RESILIENCE PLAN

Roadmap towards a resilient transportation system

November 2022

Version 1.0

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EXECUTIVE SUMMARY

The mission of the Virginia Department of Transportation (VDOT or Department) is to plan, deliver, operate, and maintain a transportation system that is safe, enables the easy movement of people and goods, enhances the economy, and improves the quality of life. Shifting environmental conditions, however, threaten the ability of Virginia's transportation network to safely and efficiently move people and goods. Consequently, the Department is faced with the challenge of identifying resilience needs and developing specific strategies to anticipate, prepare for and mitigate events that put the transportation network at risk of disruption and deterioration, while ensuring that network improvements do not undermine other climate resilience strategies or put more people at risk.

The Department has created this Resilience Plan to formalize a framework for the incorporation of resilience through such strategies into transportation planning, project development, delivery, operations, maintenance, and asset management. The Plan identifies six primary objectives and details associated strategies for each. Although the objectives and strategies listed below are in no particular order, they are interrelated and build upon each other.

1. Promote Data Driven Decisions. Successfully incorporating resilience into transportation decisions will depend upon the best available data and research regarding vulnerability, current and planned assets, and identified current and future conditions. VDOT will develop a data and research plan to support this objective.

2. Engage and Partner with Stakeholders. Outreach with key stakeholders and the public will leverage existing efforts, maximize benefits, and ensure decision-making is coordinated with statewide policy. VDOT will establish and implement a coordination and outreach plan to support this objective.

3. Identify At-Risk Infrastructure and Prioritize Needs. The application and prioritization of resilience efforts will rely on an evaluation of vulnerability across current and planned transportation infrastructure. To support this objective, VDOT will establish a risk-based methodology to measure the vulnerability of transportation assets.

4. Identify Resilience Measures. Implementation of appropriate resilience measures requires an identification of the available options to mitigate risk. To support this objective, VDOT will establish a suite of resilience measures that will be available for incorporation into planning, design, operations, and maintenance programs. The measures will include (i) adaptive design criteria based upon the best available, forward looking data; (ii) physical enhancement measures, (iii) nature-based resilience measures; (iv) operations,

maintenance, and emergency management enhancement measures; and (v) other administrative/policy measures.

5. **Utilize Feasibility and Cost Effectiveness Analyses.** Once identified, VDOT's selection of a resilience measure for implementation will be evaluated for feasibility and cost effectiveness as applied to a particular asset. To support this objective, VDOT will develop feasibility and economic analyses that are compatible with existing processes.

6. **Incorporate Resilience into Current Funding Policies.** The ultimate deployment of resilience measures rely on the effectiveness of incorporating resilience into the Department's decision-making processes for funding programs and opportunities. To support this objective, VDOT will identify new funding opportunities that are available for resilience projects and initiatives and identify and implement steps to incorporate resilience into current investment processes and programs.

The recently established Resilience Administrators Committee, comprised of leadership across VDOT's affected programs, will lead a periodic evaluation and revision of this Resilience Plan to ensure that the objectives and strategies provided above remain consistent with Department and statewide priorities. Further, semi-annual status and reporting updates will be provided to the Commonwealth Transportation Board.

DEFINITIONS

As used in this Resilience Plan, unless the context requires a different meaning:

Important Transportation Infrastructure means facilities and road networks that are necessary to maintain the successful flow of traffic during extreme weather events or conditions.

Deterioration means physical damage to infrastructure after hazards or extreme weather events or conditions with the potential to result in a reduction in level of service or limited access to critical corridors.

Nature-Based Resilience Measures are strategies to preserve, restore, or mimic risk-mitigating features that occur naturally in the landscape through the engineering and construction of features that replicate or enhance natural conditions and ecosystems services. For the purposes of this Plan, nature-based resilience measures shall include natural resilience measures such as the preservation and leverage of already occurring natural features.

Recurrent Flooding means flooding that happens repeatedly in the same area over time, typically leading to economic losses. Recurrent flooding can be due to high intensity rainfall, prolonged precipitation events, tide, storm surge, or sea level rise.

Transportation Resilience or resilience is the capability of a transportation project or strategy to anticipate, prepare for, respond to, or recover from significant multi hazard threats with minimum damage and disruption to the transportation network, while preserving and incorporating natural and built infrastructure that helps to mitigate these threats.

Sea Level refers to the average level of tidal waters, generally measured over a 19-year period to smooth out variations in water levels caused by seasonal weather fluctuations and the 18.6-year cycle in the moon's orbit. The sea level measured at a particular tide gauge is often referred to as the local mean sea level.

Vulnerability, for the purposes of this Resilience Plan, means the degree of risk to which infrastructure is susceptible to deterioration. Vulnerability is subjective to the type of infrastructure being assessed and, may be evaluated as a function of the asset's exposure, sensitivity, criticality, and/or adaptive capacity.

ACRONYMS

AMD	Asset Management Division (VDOT)
BCA	Benefit-cost analysis
BIS	Business Integrated Solutions Division (VDOT)
CRMP	Coastal Resilience Master Plan
DCR	Virginia Department of Conservation and Recreation
DEQ	Virginia Department of Environmental Quality
DHR	Virginia Department of Historic Resources
DRPT	Department of Rail and Public Transportation
DWR	Virginia Department of Wildlife Resources
DOT	Department of Transportation
EA	Economic analysis
EO	Executive order
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
GALA	Governance and Legislative Affairs Division (VDOT)
HRPDC	Hampton Roads Planning District Commission
IID	Infrastructure Investment Division (VDOT)
IDF	Intensity-duration-frequency
L&D	Location & Design Division (VDOT)
LCCA	Life-cycle cost analysis
MOI	Manual of instruction
NOAA	National Oceanic and Atmospheric Administration
MARISA	Mid-Atlantic Regional Integrated Science and Assessments
MCA	Multi-criteria analysis
MPO	Metropolitan planning organization
NCHRP	National Cooperative Highway Research Program
OIPI	Office of Intermodal Planning and Investment
RCP	Representative concentration pathway
S&B	Structure & Bridge Division (VDOT)
SLR	Sea level rise
OSSEM	Office of Safety, Security and Emergency Management (VDOT)
TMPD	Transportation Mobility and Planning Division (VDOT)
USACE	United States Army Corps of Engineers
VDEM	Virginia Department of Emergency Management
VDOT	Virginia Department of Transportation
VIMS	Virginia Institute of Marine Science
VMRC	Virginia Marine Resources Commission
VTRC	Virginia Transportation Research Council

INTRODUCTION

With a mission "to plan, deliver, operate and maintain a transportation system that is safe, enables the easy movement of people and goods, enhances the economy and improves the quality of life," the Department is responsible for building, maintaining, and operating the Commonwealth's roads, bridges, and tunnels, which comprise the third largest state-maintained highway system in the country.

Shifting environmental conditions, however, threaten the capacity to safely and efficiently move people and goods and must be addressed. To date, the most threatening conditions have included recurrent flooding and other inundation-related impacts, in both coastal and inland areas. Figure 1 exemplifies the impact of flooding on a roadway, where inundation has undermined the traveling surface and forced a closure for repairs.

Recent emphasis on resilience efforts in the Commonwealth began with the issuance of Executive Order (EO) 24, "Increasing Virginia's Resilience to Sea Level Rise and Natural Hazards," in November 2018 by then Governor Northam, which required an analysis of flooding and flood preparedness in the Commonwealth. A year later, with the issuance of EO 45, "*Floodplain Management Requirements and Planning Standards for State Agencies, Institutions, and Property*," the Governor mandated the adoption of clear building and development standards in conformance with the National Flood Insurance Program for actions by state agencies on state-owned property. EO 45 also elected the National Oceanic and Atmospheric Administration's (NOAA's) Intermediate-High scenario curve as the state standard for predicting sea level rise, which predicts nearly four (4) feet of sea level rise by 2070 in the Hampton Roads region.

Figure 1: Roadway Closure as a Result of a Flooding Event

While these statewide efforts continue, with the codification of EO 24's Virginia Coastal Resilience Master Plan requirement and the subsequent publication of the Virginia Coastal Resilience Master Planning Framework (2020), the Virginia Coastal Resilience Master Plan Phase I (2021), and the Virginia Coastal Resilience Master Plan Phase II (expected in 2024), the General Assembly has also enacted legislation specific to resilience and transportation. Chapters 51 and 52 of the 2021 Special Session I of the General Assembly require the Commonwealth Transportation Board (CTB) to consider resilience when adopting the Statewide Transportation Plan and, when evaluating projects

for the SMART SCALE prioritization process, determine whether a project has been designed to be, or the project sponsor has committed that the design will be, resilient. The legislation also requires that the Commissioner of Highways incorporate resiliency into the design standards for new construction projects. In 2022, legislation related to statewide flooding and resilience plans such as HB 516 and SB 551 have been adopted.

Consequently, the Department offers this Resilience Plan to provide a framework to incorporate legislated resilience priorities into transportation decision-making. The Plan offers specific strategies built upon broad, goal-based objectives that will support appropriate and scientifically-based options for decision-makers. It should be noted that this Plan both contributes to and borrows from other ongoing resilience efforts in which VDOT has engaged, which are shown in Appendix A and include:

- Identification and mapping of existing vulnerable infrastructure and assessing potential ecosystem impacts through a partnership with the Virginia Institute for Marine Science (VIMS);
- Development of vulnerability assessment tool and mapping interface by the Office of Intermodal Planning and Investment (OIPI);
- Identification of primary evacuation routes to supplement Hurricane Evacuation Routes; and
- Development of updates to rainfall and precipitation data such as NOAA Atlas 14 and projected Intensity-Duration-Frequency (IDF) curves.

Pertinent data examined as part of these efforts are also outlined in Appendix B.

RESILIENCE PLAN DEVELOPMENT

Under the leadership of the Commissioner of Highways, the Department is organized into several divisions within the Central Office, each serving under a designated Chief, and nine Construction Districts, each managed by a District Administrator or District Engineer reporting to the Chief Deputy Commissioner. In general, VDOT employs a decentralized implementation strategy— the Chiefs and their respective Directorates at the Central Office provide overall program policy and guidance, while District Administrators/Engineers oversee the day-to-day management of construction and maintenance programs in the field.

The development of this Resilience Plan is an agency-wide effort coordinated by VDOT's Environmental Division, with other Divisions and Districts remaining responsible for the development and implementation of specific strategies. Within the Department, the Resilience Steering Committee has been formed as a standing workgroup charged with the responsibility to produce draft recommendations for presentation to the Resilience Administrators Committee. Both the Resilience Administrators Committee and the Resilience Steering Committee may establish other standing or special committees as needed. To ensure consistency with the Department's goals and objectives, recommendations from the Administrators Committee will be provided, where appropriate, to the respective VDOT executives (Chiefs and/or the Commissioner) for information, review, and/or approval. Likewise, the CTB will be involved in setting applicable agency policy as a result of Resilience Plan initiatives.

RESILIENCE ADMINISTRATORS COMMITTEE

The Resilience Administrators Committee will meet as needed, but at least semi-annually, to evaluate the status of Plan objectives and consider recommendations offered by the Steering Committee. The Resilience Administrators Committee, largely comprised of Division Administrators and District Engineers/Administrators, is as follows:

- Environmental Division - Chairman
- Location & Design Division (L&D)
- Structure and Bridge Division (S&B)
- Maintenance Division
- Office of Safety, Security and Emergency Management (OSSEM)
- Infrastructure Investment Division (IID)
- Governance and Legislative Affairs Division (GALA)
- Virginia Transportation Research Council (VTRC)
- Asset Management Division (AMD)
- Hampton Roads District
- Salem District

The Administrators Committee will identify items, such as specific strategies that have been recommended by the Steering Committee, for Executive management information, review, and/or concurrence. As part of this, the Administrators Committee shall ensure that the appropriate level of approvals (Chiefs, Commissioner, Secretary of Transportation, CTB) are obtained as necessary.

RESILIENCE STEERING COMMITTEE

The Resilience Steering Committee will meet on at least a quarterly basis to develop draft policies, guidance, and procedures for the consideration of the Resilience Administrators Committee. The Resilience Steering Committee is comprised of representatives from the following VDOT Divisions:

- Environmental Division - Chairman
- Location and Design Division
- Materials Division
- Business Integrated Solutions Division (BIS)
- Structures and Bridge Division
- Infrastructure Investment Division
- Asset Management Division
- Office of Safety, Security and Emergency Management
- Operations Division
- Maintenance Division
- Governance and Legislative Affairs Division
- Virginia Transportation Research Council
- Transportation and Mobility Planning Division (TMPD)

The Steering Committee members will keep their respective Division or District Administrators appraised of all ongoing resilience efforts. In turn, the Steering Committee, will provide recommendations to the Administrators Committee for review, and or approval/concurrence. Note: this may include involvement from the appropriate level of executive management (Chiefs, Commissioner, Secretary of Transportation, CTB), as discussed in the previous section.

STANDING SUBCOMMITTEES

The Resilience Policy and/or Steering Committee may establish other standing or special committees, as they deem advisable, to address specific elements or components of the Resilience Plan. Subcommittees currently include a Data and Research Subcommittee and a Design Standards Subcommittee.

PLAN EVALUATION, MODIFICATION, AND REPORTING

The Department anticipates that this Resilience Plan will be a “living document” evolving throughout the implementation schedule as further information becomes available. As part of the iterative

process, the assigned responsibilities, implementation steps, measures of success, and proposed schedules may change.

On an ongoing basis, the Resilience Steering Committee will evaluate the Plan to ensure that the objectives and strategies remain consistent with the Commonwealth's priorities and make recommendations to the Resilience Administrators Committee. Any subsequent revisions to Plan strategies made by the Resilience Administrators Committee shall include an explanation as to why a specific strategy was modified, replaced, or eliminated.

Upon completion of this Plan's implementation schedule, in approximately two years, the Department intends to adopt long-term performance measures in order to track the Plan's progress towards ensuring a more resilient transportation system.

OBJECTIVES AND STRATEGIES

The subsequent sections of this Plan detail the Department's objectives and provide associated strategies for each that will provide a framework for incorporating resilience into transportation decision-making. The six objectives and the corresponding strategies, once approved and as enumerated in Figure 2, will be integrated into VDOT's existing programs, processes, and practices. As shown below in Figure 3, while much of the work on the various strategies will proceed concurrently, others may have interdependent timelines. This is uniquely true of Strategy 6a, for example, where the incorporation of resilience into funding programs necessarily depends on the identification of at-risk infrastructure and prioritization of needs in Strategy 3a and feasibility and benefit-cost analysis developed in Strategy 5a. (Note that, within this Plan, items requiring action by the Resilience Administrators Committee are indicated with a star ★ for ease of reference. The Administrators Committee action includes soliciting feedback and approval from the respective Chief(s) and/or the Commissioner as necessary and following any needed reviews by the Secretary of Transportation and Commonwealth Transportation Board)

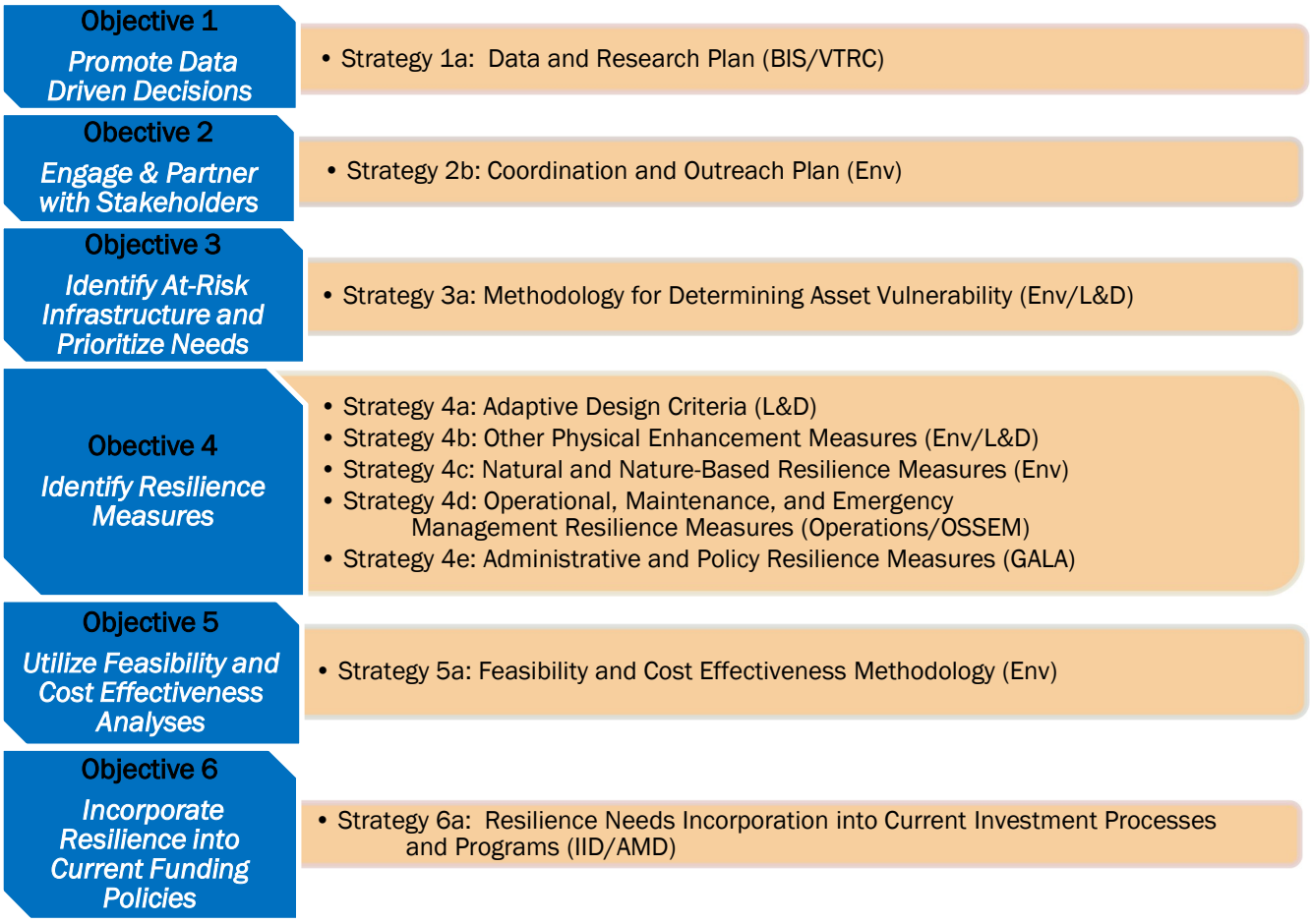


Figure 2: VDOT's Resilience Plan Objectives and Corresponding Strategies

Figure 3. Integration of Resilience Plan Strategies into VDOT's Existing Business Practices

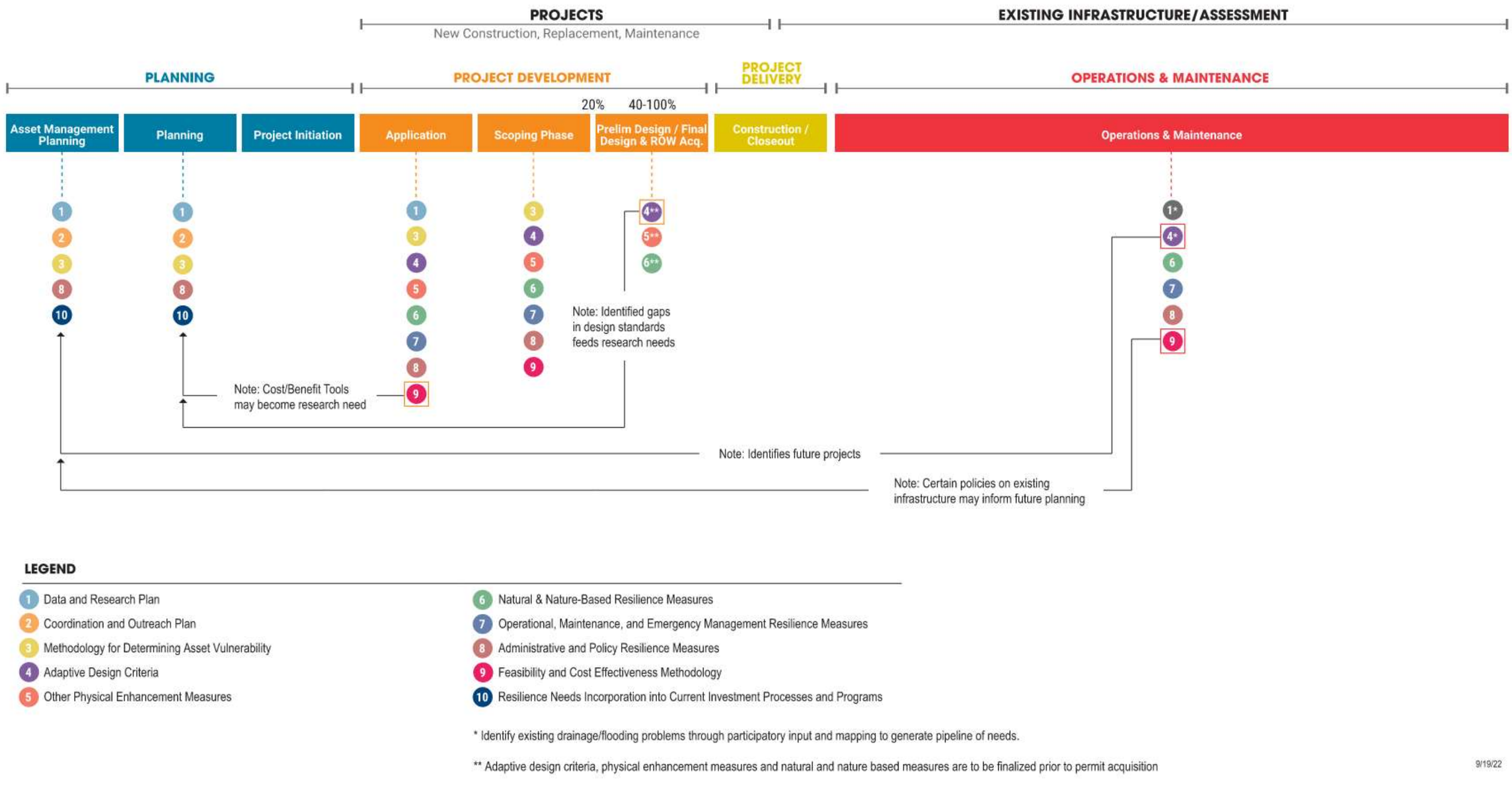
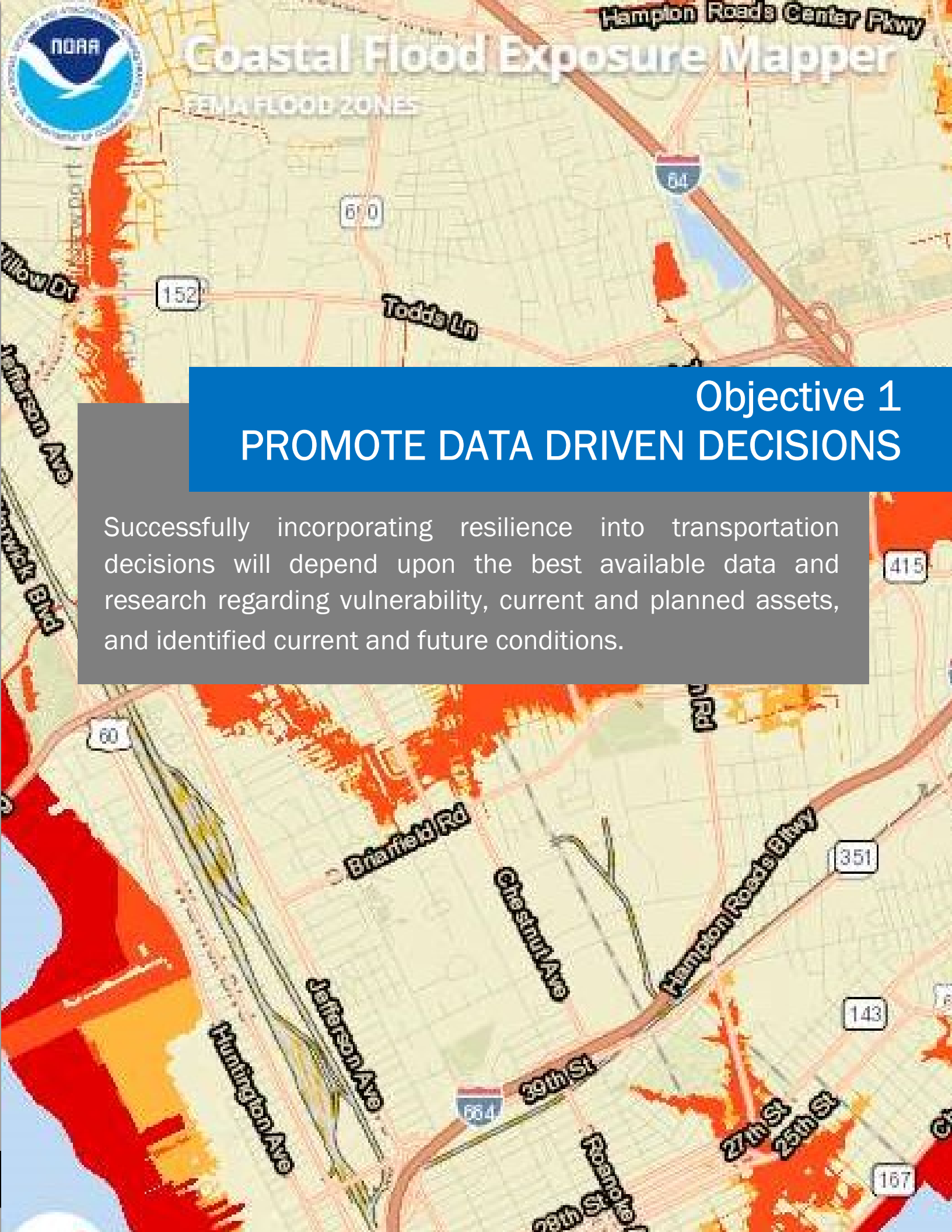


Figure 3: Integration of Resilience Plan Strategies into VDOT's Existing Business Practices



Objective 1
PROMOTE DATA DRIVEN DECISIONS

Successfully incorporating resilience into transportation decisions will depend upon the best available data and research regarding vulnerability, current and planned assets, and identified current and future conditions.

Strategy 1a
DATA AND RESEARCH PLAN

Lead Divisions: BIS, VTRC
Supporting Divisions: S&B, OSSEM, Operations, L&D, Materials, Maintenance, AMD

Timeframe: Year 1, 2

DESCRIPTION

The Department will establish a comprehensive data and research plan to identify existing and forthcoming datasets, evaluate the scope and limitations of existing datasets, designate authoritative datasets, identify data gaps and needs, and provide for the consolidation and development of consumable datasets. An inventory of pertinent existing datasets is shown in Appendix B.

STEPS TO IMPLEMENTATION

1. **Identify and create an inventory of existing and forthcoming datasets relevant to transportation network resilience.**
   VDOT will identify relevant datasets needed to promote transportation network resilience including, for example, datasets regarding stressors, hazards, threats, asset type, asset attributes, asset conditions, and vulnerability. There are many datasets, both internal and external, that could be evaluated and leveraged as appropriate to inform the needed use cases and applications. For instance, the Commonwealth of Virginia Coastal Resilience Master Plan (CRMP) Open Data Portal, DRPT's Open Data Portal and General Transit Feed Specification (GTFS) data can be a companion to existing VDOT datasets. Appendix B, Inventory of Existing Pertinent Datasets, presents an initial survey of such datasets, important features of which are discussed below.

   a) *Key climatic factors.* There are several existing and developing datasets related to projections regarding precipitation, SLR, storm surge, inland riverine flooding, and other climatic factors. Precipitation data is currently based on NOAA Atlas 14, which is based on historical precipitation data. The NOAA Atlas 14 is due to be updated in 2024. Additionally, Mid-Atlantic Regional Integrated Science and Assessments (MARISA) recently published forward looking precipitation data based on two emissions scenarios (representative concentration pathways [RCP] 4.5 and 8.5) and two time periods (2020–2070 and 2050–2100).

   b) *Important Transportation Infrastructure.* The identification and mapping of a comprehensive important transportation infrastructure layer will enable greater

resilience measures (ex. use of more resilient construction materials, enhanced ITS) to be taken on new construction projects and existing vulnerable infrastructure to minimize disruption to these important assets. In 2021, OSSEM led a collaborative effort with the Virginia Department of Emergency Management (VDEM) to identify and map primary evacuation routes, incorporating the previously designated hurricane evacuation routes and corridors of statewide significance. For the purposes of this Plan, however, VDOT will consider whether other infrastructure assets, such as certain area headquarters and traffic operations centers or rail and transit infrastructure, might be deemed important in order to minimize disruption in times of emergency situations.

c) *Vulnerable Infrastructure.* There are several existing geospatial datasets showing infrastructure vulnerability. These datasets vary in approach, status of completion, geographic scale, and method of development. Reconciliation of these datasets is desirable and should, at a minimum, consider documentation of past and known issues, projected vulnerability, and risk-based design.

2. **Investigate and evaluate the datasets, identify needs, enhancements, and gaps, and provide recommendations.**

Once a formal inventory of existing and forthcoming datasets is created, VDOT will evaluate each as to the scope and limitation of the data and perform a comparison of similar, duplicative, or overlapping datasets. Working with the internal and external data stewards, the Department will conduct a preliminary evaluation of data quality and appropriateness for the hypothesis being tested. Data gaps and needs should be clearly identified and specific recommendations, including timeframes, should be provided. Timeframes related to addressing data gaps, quality issues, and additional needs must be vetted with the internal and external data stewards to align enterprise needs holistically. The Department will prioritize the evaluation and development of datasets in a sequence that supports the overall Resilience Plan, inclusive of all strategies.

Figure 4 provides a high-level flow diagram of the steps that must be undertaken to move un-curated/un-mastered data to the enterprise data warehouse for modeling activities. Mastering data establishes authoritative sources for shared data and data of enterprise interest. This practice ensures consistent data values and meanings across data sources, systems and organizational units. In instances where non-open external data are to be mastered, data use agreements will need to be put in place as appropriate.

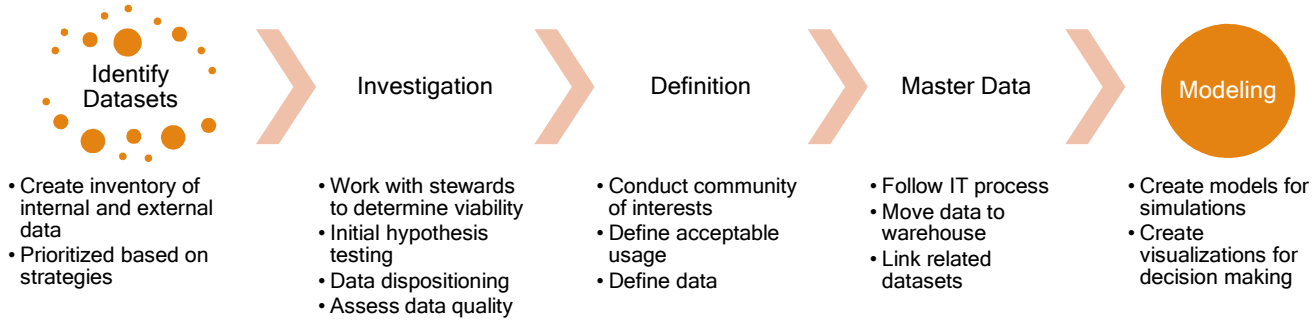


Figure 4: Data Mastering Process

3. Designate authoritative datasets based on recommendations.★

The designation of authoritative datasets will ensure that policies and guidance will be based on consistent and standard datasets and allow for periodic updates of such datasets as newer information becomes available. There will be VDOT-authoritative datasets, such as VDOT's important transportation infrastructure, and Commonwealth-authoritative datasets, such as the mandated SLR scenario provided in EO 45. For Commonwealth-authoritative datasets, VDOT should engage with external stakeholders to ensure alignment with the long-term strategic goals of the Department. Strategy 2a, Coordination and Outreach Plan, may be utilized to address the stakeholder efforts for the Commonwealth authoritative datasets.

4. Develop Research Plan to align Needs of Divisions with VTRC Research Program.★

A research plan will be developed based on the needs of the various Divisions, requiring a coordinated effort with VTRC to ensure that the information gaps to be addressed align with the Department's long-term goals. Early identification of data gaps will be critical to avoid deficiencies in resilience assessments.

5. Periodically revisit the data and research plan.

VDOT anticipates establishing and performing a periodic review (anticipated annually) of the data and research plan as newer and better data becomes available.

MEASURING SUCCESS

- ✓ Inventory and evaluation of existing and forthcoming datasets related to resilience
- ✓ List of data gaps and needs
- ✓ Consolidate or coordinate newly developed datasets as necessary
- ✓ Identification and map layer of important transportation infrastructure by OSSEM★
- ✓ Establish authoritative datasets by BIS★

- ✓ VTRC Research Plan that coordinates Divisions' needs by VTRC★
- ✓ Updates to program budgets, staffing, and revised employee performance standards, as necessary

PROPOSED IMPLEMENTATION SCHEDULE

Steps	Timeline	
	FISCAL YR 1	
	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)
1. Identify and create inventory of existing and forthcoming datasets		
2. Evaluate datasets, identify gaps, and provide recommendations		
3. Designate authoritative datasets		
4 Develop research plan to align Divisional needs with VTRC		
5. Periodically revisit the data and research plan		

Objective 2
ENGAGE & PARTNER WITH STAKEHOLDERS

Outreach to key stakeholders and the public will leverage existing efforts, maximize benefits, and ensure decision-making is coordinated with statewide policy.

Strategy 2a
COORDINATION AND OUTREACH PLAN

Lead Division: Environmental
Supporting Divisions: S&B, TMPD, Maintenance, VTRC, OSSEM, L&D

Timeframe:
Year 1, 2

DESCRIPTION

Establishing a coordination and outreach plan is key to ensure that Department resilience efforts are coordinated with statewide policy and to afford the public an opportunity for informed feedback.

STEPS TO IMPLEMENTATION

1. Identify stakeholders and initiatives.

The Department will coordinate with federal and state agencies, localities, and planning organizations that are conducting other resilience efforts affecting the Commonwealth as appropriate, which may include:

- Special Assistant to the Governor for Coastal Adaptation Protection
- Chief Resilience Officer
- DCR (VA Coastal Resilience Master Plan)
- DEQ
- Virginia Marine Resources Commission (VMRC)
- Department of Wildlife Resources (DWR)
- Department of Historic Resources (DHR)
- Department of Rail and Public Transportation (DRPT)
- VDEM (State Hazard Mitigation Plan)
- HRPDC (Draft Design Standards)
- City of Virginia Beach (Design Standards)
- Fairfax County (Fairfax Resilience Plan)
- Federal Highway Administration (FHWA)
- United States Army Corps of Engineers (USACE)

The Department will coordinate with DRPT to ensure that resilience objectives for both agencies are aligned. The Department will also consider engaging the public to communicate VDOT's goals and objectives and solicit feedback.

2. Identify communication options.

VDOT will identify communication avenues and tools, such as periodic interagency workshops, public meetings, websites, GIS StoryMap, dashboards, portals, etc., for consideration.

3. Develop and implement coordination and outreach plan.★

The Department will develop a coordination and outreach plan once stakeholders, initiatives, and communication options have been identified. The plan should include, at a minimum, point of contacts, issues of focus, frequency of coordination, and initiative milestones. The plan should clearly communicate VDOT's current efforts as well as VDOT's strategy to provide a more resilient transportation system. The coordination and outreach plan might also include a comprehensive communications plan specific to inform the public regarding locations of areas that are flooded and are anticipated to be flooded.

MEASURING SUCCESS

- ✓ List of policy stakeholders and initiatives
- ✓ List of public stakeholders
- ✓ List of communication options
- ✓ Develop coordination and outreach plan
- ✓ Hold stakeholders meetings
- ✓ Public outreach materials published/disseminated
- ✓ Comprehensive communications plan for flooded locations★
- ✓ Updates to program budgets, staffing, and revised employee performance standards, as necessary

PROPOSED IMPLEMENTATION SCHEDULE

Steps	Timeline			
	FISCAL YR 1		FISCAL YR 2	
	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)
1. Identify stakeholders and initiatives				
2. Identify communication tools and avenues				
3. Develop and implement coordination and outreach plan				

Objective 3
IDENTIFY AT-RISK INFRASTRUCTURE & PRIORITIZE NEEDS

The application and prioritization of resilience efforts will rely on an evaluation of vulnerability across current and planned transportation infrastructure.

Strategy 3a
METHODOLOGY FOR DETERMINING ASSET VULNERABILITY

Lead Division: Environmental, L&D
Supporting Divisions: S&B, Maintenance, OSSEM, Operations, TMPD

Timeframe:
Year 1, 2

DESCRIPTION

The Department will develop a methodology for determining asset vulnerability. A risk-based methodology that considers exposure, sensitivity, and criticality would provide a measure of overall vulnerability and a systematic, documented approach for the application of resilience strategies to VDOT assets.

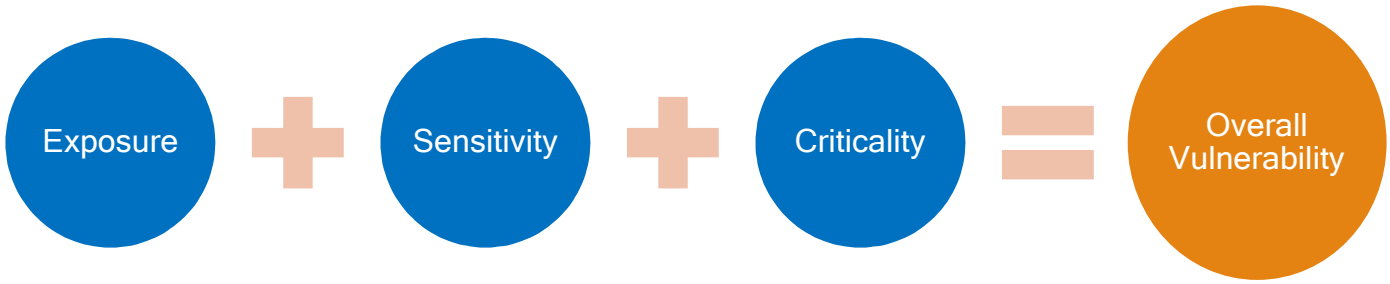


Figure 5: Contributing Factors to Overall Vulnerability of Infrastructure Asset

STEPS TO IMPLEMENTATION

1. **New Construction and other Infrastructure Projects: Develop risk-based screening approach to determine vulnerability and applicability of resilience measures.★**
   A risk-based screening approach to vulnerability is capable of determining whether, and to what extent, resilience measures are required. The risk-based methodology is anticipated to be composed of the following elements:

   a) *Exposure* The exposure criteria should determine whether a proposed asset is located in an area that is currently experiencing, or is anticipated to experience, direct environmental impacts and reflect the nature and degree of such impacts. While there are current available assessment tools for VDOT's infrastructure that would show asset location relative to a

stressor include exposure assessment to SLR, storm surge, and inland/riverine flooding, the Department intends to develop a tool that will incorporate other identified hazards.

b) *Sensitivity.* A sensitivity criteria should determine how the asset fares when exposed to a climate variable, hazard, or severe condition. The VDOT sensitivity criteria needs to include asset condition to adequately evaluate how sensitive the infrastructure will be when exposed to future hazards or severe conditions.

c) *Criticality.* A criticality criteria measures the importance of an asset to the resilience of an overall system. For VDOT, criticality of a roadway can be assessed by evaluating the annual average daily traffic, roadway designation, redundancy, and whether identified as a primary evacuation route or important infrastructure, among others.

d) Overall Vulnerability. The Department will assign appropriate weights (percentages) to the three elements above—exposure, sensitivity, and criticality—in order to determine the overall vulnerability of the infrastructure asset.

The elements of the risk-based vulnerability methodology will rely on designated authoritative data established in Strategy 1a. OIPI has recently developed a vulnerability assessment of infrastructure and that assessment incorporates the same elements in determining the infrastructure asset's overall vulnerability. The Commonwealth has also developed resources for these purposes through the Coastal Resilience Master Plan and Open Data Portal. As the Department develops a more comprehensive assessment tool, where feasible, the aforementioned assessment tools and data should be evaluated and leveraged, as appropriate, to meet the Department's needs and objectives. If multiple tools will be recommended for utilization, a clear direction on the appropriate use of the respective tools will be provided to the affected practitioners.

2. **Identify vulnerability in existing infrastructure★**

VDOT should inventory and identify those existing assets that are vulnerable and require resilience improvement. VIMS is currently under contract with VTRC to assess VDOT's at-risk infrastructure in the tidal area with an anticipated study completion date of 2024. Additional work should be performed to provide a statewide identification of asset vulnerability for multiple hazards. This step is closely tied to Strategy 1a, Data Inventory of Vulnerable Existing Infrastructure.

3. **Identify research needs and gaps and future actions**

During the process of developing the risk-based screening, certain research needs and information gaps are likely to arise. These research needs and gaps should be identified and used to inform the data and research plan (Strategy 1a).

4. **Integrate risk-based methodology into current business practices and workflows★**
   Once the risk-based screening and associated tools have been developed, and approval from the executive management is obtained, VDOT will integrate the methodology into current business practices and workflows including project planning, development, operations, and maintenance. VDOT might also evaluate the integration of the vulnerability measure into the processes established for different funding programs such as State of Good Repair, SMART SCALE, etc. Integration will require approval from executive management.

MEASURING SUCCESS

- ✓ Exposure criteria developed
- ✓ Sensitivity criteria developed
- ✓ Criticality criteria developed
- ✓ Overall vulnerability assessment for new construction developed and integrated★
- ✓ Overall vulnerability assessment for existing infrastructure developed and integrated★
- ✓ Integration of the methodology and assessments into current business practices and procedures accomplished★
- ✓ Research needs and gaps identified
- ✓ Updates to program budgets, staffing, and revised employee performance standards, as necessary

PROPOSED IMPLEMENTATION SCHEDULE

Steps	Timeline			
	FISCAL YR 1		FISCAL YR 2	
	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)
1. Develop risk-based screening approach to determine infrastructure vulnerability				
2. Identify research gaps				
3. Integrate risk-based methodology into current business practices and workflows				

Objective 4
IDENTIFY RESILIENCE MEASURES

Implementation of appropriate resilience measures requires an identification of the available options to mitigate risk.

Strategy 4a
ADAPTIVE DESIGN CRITERIA

Lead Division: L&D
Supporting Divisions: S&B, Materials, Maintenance

Timeframe:
Year 1, 2

DESCRIPTION

Translating climate projections and extreme weather data into information usable for project-level design and the development of design standards can be complex. In general, current design criteria for transportation infrastructure are developed with the assumption that the climate conditions will remain static. The Department will engage in the development and establishment of adaptive design criteria that incorporate changing climate conditions and forward-looking data, ultimately enhancing current design criteria to achieve hazard resistance where appropriate.

STEPS TO IMPLEMENTATION

1. **Identify enhanced/adaptive design criteria, as well as other related studies, used by federal agencies, other Departments of Transportation (DOTs), MPOs, and localities**
   VDOT is currently undertaking a literature review surveying the various adaptive design criteria being utilized by federal agencies, state DOTs, MPOs, and localities to provide for resilience. Thus far, identified adaptive design criteria has included the elevation of roads, enhancement of structure and bridge design elements, increased hydraulic capacity for drainage systems, and the enhancement of pavement and slope embankment design elements.

   An ongoing project by the National Cooperative Highway Research Program (NCHRP 15-80) to develop and issue a design guide and standards for infrastructure resilience has an anticipated completion date of 2024. NCHRP's stated objectives are to (1) briefly summarize how extreme weather events, long-term climate changes, and climate resilience impact transportation project delivery, infrastructure life-cycles, and asset management practices; (2) identify current and projected future climate variables to be considered during the design of transportation projects to increase resilience; (3) develop recommendations for updating design processes that include consideration of extreme weather events and increase resilience to climate impacts; and (4) develop a project delivery resilience adaptive design guide.

   Potential Adaptive Design Criteria
   - *Elevate Roads*
   - *Enhance Structure and Bridge Design*
   - *Increase Hydraulic Capacity of Drainage System*
   - *Enhance Pavement*
   - *Enhance Slope Embankment*

2. **Coordinate with FHWA, NCHRP, other DOTs, MPOs, localities, etc.**
   There may be a need to coordinate with federal agencies, other DOTs, MPOs, and localities to obtain clarification regarding the identified enhanced/adaptive design criteria above. Insights of other entities from the development of adaptive design criteria may inform the approach taken by VDOT. Stakeholder coordination might utilize the Coordination and Outreach Plan in Strategy 2a.

3. **Identify research needs and gaps and future actions**
   During the evaluation of various adaptive design criteria, certain research needs and information gaps will be seen and better understood. These research needs and gaps will be identified and used to inform the Data and Research Plan (Strategy 1a). Future actions to address these gaps and needs should be identified, clearly outlining action items, associated timeframes, level of effort, and staffing and funding requirements.

4. **Evaluate identified measures according to applicability and feasibility of implementation and determine which measures to adopt★**
   Respective Divisions will evaluate proposed adaptive design criteria in terms of applicability to VDOT's transportation network and feasibility of implementation Evaluations shall include, but not be limited to, the following.

   a) Structure and Bridge. The Department has begun to incorporate resilience into its new construction projects through the design of new structures in the coastal area. S&B published Chapter 33 of the Manual of the Structure and Bridge Division – Considerations of Climate Change and Coastal Storms in February of 2020, which details how VDOT is implementing new design standards aimed at making bridges and transportation structures more resistant to the effects of climate change. This chapter includes

   1. material considerations to address salinity changes;
   2. adjustments to deck drainage, scour, stream pressure, and buoyancy design parameters to address increased rainfall intensity and discharge; and
   3. bridge layout and profile adjustments and design considerations for abutment and riprap, erosion, slope stability and selection of materials to address sea level rise (SLR).

   S&B will revisit this document subject to improvement based on feedback or new information.

   b) Roadway. L&D will determine if there is a need to add primary evacuation routes, important infrastructure, and vulnerable infrastructure as new sub-categories for special consideration to incorporate resilience into design. L&D will also evaluate how resilience will be incorporated into roadway design and geometric criteria and standards.

c) Hydraulics. The Department has revised the VDOT Drainage Manual to ensure consistency with the provisions in Chapter 33 of the Manual of the Structure and Bridge Division, including revision to Chapter 6, Hydrology, to compute 200-year stream flows that are needed for scour computations and Chapter 12, Riverine Analysis, to add bridge scour computations associated with the 200-year streamflow discharge event.

L&D will evaluate options to incorporate the outcomes of the studies regarding precipitation updates and mapping products. The Department will adopt the NOAA Atlas 14 updates should the Transportation Research Board pooled funding project that updates historical data from 2004 to present be delivered. The purpose of the project is to update the precipitation frequency estimates for the Mid-Atlantic States due the increased amount of available information, both in the number of stations and their record lengths, since publication in 2004. This effort could have a considerable impact on the precipitation frequency estimates.

The Department also anticipates reviewing and considering adoption of Projected Rainfall IDF Curves based on studies being conducted by the Rand, Cornell, Carnegie Mellon, and MARISA consortium. The projected rainfall IDF curves include 2, 5, 10, 25, 50 and 100-year return periods for emission scenarios RCP 4.5 and RCP 8.5 for two time periods, 2020-2070 and 2050 – 2100. The incorporation of projected rainfall projections would also need to consider existing Virginia Stormwater Management Program regulations, which include explicit reference to the use of NOAA Atlas 14.

VDOT is working closely with the DCR CRMP Director to better understand the Commonwealth's adoption of projected rainfall estimates, which could impact the design of open and closed drainage and stormwater management systems. The mapping products may be considered for use as a screening tool to inform criteria-based decisions, including exposure and risk potential to SLR or other climatic factors, and applicability, including consideration of critical and vulnerable infrastructure. There may also be a potential need to evaluate existing roadway classifications and context to consider changes to current design. For example, culverts sized based on specific design storms associated with certain classifications may be assessed. Similarly, minimum clearances between low shoulder elevations and design storm high water levels may be assessed and varied depending on the roadway classification and identification as a critical or vulnerable segment.

d) Materials. The Materials Division will perform the following:

- Identify the impacts from flooding and excessive precipitation events on pavement and geotechnical assets;
- Assess if the current design standards adequately address the changed conditions (due to flooding) for the respective design;

- Develop plans (short and long term) to adjust design standards where the current design standards cannot adequately address impacts from flooding/excessive precipitation; and
- Revise Manual of Instruction (MOI) and other associated documents to reflect the changes.

For instance, for infrastructure where resilient design is deemed necessary, consideration regarding pavement thickness, subsurface drainage, material composition, etc. should be evaluated with relevant design standards and guidance. Necessary updates to the Materials Division's MOI will be evaluated and may include, among others, options for addressing common slope failures related to saturated soils. Any components of design adjustment may require significant research on the part of state and national entities.

4. **Determine inputs to or enhanced/adaptive design criteria to adopt★**
   Based on the results of the evaluation of the identified adaptive design criteria, a determination should be performed on which adaptive design criteria are going to be adopted. In addition, inputs to the development of the adaptive design criteria should be determined using the authoritative datasets established in Strategy 1a, as appropriate.

5. **Develop adaptive design criteria for respective areas to provide for resilience★**
   The various Divisions are expected to develop adaptive design criteria for their respective subject matter areas as applicable. It is anticipated that this step will include consultations with stakeholders and might utilize the Coordination and Outreach Plan in Strategy 2a.

6. **Revise and publish manuals, standards, guidance documents, and policies★**
   It is anticipated that the respective Divisions may propose revisions to the following documents:
   a) VDOT Drainage Manual
   b) Manual of the Structure and Bridge Division
   c) Materials Division's MOI

MEASURING SUCCESS

- ✓ Comprehensive list of adaptive design criteria identified
- ✓ List of studies related to adaptive design criteria compiled
- ✓ Evaluation according to applicability and ease of implementation and list of inputs to adaptive design criteria completed★
- ✓ Adaptive design criteria developed★
- ✓ Manuals, standards, guidance documents, and policies revised and published★
- ✓ Research needs and gaps identified

- ✓ Updates to program budgets, staffing, and revised employee performance standards, as necessary

PROPOSED IMPLEMENTATION SCHEDULE

Steps	Timeline			
	FISCAL YR 1		FISCAL YR 2	
	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)
1. Identify enhanced/adaptive design criteria used by federal agencies, other DOTs, MPOs, and localities for respective areas, as well as other related studies				
2. Coordinate with FHWA, NCHRP, other DOTs, MPOs, localities, etc.				
3. Identify research needs and gaps and future actions				
4. Evaluate measures according to applicability and feasibility of implementation				
5. Determine inputs or enhanced/adaptive design criteria to adopt				
6. Develop adaptive design criteria for respective areas to provide for resilience				
7. Revise and publish manuals, standards, guidance documents, and policies				

Strategy 4b
OTHER PHYSICAL ENHANCEMENT MEASURES

Lead Division: Environmental, L&D
Supporting Divisions: S&B, Materials, Maintenance

Timeframe:
Year 1, 2

DESCRIPTION

The Department will identify and evaluate other applicable physical enhancement measures that can be used to harden infrastructure and provide for resilience such as retrofits, revetments, and barriers. If available, VDOT should leverage existing design standards for such physical enhancements from other federal or state agencies.

STEPS TO IMPLEMENTATION

1. **Identify physical enhancements (retrofits, barriers, alternative designs) used by other DOTs, MPOs, or localities, as well as other related studies.**
   The Department will identify physical enhancement measures through a literature review and consultations with other federal, state, or regional/local entities. Examples of physical enhancements include seawall, riprap revetment, rock slide stabilization, slope failure stabilization, bulkhead, groins and jetties, and breakwater. Only applicability of these measures in providing resilience for transportation assets and structures will be subsequently evaluated.

   Physical Enhancements
   - *Flood Barriers/Levees*
   - *Retrofits/Revetments*
   - *Rock Slide Stabilization*
   - *Slope Failure Stabilization*
   - *Alternative Designs*

2. **Identify research needs and gaps and future actions**
   During the process of evaluating the various physical enhancements identified, certain research needs and information gaps will be seen and better understood. These research needs and gaps should be identified and used to inform the Data and Research Plan created pursuant to Strategy 1a. Future actions to address these gaps and needs should be identified, clearly outlining action items, associated timeframes, level of effort, and requirements for staffing and funding.

3. **Evaluate identified measures according to applicability and ease of implementation and determine other physical enhancements to adopt and/or enhance ★**
   Respective Divisions should evaluate the identified physical enhancement measures in terms of applicability to VDOT's transportation network and feasibility of implementation given the framework of our design standards and specifications, guidance and policies. The evaluation should include a determination on any new physical enhancement design standards needed.

4. **Identify enhanced designs for other physical enhancements (barrier, retrofit, and alternative designs) ★**
   Respective Divisions and should identify design guidelines and/or criteria for the proposed physical enhancement measures to be referenced or adopted as applicable.

5. **Revise and publish manuals, standards, guidance documents, and policies as applicable ★**
   It is anticipated that documents referencing design guidelines and criteria will need to be developed or revised to reflect the acceptable use of physical enhancement measures.

MEASURING SUCCESS

- ✓ Comprehensive list of other physical enhancements identified
- ✓ List of studies related to other physical enhancements compiled
- ✓ Evaluation according to applicability and ease of implementation completed
- ✓ List of other physical enhancement measures to adopt finalized ★
- ✓ Other physical enhancement design standards developed ★
- ✓ Manuals, standards, guidance documents, and policies revised and published as applicable ★
- ✓ Research needs and gaps identified
- ✓ Updates to program budgets, staffing, and revised employee performance standards, as necessary

PROPOSED IMPLEMENTATION SCHEDULE

Steps	Timeline			
	FISCAL YR 1		FISCAL YR 2	
	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)
1. Identify other physical enhancements used by other DOTs, MPOs or, localities, as well as other related studies				
2. Identify research needs and gaps and future actions				
3. Evaluate identified measures according to applicability and ease of implementation and determine other physical				

Steps	Timeline			
	FISCAL YR 1		FISCAL YR 2	
	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)
enhancements to adopt and/or enhance				
4. Develop new and/or enhance designs for other physical enhancements				
5. Revise and publish manuals, standards, guidance documents, and policies as applicable				

Strategy 4c
NATURAL & NATURE-BASED RESILIENCE MEASURES

Lead Division: Environmental
Supporting Divisions: L&D, S&B, Maintenance

Timeframe:
Year 1, 2

DESCRIPTION

This strategy involves the identification, evaluation, and selection of resilience measures that depend upon the use of naturally occurring features of the landscape (often referred to as natural resilience measures), as well as nature-based features that are created or enhanced by human design, engineering, and construction.[1] Nature-based resilience measures that leverage use of natural materials and processes to reduce erosion, wave damage, and flooding risks are an alternative to the hardening of infrastructure and have the potential to provide a more resilient network and extend asset lifespan. These measures are frequently less expensive than traditional methods and should be considered when building resilience into the transportation network. Additionally, nature-based resilience measures may contribute to meeting the overall mitigation goals of a project and contribute towards meeting VDOT's ongoing Total Maximum Daily Load (TMDL) efforts in the Commonwealth.

STEPS TO IMPLEMENTATION

1. Identify natural and nature-based resilience measures used by other DOTs, MPO's, localities and other applicable entities and related studies

VDOT will identify natural and nature-based resilience measures through an existing literature review conducted by VTRC and through surveying other resources. The following are examples of natural and nature-based resilience measures, largely supplied by FHWA.[2] Additional measures may also be identified and evaluated based on the results of our queries.

- Marsh Vegetation
- Marsh Breakwater
- Marsh Sill
- Beach Nourishment
- Pocket Beach
- Dune Restoration
- Constructed Wetlands
- Wetland Restoration
- Submerged Aquatic Vegetation Planting/Restoration

[1] For more information, see Torossian, K.B. (2021). *Nature-Based Solutions for Coastal Highway Resilience*. Washington, DC. USDOT

[2] U.S. Department of Transportation. Federal Highway Administration. (2021, Autumn). Nature-Based Solutions for Coastal Highway Resilience. *Public Roads Magazine*, pp. FHWA-HRT-22-001, Vol. 85 No.3.

- Woody Vegetation Planting
- Swales
- Living Shorelines
- Riverine Fluvial Techniques
- Rock Slide Stabilization
- Slope Failure Stabilization

2. **Identify research needs and gaps and future actions**
   During the process of evaluating natural and nature-based measures, certain research needs and information gaps will be seen and better understood. These research needs and gaps should be identified and used to inform the Data and Research Plan established in Strategy 1a. Future actions to address these gaps and needs should be identified, clearly outlining action items, associated timeframes, level of effort, and staffing and funding requirements.

3. **Evaluate measures according to applicability and ease of implementation and determine nature-based measures to adopt and/or enhance★**
   The respective Divisions should evaluate the identified natural and nature-based measures in terms of applicability to VDOT's transportation network and feasibility of implementation given the framework of our design standards and specifications, guidance, and policies. A determination should be performed on natural and nature-based measures that should be selected for adoption.

4. **Identify standards of practices for natural and nature-based resilience measures★**
   The respective Divisions should identify standards of practices and/or design criteria or guidelines that can be referenced or adopted for the selected natural and nature-based resilience measures to implement, as applicable.

5. **Develop and/or revise and publish manuals, standards, guidance documents, and policies★**
   Documents that reference standards of practices, design guidelines and/or criteria will need to be provided to reflect the acceptable use of these natural and nature based measures to add resilience to infrastructure.

MEASURING SUCCESS

- ✓ Comprehensive list of natural and nature-based resilience measures identified
- ✓ List of studies, tools, and resources related to natural and nature-based resilience measures compiled
- ✓ Ranking and evaluation according to applicability and ease of implementation completed
- ✓ List of natural and nature-based resilience measures to adopt finalized★
- ✓ Research needs and gaps identified
- ✓ Design criteria and standards developed as appropriate★
- ✓ Manuals, standards, guidance documents, and policies created and/or revised and published★

- ✓ Updates to program budgets, staffing, and revised employee performance standards, as necessary

PROPOSED IMPLEMENTATION SCHEDULE

Steps	Timeline			
	FISCAL YR 1		FISCAL YR 2	
	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)
1. Identify natural and nature-based resilience measures used by other DOTs, MPOs, localities, and other applicable entities and related studies				
2. Identify research needs and gaps and future actions				
3. Evaluate according to applicability and ease of implementation and determine natural and nature-based measures to adopt and/or enhance				
4. Develop new and/or enhanced designs for natural or nature-based resilience measures				
5. Develop and/or revise and publish manuals, standards, guidance documents, and policies				

Strategy 4d
OPERATIONAL, MAINTENANCE, AND EMERGENCY MANAGEMENT RESILIENCE MEASURES

Lead Division: Operations
Supporting Divisions: Maintenance, OSSEM

Timeframe:
Year 1, 2

DESCRIPTION

In cases where hardening or enhancement of infrastructure may not be feasible or cost effective, other operational, maintenance, and emergency management measures can be established to manage and mitigate disaster risks and impacts. Such measures could include proactive preparation of infrastructure in advance of forecasted weather events (focused on areas with historical impacts), updated emergency response plans, and updates to maintenance monitoring and tracking systems.

STEPS TO IMPLEMENTATION

1. **Identify operational, maintenance, and emergency management measures being used by other DOTs, MPOs, and localities to provide resilience in their transportation network as well as other related studies**

   Operational, maintenance, and emergency management measures are steps taken to mitigate and respond to disaster risks and impacts. While certain measures are already in place at VDOT, there may be opportunity to enhance implementation to provide for added resilience. Operational, maintenance, and emergency management measures include the following.

   a) *Deploy technology solutions to monitor infrastructure conditions.* These technology solutions are early flood warning devices that inform asset conditions and provide advance warning of pending failures due to weather/climate extremes. For example, mostly concerned about riverine flooding and extreme precipitation, Iowa DOT planned to integrate vulnerability scores into their maintenance monitoring and tracking systems.[3] Iowa DOT has also developed a robust real-time flood monitoring/modeling system to provide advance notice of roadway overtopping and the potential for bridge scour. [4]

[3] Iowa Department of Transportation. FHWA Climate Resilience Pilot Program. 2015. https://www.fhwa.dot.gov/environment/sustainability/resilience/ pilots/2013-2015_pilots/iowa/index.cfm
[4] Iowa FOT. https://iowadot.gov/systems_planning/freight/FAC/Sept2019/Infrastructure-Design-and-Construction-to-Improve-Resiliency.pdf

b) *Provide transportation network redundancy.* The Department will consider evaluating and mapping system linkages/interdependencies and plan for redundant network systems/detours.

c) *Provide supporting transportation technology redundancy.* The Department will consider evaluating and mapping critical supporting utilities (power and communications) for transportation technology systems (signals, detectors, etc.) and plan for redundant or backup sources.

d) *Increased maintenance activities.* For identified areas of recurrent flooding and vulnerable infrastructure, the Department should consider increased maintenance schedules to provide for proper functioning of fixed infrastructure and other protective measures. For example, the Kentucky Transportation Cabinet planned to apply their vulnerability assessment towards developing maintenance activities that proactively prepared infrastructure for severe weather, such as extreme heat and precipitation events.[5]

e) *Enhanced inspection procedures.* Similarly, the Department should consider enhanced inspection procedures to monitor condition of infrastructure and provide elevated attention to precursors of potential failures for areas of recurrent flooding and vulnerable infrastructure.

f) *Enhanced preparedness measures.* The Department should evaluate existing plans and procedures related to emergency response, recovery, and continuity of operations, and should provide enhancements and updates as necessary, especially for identified areas of recurrent flooding or vulnerable infrastructure. This includes the evaluation of coordination procedures with DRPT for emergency management and response. For example, the Massachusetts DOT expressed intent to update their emergency response plans with the findings from their vulnerability assessment (e.g., ensuring planned detour routes are not also at risk of flooding from coastal storms). [6]

g) *Early and enhanced warnings and communications to the public.* The Department should evaluate and improve communication capabilities and information sharing with customers to manage expectations and travel demand.

2. **Identify research needs, program gaps and future actions.**

During the process of evaluating the various operational, maintenance, and emergency measures, certain research needs and program gaps will be seen and better understood. These research needs and gaps should be identified and used to inform the Data and Research Plan developed pursuant to Strategy 1a. Future actions to address these gaps and needs should be identified, clearly outlining action items and associated timeframes, as well as level of effort and staffing, training, and funding requirements.

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[5] Kentucky Transportation Cabinet. Asset Management, Extreme Weather, and Proxy Indicators. 2019. https://www.fhwa.dot.gov/asset/pilot/ky.pdf

[6] Massachusetts Department of Transportation. FHWA Climate Resilience Pilot Program. 2015. https://www.fhwa.dot.gov/environment/sustainability/ resilience/pilots/2013-2015_pilots/connecticut/index.cfm

3. **Evaluate measures according to applicability and ease of implementation and determine operational, maintenance, and emergency management measures to adopt and enhance.**
   The respective Divisions should evaluate identified operational, maintenance, and emergency management measures in terms of applicability to VDOT's transportation network and feasibility of implementation given the framework of our existing operational, maintenance, and emergency management procedures, standards, and policies. A determination should be performed on current existing procedures, standards and policies that need to be enhanced as well as new measures that need to be adopted.

4. **Develop and/or revise and publish manuals, standards, guidance documents, and policies to integrate measures in current business practices and workflows.★**
   Procedures, standards, policies, and documents may need to be instituted or revised to reflect the adopted measures in order to become effective and integrated into current business practices and workflows.

MEASURING SUCCESS

- ✓ Comprehensive list of operational, maintenance, and emergency management measures identified
- ✓ List of studies related to operational, maintenance, and emergency management measures compiled
- ✓ Evaluation according to applicability and ease of implementation completed
- ✓ List of operational, maintenance, and emergency management measures to adopt and/or enhanced finalized
- ✓ Research needs and program gaps identified
- ✓ Manuals, standards, guidance documents, and policies created and/or revised and published
- ✓ Updates to program budgets, staffing, and revised employee performance standards, as necessary

PROPOSED IMPLEMENTATION SCHEDULE

Steps	Timeline			
	FISCAL YR 1		FISCAL YR 2	
	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)
1. Identify operational, maintenance, and emergency management				

Steps	Timeline			
	FISCAL YR 1		FISCAL YR 2	
	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)
measures being used by other DOTs, MPOs, or localities to provide resilience in their transportation network, as well as other related studies				
2. Identify research needs, program gaps, and future actions.				
3. Evaluate measures according to applicability and ease of implementation and determine operational, maintenance, and emergency management measures to adopt and enhance				
4. Develop and/or revise and publish manuals, standards, guidance documents, and policies to integrate measures into current business practices and workflows				

Strategy 4e
ADMINISTRATIVE AND POLICY RESILIENCE MEASURES

Lead Division: GALA
Supporting Divisions: Environmental, L&D

Timeframe:
Year 1, 2

DESCRIPTION

This strategy is aimed at evaluating other possible resilience measures intended to mitigate disaster risks and impacts not otherwise captured in this Plan that might be administrative or policy-driven. Some of these resilience measures may be in reaction to, or dependent upon, the policies and actions of other federal, state, regional, or local entities with whom preparation and coordination is imperative.

STEPS TO IMPLEMENTATION

1. **Identify administrative and policy measures that support resilience and are used by other DOTs, MPO's or localities and related studies.**
   Other possible measures beyond hardening of infrastructure, operational measures, and maintenance mitigation measures may be available to address resilience for the transportation network. A review of administrative or policy measures being adopted by others should be conducted to evaluate VDOT's preparedness and responsibilities, as well as which options might be within the authority of the CTB and/or VDOT to implement. These options may include, but are not limited to, measures related to managed retreat, land use, and floodplain management.

2. **Identify research needs and gaps and future actions**
   During the process of evaluating other possible measures, certain research needs and gaps will be seen and better understood. These research needs and gaps should be identified and used to inform the Data and Research Plan developed pursuant to Strategy 1a. Future actions to address these gaps and needs should be identified, clearly outlining action items, associated timeframes, level of effort, and staffing and funding requirements.

3. **Evaluate identified measures according to applicability and ease of implementation and determine measures to adopt★**
   The identified measures should be evaluated by the appropriate Divisions in terms of cost, applicability to VDOT and feasibility of implementation given the framework of our guidance and policies. The evaluation should include an analysis of legal authority and VDOT's role in

implementation, as well as the appropriateness of the measure to meet the agency's goals. It should also be recognized that some of these measures may be in reaction to or dependent upon the policies and actions of other federal, state, regional, and local entities. Coordination with the aforementioned entities will be critical in the evaluation of these measures and the determination of which measures are within the agency's purview to adopt. Consistency with other Commonwealth policies, directives, etc. should be maintained to ensure VDOT is aligned with other agency/Secretariat objectives to the extent appropriate.

4. **Develop and/or revise and publish manuals, standards, guidance documents, and policies as appropriate★**

   It is anticipated that agency procedures, standards, policies, and documents may need to be implemented or modified to accommodate any necessary additions or changes to current business practices and workflows. There may also be a need for proposed legislation, as appropriate. As appropriate, CTB consultation will be performed and approval will be sought for items requiring CTB action.

MEASURING SUCCESS

- ✓ Comprehensive list of other possible measures identified
- ✓ List of studies and other research related to other possible measures compiled
- ✓ Coordination with other federal, state agencies, localities, and MPOs
- ✓ Evaluation according to applicability and ease of implementation completed
- ✓ List of measures to adopt★
- ✓ Research needs and gaps identified
- ✓ Associated regulations, manuals, standards, guidance documents, and policies revised and/or created and published as appropriate★
- ✓ Propose legislation, as appropriate★
- ✓ Updates to program budgets, staffing, and revised employee performance standards, as necessary

PROPOSED IMPLEMENTATION SCHEDULE

Steps	Timeline			
	FISCAL YR 1		FISCAL YR 2	
	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)
1. Identify other possible resilience measures used by other DOTs, MPOs, or localities and related studies				

Steps	Timeline			
	FISCAL YR 1		FISCAL YR 2	
	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)
2. Identify research needs and gaps and future actions				
3. Evaluate identified measures according to applicability and ease of implementation and determine possible measures to adopt				
4. Develop and/or revise and publish manuals, standards, guidance documents, and policies				

Objective 5
UTILIZE FEASIBILITY AND COST EFFECTIVENESS ANALYSES

VDOT's selection of a resilience measure for implementation will be evaluated based upon its feasibility and cost effectiveness for a particular asset

Strategy 5a
FEASIBILITY AND COST EFFECTIVENESS METHODOLOGY

Lead Division: Environmental
Supporting Divisions: L&D, TMPD, Cost Estimation, IID, AMD, S&B, Maintenance, Operations, OSSEM, GALA

Timeframe: Year 1, 2

DESCRIPTION

The Department should develop a methodology for determining whether adaptation, protection, or retreat is appropriate for a particular asset and selecting which resilience measures are needed to address resilience. As shown in Figures 6 and 7, the methodology should consider the feasibility of the various resilience measures and, if feasible, the cost effectiveness of its application. An effective methodological process will provide and document a standardized approach to incorporate resilience into transportation infrastructure.

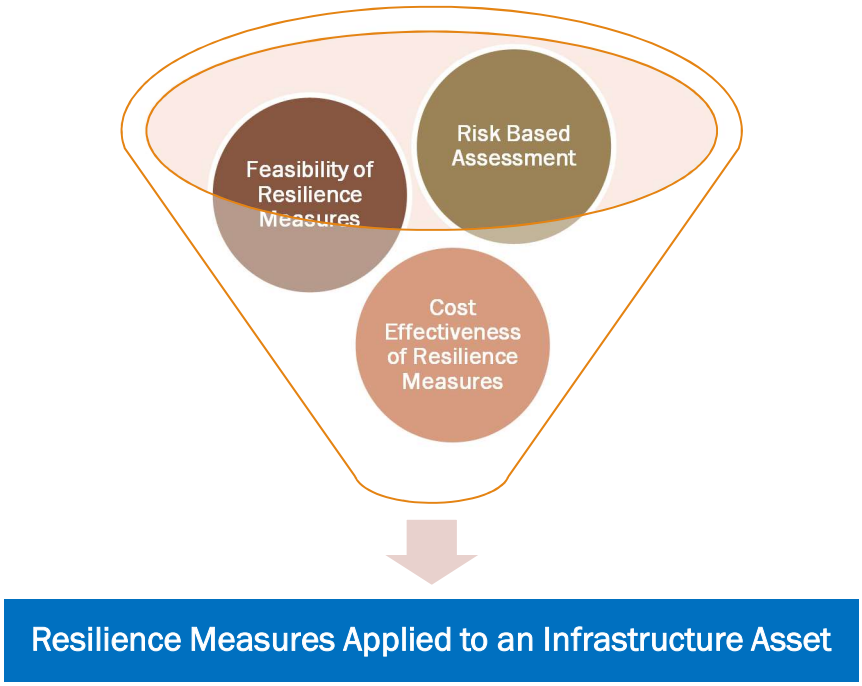


Figure 6: Factors affecting the selection of resilience measures for transportation infrastructure

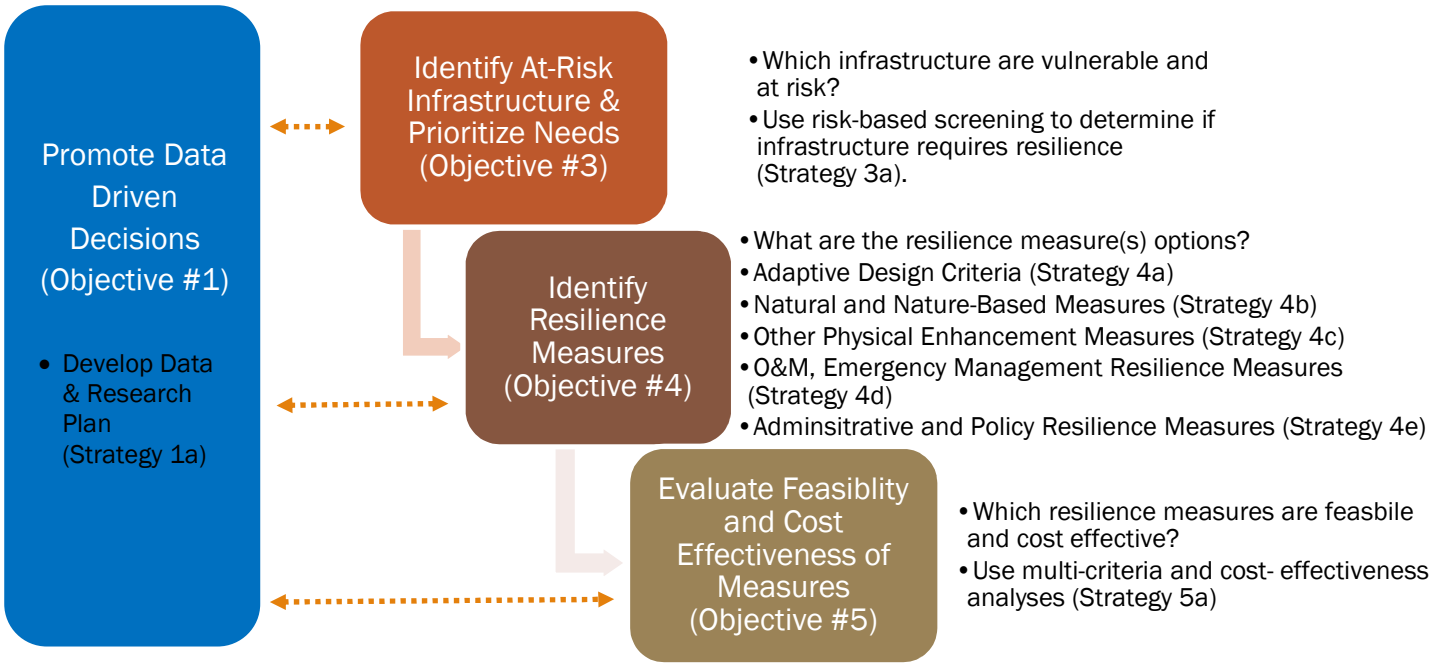


Figure 7: Process flow from identification of at-risk infrastructure to evaluating most feasible and cost-effective measures.

STEPS TO IMPLEMENTATION

The FHWA Vulnerability Assessment and Adaptation Framework[7] offers the use of a multi-criteria analysis to evaluate the feasibility of a resilience measure and an economic analysis to evaluate cost effectiveness of a resilience measure. The following provides excerpts of FHWA analyses that can be used for evaluating adaptation options.

1. **Develop a multi-criteria analysis (MCA) for evaluating feasibility of resilience measures★**
   MCA involves comparing resilience measures across a range of qualitative and quantitative criteria. Potential criteria to consider in the analysis include the resilience measure's environmental impacts, technical feasibility, and permitting constraints, among others. VDOT will prioritize the criteria most important to the Department by giving these criteria higher weight in the analysis or by eliminating resilience measures that do not score well on these criteria. The Steering Committee should be involved in selecting the criteria, determining the weightings for each criterion, and rating the resilience measures.

[7] U.S. Department of Transportation, Federal Highway Administration. (2017). *Vulnerability Assessment and Adaptation Framework.*

2. **Develop economic analysis (EA) to evaluate cost effectiveness of resilience measures and develop associated tools★**

   An EA is a useful tool to evaluate public investments and can help the Department evaluate and prioritize resilience measures by clarifying the potential long-term costs and benefits of the various resilience measures. It offers a systematic and transparent framework to organize information on asset vulnerability, compare resilience measures for reducing vulnerability, evaluate benefits and costs of each approach, and inform decisions on which resilience measures to pursue.

   Although there are different types of economic analysis that can be used to evaluate the costs and benefits of resilience measures, the Benefit Cost Analysis (BCA) and Life Cycle Cost Analyses (LCCA) are deemed to be most applicable in evaluating the cost effectiveness of the different resilience measures and are being offered for consideration.

   1. *Benefit Cost Analysis (BCA)* evaluates the benefits and costs of resilience measures to include justification for the options in terms of benefits to travelers and businesses and identifies the best timing for implementation by quantifying the level of benefits under different scenarios. Direct benefits can include the value of reduced delays to travelers and shippers, reductions in crashes, improved emergency responder access, less damage to or loss of freight shipments, and faster restoration of capacity.

   2. *Life-cycle cost analysis (LCCA),* a subset of BCA, is an approach commonly used to evaluate the differential costs of alternative designs or initial investment levels for transportation infrastructure. LCCA focuses primarily on identifying the long-term costs to transportation agencies of different alternatives over the complete time horizon that captures a major reconstruction. This analysis is typically less intensive than a full BCA since the options and anticipated performance being compared have been identified. LCCA does not consider the external cost and benefits of adaptation options, i.e., the impacts to travelers, businesses, and/or the environment.

3. **Develop necessary measures (policy, guidance, procedures, etc.) to integrate the analyses into current business practices and workflows★**

   Currently, the Department already utilizes some cost benefit analysis tools for operational management strategies as well as processes similar to multi criteria analyses described above (e.g., environmental review, permitting constraints evaluation). The next step is to determine whether additional analyses are necessary to evaluate feasibility and cost effectiveness of resilience measures and the development of such. Once the Department analyzes and develops the associated tools, the next step will be to integrate the conduct of these analyses into current business practices and workflows. This will include determining at what stage of the business

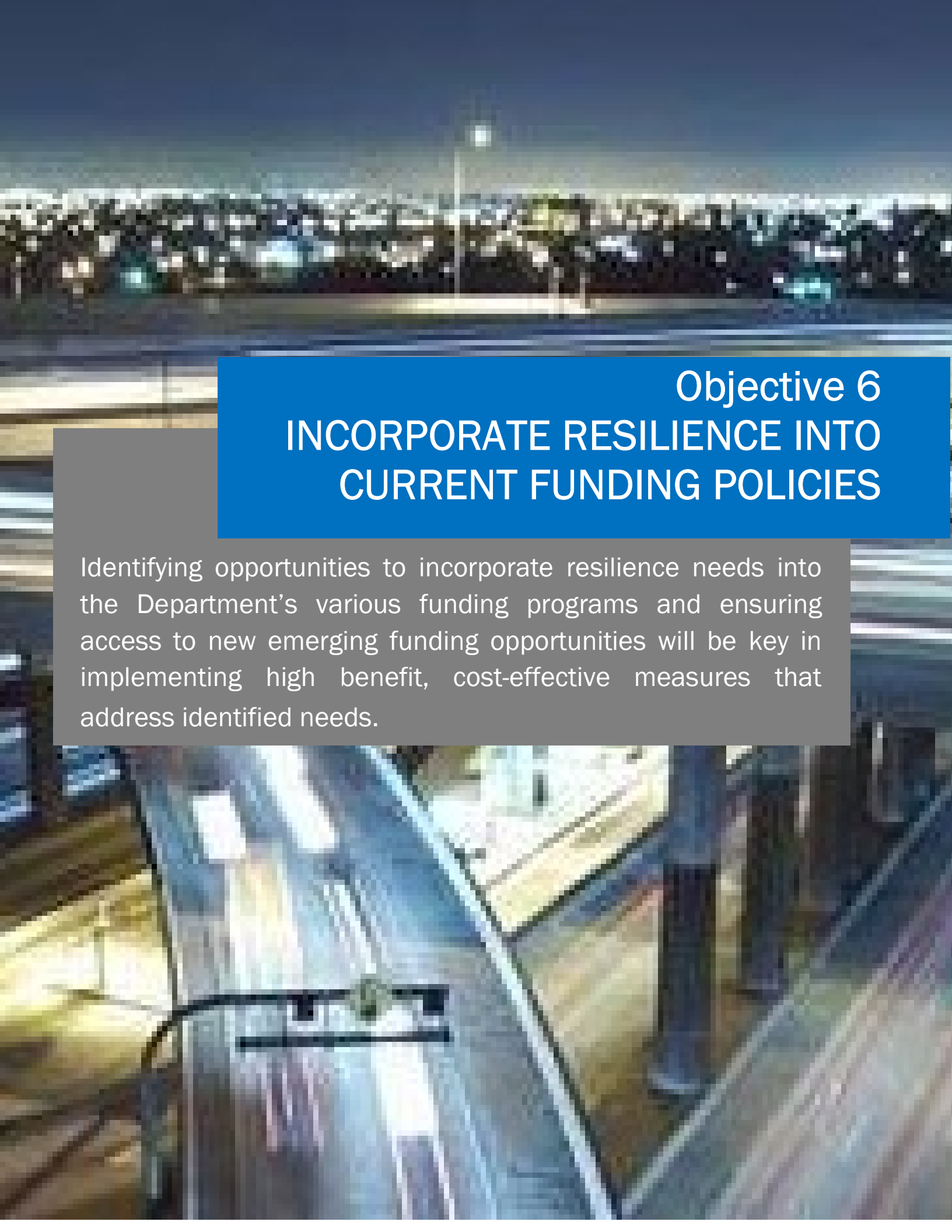
workflows these analyses will be employed (project scoping phase for project development, prioritization of projects for asset management, etc.).

MEASURING SUCCESS

- ✓ Multi criteria analysis and tools for determining feasibility of measures developed★
- ✓ Economic analysis and tools for determining cost effectiveness of measures developed★
- ✓ Measures (policies, guidance, procedures) for integrating multi-criteria analysis into business practices and workflows developed and published★
- ✓ Updates to program budgets, staffing, and revised employee performance standards, as necessary

PROPOSED IMPLEMENTATION SCHEDULE

Steps	Timeline			
	FISCAL YR 1		FISCAL YR 2	
	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)	1st Semester (Jul – Dec)	2nd Semester (Jan – Jun)
1. Establish MCA for evaluating feasibility of resilience measures and develop associated tools				
2. Establish EA to evaluate cost effectiveness of resilience measures and develop associated tools				
3. Develop necessary measures (policy, guidance, procedures, etc.) to integrate the analyses into current business practices and workflows				



Objective 6
INCORPORATE RESILIENCE INTO CURRENT FUNDING POLICIES

Identifying opportunities to incorporate resilience needs into the Department's various funding programs and ensuring access to new emerging funding opportunities will be key in implementing high benefit, cost-effective measures that address identified needs.

Strategy 6a
RESILIENCE NEEDS INCORPORATION INTO CURRENT INVESTMENT PROCESSES AND PROGRAMS

Lead Division: IID, AMD
Supporting Divisions: L&D, S&B, Maintenance, Environmental

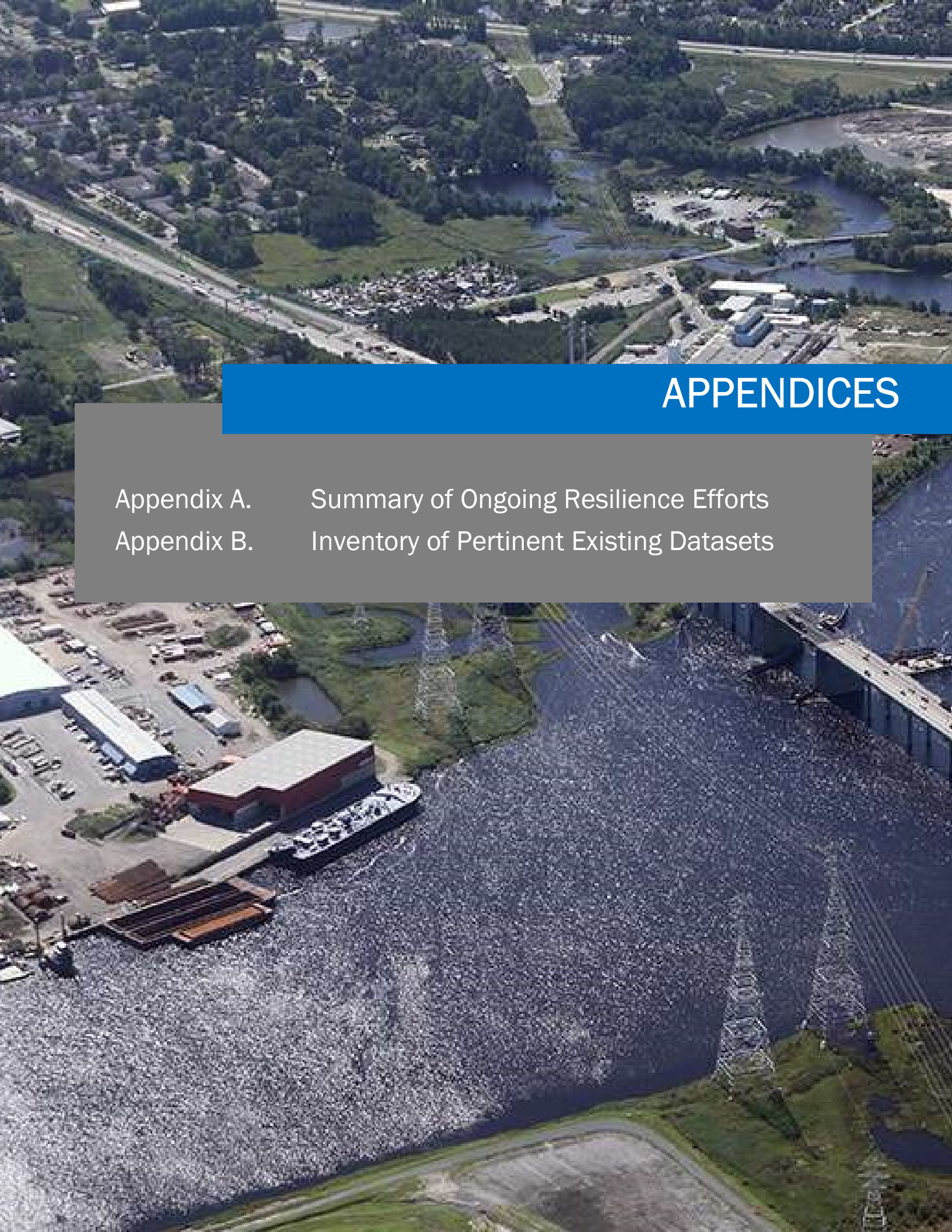
Timeframe:
Year 1, 2

The Department recognizes that the incorporation of resilience needs in current investment processes and programs will be critical to the success of the overall VDOT Resilience Plan. Identifying opportunities to incorporate resilience into the Department's various funding programs will be key in implementing high benefit, cost-effective measures that address identified needs on a long term basis. However, the Department is also aware that the strategy cannot be properly developed until the rest of the identified strategies are more mature and their implications understood.

While the rest of the strategies are being developed, new funding opportunities available for resilience projects and initiatives will be identified. The criteria, requirements, available dollars, and other parameters of these funding opportunities will be documented.

Once the determination and prioritization of resilience needs and evaluation of resilience measures are further established, the development of this strategy can be initiated. The necessary steps towards the incorporation of investment in resilience into existing funding programs including efforts to obtain funding from other sources, such as discretionary grants, can then be identified and subsequently implemented.

It should be duly noted that important decisions relating to investments will need to undergo vetting and approval by VDOT's Executive team and the Secretary of Transportation with ultimate investment decisions being made by the CTB.



APPENDICES

Appendix A. Summary of Ongoing Resilience Efforts

Appendix B. Inventory of Pertinent Existing Datasets

A. SUMMARY OF ONGOING RESILIENCE EFFORTS

Project ID	Project Name	Project Objective	Implications to VDOT	Stakeholder Lead	Division Lead	Collaborators	Point of Contact from Workgroup	Status	Link	Notes
1	**Project Atlantis – Phase 1 & 2**	Assess historical intensity of storms, assess against infrastructure damage and maintenance needs.	Provide findings and master datasets and internal datasets that will enable the project to move to operationalizing the findings (Phase 3).	VDOT	BIS	Maintenance & Operations	Michael Hibbard	Complete		
2	**Project Atlantis – Phase 3**	Look at Bristol and Salem and operationalize the data. It will provide a predictive model using data that we know is good. It can be used by a variety of entities not just Maintenance.	Provide machine learning algorithms that would help the superintendents be warned early that if it is raining, need to start doing these types of activities. Going to assist MN Division and superintendents identify what data is critical to support effort in collection through HMMS.	VDOT	BIS	Maintenance & Operations	Michael Hibbard	On Hold		
3	**Environmental Documentation Process**	Develop a process for documenting information pertaining to the incorporation of resilience into project design for purposes of documenting avoidance/minimization of environmental resources and agency coordination.	Provide a location for documenting residency in project design - interim process will incorporate information into existing locations in CEDAR with ultimate objective to develop a new location in CEDAR specifically to document resilience	VDOT	Environmental	L&D, S&B	Steve Begg	Underway		Concluded discussion with District Environmental. Draft Environmental Memorandum under development along with the draft documentation form.
4	**Geotechnical Manual of Instruction Update**	Proposing to review to address common slope failure mechanism. Statewide issue.	Updating to address saturated soil thickness thresholds which can lead to failure; may be more common with increased rainfall.	VDOT	Geotechnical		Carl Benson	On Hold		Distributed to Districts for review. Not planned for implementation at this time.

Project ID	Project Name	Project Objective	Implications to VDOT	Stakeholder Lead	Division Lead	Collaborators	Point of Contact from Workgroup	Status	Link	Notes
5	**HB 561: Project Evaluation; primary evacuation routes**	Requires OIPI to include results of screening candidate projects in Six-Year Improvement Program whether such projects are located on a primary evacuation route.	Statewide prioritization process; SMART SCALE	VDOT	IID	OSSEM, OIPI		Underway	https://lis.virginia.gov/cgi-bin/legp604.exe?201+cab+SC10213HB0561+HB1REF	
6	**HB 1217 Study Report**	Identification of Infrastructure at risk and causes (within Planning District 8); policy and budget recommendations	Identification of Infrastructure at Risk and causes; policy and budget recommendations.	VDOT	L&D	VTRC, VIMS, NOVA District, Workgroup, GALA	Alex Foraste/Maria Mutuc	Complete. Published January 2022		
7	**Drainage Manual Updates**	Revise the Drainage Manual to create consistent analysis (hydrology, riverine, and scour analysis) with Chapter 33 of S&B Manual.	Possible changes to drainage and culvert design.	VDOT	L&D	S&B, Hydraulics	Alex Foraste	Complete. Published January 2021		
8	**Incorporation of Resilience in the Design of New Construction Projects**	Develop a Joint IIM/policy to address incorporation of resilience in new construction design. Legislative mandate -- Chapter 52, S 1350, 33.2-353 D.2 Approved March 11, 2021. "That the Commissioner of Highways shall ensure resilience is incorporated into the design standards for new construction projects."	Provide a Joint IIM/policy that includes risk-based approach to determine project vulnerability and applicability of adaptive design criteria. Divisions would develop their respective adaptive design criteria for incorporation in the IIM. Would result in potential changes to design criteria, standards, and policies.	VDOT	L&D	Various. Materials, S&B, Hydraulics, PMO, etc.	Alex Foraste/Maria Mutuc	Underway		Draft memo to incorporate resilience in design of new construction has been developed. Draft risk-based approach assessment to determine applicability based on OIPI's geospatial and vulnerability assessment data on VDOT infrastructure along with documentation is under development. *Potential Challenge: Identification of authoritative dataset to use for risk-based approach and basis for adaptive design criteria*
9	**Literature Review of Adaptive Design Criteria (FHWA, DOTs, Localities & MPOs)**	Perform a literature review of the adjustments to design criteria to provide for resilience of various DOTs,	Inform the development of adaptive design criteria by the different VDOT Divisions and Sections.	VDOT	L&D		Alex Foraste/Maria Mutuc	Underway		

Project ID	Project Name	Project Objective	Implications to VDOT	Stakeholder Lead	Division Lead	Collaborators	Point of Contact from Workgroup	Status	Link	Notes
		FHWA, localities, and MPOs. Evaluate applicability to VDOT and provide recommendations.								
10	**Adaptive Design Criteria Pilot Study**	Evaluate the effects of forecasted data on increase precipitation and SLR on the design and cost of projects in the coastal, blue ridge/mountain valley and piedmont regions.	Provide design and cost implications and inform adaptive design criteria inputs.	VDOT	L&D		Alex Foraste/Maria Mutuc	Underway		
11	**Drainage Manual Updates**	Revise the Drainage Manual to incorporate forward looking conditions (Increased precipitation, SLR and design tidal elevations, etc.).	Provide hydraulic adaptive design criteria to address increased precipitation, joint probability analysis, etc.	VDOT	L&D		Tory Bains/Maria Mutuc	Planned		Planned, pending results of studies, resilience plan, etc.
12	**Considerations of Climate Change and Coastal Storms. Chapter 33 of S&B Manual**	Research the possible future conditions due to climate change (SLR, salinity, temperature change, river discharges) that could affect the structure's life span (~100-year life spans).	Possible Changes to Bridge Design and Materials Selection	VDOT	S&B	VTRC, L&D Hydraulics	Todd Springer	Complete. Published February 2020		
13	**Emergency Response Manual for Natural Disasters**	Develop a manual to outline steps within VDOT systems and processes to be able secure emergency relief funding efficiently.	Provide a more efficient way of securing funding during emergency situations.	VDOT	S&B Maintenance & Management		Todd Springer	Planned, no timeline yet		
14	**BRIC Grant**	Apply through VDEM, for more resilient scour protection on various bridges.	Enhanced scour protection of select VDOT bridges.	VDOT	OSSEM	L&D, S&B, Maintenance, Asset Management, GALA	Matt Lott	Halted		Decided to no longer pursue for FY21

Project ID	Project Name	Project Objective	Implications to VDOT	Stakeholder Lead	Division Lead	Collaborators	Point of Contact from Workgroup	Status	Link	Notes
15	**HB 1561: Primary Evacuation Routes**	Develop, maintain, and make publicly available a map of primary evacuation routes.	Directs VDOT in consultation with VDEM to develop. Requires review of transportation infrastructure along such routes and submit report every five years to GA.	VDOT	OSSEM/VDEM		Matt Lott	Completed 2021	https://lis.virginia.gov/cgi-bin/legp604.exe?201+cab+SC10213HB1560+HB1REF	
16	**Incorporating Potential Climate Change Impacts in Bridge and Culvert Design**	Evaluate/validate existing Dewberry study and extend through 2100. Investigate relationship between projected increased rainfall, peak discharges, and watershed area. Analyze statewide.	Provided recommendations to VDOT reflecting findings related to projected increases of rainfall and stream flow discharges.	VDOT	VTRC		Mike Fitch	Complete. Published Oct 2019		
17	**Considerations for Integrating Climate Adaptation Measures into VDOT Structure Design Decisions**	Evaluate the effects of climatic factors relative to Structure and Bridge.	Provided recommendations to VDOT relative to Structure and Bridge,	VDOT	VTRC		Mike Fitch	Complete. Published Sept 2018		
18	**Developing a Strategy for Understanding & Addressing Sea Level Rise, Land Subsidence & Recurrent Flooding Impacts on Road Infrastructure (VIMS Study)**	Assess potential for recurrent flooding and map relevant segments of roadways by jurisdiction. Map SLR impacts. Ecological and T&E impacts.	Mapping and Identification of Infrastructure in Floodplain overlay areas and historical road closures. Assessing future potential impacts due to SLR. Potential to inform moving assets to accessible facilities, managed retreat decisions. Impacts to T&E and habitat.	VDOT	VTRC/L&D	L&D, Environmental	Alex Foraste	Underway, Anticipated completion by 2024		*Potential Challenge: Does the product (dataset) align with other datasets produced for other VDOT efforts (other VIMS study, Atlantis, CRMP, OIPI)*
19	**Land Use Change and Recurrent Flooding Issues in Northern Virginia**	A study to better understand the factors that are contributing to recurrent flooding focusing on historical changes to the landscape over approximately a 15-year period, including land use and land changes, topographic changes, and possible flow regime changes at a large geographic scale. Determine if	Provide results to be incorporated in HB 1217 response.	VDOT	VTRC/L&D	VIMS	Alex Foraste/Maria Mutuc	Completed December 2021		*Potential Challenge: Does the product (dataset) align with other datasets produced for other VDOT efforts (other VIMS study, Atlantis, CRMP, OIPI)*

Project ID	Project Name	Project Objective	Implications to VDOT	Stakeholder Lead	Division Lead	Collaborators	Point of Contact from Workgroup	Status	Link	Notes
		a link between increase recurrent flooding can be attributed to the increase in impervious surface through intensive run-off.								
20	**Piloting the Development of Probabilistic Intensity Duration Frequency (IDF) Curves for the Chesapeake Bay Watershed**	Develop Rainfall IDF Curves utilizing more recent historical records and projections for CB area within Virginia from 1 hour to >24 hours.	Provide rainfall amounts comparable to NOAA Atlas 14, which is used in the design of small culverts, drainage, and related designs.	USWG & CBP facilitating contract with RAND/Cornell/ MARISA	USWG & CBP facilitating contract with RAND/Cornell /MARISA		Chris Swanson	Completed and Released August 2021		*Potential Challenge: Published IDF Curves are based on existing NOAA Atlas 14 data. The updated NOAA Atlas 14 data will not be done until 2024 and there may be potential impacts to the published IDF curves.*
21	**VTrans Vulnerability Assessment Task 5.2.1**	1.) Conduct a screening level analysis (using mapping tool) of transp. system to current and future flood hazards, and 2.) Establish magnitude of needs to preserve trans. system.	Provide a tool to evaluate potential flooding and vulnerability of VDOT network.	OIPI	OIPI	Various	Jitender Ramchandani	Complete.		Vulnerability Assessment Tool has been developed by OIPI. *Potential Challenge: Does the product (dataset) align with other datasets produced for other VDOT efforts (VIMS, Atlantis)*
22	**Floodcast**	Develop a data architecture and framework for a flood forecasting decision-support prototype tool to make rapid response decisions and communicate them during flooding events to reduce impacts to transportation infrastructure and its users.	Provide a tool for flood forecasting. Provide early warning for public and lead time for VDOT maintenance and operational crews.	NCHRP	VDEM	Operations, L&D	Matt Lott	Underway		VDOT confirmed participation in the study. Provided locations/points of interests for inclusion in the model.
23	**Update Precipitation Frequency Estimates for Delaware, Maryland, North Carolina, and Virginia (NOAA ATLAS 14 VOLUME 13)**	Update the NOAA Atlas 14 Volume 2 last published in 2004 to incorporate more recent rainfall records.	Would update the existing NOAA Atlas 14 rainfall records currently in use for design of drainage structures.	FHWA	FHWA	L&D	Chris Swanson	Underway, Anticipated completion by 2024	https://www.pooledfund.org/Details/Solicitation/1534	*Potential Challenge: Updated NOAA Atlas 14 data will not be done until 2024 and may not align with our timeframe requirements. Potential for further revisions down the road to incorporate if*

Project ID	Project Name	Project Objective	Implications to VDOT	Stakeholder Lead	Division Lead	Collaborators	Point of Contact from Workgroup	Status	Link	Notes
										there are any pertinent changes that were not previously considered.
24	**Coastal Resilience Master Plan Phase 1**	Virginia's Coastal Resilience Master Plan aims to protect communities vulnerable to flooding and provides a roadmap for adapting to climate change. The master plan includes priority resilience projects, financing strategies, and a plan for coordination among state, federal, and local governments. The plan builds on a framework issued last year and incorporates public comment from recent meetings across coastal Virginia.	Provide a plan for coordination among state, federal, and local government. Would provide additional data and analysis regarding SLR, etc.	DCR	L&D		Chris Swanson	Completed December 2021		
25	**Coastal Resilience Master Plan Phase 2**	Expand the Phase I work to help better understand the full risk to our coastal region as soon as possible to not only include coastal flooding but incorporate the future condition rainfall and riverine flooding analysis.	Provide potential collaboration on data needs and task outputs. Inform the development of adaptive design criteria standards and applicability and other policies such as managed retreat, etc.	DCR	L&D		Chris Swanson	Underway		Scoping phase, anticipated work to begin early 2022 and completion by 2023. There is ongoing coordination with DCR regarding potential parameters on studies. *Potential Challenge: Does the product (dataset) align with other datasets produced for other VDOT efforts (VIMS, Atlantis)*

B. INVENTORY OF PERTINENT EXISTING DATASETS

Dataset Name	Entity Host	Description	Format	Status	Availability & Links	Authoritative	Desired/ Needed Improvements?	Resilience Projects utilizing dataset	Point of Contact	Notes/Comments
VDOT										
LRS – Master Route Responsibility	VDOT – Virginia Roads & ArcGIS Online	Mapping layer indicating roadways maintained by VDOT.	Mapping, GIS	Available, updated quarterly	https://vdot.maps.arcgis.com/home/item.html?id=c557bfd8c83e4ff4a93699ddf3c956b8			VTRC/VIMS/L&D	Eric Hetzler or Michele Mandelle	
Culverts and Bridges	VDOT – Virginia Roads & ArcGIS Online	Large culverts (>x") and certain bridges; provides the location and condition of all bridges and large culverts in the Commonwealth.	Mapping	Updated quarterly	https://vdot.maps.arcgis.com/home/item.html?id=6310f7c137aa4f4489c8539ad7f599e9			VIMS, L&D HB 1217	Eric Hetzler or Michele Mandelle	Due to data collection efforts, some bridges may show multiple icons.
VDOT facilities	VDOT – Virginia Roads & ArcGIS Online	VDOT Facilities including District Complexes, Residencies, Area Headquarters, District boundaries,	Mapping, GIS	Available				VTRC/VIMS/VDOT	Eric Hetzler or Michele Mandelle	Needs verification on accuracy and updates made
511 Virginia database	VDOT Transportation Operations Center	Traffic information on road conditions, congestion, construction, etc. Does not differentiate between precip related flooding versus tidal flood or storm surge	Online viewer, and database	Available	https://www.511virginia.org/ and database			VTRC/VIMS/VDOT; Project Atlantis; OIPI		Quality varies; duration not reliable, as end date/time often not recorded.
VA Traffic database	VDOT Operations	Five Traffic Operations Centers record road closures to incidents and weather. Differentiates between precip related flooding versus tidal flood or storm surge	Database	Updated.	Difficult to access underlying data. Need to work with IT for pull.			VTRC/VIMS/VDOT; Project Atlantis; OIPI	Josh Byrd	
Inventory of Bridges	VDOT S&B Bridge database	National Bridge Inventory							Todd Springer	
Project Atlantis - Roadways at Risk	VDOT - Office of Strategic Innovations & Business Integrated Solutions	Roadway Network analysis overlay of LRS roads, FEMA floodplains, annual average daily traffic counts.	GIS Geodatabase mapping	Complete	Available, contact OSI & BIS			Project Atlantis	Michael Hibbard and Joe Grubbs	
Primary Evacuation Routes	VDOT OSSEM	VDOT in consultation with VDEM to develop, maintain, and make map.	GIS Geodataba	Completed	https://vdot.maps.arcgis.com/home/webmap/viewer.ht			OIPI, L&D Risk Based Screening Tool	Matt Lott	Available

Dataset Name	Entity Host	Description	Format	Status	Availability & Links	Authoritative	Desired/ Needed Improvements?	Resilience Projects utilizing dataset	Point of Contact	Notes/Comments
			se mapping		ml?webmap=bac771e4bcdf4dc0a77dcebb22addb45&extent=-85.3622,35.5226,-74.5132,40.6509					
Roadway and Floodplain Overlay	VTRC/VIMS/VDOT	Mapping of Floodplain overlay with roadways, inundated areas (Tidewater).	Online website (GIS)	Underway, Draft format	Link: http://cmap2.vims.edu/riva/			L&D HB 1217	Alex, Foraste; Mike Fitch	Tabular data for coastal areas and Planning District 8 available.
Road Closures	VTRC/VIMS/VDOT	Mapping of closures due to flooding, utilizing the 511 historical dataset.	Online website (GIS)	Underway, Draft format				VTRC/VIMS/VDOT, L&D HB 1217	Alex, Foraste; Mike Fitch	See comment above regarding 511 Database. Partially developed for Planning District 8 (NOVA), Other areas under development.
Sea Level Rise Impacting Roadways	VTRC/VIMS/VDOT	Mapping of roadways impacted due to SLR under various scenarios.	Online website (GIS)	Underway. Anticipated 2024					Alex, Foraste; Mike Fitch	Underway
Non-VDOT										
Hurricane Evacuation Routes	VDEM	Specific routes identified as hurricane evacuation routes on a map.	PDF map. Also GIS, but permissions limited	Complete and mapped	https://www.vaemergency.gov/wp-content/uploads/2020/07/Hurricane-Evacuation-Guide-2020-COVID-19-Edit-Spread-View.pdf. Access Limited. http://vdot.maps.arcgis.com/apps/webappviewer/index.html?id=5797524b9a58440c8dbc06816e060492			VTRC/VIMS/VDOT	Matt Lott	Permissions limited

Dataset Name	Entity Host	Description	Format	Status	Availability & Links	Authoritative	Desired/ Needed Improvements?	Resilience Projects utilizing dataset	Point of Contact	Notes/Comments
Coastal Virginia Sea Level with Minor and Moderate Flooding	ODU	Mapping. Utilizes NOAA work and overlays. Utilizes NOAA Int-High Scenario 2017	Mapping, ArcGIS Online.	Complete, available via website	Link to site https://www.arcgis.com/home/webmap/viewer.html?webmap=36e758f7e2b544a980962faef1faaeb4&extent=-77.3554,36.7822,-74.4825,38.0106				George McCleoud (ODU)	Presented by Adm. Ann Phillips during presentation.
Tidewatch Map	VIMS	Visualize and predict the magnitude and impacts of coastal flooding at specific locations within the Chesapeake Bay and along Virginia's seaside Eastern Shore.	Online mapping	Available via website	http://cmap2.vims.edu/SCHISM/VACoastalFloodingPredictor_DT.html					
AdaptVa	VIMS	Gateway to information for individuals, local programs, and agencies engaged in climate adaptation. ADAPTVA focuses on the physical and social vulnerabilities by integrating the best available science, legal guidance, and planning strategies.	Online website	Available via website	http://cmap2.vims.edu:8080/geoportal/catalog/search/browse/browse.page				Molly Mitchell	Will be highly leveraged by VDOT as appropriate
Interact VTrans	OIPI	This online application provides over 50 datasets developed as part of VTrans - Virginia's Transportation Plan. These datasets include those used for SMART SCALE and state funding allocations. One of the goals of VTrans - Virginia's Transportation Plan is to build capacity at the local and regional levels. OIPI develops and provides access to over 50 datasets. Some of these are currently being used for SMART SCALE, VDOT's Revenue Sharing Program, and other funding programs. InteractVTrans allows localities and other stakeholders to access these datasets.	Online mapping	Available via website	https://vtrans.org/interactvtrans/map-explorer			L&D Risk-based Screening Tool	Jitender Ramanchandi	Will be highly leveraged by VDOT as appropriate

Dataset Name	Entity Host	Description	Format	Status	Availability & Links	Authoritative	Desired/ Needed Improvements?	Resilience Projects utilizing dataset	Point of Contact	Notes/Comments
VA specific Mitigation and Mapping Data	Virginia Flood Risk Information System	Mitigation maps and data showing a variety of information pertaining to the Region III States of West Virginia, Delaware, Virginia, Maryland, Pennsylvania, and DC.	Online Mitigation Mapping and Data	Available	https://consappsrpt.dcr.virginia.gov/vafloodrisk/vfris2.html					Referenced by FEMA site https://fema.maps.arcgis.com/apps/MapSeries/index.html?appid=f3bb86e451d74093a0bd46e4501aa9f1
Severe Weather Events	NWS/NOAA		Excel	Available, downloaded in 2019				Project Atlantis	Michael Hibbard	Utilized in project.
Digital Coast-Sea Level Rise Viewer	NOAA	Use this web mapping tool to visualize community-level impacts from coastal flooding or SLR (up to 10 feet above average high tides). Photo simulations of how future flooding might impact local landmarks are also provided, as well as data related to water depth, connectivity, flood frequency, socio-economic vulnerability, wetland loss and migration, and mapping confidence.	Online mapping & Photography	Available	https://coast.noaa.gov/digitalcoast/tools/slr.html					
MARISA Projected IDF Curves	Chesapeake Bay	This interactive tool makes climate-change informed IDF curves available to view and download for counties across the Chesapeake Bay Watershed and Virginia. Using the tool, IDF curves can be easily integrated and used to plan, design, and build infrastructure assets to be more resilient to climate change.	Online website, Tabular data downloadable	Available	https://midatlantic-idf.rcc-acis.org/				Norm Goulet	
Coastal Flood Exposure	NOAA	This online visualization tool supports communities that are assessing their coastal hazard risks and vulnerabilities. The tool creates a collection of user-defined maps that show the people, places, and natural resources exposed to coastal flooding.	Online mapping	Available	https://coast.noaa.gov/digitalcoast/tools/flood-exposure.html					
Region III Mitigation Mapping and Data	FEMA	Mitigation maps and data showing a variety of information pertaining to the Region III States of West	Online Mitigation Mapping and Data	Available via website	https://fema.maps.arcgis.com/apps/MapSeries/index.html?appid=f3bb86e4					

Dataset Name	Entity Host	Description	Format	Status	Availability & Links	Authoritative	Desired/ Needed Improvements?	Resilience Projects utilizing dataset	Point of Contact	Notes/Comments
		Virginia, Delaware, Virginia, Maryland, Pennsylvania, and DC			51d74093a0bd46e4501aa9f1					
U.S. Climate Resilience Toolkit*	United States Global Change Research Program	The U.S. Climate Resilience Toolkit is a website designed to help people find and use tools, information, and subject matter expertise to build climate resilience. The Toolkit offers information from across the U.S. federal government in one easy-to-use location.	Website, Climate Projections	Available via website	https://toolkit.climate.gov/					
VA Coastal Resilience Web Explorer	DCR/CRMP	The Coastal Resilience Web Explorer allows users to interact with products of the Master Plan. These include: coastal hazards, impacts, community context, building coastal resilience, and funding coastal resilience.	Website	Available via website	https://experience.arcgis.com/experience/9e32e928ed304fa98518b71905e43085/page/Hazards/			VDOT Program Plan Funding Opportunities	Matt Dalon	Will be highly leveraged by VDOT as appropriate
Floodcast	NHCRP	Tool to better predict the timing and magnitude of flooding to enable state DOTs to issue advanced early-warnings, reducing transportation-related deaths and expensive damage to critical assets.	Online mapping	Available via website. Ongoing	http://54.225.76.222/NCHRP/				Matt Mampara	

ACKNOWLEDGMENTS

We would like to extend our gratitude to the members of the Administrators and Steering Committees for their leadership, support, time, input, and contribution towards the development of this Plan.

RESILIENCE ADMINISTRATORS COMMITTEE

Christopher Swanson, PE
Division Administrator
Environmental Division

Emmett Heltzel, PE
Division Administrator
Location and Design Division

Michael Fitch, PhD
Director
Virginia Transportation and Research Council

Jennifer Ahlin
Division Administrator
Asset Management Division

Jo Anne Maxwell
Division Administrator
Governance and Legislative Affairs

Kimberly Pryor
Division Administrator
Infrastructure Investment Division

Robert Prezioso, PE
Division Administrator
Maintenance Division

John Scrivani, CEM
Director
Office of Safety, Security, and Emergency Management

Kendal Walus, PE
Division Administrator (Former)
Structure and Bridge Division

Christopher Hall, PE
District Engineer
Hampton Roads District

Kenneth King, PE
District Engineer
Salem District

RESILIENCE STEERING COMMITTEE

Christopher Berg
Assistant Division Administrator
Environmental Division

Maria Mutuc, PE
Resilience Program Manager
Environmental Division

Steven Begg
Special Projects Lead
Environmental Division

Ellen Porter
Policy Analyst
Governance and Legislative Affairs

J. Alex Foraste, PE
Water Resources Program Manager
Location & Design Division

Victoria Bains, PE
State Hydraulics and Utilities Engineer
Location & Design Division

Abiot Gemechu, PE
Senior Hydraulics Engineer
Location & Design Division

John Matthews, PE
River Mechanics Engineer
Location & Design Division

Angela Quinn
Assistant Division Administrator
Asset Management Division

E. Michael Hibbard
Business Architecture Manager
Business Integrated Solutions Division

Kathryn Benedict
Program Management Specialist
Infrastructure Investment Division

Rob Crandol, PE
Assistant Division Administrator
Maintenance Division

Joseph Williams, PE
Assistant Division Administrator
Maintenance Division

Martin Krebs
Environmental Stewardship Manager
Maintenance Division

Chad Baker
Director
Maintenance Training Academy

Affan Habib, PE
Assistant Division Administrator
Materials Division

Matt Lott, MPA
Emergency Planning Manager
Office of Safety, Security, and Emergency Management

Paul Szatkowski, PE
Assistant Division Administrator
Operations Division

Joshua Byrd
Data Specialist
Operations Division

C. Todd Springer, M.Sc., PE
Assistant Division Administrator
Structure and Bridge Division

Gary Wilmouth, PE
Assistant Division Administrator
Transportation and Mobility Planning Division

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