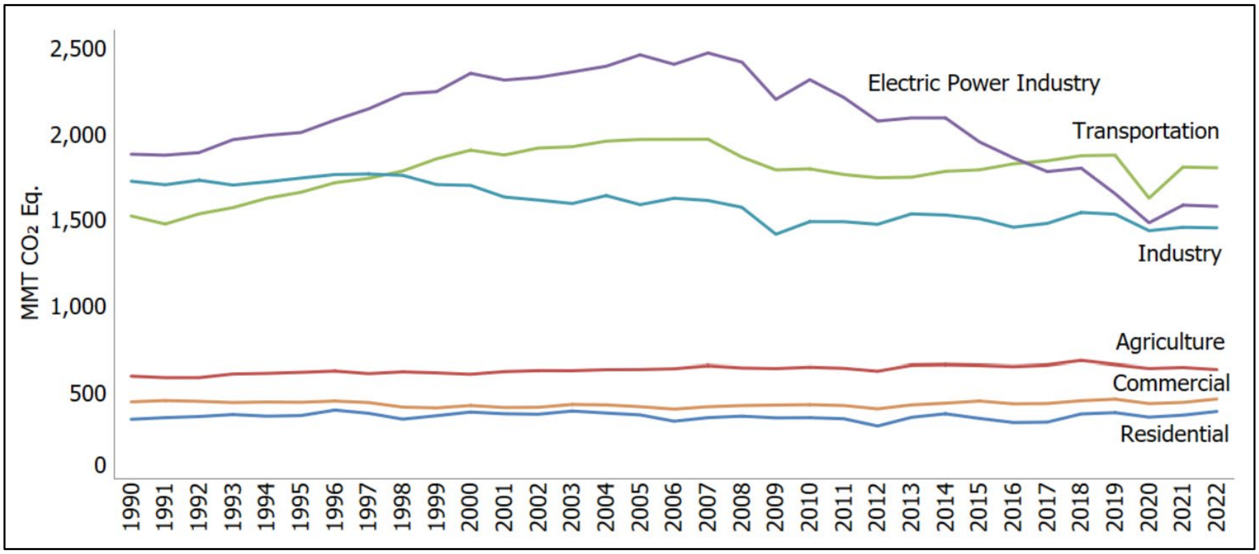
Maintenance activities contribute to GHG emissions directly through the use of trucks, equipment, facilities, and materials. Indirectly, maintenance can influence GHG emissions through traffic delays associated with service interruption. Highway system user emissions are significantly larger than maintenance emissions. Increased emissions from congestion caused by maintenance can overshadow any emission reductions achieved through optimized maintenance strategies.

Neither cumulative nor annualized GHG emissions are calculated or included for the No-Build Alternative maintenance-related lifecycle emissions of the project, nor are emissions from the use phase or post-use phase of the build alternatives. This is due to the current lack of adequate modeling tools capable of accurately estimating or characterizing lifecycle emissions for large bridge structures. While some evidence suggests that capital cost can be used as a proxy to estimate emissions for certain types of transportation infrastructure, such as asphalt roadways, no reliable research currently supports extending this methodology to large bridge projects. Although use- and post-use stage emissions could theoretically be estimated based on detailed material quantities, such data is not available at this stage of the Bay Crossing Study.

6.1.1.3 National Greenhouse Gas Emissions

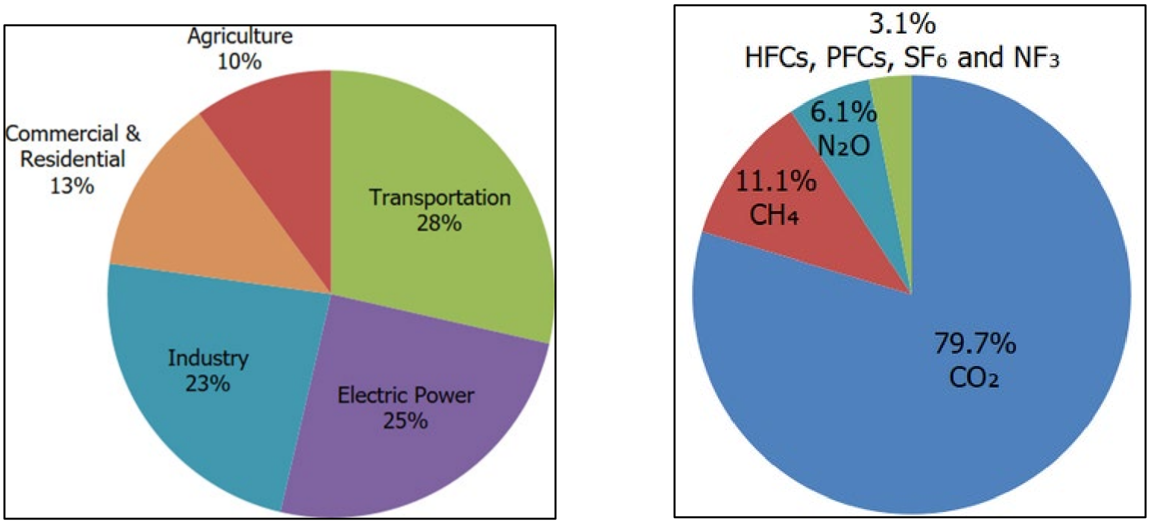
CO_2 is the primary GHG emitted through human activities. In 2022, CO_2 accounted for approximately 80 percent of all U.S. GHG emissions from human activities, and total gross U.S. GHG emissions were approximately 6,343 million MT CO_2e (EPA, 2024b). Net GHG emissions increased by six percent in 2021 due to economic activity rebounding after the COVID-19 pandemic; however, they were 17 percent below 2005 levels. The recent decline in GHG emissions in the U.S. is mostly due to a shift to less CO_2-intensive natural gas for generating electricity and a rapid increase in the use of renewable energy in the electric power sector. **Figure 6-1** presents the GHG emissions trends by sector from 1990 to 2021 in the U.S. Overall, from 1990 to 2021, total emissions of CO_2, CH_4, and N_2O decreased by approximately two, 16, and three percent, respectively. U.S. GHG emissions were partly offset by carbon sequestration in managed forests, trees in urban areas, agricultural soils, landfilled yard trimmings, and coastal wetlands. These were estimated to offset 12 percent of total gross CO_2 emissions in 2021. From 1990 to 2021, transportation CO_2 emissions from fossil fuel combustion increased by 19 percent. In 2021, CO_2 emissions increased by 11 percent, which followed a decline of 13 percent in 2020 due to reduced travel demand during the COVID-19 pandemic. In 2021, light-duty vehicles represented 58 percent of CO_2 emissions from transportation fossil fuel combustion and medium- and heavy-duty trucks and buses represented 25 percent. The remainder was due to off-road sources (EPA, 2024b).

Figure 6-1: U.S. GHG Emissions 1990 to 2021 by Sector (EPA, 2024b)



Transportation activities were the largest source (28 percent) of total U.S. GHG emissions in 2021, followed by the electric power and industry sectors (EPA, 2024b). Approximately 79 percent of these GHG emissions were CO_2, as shown in **Figure 6-2**. Worldwide, the construction industry accounts for approximately 37 percent of carbon emissions, with steel and cement production each accounting for about 7 percent (United Nations Environment Programme, 2023).

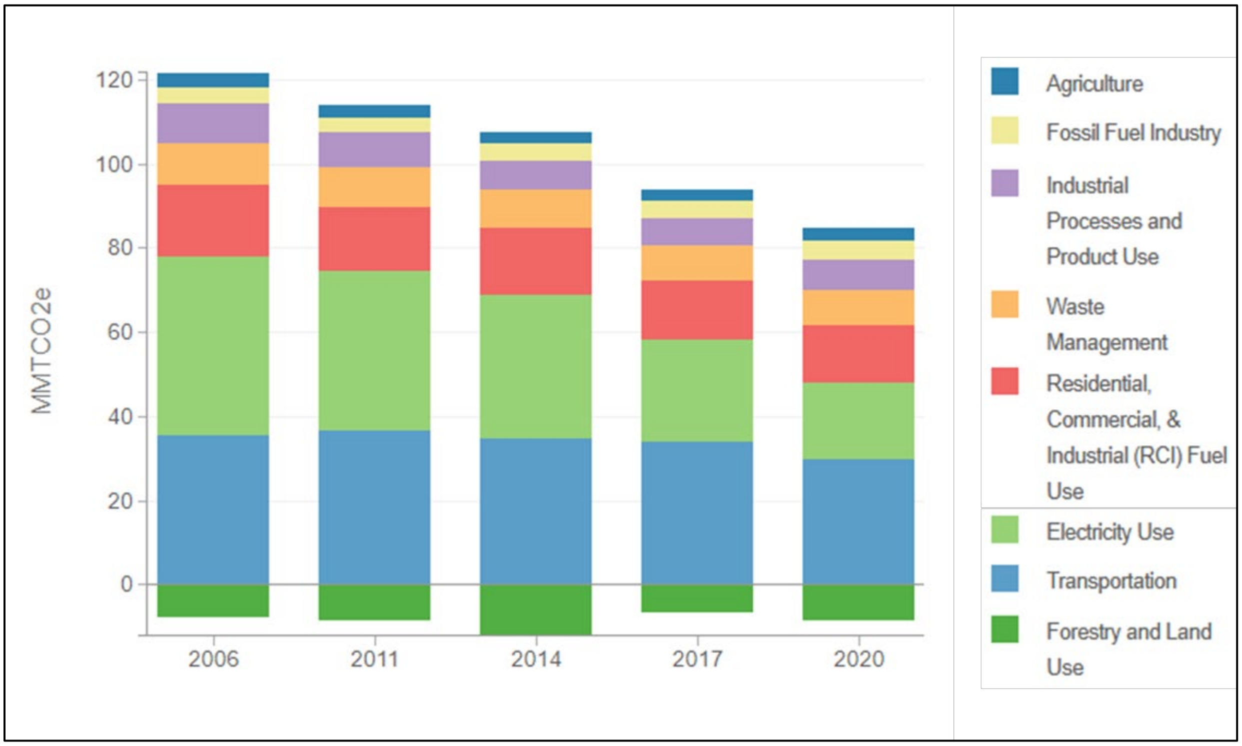
Figure 6-2: 2022 U.S. GHG Emissions by Economic Sector and GHG Composition (EPA, 2024b)



6.1.1.4 State of Maryland Greenhouse Gas Emissions

In 2020, Maryland achieved a 30 percent reduction in GHG emissions from 2006 levels, surpassing its 25 percent reduction by 2020 target (MDE, 2022a). Emissions from the transportation sector are the largest contributor at approximately 34 percent of emissions, with on-road gasoline and diesel vehicles representing 82 percent of the total. However, the transportation sector has benefited from efforts promoting electric vehicles (EV) and public transit, as shown in **Figure 6-3** (MDE, 2022b; MDOT, 2023a). Residential, commercial, and industrial sectors reduced emissions through energy-efficient retrofits and cleaner fuels. Waste management advancements, such as CH_4 capture and recycling programs, and sustainable practices in agriculture, further contributed to emission reductions.

Figure 6-3: Maryland GHG Emissions Trend by Sector, in million MT CO_2e (MDE, 2022b)[1]



On-road emissions are directly associated with trends around VMT, vehicle efficiency, and GHG intensity of the energy used in vehicles. As shown in **Figure 6-4**, on-road emissions in Maryland decreased each year between 2006 and 2020, with a significant reduction in 2020 from the COVID-19 pandemic. Emissions between 2021 and 2023 remained below 2019 levels but above 2020 levels due to recovery from the pandemic. Maryland is currently targeting a four percent reduction in CO_2 emissions from on-road sources by 2025, as compared to 2022 levels (MDOT, 2024a).

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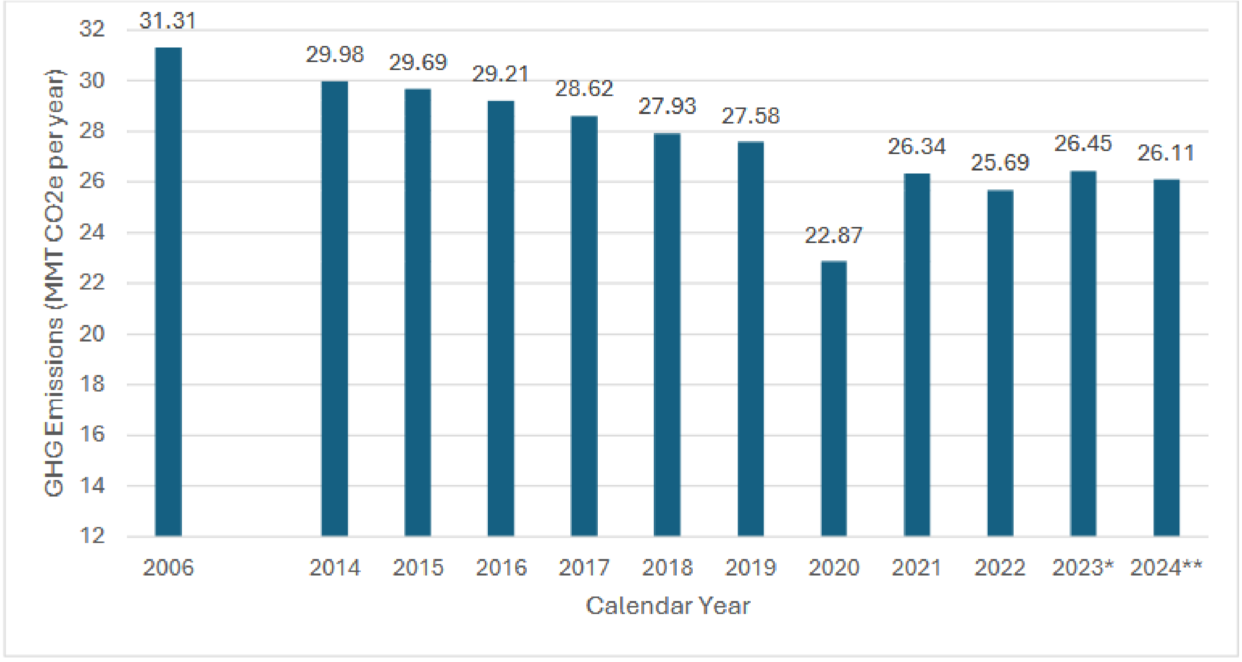
[1] The Forestry and Land Use category shows negative values for GHG emissions because these activities play a crucial role in removal of CO_2 emissions from the atmosphere. Forestry and land use activities in Maryland mitigate GHG emissions by actively removing CO_2 from the atmosphere through forest growth and soil carbon sequestration.

Figure 6-4: Maryland GHG Emissions from On-Road Sources (MDOT, 2024a)



**2023 data has been revised from estimate to actual*
***2024 data is estimated*

6.1.2 Environmental Consequences

Transportation projects contribute to climate change due to the GHG emissions from construction, maintenance, and operation of the transportation system. The following sections describe the direct and indirect GHG emissions expected to result from the Bay Crossing Study ARDS.

6.1.2.1 Lifecyle GHG Emissions

Lifecycle GHG emissions from construction and operations and maintenance (O&M) for the build alternatives are summarized in **Table 6-1**. ICE 2.2.8 annualizes construction-related emissions over a project's assumed lifetime. In this analysis, ICE was used exclusively to quantify emissions associated with the roadway improvements for each of the build alternatives. A conservative project lifetime of 15 years was applied, even though most transportation infrastructure is typically expected to last 50 to 75 years, and major bridges are often designed for service lives of 75 to 100 years. The shorter 15-year timeframe was selected because the ICE model only projects emissions through the year 2060. Presenting emissions in this manner also ensures consistency across build alternatives. **Table 6-1** presents cumulative emissions for bridge components, estimated using capital carbon factors, and for roadway components, estimated using ICE modeling. All lifecycle GHG emissions are reported in metric tons of carbon dioxide equivalent (MT CO_2e).

The lifecycle emissions of the No-Build Alternative are not included in **Table 6-1** because current modeling limitations do not allow for accurate quantification of emissions associated with maintenance activities for large-scale bridge infrastructure. Major bridges that extend over significant heights or water depths require specialized maintenance procedures and equipment that are characteristically unique in their carbon intensity compared to standard roadway maintenance operations. Therefore, including No-Build Alternative maintenance emissions without proper quantification methodology would introduce significant uncertainty and potential underestimation of the true lifecycle emissions, making meaningful comparison with the build alternatives inappropriate for this analysis.

Table 6-1: Cumulative Lifecycle GHG Emissions (MT CO_2e/Year)[1,2,3]

Cumulative Lifecycle GHG Emissions	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
Bridge Capital Carbon	774,075	758,684	744,075	758,684	843,612	875,405
Roadway Lifecycle	17,449	17,449	28,229	28,229	28,229	28,229
Total Cumulative	**791,524**	**776,133**	**802,304**	**786,913**	**871,841**	**903,634**

Table Notes:

1. Cumulative GHG emissions for roadway activity were taken from the ICE Version 2.2.8 tool used for this Study, with the exception of vehicle operational emissions, which were taken from the EPA MOVES4 modeling performed for the build alternatives. Emissions from the ICE tool were annualized, assuming a 15-year timespan.

2. GHG emissions estimates are based on normalized carbon intensity factors for bridge construction. Collings (2021) identified a correlation between bridge deck area and emissions, with an average of 2.4 MT CO_2e/m^2. This factor was applied to conceptual deck areas derived from proposed alignments and structure types to estimate capital carbon for each alternative.

3. The dimensions and normalized carbon in tons of each bridge alternative can be found in Table 36 of Appendix B.

Although quantitative modeling of direct lifecycle emissions is not feasible for the No-Build Alternative due to limitations in modeling maintenance activities for large-scale bridge infrastructure, qualitative analysis based on the Bay Bridge LCCA provides compelling evidence that cumulative CO_2e emissions will substantially increase over time. The LCCA documents programmed and anticipated maintenance and rehabilitation activities with cumulative expenditures estimated at $3.8 billion (2025 dollars) through 2065 for the eastbound and westbound bridge structures.

The carbon intensity profile of these maintenance activities demonstrates an accelerating emissions trajectory. Early-phase maintenance focuses on relatively low-carbon preventive measures such as deck resurfacing and protective coating applications. However, the LCCA projections show that maintenance requirements intensify significantly as the structures age, necessitating carbon-intensive interventions including full deck replacements, superstructure rehabilitations, suspension span overhauls, and potential substructure modifications. These later-stage activities require substantially more embodied carbon per maintenance event due to the scale of material replacement, specialized equipment deployment, and complex logistics required for major bridge components.

Based on the maintenance schedule and activity intensity outlined in the LCCA, the cumulative CO_2e lifecycle emissions for the No-Build Alternative are projected to rise at an accelerating rate approaching and beyond 2060. This acceleration occurs because carbon-intensive major rehabilitation activities become increasingly frequent and extensive as structural deterioration compounds over time. Therefore, while specific emission quantities cannot be modeled using available tools, the LCCA findings demonstrate that deferring major infrastructure investments will result in significantly higher lifecycle GHG emissions due to the compounding carbon intensity of future maintenance requirements compared to implementing the build alternatives with modern, efficient infrastructure.

6.1.2.2 Ecosystem Carbon Impacts

Table 6-2 summarizes the ecosystem carbon impacts for each of the build alternatives. Alternatives B and C would disturb substantially smaller areas of forest and wetlands, resulting in approximately one-third of the estimated carbon emissions associated with Alternatives D, E, F, and G. Alternative C demonstrates the lowest total ecosystem carbon impact at 8,398 MT CO_2e, while Alternative F shows the highest impact at 30,978 MT CO_2e. The total ecosystem carbon impacts include both the immediate release of stored carbon from disturbed ecosystems and the foregone carbon sequestration capacity through 2060. Build alternatives that disturb larger areas of forested and wetland habitat result in greater carbon storage loss and reduced sequestration capacity. Recognizing these ecosystem-carbon functions provides important context for comparing the built alternatives and supports informed decision-making regarding avoidance, minimization, and mitigation measures in future project phases.

Table 6-2: Ecosystem Carbon Impacts

Metric	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
Wetland Acres Impacted	5.91	5.53	11.46	11.08	11.98	11.46
Forest Acres Impacted	27.33	27.33	87.71	87.71	89.10	89.10
SAV Acres Impacted	0.37	0.00	0.68	0.32	0.88	0.32
Wetland Carbon (Megagrams of Carbon [Mg C] per acre)	85.57	40.39	57.28	24.50	54.88	24.50
Forest Carbon (Mg C per acre)	38.72	38.72	46.36	46.36	46.59	46.59
SAV Carbon (Mg C per acre)	18.65	18.65	18.65	18.65	18.65	18.65
Total Carbon Storage Impact (Mg C)	**1,903**	**1,619**	**6,149**	**5,764**	**6,262**	**5,884**
Total Carbon Storage Impact (MT CO2e)	**6,976**	**5,938**	**22,545**	**21,135**	**22,960**	**21,576**
Lost Forest Carbon Sequestration (2030–2060, MT CO2e)	2,460	2,460	7,894	7,894	8,019	8,019
Total (MT CO2e)	**9,436**	**8,398**	**30,439**	**29,028**	**30,978**	**29,595**

Sources: Hoover and Smith, 2021; Hurtt and Ma, 2024; Kerns, 2025; MDE, 2023d; Uhran, 2021

6.1.2.3 Operational GHG Emissions for the Bay Crossing Study ARDS

The operational GHG emissions analysis estimated annual well-to-wheel emissions in MT CO_2e based on VMT for each of the ARDS. The analysis accounts for both direct tailpipe emissions, modeled using the EPA's MOVES4, and indirect upstream emissions associated with fuel extraction, production, and transportation. Upstream emissions were estimated by applying a multiplier of 1.27, consistent with Washington State Department of Transportation ([WSDOT], 2018). The resulting well-to-wheel emissions reflect the total GHG emissions from vehicle operations in the analysis area for each scenario. Daily VMT and annual GHG emissions are summarized in **Table 6-3** and **Table 6-4** for 2045 and 2060.

Table 6-3: VMT and Well-to-Wheel GHG Emissions as MT CO_2e from Operations in 2045

VMT and Well-to-Wheel GHG Emissions	Existing	Alt A	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
Daily VMT (miles/day)	1,348,31	2,073,717	2,211,515	2,194,067	2,269,391	2,251,487	2,273,700	2,255,761
Well-to-Wheel Emissions (MT/CO2e/year)	757,090	622,232	663,579	658,343	680,945	675,573	682,238	676,855
Differences Between No-Build and Build Alternatives	**Existing**	**Alt A**	**Alt B**	**Alt C**	**Alt D**	**Alt E**	**Alt F**	**Alt G**
Daily VMT	NA	NA	137,797	120,349	195,674	177,770	199,982	182,044
Daily VMT (% change)	NA	NA	(7%)	(6%)	(9%)	(9%)	(10%)	(9%)
Well-to-Wheel Emissions (MT CO2e/year)	NA	NA	41,347	36,112	58,713	53,341	60,006	54,623
Well-to-Wheel Emissions (% change)	NA	NA	(7%)	(6%)	(9%)	(9%)	(10%)	(9%)

Table 6-4: VMT and Well-to-Wheel GHG Emissions as MT CO_2e from Operations in 2060

VMT and Well-to-Wheel GHG Emissions	Existing	Alt A	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
Daily VMT (miles/day)	1,608,511	2,476,355	2,640,907	2,620,071	2,710,021	2,688,640	2,715,166	2,693,744
Well-to-Wheel Emissions (MT/CO2e/year)	757,090	542,420	578,464	573,900	593,603	588,919	594,730	590,037
Differences Between No-Build and Build Alternatives	**Existing**	**Alt A**	**Alt B**	**Alt C**	**Alt D**	**Alt E**	**Alt F**	**Alt G**
Daily VMT	NA	NA	164,552	143,717	233,666	212,286	238,811	217,390
Daily VMT (% change)	NA	NA	(7%)	(6%)	(9%)	(9%)	(10%)	(9%)
Well-to-Wheel Emissions (MT CO2e/year)	NA	NA	36,043	31,480	51,182	46,499	52,309	47,617
Well-to-Wheel Emissions (% change)	NA	NA	(7%)	(6%)	(9%)	(9%)	(10%)	(9%)

In general, VMT in both years 2045 and 2060 are higher under projected conditions compared to the 2022 Existing Condition, reflecting anticipated regional growth. Among the build alternatives, Alternative C results in the lowest amount of operational GHG emissions. Alternative G is associated with the highest VMT and therefore, higher GHG emissions compared to the No-Build Alternative. Despite the increase in travel demand and VMT, future-year emissions for all ARDS are projected to be lower than the 2022 Existing Condition. This trend is primarily due to fleet turnover, improvements in fuel economy, and increased adoption of alternative fuel technologies over time. MOVES4 accounts for these trends by assuming ongoing fleet turnover, with older, higher-emitting vehicles being replaced by newer models that comply with more stringent emissions and fuel economy standards, including revised GHG standards for light-duty vehicles (EPA, 2023b). The model also reflects improved fuel efficiency and increased electrification across both light- and heavy-duty fleets, driven by national policy (such as the Inflation Reduction Act). As a result, MOVES4 projects declining emissions through 2045 and 2060, despite increasing travel demand. It is also important to note that although VMT rises over time, vehicle energy efficiency is expected to increase across all light-duty vehicles in use, and fuel economy is expected to increase by 55 percent by 2050 as newer, more fuel-efficient vehicles enter the market, and cars, which are more fuel efficient than light trucks, gain market share (EPA, 2023b).

In 2045, the No-Build Alternative is projected to result in 622,232 MT CO_2e annual well-to-wheel GHG emissions, an 18 percent decrease compared to the 2022 Existing Condition (757,090 MT CO_2e). The build alternatives would result in slightly higher annual well-to-wheel emissions than the No-Build Alternative, ranging from 658,343 to 682,238 MT CO_2e, or approximately 36,000 to 60,000 MT CO_2e more than the No-Build Alternative. The largest increase occurs under the Alternative F configuration, which would result in a 10 percent increase in annual well-to-wheel GHG emissions over the No-Build Alternative in 2045.

By 2060, emissions are expected to continue declining across all scenarios. The No-Build Alternative is projected to produce annualized GHG emissions of 542,420 MT CO_2e, representing a 9 percent reduction from the 2022 Existing Condition. The build alternatives show annualized GHG emissions ranging from 585,871 to 607,134 MT CO_2e, remaining below 2022 levels but exceeding the No-Build Alternative by approximately 32,000 to 53,000 MT. The largest increase occurs under the Alternative F configuration, which would result in a 10 percent increase in annualized GHG emissions over the No-Build Alternative in 2060.

6.1.2.4 Cumulative GHG Emissions for the Bay Crossing Study ARDS

The cumulative GHG emissions for the ARDS were estimated by combining several components: the lifecycle emissions from the capital carbon associated with the pre-use phases of the bridge (including material extraction through construction completion), the lifecycle emissions from roadway improvements for each of the ARDS, and the annual vehicle operational emissions projected from 2045 to 2060. Year-by-year operational emissions were estimated based on activity growth rates derived from MOVES4 modeling. Cumulative GHG emissions for the ARDS are summarized in **Table 6-5**, with annual estimates presented in **Appendix A**.

Emission trends across the ARDS align with the patterns observed in annualized emissions, with the ARDS generally showing an increase in emissions. Pre-use lifecycle emissions related to materials and construction contribute significantly to the total cumulative emissions.

It is important to note that the cumulative GHG emissions do not include the lifecycle emissions of the No-Build Alternative, nor do they account for the use-phase or post-use-phase emissions of the build alternatives. This exclusion is due to the current lack of adequate modeling tools to accurately estimate or characterize lifecycle emissions for large bridge structures of those phases.

Table 6-5: Cumulative GHG Emissions (Pre-use Phase Lifecycle and Operational), MT CO_2e

Cumulative (Pre-use Phase Lifecycle and Operational) GHG Emissions	Alt A	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
Cumulative	8,039,899	9,365,669	9,282,632	9,600,840	9,516,033	9,687,080	9,649,325
Differences Between No-Build and Build Alternatives	**Alt A**	**Alt B**	**Alt C**	**Alt D**	**Alt E**	**Alt F**	**Alt G**
Cumulative	NA	1,325,770	1,242,733	1,560,941	1,476,134	1,647,181	1,609,426
% Change		16%	15%	19%	18%	20%	20%

6.1.2.5 GHG Equivalency

Agencies may provide accessible comparisons or equivalents for the public and decision-makers to understand GHG emissions in more familiar terms, such as placing GHG emissions as amount of crude oil and gasoline consumption or amount of fuel burned. Based on the annualized operational emissions for the build alternatives for 2045 and 2060, GHG equivalency values were calculated using EPA's GHG Equivalencies Calculator (EPA, 2025b) and are summarized in **Table 6-6**.

Table 6-6: GHG Emissions Equivalency for the GHG Emissions Increases from Build Alternatives (Compared to No-Build Alternative)

Equivalency Category	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
2045 GHG Emissions Increase from No-Build (MT CO_2e/Year)	**32,557**	**28,434**	**46,231**	**42,001**	**47,249**	**43,011**
Barrels of crude oil consumed	75,303	65,769	106,932	97,148	109,286	99,483
Gasoline powered passenger vehicles driven for one year (gallons consumed)	7,260	6,341	10,309	9,366	10,536	9,591
Tanker truck's worth of gasoline	430	375	610	554	624	568
Natural gas fired power plant in one year	0.10	0.09	0.14	0.13	0.14	0.13
Equivalency to 2060 GHG Emissions (MT CO_2e/Year)	**Alt B**	**Alt C**	**Alt D**	**Alt E**	**Alt F**	**Alt G**
2060 GHG Emissions Increase from No-Build	**36,043**	**31,480**	**51,182**	**46,499**	**52,309**	**47,617**
Barrels of crude oil consumed	83,369	72,812	118,385	107,552	120,991	110,138

Gasoline powered passenger vehicles driven for one year (gallons consumed)	8,038	7,020	11,414	10,369	11,665	10,619
Tanker truck's worth of gasoline	476	416	676	614	690	629
Natural gas fired power plant in one year	0.10	0.09	0.15	0.14	0.16	0.14

Source: EPA's GHG Equivalencies Calculator (EPA, 2025b)

6.1.2.6 Social Cost of GHG (SC-GHG)

To provide additional context for GHG emissions, SC-GHG from the cumulative lifecycle GHG emissions for the build alternatives and operational conditions of the ARDS were estimated to translate climate impacts into the more accessible metric of dollars to allow decision-makers and the public to make comparisons, help evaluate the significance of an action's climate change effects, and better understand the tradeoffs associated with an action and its alternatives. Annual SC-GHG values resulting from the build alternatives for the cumulative lifecycle emissions are summarized in **Table 6-8**, **Table 6-9** and **Table 6-9** provide SC-GHG comparisons between the build alternatives and No-Build Alternative for the operation emission year 2045 and 2060, respectively. Further data and figures of the calculation of SC-GHG can be found in **Appendix A**.

The SC-GHG analysis provides a monetized assessment of the climate impacts associated with the ARDS. For the same emission year and discount rate, the operational SC-GHG of the build alternatives (B through G) would be, on average, 8% higher than the No-Build Alternative (A) for both the 2045 and 2060 emission years. This finding is consistent with the ARDS's cumulative GHG emission trends. The percentage increases range from 5.80 percent for Alternative C to 9.64 percent for Alternative F, with corresponding monetary values ranging from approximately $0.8 million to $11.5 million in 2045 (depending on discount rate), and from $1.2 million to $15.7 million in 2060.

When examining lifecycle emissions, Alternative G demonstrates the highest SC-GHG values across all discount rates, ranging from approximately $25.3 million (5 percent discount rate) to $218.7 million (3 percent 95th percentile), while Alternative C shows the lowest values. The analysis employs multiple discount rates (5 percent, 3 percent, 2 percent, and 3 percent 95th percentile) to account for uncertainty in valuing future climate impacts, with the variation between rates illustrating how different approaches to valuing future impacts can substantially affect the economic assessment. In accordance with EPA guidance on the social cost of GHGs, the discount rates used—2.5 percent, 3 percent, and 5 percent—reflect different assumptions about how we value future climate damages relative to the present. The 3 percent rate serves as the central estimate and is commonly used in regulatory analysis, striking a balance between present and future values. The 2.5 percent rate places a higher value on long-term climate impacts, emphasizing intergenerational equity by assigning greater importance to damages affecting future generations. In contrast, the 5 percent rate heavily discounts future harms, illustrating a scenario where society prioritizes near-term costs and benefits. Additionally, EPA includes a 95th-percentile estimate at the 3 percent discount rate to represent a high-impact, low-probability outcome—capturing the potential for catastrophic climate risks that fall in the extreme tail of the damage distribution. These monetized values translate abstract emissions quantities into more accessible dollar figures, enabling more direct comparisons with other project costs and benefits, and providing decision-makers with important context for evaluating the significance of climate change implications within the broader assessment of project benefits and impacts.

Cumulative Social Cost

Cumulative SC-GHG of the ARDS are summarized in **Table 6-10**. Cumulative SC-GHG trends are consistent with the trends of the annual SC-GHG. The build alternatives would result in higher cumulative SC-GHG than the No-Build Alternative due to the increase in emissions from construction.

Table 6-7: Social Cost of Greenhouse Gases for Cumulative Lifecycle Emissions (in 2020 dollars)

Discount Rate (%)	SC-GHG ($) for Cumulative Lifecycle GHG Emissions					
	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
5%	$22,162,673	$21,731,725	$22,464,512	$22,033,564	$24,411,548	$25,301,752
3%	$62,530,399	$61,314,510	$63,382,016	$62,166,127	$68,875,439	$71,387,086
2.5%	$87,067,645	$85,374,635	$88,253,440	$86,560,430	$95,902,510	$99,399,740
3% 95th Percentile	$191,548,818	$187,824,196	$194,157,568	$190,432,946	$210,985,522	$218,679,428

Table 6-8: Social Cost of Greenhouse Gases for Operational Emissions in 2045 (in 2020 dollars) and Comparisons to No-Build Alternative

SC-GHG ($) for 2045 GHG Emissions							
Discount Rate (%)	**Alt A**	**Alt B**	**Alt C**	**Alt D**	**Alt E**	**Alt F**	**Alt G**
5%	$13,829,218	$14,748,161	$14,631,805	$15,134,130	$15,014,728	$15,162,860	$15,043,232
3%	$38,885,006	$41,468,890	$41,141,719	$42,554,158	$42,218,425	$42,634,942	$42,298,571
2.5%	$54,138,123	$57,735,567	$57,280,059	$59,246,544	$58,779,116	$59,359,016	$58,890,701
3% 95th Percentile	$118,822,339	$126,718,007	$125,718,259	$130,034,299	$129,008,388	$130,281,153	$129,253,294

Changes of SC-GHG Compared to No-build ($)							
Discount Rate (%)	**Alt A**	**Alt B**	**Alt C**	**Alt D**	**Alt E**	**Alt F**	**Alt G**
5%	N/A	$918,943	$802,586	$1,304,912	$1,185,510	$1,333,642	$1,214,014
3%	N/A	$2,583,884	$2,256,713	$3,669,152	$3,333,419	$3,749,935	$3,413,565
2.5%	N/A	$3,597,443	$3,141,936	$5,108,421	$4,640,993	$5,220,893	$4,752,577
3% 95th Percentile	N/A	$7,895,668	$6,895,920	$11,211,961	$10,186,049	$11,458,815	$10,430,956

Changes of SC-GHG Compared to No-Build (%)							
Discount Rate (%)	**Alt A**	**Alt B**	**Alt C**	**Alt D**	**Alt E**	**Alt F**	**Alt G**
5%	N/A	6.64%	5.80%	9.44%	8.57%	9.64%	8.78%
3%	N/A	6.64%	5.80%	9.44%	8.57%	9.64%	8.78%
2.5%	N/A	6.64%	5.80%	9.44%	8.57%	9.64%	8.78%
3% 95th Percentile	N/A	6.64%	5.80%	9.44%	8.57%	9.64%	8.78%

Table 6-9: Social Cost of Greenhouse Gases for Operational Emissions in 2060 (in 2020 dollars) and Comparisons to No-Build Alternative

SC-GHG ($) for 2060 GHG Emissions

Discount Rate (%)	Alt A	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
5%	$20,797,156	$22,179,114	$22,004,130	$22,759,555	$22,579,993	$22,802,762	$22,622,858
3%	$53,057,189	$56,582,805	$56,136,392	$58,063,614	$57,605,518	$58,173,840	$57,714,875
2.5%	$71,479,825	$76,229,614	$75,628,197	$78,224,592	$77,607,436	$78,373,092	$77,754,764
3% 95th Percentile	$163,020,164	$173,852,749	$172,481,130	$178,402,589	$176,995,074	$178,741,264	$177,331,077

Changes of SC-GHG Compared to No-build ($)

Discount Rate (%)	Alt A	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
5%	N/A	$1,381,958	$1,206,974	$1,962,399	$1,782,837	$2,005,606	$1,825,702
3%	N/A	$3,525,616	$3,079,203	$5,006,425	$4,548,329	$5,116,652	$4,657,686
2.5%	N/A	$4,749,788	$4,148,371	$6,744,767	$6,127,611	$6,893,267	$6,274,939
3% 95th Percentile	N/A	$10,832,585	$9,460,966	$15,382,425	$13,974,909	$15,721,100	$14,310,913

Changes of SC-GHG Compared to No-Build (%)

Discount Rate (%)	Alt A	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
5%	N/A	6.64%	5.80%	9.44%	8.57%	9.64%	8.78%
3%	N/A	6.64%	5.80%	9.44%	8.57%	9.64%	8.78%
2.5%	N/A	6.64%	5.80%	9.44%	8.57%	9.64%	8.78%
3% 95th Percentile	N/A	6.64%	5.80%	9.44%	8.57%	9.64%	8.78%

Table 6-10: Cumulative Social Cost of Greenhouse Gases for Emissions in 2045 to 2060 (in 2020 dollars) and Comparisons to No-Build Alternative

SC-GHG ($) for 2045-2060 GHG Emissions							
Discount Rate (%)	**Alt A**	**Alt B**	**Alt C**	**Alt D**	**Alt E**	**Alt F**	**Alt G**
5%	$274,003,022	$292,210,346	$289,904,939	$299,857,682	$297,491,941	$300,426,924	$298,056,692
3%	$724,871,192	$773,038,415	$766,939,493	$793,269,335	$787,010,800	$794,775,259	$788,504,842
2.5%	$989,031,685	$1,054,752,204	$1,046,430,687	$1,082,355,757	$1,073,816,461	$1,084,410,475	$1,075,854,969
3% 95th Percentile	$2,220,971,671	$2,368,553,809	$2,349,866,994	$2,430,540,407	$2,411,364,545	$2,435,154,487	$2,415,942,223
Changes of SC-GHG Compared to No-Build ($)							
Discount Rate (%)	Alt **A**	**Alt B**	**Alt C**	**Alt D**	**Alt E**	**Alt F**	**Alt G**
5%	N/A	$18,207,324	$15,901,917	$25,854,660	$23,488,919	$26,423,902	$24,053,670
3%	N/A	$48,167,224	$42,068,302	$68,398,143	$62,139,608	$69,904,067	$63,633,651
2.5%	N/A	$65,720,519	$57,399,002	$93,324,072	$84,784,776	$95,378,790	$86,823,284
3% 95th Percentile	N/A	$147,582,138	$128,895,323	$209,568,735	$190,392,874	$214,182,816	$194,970,552
Changes of SC-GHG Compared to No-Build (%)							
Discount Rate (%)	**Alt A**	**Alt B**	**Alt C**	**Alt D**	**Alt E**	**Alt F**	**Alt G**
5%	N/A	6.64%	5.80%	9.44%	8.57%	9.64%	8.78%
3%	N/A	6.64%	5.80%	9.44%	8.57%	9.64%	8.78%
2.5%	N/A	6.64%	5.80%	9.44%	8.57%	9.64%	8.78%
3% 95th Percentile	N/A	6.64%	5.80%	9.44%	8.57%	9.64%	8.78%

6.1.3 Potential Minimization and Mitigation Strategies

Reducing GHG emissions is a key strategy of MDOT to address climate change impacts. GHG emissions would be produced at different levels throughout construction phasing of a build alternative. At a Study level, although GHG mitigation measures are not specifically required under State regulations, MDOT will follow the approach set forth in the *Climate Pollution Plan* (MDOT, 2023), which presents MDOT's approach to support the requirements of the CSNA of 2022 and goals set forth by the MCCC Act.

Through transportation technology, climate action policies, regulations, pilot programs, and incentives for new vehicle technologies, the State stays on a course for increased EV market penetration. Maryland's leadership will continue to increase overall fleet efficiency across multiple modes and vehicle types by implementing the Zero Emission Vehicles Memorandum of Understanding. New vehicle technologies, including EVs, could reduce average annual CO_2 emissions from each vehicle by 34 percent (or 1.5 MT) by 2030. MDOT has approved installation of Utility-owned EV charging stations on 17 MDOT-owned sites. Maryland also leads the country in supporting hydrogen fueling infrastructure. Through implementation of hydrogen fueling projects, Maryland now has one of the highest concentrations of hydrogen refueling stations on the East Coast. These investments in hydrogen infrastructure have positioned Maryland as a leader in promoting the adoption of fuel cell vehicles. MDOT's Motor Carrier Division has been working with the Federal Motor Carrier Safety Administration to advance clean truck technology, improving air quality by replacing older diesel engines with newer, more efficient technologies.

Consideration of multimodal and operational enhancements—such as a potential bicycle and pedestrian SUP, park-and-ride facilities, and dedicated bus-on-shoulder or bus facility enhancements—into the proposed Bay Crossing Study improvements reflects a broad strategy to reduce GHG emissions through mode shift and congestion mitigation. The inclusion of a SUP would provide non-motorized travelers a safe and direct connection across the Chesapeake Bay for the first time, supporting regional active transportation goals and enabling low-emission travel options. Similarly, park-and-ride facilities would encourage carpooling and enable travelers to access enhanced transit services, reducing VMT and helping to manage peak period demand. These strategies align with the Study's stated objective of environmental responsibility, recognizing the transportation sector's contribution to GHG emissions and the need for sustainable alternatives.

Through TDM, MDOT will continue activities to reduce the total amount of VMT and GHG emissions from on-road vehicles. The Maryland Transportation Alternatives Program encourages the use of walking, biking, and transit and provides the infrastructure to support these options. The program funds pedestrian and bicycle facilities, Safe Routes to Schools projects, and recreational trails. The program also funds environmental mitigation related to these projects, such as water quality and SWM measures. SHA's Maryland Bikeways Program has expanded the network of bike facilities throughout the State, by funding new projects and providing a resource to local partners. MTA has implemented policies and programs to encourage transit use. MTA has also implemented its Vision Plan for Transit and will continue to implement projects that make transit a more competitive choice for travel in Maryland. By providing a range of transportation options, TDM can help to reduce GHG emissions from on-road vehicles.

Through Transportation Land Use Policies and Programs, MDOT will continue to implement land use policies and programs that promote smart growth and reduce the total amount of VMT and

GHG emissions from on-road vehicles. The Maryland Department of Planning (MDP) provides guidance, analysis, outreach and support to ensure that all of the State's natural resources, built environment, and public assets are preserved and protected to achieve its goals for economic, community, and environmental vitality. On October 1, 2025, Maryland enacted the Sustainable Growth Policy, also known as the Eight Planning Principles, which comprise the following areas: Land, Transportation, Housing, Economy, Equity, Resilience, Place, and Ecology. MDP will soon publish the Planning Principles Implementation Guide, which includes a set of key performance indicators (KPI) to measure the effectiveness of the State Sustainable Growth Policy and associated strategies and programs. VMT Per Capita, one of the KPIs, will be used to monitor progress toward the reduction of VMT and GHG emissions from on-road vehicles. MDP leads and coordinates the implementation of the new Planning Principles through active partnerships with local jurisdictions, state agencies, and other public and private stakeholders, as well as planning processes, analysis, policies, and actions to create sustainable communities and protect the environment in order to foster a high quality of life for all residents of the State. These collective efforts will promote sustainable transportation and further direct development in population centers and planned growth areas, such as transit-oriented development areas, to enhance placemaking and improve walkability. This will enable walking, biking, using public transit, and traveling shorter distances to reach jobs, housing, and services, thereby discouraging single-occupancy vehicle (SOV) travel and reducing VMT and GHG emissions from SOVs.

Through Transportation System Operations, MDOT will continue to improve the efficiency of the transportation system using technology and innovative operational strategies. SHA has implemented a variety of ITS projects throughout the State. ITS projects improve safety and reduce congestion by providing real-time traffic information to motorists, enabling more efficient traffic signal operations, and facilitating the movement of freight. The MDTA has also implemented innovative pricing strategies, such as dynamic tolling, to manage congestion and maximize the efficiency of the toll facilities. By improving the efficiency of the transportation system, MDOT can reduce GHG emissions from on-road vehicles.

Mitigation efforts should also focus on improving maintenance efficiency through advanced technology and planning, rather than restricting activities essential for maintaining a state of good repair. MDOT will continue to implement a comprehensive GHG mitigation strategy to reduce the total amount of GHG emissions from on-road vehicles. The strategy includes a combination of transportation technology, TDM, transportation land use policies and programs, and transportation system operations. By implementing these measures, MDOT can help Maryland achieve its GHG reduction goals and minimize the impacts of climate change.

6.2 Climate Change Analysis

Climate change has already started to impact Maryland through gradual warming, extreme weather, and other climate-driven changes. This section provides an analysis of existing and projected climate change conditions and describes how these changes are currently impacting critical assets within the analysis area. This analysis includes historic extreme weather events, road closures, detours, and climate-related damages to provide insight into the extent of impacts to transportation infrastructure and mobility to date. These parameters are important to understand the relative impact of climate change on this region currently and in the future.

6.2.1 *Affected Environment*

Existing conditions for climate change within the analysis area are discussed at the county, state, and regional levels. Climate trends on a national and global scale are included where applicable to discuss any deviations, similarities, or regional differences that are present. This information is used to contextualize climate change for the region and will be used as a basis for the impacts analysis. Critical assets and infrastructure are identified and their locations and proximity to evacuation routes and opportunity for hazard mitigation and resiliency enhancements are discussed. An analysis of current and projected trends for climate change and extreme weather in the region is also included.

6.2.1.1 Critical Assets & Infrastructure

Critical infrastructure assets in the analysis include roadway pavement, structures, facilities, vehicle fleet and equipment, and major information technology systems, as outlined in the MDOT Strategic Asset Management Plan (MDOT, 2025a). Along the approximately 20 miles of U.S. 50/301 within the analysis area, there are seven bridge structures over water recorded in the Maryland Bridge / Structure database, which further contribute to the area's connectivity (MDOT, 2025a). Roadway conditions within the analysis area range from very good to poor. The stormwater drainage infrastructure is extensive, including thousands of stormwater inlets, pipe/culvert end walls, head walls, and storm drain manholes. Other assets and infrastructure within the analysis area include communities, natural resources, and emergency and essential services.

Natural resources are abundant, with over 30 named bodies of water and a substantial floodplain area. The many delineated wetlands and waterways highlight the ecological diversity within the corridor. Forests also cover a notable portion of the analysis area, providing environmental benefits and recreational opportunities such as parks and trails.

As discussed in the Bay Crossing Study Socioeconomic and Land Use Technical Report, the analysis area is comprised of 42 block groups, with 24 in Anne Arundel County and 18 in Queen Anne's County (MDE, 2025) and encompasses the communities of Arnold, Broadneck, Cape St. Claire, Kent Island, Kent Narrows/Grasonville, and Queenstown. The Chesapeake Bay is a vital natural resource that significantly influences the region's economy, culture, and environment. Within these communities, there are vulnerable and equity populations characterized by available demographic and field data collection, such as rural areas, persons with disabilities, small businesses, and emergency service facilities; each of which are expected to experience unique effects from climate change. The communities within the analysis area include a mix of unincorporated communities, neighborhoods, and census-designated places ranging from rural to suburban. Essential services such as health care facilities, grocery stores, fire stations, and emergency medical services ensure the safety and well-being of these communities. See the Bay Crossing Study Socioeconomic and Land Use Technical Report for additional details on these communities.

6.2.1.2 Existing Climate Conditions Analysis

The Northeast region of the United States, which includes the analysis area, is characterized by four distinct seasons and diverse landscapes, including heavily forested areas, heavily populated urban areas, rural and agricultural areas, beaches, marshes, and other natural areas. The coastal areas support important economic and ecological resources and services, including fisheries, tourism, maintaining water quality, providing flood protection, and preserving biodiversity. Maryland‘s Atlantic Coastal Plain is heavily influenced by the Chesapeake Bay and Atlantic Ocean. Hurricanes, coastal storms (“nor’easters”), and tropical storms affect the analysis area with high winds, heavy rains, storm surge, and flash flooding (May et al., 2023).

Chronic Climate Variables

Chronic climate variables refer to physical risks arising from long-term shifts in climate patterns, such as sustained higher temperature, sea level rise and associated high tide flooding, and changing precipitation patterns.

Average Annual Temperature and Precipitation

Temperature and precipitation are moderated across Maryland‘s Atlantic Coastal Plain by the Chesapeake Bay and Atlantic Ocean, leading to seasonal variations in temperatures. Within the analysis area, weather station data from the U.S. Naval Academy in Annapolis and Stevensville on Kent Island indicate that between 2010 and 2023, annual temperatures have ranged from a low of 3 degrees Fahrenheit (°F) to a high of 103°F and averaged around 57-58°F (**Table 6-11**) (Northeast Regional Climate Center, 2024). Average total annual precipitation ranged between 42 and 44 inches and fell mostly as rain, as snowfall is uncommon in the region (Northeast Regional Climate Center, 2024).

Table 6-11: Average Temperature and Precipitation 2010-2023

Climate Variable	U.S. Naval Academy Weather Station	Stevensville Weather Station
Average Temperature (°F)	58.7	57.7
Average High Temperature (°F)	97.0	98.0
Average Low Temperature (°F)	14.0	14.0
Average Total Precipitation (in.)	42.8	44.7
Average Total Snow Fall (in.)	Not Available	12.3

Source: Northeast Regional Climate Center, 2024

According to the Fifth National Climate Assessment, the global average temperature has increased around 2°F above pre-industrial (1851-1900) levels (Marvel et al., 2023). Temperatures in Maryland have risen approximately 2.5°F since the beginning of the 20th century, with 2012 and 2020 as the warmest and second-warmest years on record, respectively (Runkle et al., 2022). Total annual precipitation has shown an above average trend between 1995 and 2020, compared to observed data going back to 1900 (Runkle et al., 2022). Ocean and coastal temperatures along the Northeast Continental Shelf have warmed by 0.15 to 0.7°F per decade (Friedland et al., 2020). The Chesapeake Bay has been warming since 1985, mostly driven by atmospheric changes and ocean warming in the lower Bay (Hinson et al., 2022).

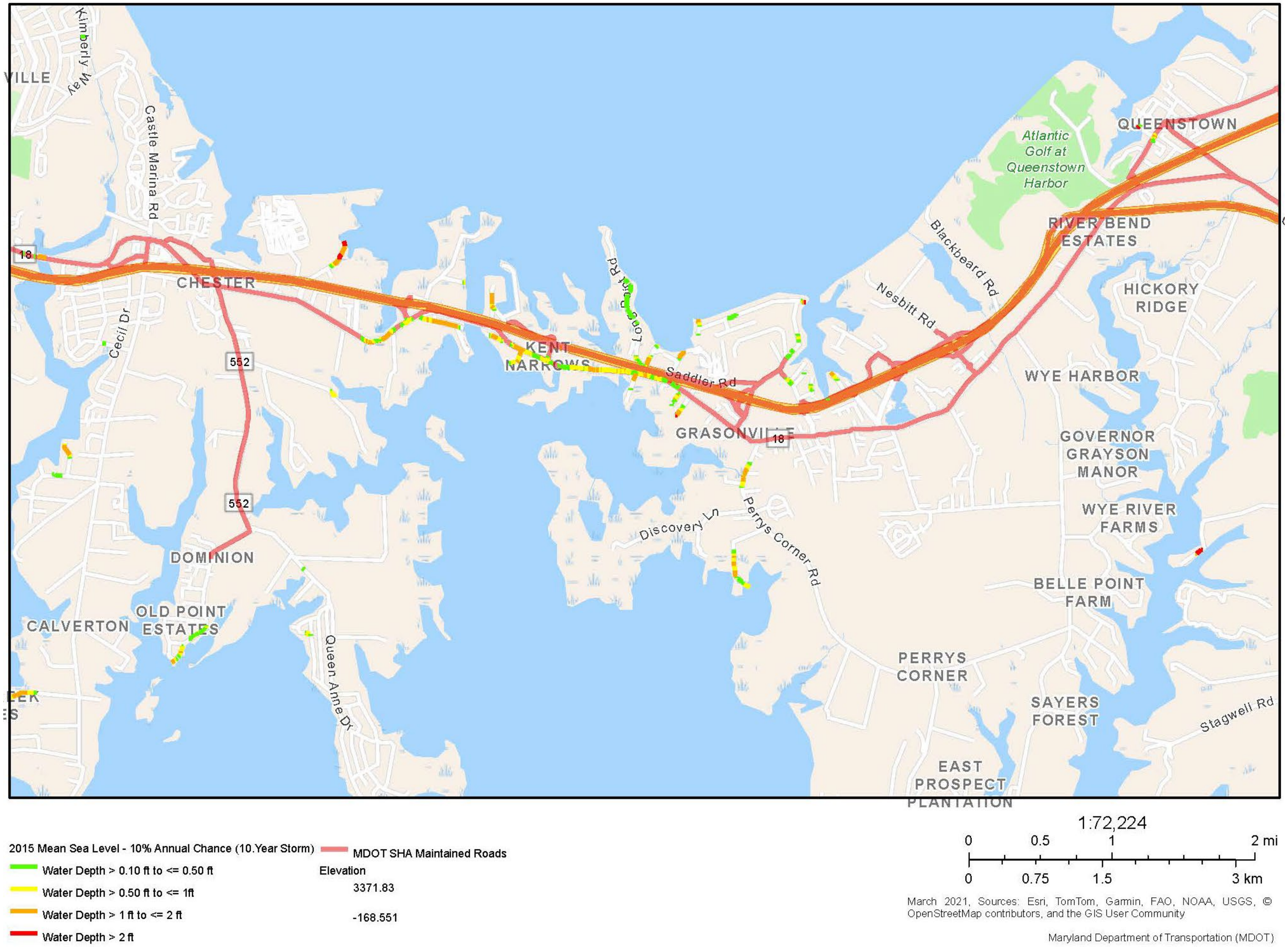
Sea Level Rise and Flooding

Sea levels along the contiguous U.S. coastlines have risen approximately 11 inches over the last 100 years (1920-2020), with roughly half (5 to 6 inches) occurring between the 30-year period of 1990 to 2020 (May et al. 2023). Regionally, the greatest rise has been observed along the western Gulf Coast, followed by the northeast and southeast Atlantic, and eastern Gulf Coasts (May et al., 2023). In Maryland, the rate of sea level rise measured by tide gauges in the

Chesapeake Bay has been, on average, 4.5 millimeters per year since 1975 (Boesch et al., 2023), or approximately 8.9 inches in the last 50 years.

Sea level rise contributes to the frequencies of both minor and moderate coastal flooding (nuisance flooding), which increased by a factor of 2 to 3 along most Atlantic and Gulf coastlines between 1990 and 2020 (May et al., 2023). According to the National Oceanic and Atmospheric Administration (NOAA), in Annapolis, high tide (or "sunny day") flooding days increased from 2 days typical in 2000 to 18 days in 2019 (NOAA 2020). High tide flooding has been reported at various locations within the analysis area between 2021 and 2024 (Maryland MyCoast, 2024). On- and off-ramps, service roads, and arterial roads are currently experiencing nuisance flooding near Kent Narrows (**Figure 6-5**), according to the MDOT CCVV (MDOT, 2025b). Two roads within the analysis area are identified as frequently flooded and defined as having unpassable conditions on the road due to water overtopping during or after a major storm event at least once every three years: MD 18A near Thompson Creek, and U.S. 50 over an unnamed tributary to Mill Creek (SHA, 2025).

Figure 6-5: Kent Narrows Roadway Inundation at 2015 Mean Sea Level with 10-year Storm



March 2021, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

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Acute Climate Variables

Acute climate variables refer to those that are event-driven including extreme weather events, such as extreme temperatures and precipitation, hurricanes, severe storms and floods, and wildfire. Drought conditions are considered an acute climate variable because they are periodic, though they can vary in duration and severity.

Extreme Temperatures and Precipitation

July 2023 was the hottest month on record on Earth, as confirmed by NOAA, the National Aeronautics and Space Administration, and the European Union Copernicus Climate Change Service, as well as having the highest-ever ocean surface temperatures (MCCC, 2023). The number of very hot days (defined as 95°F or higher) and nights (defined as 75°F or higher) in Maryland statewide has averaged 7 days and 5 nights since 1985, compared to 6 days and 3 nights between 1950-1984 (Runkle et al., 2022). Despite the increase in frequency of very hot days, the extreme heat record of 109°F has not been exceeded since reported in 1936 (**Table 6-12**) (NOAA, 2024c). The average number of 2-inch extreme precipitation events averaged 2.5 days per year during the 2005-2020 interval, compared to 1.8 days per year during the 1950-2004 interval (Runkle et al., 2022).

Table 6-12: Maryland Climate Extremes

Climate Variable	Value	Date(s)	Location
Maximum Temperature (°F)	109	July 10, 1936	Cumberland, Frederick
		August 7, 1918	Cumberland
		August 6, 1918	Cumberland, Keedysville
		July 3, 1898	Boettcherville
Minimum Temperature (°F)	-40	January 13, 1912	Oakland
24-hour precipitation (in)	14.75	July 26-27, 1897	Jewell
Maximum Annual Precipitation (in.) (Jan 1 – Dec 31)	84.56	January 1 – December 31, 2018	Catonsville

Source: State Climate Extremes Committee (NOAA, 2024c) using the National Centers for Environmental Information Historical Observing Metadata Repository.

Severe Storms

Hurricanes, nor'easters, and tropical storms affect the analysis area with high winds, heavy rains, storm surges, and flash flooding. Climate change is resulting in more extreme weather across the United States' coastal areas, with sea level rise amplifying flooding levels. Nationwide, there were 38 tropical cyclones between 2000 and 2021 that caused over $1 trillion in losses (in 2002 dollars) and 6,200 deaths (May et al., 2023). Hurricanes have historically impacted the analysis area, within Queen Anne's County and Anne Arundel County, including Hurricane David in 1979, Hurricane Floyd in 1999, Hurricane Isabel in 2003, Hurricane Irene in 2011, and Tropical Storm Isaias in 2020 (Anne Arundel County, 2025; Queen Anne's County, 2025). Hurricane Isabel caused record breaking tide and storm surge damage in Queen Anne's County, estimated at $37 million (NOAA, 2024a), and approximately $500 million in damages in Anne Arundel County (Anne Arundel County, 2025). While the National Centers for Environmental Information list only a few past major events for Queen Anne's County, the analysis area may have experienced impacts by other hurricane and tropical storm events that affected the State of Maryland. Thirtyfive tropical storms, tropical depressions, extratropical storms and hurricanes occurred in Maryland[2] since 2000 with five Category 1 or greater storms including Hurricane Sandy (2012), Hurricane Arthur (2014), and Hurricane Dorian (2019) (NOAA, 2025). Damage from flooding associated with Hurricane Sandy in 2012 was estimated at around $5 million for the Eastern Shore of Maryland, with a majority of the damage linked to excessive rainfall of up to 13 inches and high winds (NOAA 2024b, NOAA, 2013). Since February 2021, Maryland experienced 583 general flooding events, 454 flash flooding events, and 215 heavy rain events (MDOT, 2024c).

Wildfire

Wildfire trends in the analysis area align with the seasonal trends for the state of Maryland, with the peak seasons in spring and fall when deciduous trees have no leaves, allowing sunlight and wind to reach the forest floor and dry the fuels (MDNR, 2024). An analysis of wildfires within the analysis area has not been completed but data from Anne Arundel County and Queen Anne's County are available through their respective Hazard Mitigation Plans. Anne Arundel County experienced 48 wildfires which burned a total of 716.6 acres between 2000 and 2023 (Anne Arundel County, 2025). Between 2000 and 2022, Queen Anne's County experienced 233 wildfires with a total of 486 acres (Queen Anne's County, 2025).

Outside the analysis area, wildfires across the state of Maryland impact the analysis area through smoke exposure. Wildfires are a common occurrence in Maryland, with approximately 200 wildfires annually that have burned up to 2,200 acres of land in a given year (MDNR, 2025). In 2024, the Maryland Forest Service reported a total of 165 fires, burning a total of 953 acres (MDNR, 2024). Maryland Forest Service data starts in 2004 and is not sufficient to describe trends in fire frequency or intensity compared to historical data. The EPA reports the extent of burned land increased by 0.15 acres per square mile in Maryland from 2003-2021 compared to the period between 1984-2002 (EPA, 2025c).

Drought

Droughts occur in Maryland despite increases in precipitation, namely due to the amount of rainfall in extreme precipitation events, which can affect natural processes for groundwater storage and recharge. Since 2000, the U.S. Drought Monitor has tracked drought conditions nationally and assigned a category or level of severity based on percentiles to place each event in a historical context. The Drought Monitor shows Anne Arundel County and Queen Anne's County experienced an exceptional (D4) drought (defined as the most severe category and expected to occur once or twice within a 100-year period) in 2002. Anne Arundel County and Queen Anne's County experienced extreme drought (D3) (among the worst on record and expected to occur once every 20-50 years) or severe (D2) drought (expected to occur once every 10-20 years) in 2002, 2007, 2010 (Anne Arundel only), 2012, 2017 (Anne Arundel only), 2018 (Anne Arundel only), 2019, 2023 (Anne Arundel only), 2024, and 2025 (U.S. Drought Monitor, 2025).

It is difficult to show a trend in droughts influenced by climate change. A recent research article from researchers at Dartmouth College and Columbia University described the frequency of Maryland droughts compared with the expected frequency based on historical trends, which

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[2] Based on hurricane tracks located within 150 miles of the state border.

indicated that droughts are increasing in frequency and severity, though the trends are gradual (Li et al., 2024).

6.2.1.3 Projected Climate Conditions Analysis

Climate change is already experienced in Maryland through warmer temperatures, increased precipitation, increased extreme weather such as heat waves and precipitation events, and sea level rise and associated flooding. The trends already observed in both chronic and acute climate variables are expected to continue and, in some cases, accelerate due to climate change.

The IPCC Fifth Assessment Report (AR5) introduced Representative Concentration Pathways (RCPs) to describe potential climate futures based on varying levels of GHG emissions by representing different GHG concentration trajectories that describe potential climate futures based on varying levels of emissions. The IPCC Sixth Assessment Report (AR6) introduced an updated framework called Shared Socioeconomic Pathways (SSPs), which describe different socio-economic futures. The SSPs are combined with an updated set of RCPs to form the following five scenarios that capture how different socio-economic pathways can shape future climate outcomes (IPCC, 2021):

- **SSP1-1.9** and **SSP1-2.6** represent a scenario with sustainability-focused development;
- **SSP2-4.5** represents a scenario with continued historical trends for development;
- **SSP3-7.0** represents a scenario where individual countries increasingly focus on domestic or regional issues;
- **SSP4-3.4** represents a scenario with inequality-driven futures; and
- **SSP5-8.5** represents a scenario of very high emissions resulting from fossil-fuel-driven growth.

These integrated scenarios are utilized across international climate-related scientific literature and are integrated into the discussion of projected climate conditions within the analysis area.

Chronic Climate Variables

Average Annual Temperature and Precipitation

The observed increases in average temperature and precipitation are projected to continue and accelerate within the analysis area. Projected climate conditions for Anne Arundel County and Queen Anne’s County include an increase in average annual temperature at a rate slightly higher than what is anticipated globally, a decrease in the number of days below freezing (32°F), and an increase in average annual precipitation (**Table 6-13**) (Marvel et. al., 2023). The most recent models do not assign a time frame for these anticipated changes due to uncertainties over global rates of GHG emissions, and instead, calibrate the anticipated future changes based on a threshold of global temperature increase of 3.6˚F.

Table 6-13: Climate Projections for Anne Arundel County and Queen Anne's County

Climate Projections*	Anne Arundel County	Queen Anne's County
Change in Average Annual Temperature	Increase by 3°F	Increase by 3°F
Change in the Number of Days per Year Under 32°F	Decrease by 23 days	Decrease by 24 days
Change in Annual Precipitation	Increase by 6 percent	Increase by 5 percent

Table Notes:

*Projections are anticipated to occur at the point when global temperature increases by 3.6°F over pre-industrial average (1851-1900), data from downscaled Coupled Model Intercomparison Project (CMIP6) reported in the Fifth National Climate Assessment (Marvel et al., 2023).

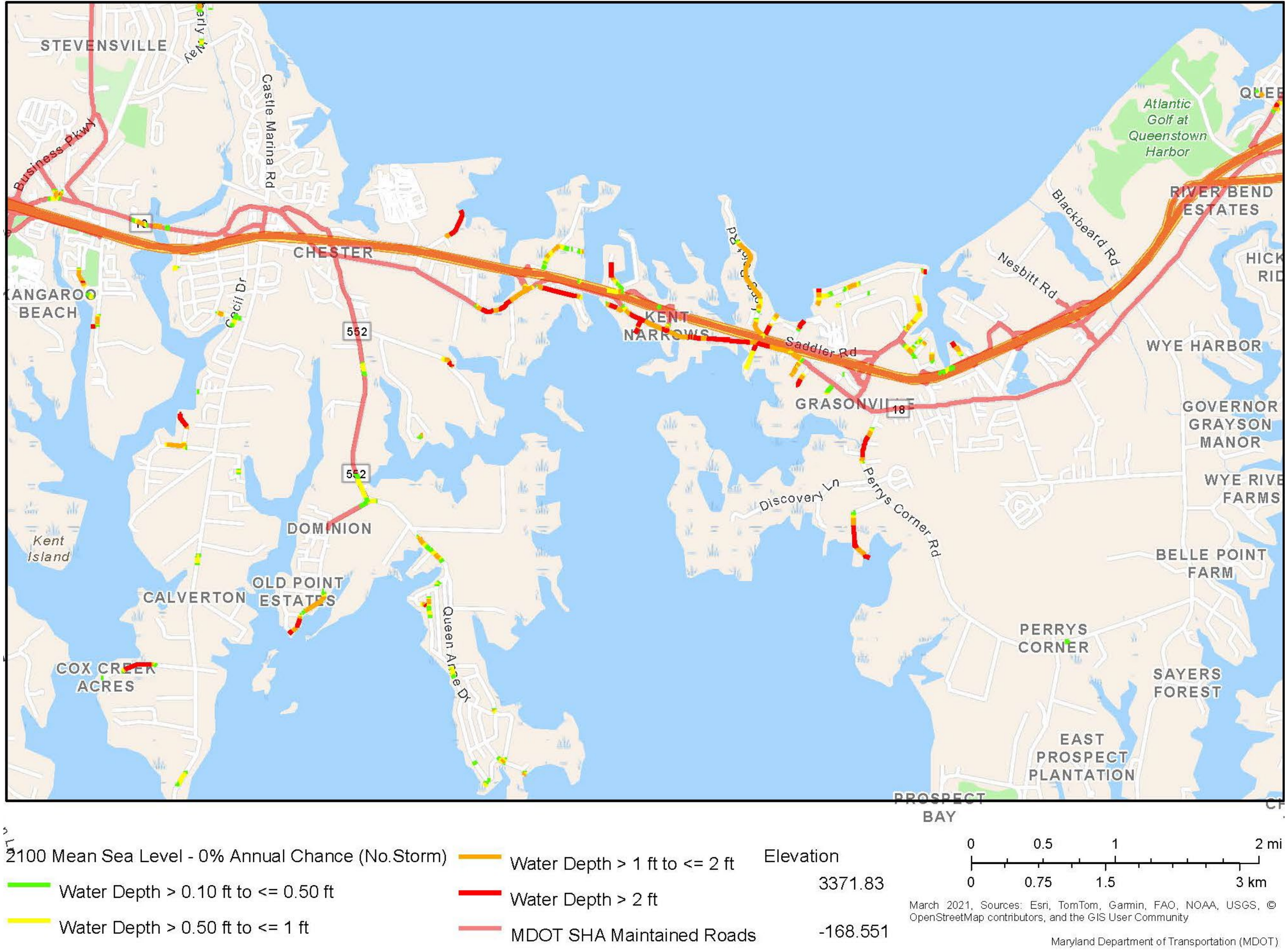
According to the IPCC, global warming of 3.6°F relative to 1850-1900 is very likely to be exceeded in the mid-term time period (2041-2060) under a very high GHG emissions scenario (SSP5-8.5), likely to occur under the high GHG emissions scenario (SSP 3-7.0), and more likely than not to occur in the intermediate GHG emissions scenario (SSP2-4.5) (IPCC,2021).

Sea Level Rise and Flooding

The U.S. Interagency Sea Level Rise Task Force established five future global sea level rise scenarios relative to 2000 levels by 2100, from a low of 1 foot to a high of 6.6 feet, with regional variation (May et al., 2023). The Northeast has experienced some of the highest rates of sea level rise and ocean warming in the U.S., and these increases relative to other regions are projected to continue through the end of the century (Marvel et al., 2023). The University of Maryland Center for Environmental Science projects that the State could experience a sea level rise of 2 to 3.5 feet by 2100, factoring in local conditions such as land subsidence (MCCC, 2023).

In Maryland, 356 miles of the approximately 7,920 linear miles of roadways that are maintained by the State will be threatened by sea level rise by 2100 (MDE, n.d.). By 2050, high tide or nuisance flooding associated with sea level rise is not expected to result in roadway inundation within the analysis area; however, portions of the analysis area including on-ramps and adjacent roads and streets could be inundated by over 2 feet by 2100, not including U.S. 50/301 (**Figure 6-6**) (MDOT, 2025b).

Figure 6-6: Kent Narrows Projected Roadway Inundation from Sea Level Rise by 2100



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Acute Climate Variables

Extreme Temperatures and Precipitation

Climate projections for Anne Arundel County and Queen Anne’s County predict increased frequency and severity of extreme heat and an increase in extreme precipitation (defined as an annual number of days with precipitation in the top one percent of historical rainfall events) (**Table 6-14**). Rather than assigning a time horizon for these projected changes, the most recent modeling uses a global temperature increase of 3.6°F as a proxy due to the uncertainties over future GHG emission rates. In other words, by the time global temperatures have increased 3.6˚F, local projected changes include an increase in extreme heat days and extreme precipitation. Marine heatwaves are increasing in frequency in the Northeast and are projected to reach a semi-permanent marine heatwave state (defined as extreme temperatures occurring for more than six months in a year) by 2100. Increases in precipitation will continue to increase the risk of coastal flooding, poor water quality, and changes to habitats in the Chesapeake Bay.

Table 6-14: Climate Projections for Anne Arundel County and Queen Anne’s County

Climate Projections*	Anne Arundel County	Queen Anne’s County
Change in the Annual Number of Days over 95°F	Increase by 14 days	Increase by 12 days
Change in Extreme Precipitation (annual number of days with precipitation in the top 1% of historical rainfall events)	Increase by 31%	Increase by 25%

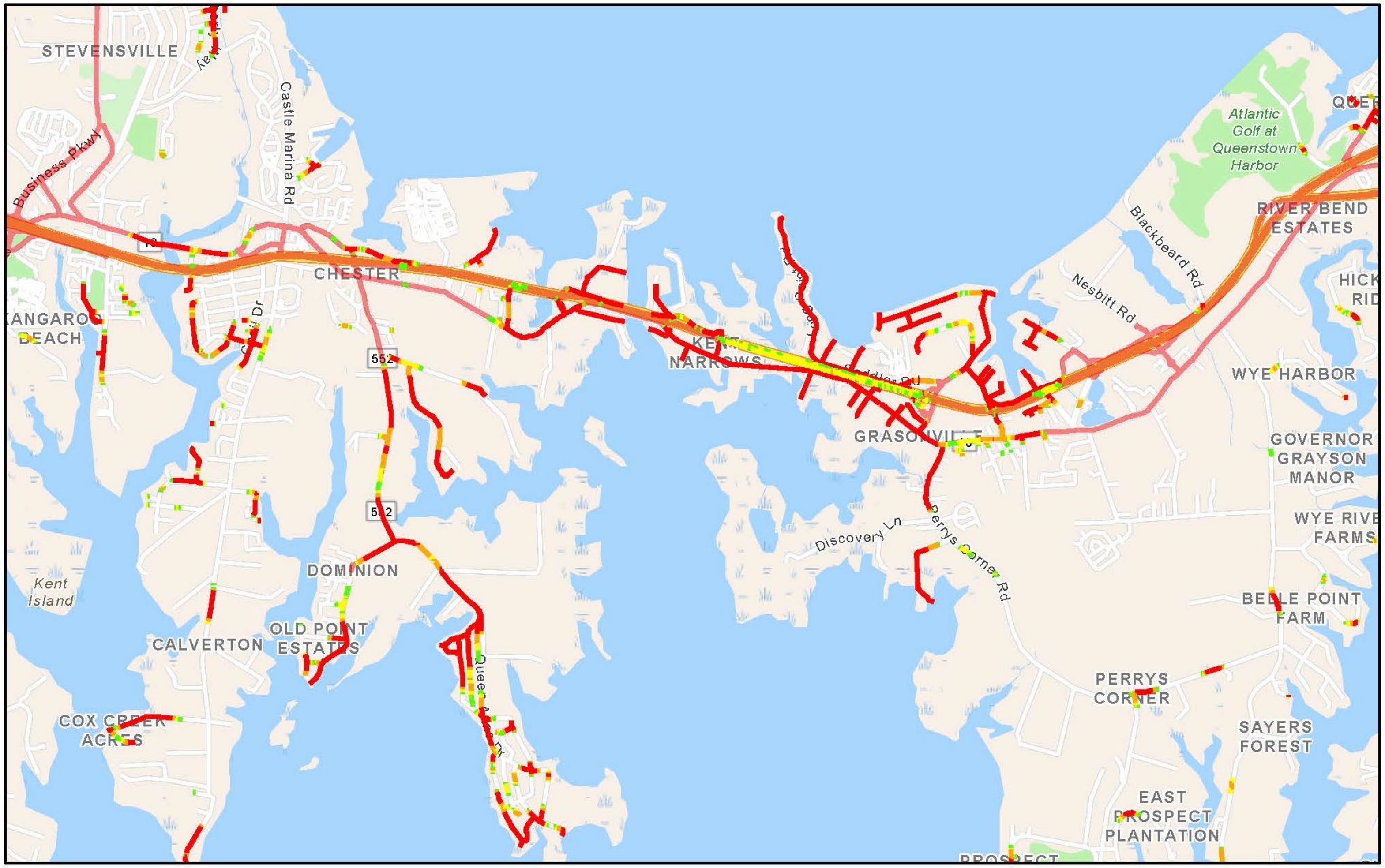
Table Notes:

*Assuming global temperature increases by 3.6°F over pre-industrial average (1851-1900), data from downscaled CMIP6. According to the IPCC, global warming of 3.6°F relative to 1850-1900 is very likely to be exceeded in the mid-term time period (2041-2060) under a very high GHG emissions scenario (SSP5-8.5), likely to occur under the high GHG emissions scenario (SSP 3-7.0), and more likely than not to occur in the intermediate GHG emissions scenario (SSP2-4.5) (IPCC, 2021).

Severe Storms and Flooding

Various models have been run to predict the location and extent of flooding on arterial roads and interstates under different scenarios associated with severe storms. The MDOT CCVV shows roadway inundation on arterials and collectors that intersect with U.S. 50/301 within the analysis area by the year 2100 when combined with a 100-year storm event, particularly near Kent Narrows (**Figure 6-7**).

Figure 6-7: Kent Narrows Projected Roadway Inundation from 100-year Storm and Sea Level Rise by 2100



March 2021, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

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Wildfire

The influence of climate change on wildfire risk can be tied to extreme heat waves that are expected to become more frequent and severe, leading to drying of vegetation and increased wildfire risk. Periods of drought and the potential for invasive species to alter the fuel load and condition of vegetation further increase the risk. Increased wildfires, including large fires burning in other regions in North America, are likely to cause increased air quality issues in Maryland.

Drought

A state's vulnerability to drought is defined by the likelihood of negative economic impacts from droughts, how often droughts occur, and the ability of the state to recover from drought events. Maryland's vulnerability to drought is low (Engström et al., 2020); however, droughts are expected to continue to occur in Maryland despite the projected increases in precipitation (Runkle et al., 2022). Maryland's droughts are expected to worsen because higher temperatures increase the rate of soil moisture loss during dry spells (Runkle et al., 2022).

6.2.1.4 Existing Climate Impacts on Critical Assets and Transportation Features

Climate-related impacts are already occurring in the analysis area, impacting roadways and associated infrastructure and systems with damage and increased maintenance requirements. These impacts also influence individuals using the infrastructure, leading to behavioral changes, and potential short- and long-term health effects. High tide flooding currently impacting on- and off-ramps, service roads, and arterial roads near Kent Narrows, MD 18A near Thompson Creek, and U.S. 50 over an unnamed tributary to Mill Creek is expected to continue worsening with sea level rise. Severe storms have the potential to further increase flooding in these low-lying areas and cause damage to roads, bridges, and other associated infrastructure.

Extreme heat impacts the transportation infrastructure and poses health risks related to heat-related illnesses for people using the transportation system, including employees. Within the analysis area, traffic volumes may increase during extreme heat events as people travel to beaches and other natural areas. Extreme heat can also impact the structural integrity of roadway and bridge materials, potentially leading to buckling, cracking, and potholes.

Climate-related impacts do not occur in isolation, and compounded climate impacts often contribute to the greatest threats to transportation infrastructure, such as coastal flooding from extreme precipitation and sea level rise. **Table 6-15** summarizes the existing climate-related impacts to transportation infrastructure and notes where such impacts can be compounding.

6.2.1.5 Existing Climate Impacts on Natural Resources

Chronic and acute climate change hazards have already impacted natural environments within the analysis area. Chronic climate change impacts include increased depth and frequency of inundation in estuarine habitats; introduction of salt water to uplands or forest habitat; shifts in species distributions and abundance, impacting fisheries and wildlife and potentially facilitating the spread of invasive species and diseases; and acidification impacting shell-building organisms (Whitehead et al., 2023). The warming water of the Chesapeake Bay has led to changes in fish and shellfish community structures, with declines in economically important species (blue crabs, striped bass, oysters, Atlantic menhaden) in the Chesapeake Bay from 2008-2019, and the appearance and abundance changes of subtropical species such as pinfish and white shrimp (Tuckey et al., 2021).

Acute climate change impacts include damage to habitats from extreme events or severe storms, with sudden and dramatic changes in nutrient, oxygen, and salinity levels. Extreme temperatures and precipitation can stimulate algal growth from increased nutrients or warm water temperatures resulting in hypoxia, or areas of very low or no oxygen within the water column. This can displace mobile aquatic species and kill immobile shellfish (NOAA, 2021). Intense rainfall events can lower salinity and change the distribution of different types of fish, including invasive species (NOAA, 2021). **Table 6-16** summarizes the existing climate-related impacts to natural resources.

6.2.1.6 Existing Climate Impacts on Communities

Communities within the analysis area are exposed to climate-related risks associated with hazards such as sea level rise, severe storms (tropical storms and hurricanes, derechos, thunderstorms, blizzards and ice storms, Nor'easter events), extreme precipitation and flooding, and extreme heat. The frequency and intensity of these events are impacted by climate change, which is contributing to increases in sea level rise for the region, more intense and unpredictable storm events, more frequent flooding, and more frequent and prolonged extreme heat events. Climate-related impacts to communities within the analysis area vary depending on location and access to essential resources and include damage to homes and regional infrastructure that can disrupt business operations and emergency access routes, as well as creating public health concerns regarding safety and exposure to climate-related hazards.

Communities within the analysis area and those that are accessed by U.S. 50/301 rely on recreation access and tourism to beaches in Sussex County, Delaware, and Worcester County, Maryland. According to the Delaware Resiliency Report (Wakefield and Falk, 2017), the peak of the tourist season is summer, with a decreased level of tourism occurring during the spring and fall shoulder seasons. Rising air and sea surface temperatures associated with climate change may extend the length of the peak and shoulder tourism seasons and may facilitate increased beach visitation during periods of extreme heat. However, beach areas are vulnerable to impacts from sea level rise and storm surge, which can lead to erosion and loss of beach width and can limit the ability for nearby communities and tourists to recreate in impacted areas.

Underserved populations within the analysis area face heightened risks from climate change impacts. Low-income households often lack the financial resources needed to prepare for or recover from extreme weather events such as severe storms, heatwaves, and flooding, increasing their risk of adverse health outcomes and property damage (EPA, 2021). These risks are particularly pronounced in this region, where many communities fall within the top quintile of flood risk nationwide (FEMA, 2025). Limited access to personal vehicles further compounds vulnerability, as many residents rely on public transportation, which may be disrupted during emergencies.

Public health risks from climate change extend beyond acute weather events. Prolonged exposure to extreme heat and poor air quality can significantly affect individuals with preexisting conditions, particularly in vulnerable populations. The analysis area includes several small industrial zones in Broadneck, Arnold, Kent Island, and Kent Narrows/Grasonville communities.

Vulnerable populations may face elevated exposure to air pollution due to the proximity of their neighborhoods to industrial areas, conditions that can worsen respiratory illnesses and other chronic health problems (EPA, 2021).

These same populations often live in areas projected to experience greater increases in asthma diagnoses, heat-related illnesses, and delays in mobility due to coastal flooding (EPA, 2021). Limited access to healthcare and emergency services further reduces their capacity to respond to climate-related events. Additionally, changing seasonal patterns, such as shorter winters and longer, warmer summers, are creating conditions favorable to vector-borne diseases. Warmer temperatures have already contributed to an increase in tick-borne illnesses across Maryland and the broader Mid-Atlantic region (University of Maryland, 2023).

In addition to health and mobility challenges, climate change also places financial strain on low-income households through increased energy burdens and reliability concerns. Households with limited income may spend a disproportionate share of their earnings on energy costs, particularly as stronger climate policies drive up energy prices (UH Energy White Paper, 2025). Grid disruptions caused by storms or heatwaves can further compound these issues by cutting off access to essential services such as heating, cooling, and municipal water supplies.

Rural areas within the analysis area, including parts of Arnold, Broadneck, Kent Narrows/Grasonville, and Queenstown, face distinct vulnerabilities due to land use patterns and physical isolation. These communities are often surrounded by undeveloped parcels, agricultural land, or very low-density residential zones, which can limit access to communication networks and emergency services during climate-related events (AARP, 2025). Residents in these areas are frequently dependent on regionally based infrastructure and industries such as agriculture, forestry, and recreation—sectors that are highly sensitive to climate stressors like droughts, flooding, and severe storms (EPA, 2021; CDC Climate and Health Data, 2025). Economic instability, coupled with fewer local resources and lower population densities, makes adaptation and recovery efforts more difficult in these communities (Maryland Department of Emergency Management, 2025).

The continued functionality of emergency facilities, such as police stations, firehouses, hospitals, and disaster recovery centers, is critical for community resilience and response during emergencies. However, many of these facilities are exposed to flooding and coastal storm impacts. Rising sea levels and more frequent extreme weather events pose a dual threat: increasing the cost and complexity of infrastructure maintenance while potentially limiting access during emergencies. Communities such as Arnold, Broadneck, Cape St. Claire, and southern Kent Island are particularly susceptible to flooding that could hinder emergency operations (Maryland Department of Emergency Management, 2025; MDOT, 2025b). Even areas with relatively lower flood exposure, like Queenstown, may still face access challenges during major events (MDOT, 2025b). **Table 6-17** summarizes the existing climate-related impacts to communities within the analysis area.

Table 6-15: Existing Climate Impacts on Transportation

Hazards	Associated Climate Impacts	Description
Coastal Flooding	Sea level rise, extreme precipitation	• Bridge overtopping, seawater-related corrosion and structural damage potentially accelerating bridge deterioration, or resulting in reduced structural integrity • Damage due to flooding, erosion, and saturated soil • Reduced infrastructure life cycle from repeated runoff events • Shift from active transport (walking/biking) to vehicle or public transit • Road detours and closures; travel lanes and bus routes blocked or rerouted due to flooding
Extreme Temperatures	Average annual temperature, drought, wildfire	• Roadways impacted through cracking, buckling, and rutting from heat • Increased maintenance frequency • Adverse health impacts for walkers and cyclists • Public health risks for MDOT employees due to unsafe working conditions • Shift from active transport to vehicle or public transit • Power outages and interruptions to communication systems
Severe Storms and Extreme Precipitation	Sea level rise, average annual temperature	• Damage to roadways from blowing debris or washed-out roads and erosion from extreme precipitation • Damage to roadways from flooding, erosion, and saturated soil • Reduce infrastructure life cycle from repeated events • Damage to traffic signals, road signs, and other associated infrastructure • Power outages and interruptions to communication systems • Shift from active transport to vehicle or public transport • Road detours and closures due to flooding or downed trees; critical access routes closed (e.g., Chesapeake Bay Bridge during Hurricane Isabel (2003) and Hurricane Irene (2011))
Wildfire and Drought	Extreme temperature, average annual temperature	• Road closures and reduced visibility from smoke • Obstructions, debris flows, and other runoff concerns from fires along streams and other waterways • Reduced slope stability due to burn scars • Shift from active transport to vehicle or public transit • Reduced active transport due to short- and long-term health impairments • Reduced pavement integrity from subsidence, collapsible soils, and increased groundwater pumping • Reduced slope stability due to decreased roadside seeding establishment

Table 6-16: Existing Climate Impacts on Natural Resources

Hazards	Associated Climate Impacts	Description
Coastal Flooding	Sea level rise, storm surge, extreme precipitation	• Wetlands will experience more frequent and longer periods of inundation; some wetlands may shift or expand into areas previously considered upland or convert to submerged aquatic habitat if elevation or development pressures prevent the shift • Saltwater intrusion can result in tree mortality creating "ghost forests"
Extreme Temperatures	Average annual temperature, drought, wildfire	• Extreme temperatures are associated with harmful algal blooms and impacts on commercial fisheries and aquaculture (Mazzini and Pianca 2022) • Extreme temperatures result in tree stress and mortality, alter growth rates or phenology, and contribute to higher wildfire risk due to increased fuel load • Shift of species abundance and distribution as temperatures increase, negatively impacting temperate species and favoring subtropical species
Severe Storms and Extreme Precipitation	Sea level rise, severe storms, extreme precipitation	• Coastal flooding and erosion from severe storms can expose and destabilize tree roots making forests more vulnerable to storm damage • Heavy precipitation events cause increased runoff and nutrient loading into the Chesapeake Bay, which contributes to algae growth and low oxygen levels (hypoxia)
Wildfire and Drought	Extreme temperature, average annual temperature	• Drought can increase the salinity of portions of the Chesapeake Bay from reduced freshwater flow • Drought stress causes trees to brown or drop leaves and can contribute to increased fire risk. • Wildfires can disrupt habitat for wildlife temporarily, and impact water quality and soil stabilization in recently burned areas.

Table 6-17: Existing Climate Impacts on Communities

Hazards	Associated Climate Impacts	Description
Coastal Flooding	Sea level rise, storm surge, extreme precipitation	• Damage to homes, infrastructure, and recreation areas due to flooding, erosion, seawater-related corrosion, and saturated soil • Disruption of access to emergency services and essential facilities • Increased insurance premiums or lack of insurability • Damage to beaches impacting tourism, port operations and regional commerce
Extreme Temperatures	Average annual temperature, drought, wildfire	• Elevated health and safety risks, especially for vulnerable populations and those with preexisting conditions. • Increased risk of vector-borne diseases • Increased visitation to beach areas during extreme heat events
Severe Storms and Extreme Precipitation	Sea level rise, severe storms, extreme precipitation	• Damage to transportation infrastructure including roads, traffic signals, and signs • Reduce infrastructure lifespan from repeated storm events • Power outages and communication disruptions • Delays in mobility and emergency response • Closure of critical corridors (e.g., Chesapeake Bay Bridge during Hurricane Isabel (2003) and Hurricane Irene (2011))
Wildfire and Drought	Extreme Temperatures, annual average temperature	• Agricultural impacts from drought include reductions in crop yields, size and quality of products. • Limited access to municipal water supplies from prolonged periods of drought • Degraded air quality resulting from extreme temperatures and wildfire smoke

6.2.2 Environmental Consequences

Changing climate conditions can further exacerbate Study-related impacts to resources within the analysis area. The following sections describe the direct and indirect climate change effects on the Bay Crossing Study ARDS.

6.2.2.1 Alternative A: No-Build

Alternative A (No-Build) retains the existing Chesapeake Bay Bridge, U.S. 50/301 alignment, and number of lanes. Chronic and acute climate hazards are expected to continue to impact the existing Chesapeake Bay Bridge and U.S. 50/301 corridor and associated infrastructure, as well as natural resources and communities within the analysis area and beach communities connected to the U.S. 50/301 corridor, as described in **Section 6.2.1**.

6.2.2.2 Alternatives B and C

Both chronic and acute climate hazards are expected to impact Alternatives B and C similarly, as these alternatives include the same number of lanes with either a north or south alignment. These impacts are expected to be experienced through road closures, seawater-related corrosion and structure damages, construction schedule impacts, changes in traffic patterns and patterns of active transportation, and impacts to natural resources adjacent to the roadways. Extreme heat and drought are expected to impact all build alternatives equally because these impacts are regional.

Specific examples of impacts of climate change to Alternatives B and C were derived from the MDOT CCVV. By 2050, current nuisance flooding would worsen conditions of on- and off-ramps, service roads, and arterial roads near Kent Narrows. By 2100, flooding would impact the U.S. 50/301 alignment within the footprint of Alternatives B and C when combined with a 10-year storm, with a potential for over 2 feet of flooding on the road when combined with a 100-year storm. The locations where flooding is projected to occur (assuming a 100-year storm by the year 2100) include: the eastern terminus of the bridge span near Oceanic Drive, westbound lanes of the bridge span near the western terminus in the vicinity of Pier 1 Road and near Shopping Center Road west of the Cox Creek Bridge.

Natural resources located within Alternatives B and C are impacted by climate change from more frequent and longer periods of flooding, saltwater intrusion, shifts of species abundance and distribution, coastal flooding and erosion, harmful algal blooms and hypoxia, and ocean acidification. According to the CCVV, Targeted Ecological Areas and Sensitive Species Project Review Areas located within the footprints of Alternatives B and C that are projected to be inundated by 2100 under nuisance tidal conditions as well as storm conditions include Mezick Pond at the western terminus of the bridge crossing, and in the vicinity of Thompson Creek and Cox Creek. A habitat protection area is located between the Oceanic Drive interchange and Mezick Pond, within Sandy Point State Park in Anne Arundel County, due to the presence of rare breeding birds, including the State threatened least tern (*Sternula antillarum*), State rare sora (*Porzana carolina*), and State endangered and federally threatened black rail (*Laterallus jamaicensis*). Climate change may impact these birds through reductions in prey availability from changes in distribution and abundance of aquatic species, hypoxia, and harmful algal blooms.

As stated in the NETR, Study impacts to wetlands are comparable for Alternatives B and C (**Table 6-18**). Study-related impacts to forests, oyster beds and SAV are lower for Alternatives B and C when compared to Alternatives D, E, F, and G (**Table 6-18**). Alternatives B and C would result in forest impacts, primarily within previously disturbed areas (i.e., associated with development and transportation infrastructure). Alternative C is the only build alternative that is anticipated to avoid impacts to SAV because of its short southern alignment, which avoids an area of SAV just north of the bridge, along the eastern shoreline (**Table 6-18**). More detail on analysis methodologies is provided in the *Natural Environment Technical Report*.

Study impacts to wetlands and other aquatic and terrestrial habitat types could increase the vulnerability of infrastructure and adjacent communities. Alternatives B and C could create adverse impacts to communities within and near the analysis area through the loss of wetlands and other aquatic and terrestrial habitat types, which makes communities more vulnerable to hazards from reduction of services those areas provide, such as wave attenuation, flood protection, groundwater recharge, improved water quality, and shoreline stabilization.

Study impacts to wetlands and other aquatic and terrestrial habitat types would also decrease the potential for carbon storage within the analysis area. Coastal forests store high concentrations of carbon per unit area, with significant quantities held in both above-ground biomass (tree trunks, branches, and foliage) and below-ground root systems. Wetlands function as carbon sinks through accumulation of organic matter in saturated soils, where anaerobic conditions slow decomposition and enable long-term carbon storage in sediments. SAV sequesters carbon through photosynthesis while trapping and stabilizing carbon-rich sediments on the bay floor. Oyster reefs contribute to carbon storage through the calcium carbonate in their shells and by filtering organic matter from the water column that subsequently settles and becomes buried in sediments. The removal or degradation of these habitats releases stored carbon and eliminates ongoing sequestration capacity, thereby contributing to net atmospheric CO_2 increases and reducing the natural carbon storage services these ecosystems would otherwise provide over project timescales of 75-100 years (IPCC, 2022). While the scientific basis for linking habitat impacts to carbon emissions and sequestration losses is well established, the development of standardized and fully defensible carbon accounting methodologies for coastal resources, especially below-ground and sediment carbon is ongoing; therefore, this comparison of carbon storage among the project alternatives is presented qualitatively.

Alternatives B and C result in the lowest levels of carbon storage impacts among the build alternatives. Both alternatives involve approximately 1.2 acres of wetland impacts, and Alternative C uniquely avoids impacts to SAV. Forest impacts are also lower under these alternatives: 73.7 acres for Alternative B and 87.2 acres for Alternative C, primarily within previously disturbed areas. As a result, Alternatives B and C are expected to minimize loss of stored carbon, retain greater future sequestration potential, and better preserve natural systems that buffer climate-driven flood and erosion hazards. These benefits are especially relevant in areas near Kent Narrows, where flooding is projected to increase substantially by 2050–2100 under the MDOT CCVV.

Specific roadway and bridge and culvert design varies by alternative; however, design of these components under Alternatives B and C would consider future flood elevations along U.S. 50/301. This could create beneficial impacts to communities by minimizing flood-related hazards. Climate-related impacts to communities may evolve throughout the project lifecycle as climate conditions change; however, these impacts cannot be predicted with certainty.

6.2.2.3 Alternatives D, E, F, and G

Alternatives D, E, F, and G extend the footprint of the analysis area to the east and west. Therefore, the impacts described for Alternatives B and C also apply to Alternatives D, E, F, and G.

According to the MDOT CCVV, additional locations of anticipated chronic flooding hazards for both the medium- (2050) and long-term (2100) include most of the interchanges in Kent Narrows along the U.S. 50/301 corridor. When combined with a 100-year storm event, some portions of U.S. 50/301 near Chester and in Kent Narrows would experience roadway inundation. In the medium-term, mainly on- and off-ramps and arterial roadways in this area would be impacted and could experience over 2 feet of flooding. In the longer term, additional portions of the U.S. 50/301 roadway could experience up to 1 foot of flooding. Additional locations of anticipated nuisance flooding and storm surge-related flooding impacting Targeted Ecological Areas and Sensitive Species Project Review Areas include Macum Creek, Kent Narrows, Winchester Creek, and Walsey Creek.

Alternatives D, E, F, and G would impact a greater area of nontidal and tidal wetlands, nontidal and tidal waterways, SAV (2019-2023), historic oyster beds, forests, RCA, and SSPRA areas than Alternatives B and C (**Table 6-18**, **Table 6-19**). Alternatives D, E, F, and G would have the potential to affect mature forest habitat near the U.S. 50/301 split. Loss of habitat area and the elevational gradient associated with adjected buffer areas reduces the ability of natural resources to adapt to climate hazards and inhibits the effectiveness of the habitat types as a protection against acute climate hazards, such as storm surges. More detail on analysis methodologies is provided in the *Natural Environment Technical Report*.

Specific roadway and bridge and culvert design varies by alternative; however, design of these components under Alternatives D, E, F, and G would consider future flood elevations along U.S. 50/301. This could create beneficial impacts to communities by minimizing flood-related hazards. Alternatives D, E, F, and G could create additional adverse impacts to communities exposed to climate hazards within the analysis area through the loss of wetlands and other aquatic and terrestrial habitats, which makes communities more vulnerable to hazards through reduction of services those areas provide such as wave attenuation, groundwater recharge, improved water quality, and shoreline stabilization. Climate-related impacts to communities may evolve throughout the project lifecycle as climate conditions change; however, these impacts cannot be predicted with certainty.

Considering impacts to carbon storage resources, Alternatives D, E, F, and G would affect greater acreages across all high-value coastal habitats than Alternatives B and C. These alternatives would involve approximately 3 to 5 times more wetland impacts (5.6 to 6.3 acres), impact 0.4 to 0.9 acres of SAV, and remove 20 to 40 more acres of forest than Alternatives B and C, including mature forest stands near the US 50/301 split. These habitats have among the highest carbon storage densities regionally, and their disturbance also reduces shoreline stabilization, habitat migration pathways, and recovery potential from acute climate hazards such as storm surge and coastal erosion. Additionally, historic oyster bottom impacts are highest in Alternatives E and F, reducing natural filtering functions that help prevent hypoxia and harmful algal blooms under warming waters.

Consistent with the EPA (2023) and IPCC (2022) findings, natural systems such as forests, wetlands, SAV, and oyster habitat play critical roles in carbon storage and sequestration, and community climate resilience, including flood mitigation, wave attenuation, and water-quality protection. Impacts to these systems, therefore, also represent climate-related consequences. To support this understanding, **Table 6-18** and **Table 6-19** provide a qualitative comparison of the alternatives based on the quantified acreages of natural resource impacts.

Table 6-18: Summary of Natural Resources Impact Totals (Acres)

Resource	Alt A	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
Chesapeake Bay Tidal Water Impacts	0	130.7	131.9	130.7	131.9	134.1	135
Nontidal and Tidal Wetland**	0	6	5.6	11.5	11.1	12	11.5
Nontidal and Tidal Waterways*	0	1.2	1.2	5.8	5.6	6.3	6.2
SAV (2019-2023)	0	0.4	0	0.7	0.4	0.9	0.4
Historic Oyster Bottom	0	24.8	24.1	28.7	28	29.5	28.9
Mapped Forested Area	0	27.3	27.3	87.2	87.2	88.6	88.6
RCA	0	70.7	67.6	112.8	109.6	113.9	110
SSPRA	0	110	109.4	119.4	118.8	122.5	121.2

**Includes palustrine emergent, palustrine shrub/scrub, palustrine forested, palustrine unconsolidated bottom, estuarine emergent, estuarine scrub/shrub or forested

*Nontidal and tidal wetland and waterway impacts do not include habitat within the Chesapeake Bay.

Table 6-19: SUP Summary of Natural Resources Impact Totals (Acres)

Resource	Alt A	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G
Chesapeake Bay Tidal Waters	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nontidal and Tidal Wetlands** (Acres)	0	0.7	0.7	0.7	0.7	0.8	0.7
Nontidal and Tidal Waterways* (Acres)	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SAV (2019-2023)	0	0.3	0	0.3	0	0.4	0
Historic Oyster Bottom	0	1	1	1	1	1	1.1
Mapped Forested Area	0	0.5	0.2	0.5	0.2	0.5	0.2
RCA	0	2.5	0	2.5	0	2.7	2.3
SSPRA	0	4.3	4.5	4.3	4.5	4.2	4.6

**Includes palustrine emergent, palustrine shrub/scrub, palustrine forested, palustrine unconsolidated bottom, estuarine emergent, estuarine scrub/shrub or forested.

*Nontidal and tidal wetland and waterway impacts do not include habitat within the Chesapeake Bay.

6.2.3 Potential Minimization and Adaptation Strategies

Flooding resulting from extreme precipitation, sea level rise, and storm surges has the potential to impact various resources and assets throughout the transportation corridor. Strategies to improve resiliency for natural resources against climate-related stressors include stabilizing shorelines, restoring and enhancing SAV, seeding and/or creating oyster reefs, eradicating common reed, restoring fish passage, facilitating stream restoration, and establishing root protection zones. Compensatory mitigation for unavoidable impacts, which will be coordinated with regulatory agencies, should consider the anticipated climate change-related conditions, such as avoiding marsh restoration in areas projected to be inundated.

To further mitigate the potential climate-related impacts, the following strategies could be considered:

- Elevating roadways in areas currently experiencing flooding or projected to experience flooding.
- Design drainage features surrounding roadways to divert or protect roadways from storms or during periods of nuisance flooding.
- Improving culverts or other structures to facilitate the movement of water and improve water quality.
- Natural and nature-based flood protection features within the analysis area, such as wetland and coastal forest restoration and living shoreline projects for further stabilization and wave attenuation benefits.
- Pavement composition and design of all signage and communication components to withstand extreme temperatures.
- Design signage and communication features to withstand high winds and ensure redundant power sources maintain communications during severe storms.
- Incorporating shade structures and/or benches at certain intervals on the design of the bridge span to provide protection for people on the SUP during extreme heat events.
- Maintain supplies and establish systems to clearly mark lane closures and detour routes and provide real-time information to all users, vehicle navigation systems, and other vehicle communication systems.
- Continue to monitor and track roads closures and flooding using remote sensing, community reporting such as Maryland MyCoast, and other technologies.

6.3 Cumulative Effects of GHG Emissions and Climate Change

While the cumulative effects of climate change are felt locally and regionally, impacts experienced at localized levels are the result of cumulative global contributions and are not the direct result of a single project's contributions. As such, potential GHG emissions resulting from the Bay Crossing Study are expected to make a relatively small contribution to overall global atmospheric GHG concentrations. The quantification of GHG emissions in **Section 6.1.2** provides a basis for the analysis of cumulative effects. The GHG emissions estimates and SC-GHGs serve as a proxy for the potential contribution from the construction, operation, and continued maintenance of the ARDS to regional and global climate change. However, regional levels of GHG emissions will be affected in ways that cannot be accurately accounted for at this time.

Changes related to various regulations, the energy transition, technological advances, and alternative fuels will affect global GHG emissions. Additionally, natural disasters, societal changes, market forces, economics, and personal decisions could alter where and how people live, work, or travel, further impacting GHG emission rates. Therefore, the extent to which the mix of these activities and the ARDS would incrementally contribute to global cumulative effects related to climate change and GHG emissions in the short- or long-term cannot be predicted with certainty.

While all the ARDS would result in GHG emissions, the build alternatives would reduce congestion and increase reliability within the Chesapeake Bay transportation corridor. This is expected to help reduce GHG emissions on an incremental basis and could contribute in the long term to a meaningful cumulative reduction in GHG emissions when considered across the region.

Climate change cumulative effects are accounted for in **Section 6.2** in terms of projected climate trends and the anticipated impacts to transportation infrastructure within the transportation corridor and region and thus are not further discussed in this section.

6.4 Consistency with State Plans and Goals

The State of Maryland has prioritized climate action by enacting legislation such as the CSNA and pledging to reach net zero emissions by 2045. Through this legislation, the State has developed various plans aimed at adapting infrastructure to the impacts of climate change and reducing transportation-related GHG emissions. State legislation, plans, and goals emphasize the importance of investing in clean fuel technologies, reducing roadway congestion, creating more resilient infrastructure, increasing regional mobility options, providing safe and improved walking and biking facilities, reducing the percentage of lane miles at flood risk, as well as reducing other flood-related hazards, impacts, and losses. In alignment with the State's plans and goals, the Bay Crossing Study objectives include reducing congestion and improving reliability, mobility, and roadway deficiencies, while minimizing impacts to local communities and the environment.

Alternative A (No-Build) would retain the existing Chesapeake Bay Bridge, number of lanes, and existing alignment. Because it defers major infrastructure investment, the No-Build Alternative would result in increasingly carbon-intensive maintenance activities over time, leading to higher cumulative GHG emissions. As such, this alternative would not be consistent with the State's plans and goals related to climate action and resilience. Alternatives B and C would add lanes to the Chesapeake Bay Bridge, and Alternatives D through G would add lanes to both the Chesapeake Bay Bridge and its roadway approaches. The build alternatives would increase roadway capacity to varying degrees, reducing congestion and improving reliability. Alternatives B through G could potentially include a SUP along the bridge, which would create alternative transportation options and increase mobility. Reducing congestion, which reduces GHG emissions, and creating mobility options are consistent with the State's plans and goals.

While the Chesapeake Bay Bridge approach and span elevations are not vulnerable to flood risk, other areas within the analysis area, such as the Kent Narrows area along U.S. 50/301, are expected to be impacted by increased flood events. With these measures to mitigate flood risk and create more resilient infrastructure, the build alternatives align with the State's plans and goals focused on mitigating these hazards.

Although all ARDS will result in GHG emissions, the build alternatives are expected to reduce congestion and create a more reliable travel corridor within the Chesapeake Bay region. Although it cannot be quantified whether GHG emission impacts will be fully mitigated by these benefits, the build alternatives would support a continued transition to a more efficient and resilient transportation corridor by increasing capacity, reliability, and mobility, and improving existing roadway deficiencies. This would be in alignment with Study objectives and regional goals.

7 SUMMARY

The Bay Crossing Study is analyzing alternatives to improve transportation across the Chesapeake Bay, specifically focusing on the U.S. 50/301 corridor and the Chesapeake Bay Bridge. This GHG Emissions and Climate Change Analysis of the Bay Crossing Study ARDS is a review of the ARDS based on the MEPA framework and is not part of the NEPA process. The analysis includes both the potential effects of the ARDS on climate change in a discussion of GHG emissions, and the effects of climate change on the ARDS and its environmental impacts. Overall, Alternative C would result in the fewest GHG emissions and associated impacts, and Alternatives B and C would be the least impacted by climate hazards.

Transportation projects contribute to climate change through GHG emissions from construction, operations, and maintenance. Alternative G is expected to have the highest cumulative pre-use phase lifecycle emissions among the build alternatives at 903,634 MT CO_2e, followed by Alternative F (871,841 MT CO_2e) and Alternative D (802,304 MT CO_2e). Alternative C is expected to have the lowest cumulative pre-use phase lifecycle emissions at 776,133 MTCO_2e.

In 2045, the build alternatives would result in slightly higher annual well-to-wheel operational emissions than the No-Build Alternative, these emissions account for the changing VMT according to the design of each alternative. By 2060, emissions are expected to continue to increase across all scenarios. The build alternatives show annualized 2045 GHG emissions ranging from 518,380 to 537,195 MT CO_2e, remaining below 2022 levels but exceeding the No-Build Alternative by approximately 28,000 to 47,000 MT CO_2e. The build alternatives show annualized 2060 GHG emissions ranging from 573,900 to 594,730 MT CO_2e, remaining below 2022 levels but exceeding the No-Build Alternative by approximately 31,500 to 52,000 MT CO_2e. The largest increases occur under the Alternative F configuration, which would result in a 10 percent increase in annualized GHG emissions over the No-Build Alternative in both 2045 and 2060. While Alternative F is associated with the highest VMT among the ARDS, future-year emissions for all ARDS are projected to be lower than the 2022 Existing Condition, primarily due to the trends of fleet turnover, improvements in fuel economy, and increased adoption of alternative fuel technologies over time. When considering operational emissions in this analysis, it is important to note that congestion-related emissions are not accounted for. Vehicle emissions are directly influenced by traffic conditions—idling, frequent acceleration, and stop-and-go driving associated with congestion increases pollutant output compared to free-flow conditions.

Among the build alternatives, cumulative GHG emissions are expected to be the highest under Alternative F at 9,687,080 MT CO_2e, followed by Alternative G (9,649,325 MT CO_2e) and Alternative D (9,600,840 MT CO_2e). Alternative C is expected to result in the lowest cumulative emissions among the build alternatives at 9,282,632 MT CO_2e.

Climate change has the potential to affect many aspects of the transportation system. Both chronic and acute climate hazards are expected to impact Alternatives B and C similarly, as these build alternatives include the same number of lanes with either north or south alignment. These impacts are expected to be experienced through road closures and structure damages, construction schedule impacts, changes in patterns of active transportation, and impacts to natural resources adjacent to the roadways. The extended footprint of Alternatives D, E, F, and G would create additional chronic flood hazards for most of the interchanges in Kent Narrows along the U.S. 50/301 corridor.

Natural resource impacts include frequent and longer periods of flooding, saltwater intrusion, shifts of species abundance and distribution, coastal flooding and erosion, harmful algal blooms and hypoxia, ocean acidification, loss of wetlands, SAV, oyster beds and forests. As Alternatives D, E, F, and G expand the footprint of the analysis area to the east and west, Study-related impacts to forests, oyster beds and SAV would be lower for Alternatives B and C. Extreme heat and drought are expected to impact all build alternatives equally because these impacts are regional. Alternative C is the only build alternative that is anticipated to avoid impacts to SAV. Loss of habitat area and the elevational gradient associated with adjected buffer areas reduces the ability of natural resources to adapt to climate hazards and inhibits protection of the infrastructure and communities against acute climate hazards, such as storm surges.

The analysis area encompasses the communities of Arnold, Broadneck, Cape St. Claire, Kent Island, Kent Narrows/Grasonville, and Queenstown. Communities within the analysis area are vulnerable to the impacts of climate change, including sea level rise, flooding, severe storms, and extreme heat events. These climate-related hazards can impact residences, businesses, land use, and public health and safety. Underserved populations are more vulnerable to the impacts of climate change.

Alternative A (No-Build) would retain the existing Chesapeake Bay Bridge, number of lanes, and existing alignment. Because it defers major infrastructure investment, the No-Build Alternative would result in increasingly carbon-intensive maintenance activities over time, leading to higher cumulative GHG emissions. As such, this alternative would not be consistent with the State's plans and goals related to climate action and resilience. The build alternatives would increase capacity to varying degrees, reducing congestion and improving reliability, and have the potential to improve mobility within the analysis area. These measures, as part of the build alternatives, align with the State's plans and goals focused on mitigating GHG emissions and climate-related hazards. Furthermore, with the build alternatives allowing for consistent assessment of life-cycle emissions and supporting long-term reductions in transportation-related carbon impacts through operational efficiency, the build alternatives provide a more direct pathway to meeting the state's climate goals.

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