Project Prioritization Subcommittee

Coastal Resilience TAC | Q2 2024 Meeting Materials

Contents

Virginia Coastal Resilience Technical Advisory Committee

Project Prioritization
Quarterly Subcommittee Meeting

Friday, May 17, 2024, 10:00 am

Virtual Meeting: Zoom Webinar

Virtual Access: Register Online

VIRGINIA COASTAL RESILIENCE MASTER PLAN

DCR Virginia Department of Conservation & Recreation

Name	Organization
Ken Pfeil (Chair)	Office of Data Governance and Analytics
Marcus Thornton (A)	
Kellen Singleton	Accomack-Northampton Planning District Commission
Jack Krolikowski	American Flood Coalition
Jay Ellington	Crater Planning District Commission
Andrew Franzyshen (A)	
Ben McFarlane	Hampton Roads Planning District Commission
Whitney Katchmark (A)	
Brianna Heath	Northern Neck Planning District Commission
Sarah Stewart	PlanRVA
Eli Podyma (A)	
Chris Swanson	Virginia Department of Transportation
Christopher Berg (A)	
Rachael Peabody	Virginia Marine Resources Commission
Scott Whitehurst	Virginia Port Authority
Mary-Carson Stiff	Wetlands Watch
Ian Blair (A)	
Thomas Ruppert	William & Mary Virginia Coastal Resilience Collaborative

Meeting Agenda

1. Call to Order, Roll Call
2. Adoption of Agenda
3. Adoption of Q1 2024 Meeting Minutes
4. Subcommittee Overview
5. Old Business
   a. Impact Assessment Updates
   b. Planned Resilience Actions Analysis Updates
6. New Business
   a. Recommendations Development
   b. Subcommittee discussion
7. Public Comment
8. Action Items, Scheduling
9. Adjourn

Coastal Resilience Master Plan, Phase II

Purpose

A **place-specific** plan for mitigating severe and repetitive flooding.

Incorporates:

- **all major flood hazards**, including precipitation-driven flooding
- a **comprehensive risk assessment** of critical human and natural infrastructure
- **a list of all projects** considered and an update of the status of all projects previously implemented

Elements

1. Flood Hazard Exposure Model
2. **Flood Hazard Impact Assessment**
3. **Planned Resilience Actions**
4. Financial Needs for Flood Resilience
5. **TAC Subcommittee Recommendations**

Details

- Dec. 2024 timeline for delivery
- Updated every five years
- Est. in Code §10.1-658, 659

Subcommittee Objectives

1. **Inform and support the flood hazard risk assessment.**
    - Specifically: the asset data inputs; the approach to quantifying the vulnerability of assets; and impact assessment outputs needed to support decision-making, coordination, and collaboration.

2. **Inform and support the identification of planned resilience actions.**
    - Specifically, identify shared themes, and gap trends between projects and initiatives submitted to the Coastal Resilience Web Explorer User Portal.

3. **Develop recommendations for future planning.**
   This includes, but is not limited to:
    - Identify goals and associated metrics for resilience that should be used to determine project/needs evaluation and prioritization in future plans.
    - Develop objective protocols for evaluating and prioritizing identified project **needs** for the Coastal Region.
    - Develop a process and objective protocols for evaluating and prioritizing resilience **actions**. (Consider separate evaluation protocols for critical human, built, and natural infrastructure needs.)

Subcommittee Schedule

Q3 2023	CRMP PII – Impact Assessment Outputs
Q4 2023	CRMP PII – Impact Assessment Outputs + Inputs
Q1 2024	CRMP PII – Impact Assessment Approach
	CRMP PII – Discuss Planned Resilience Actions
Q2 2024	**CRMP PII – Analyze Planned Resilience Actions**
	Future Plans – Recommendations
Q3 2024	CRMP PII – Analyze Planned Resilience Actions
	Future Plans – Recommendations
Q4 2024	Future Plans – Final Recommendations

General Updates

Contractor Support for CRMP Phase II

Stantec/Launch! Team:

- Report design and production
- Stakeholder engagement
  - TAC recommendations facilitation
- Data review and analysis
- Planned resilience actions
  - Includes assistance to end users to submit projects

Dewberry Team:

- Flood hazard data
- Impact assessment
- ✓ End user survey analysis
- Web explorer update mock-up

AECOM Team:

- Public outreach campaign
  - Underserved community meetings

Old Business

Impact Assessment Updates

Planned Resilience Actions Analysis Updates

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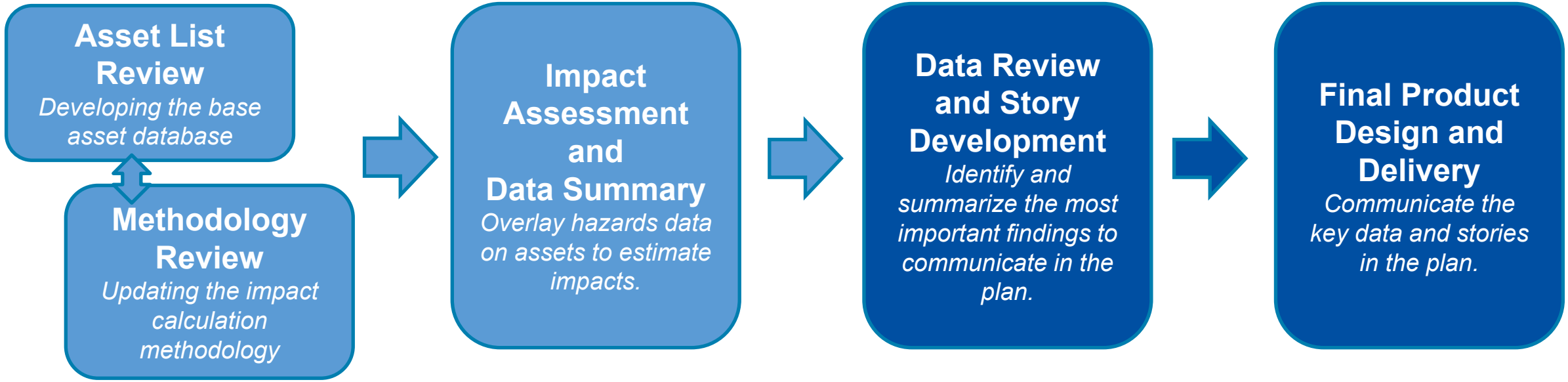
Impact Assessment Process

In Dewberry scope

In Stantec scope



January – April
(Complete)

March – July
(In Progress)

May – September
(In Progress)

August – December
(Not Started)

Planned Resilience Actions Analysis

In Stantec scope

In future scope

Review Data & Build Approach

- Initial Review and Summary
- Analysis Content Outline
- Data Quality Improvement Plan

May

Improve Data

- Data Entry Support
- Data Quality Improvement

May - July

Produce Summary

- Final Report PDF
- Coastal Resilience Web Explorer

July - December

Planned Resilience Actions

Outline of Summary for Phase II Plan:

- Inventory Summary
  - Number, cost, and type of action for each locality, watershed, planning district, and full coastal region
  - Common themes in classes and types of actions
- Gaps and Opportunities Analysis
  - Areas with no actions that are at high flood risk (from coastal, riverine, and rainfall-driven sources) at multiple planning horizons
  - Potential opportunities for coordination based on geographic proximity and action type

Initial Review and Summary

Planned Resilience Actions | Stantec Presentation

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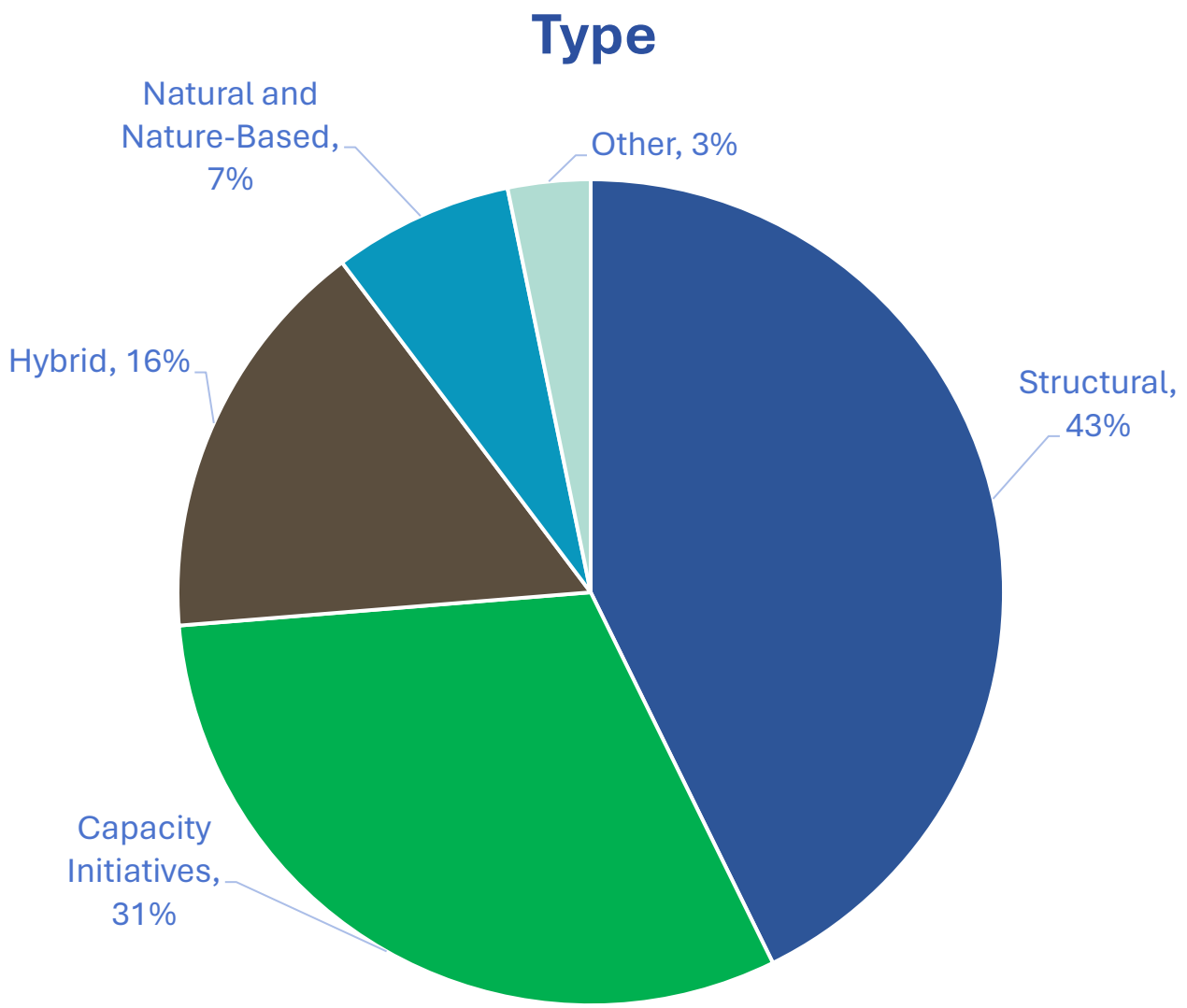
Initial Review of CRWE
(Planned Resilience Actions)

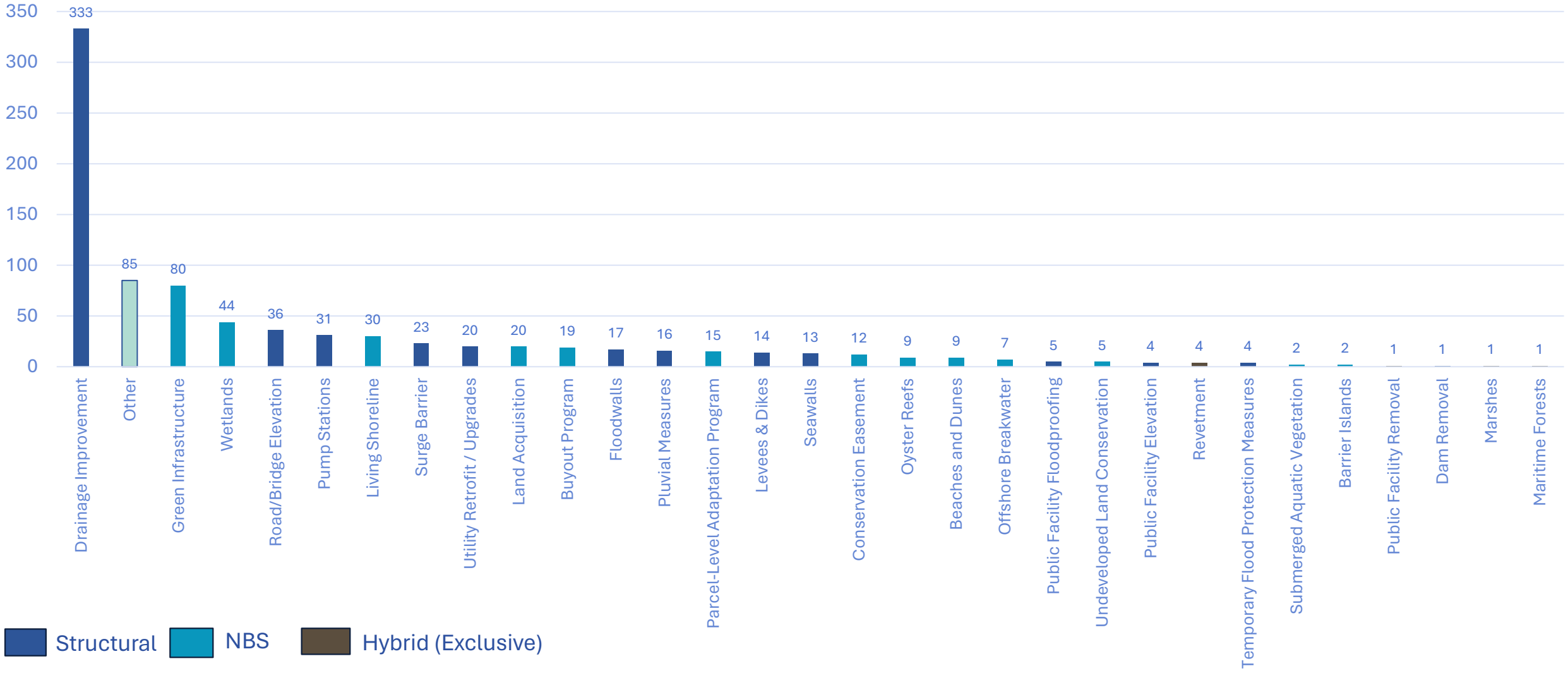
- New projects and initiatives since Phase 1
- Gaps/trends in project data
- Potential issues with the data
- Summarize inventory of projects and initiatives
- Gaps and opportunities analysis for inclusion in final report

Projects and Initiatives Since Phase 1

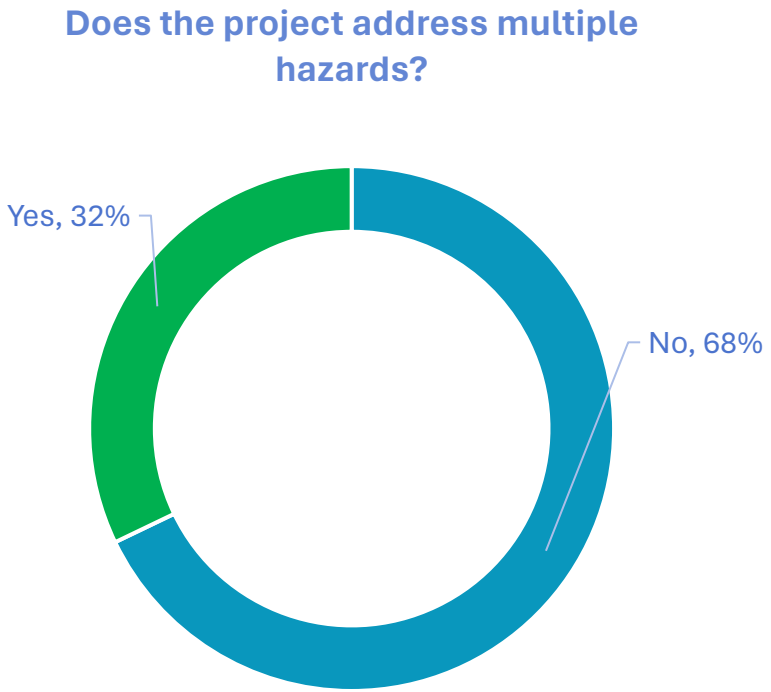
- 681 total submissions
  - 516 approved submissions during Phase 1
  - 165 approved submissions since Phase 1

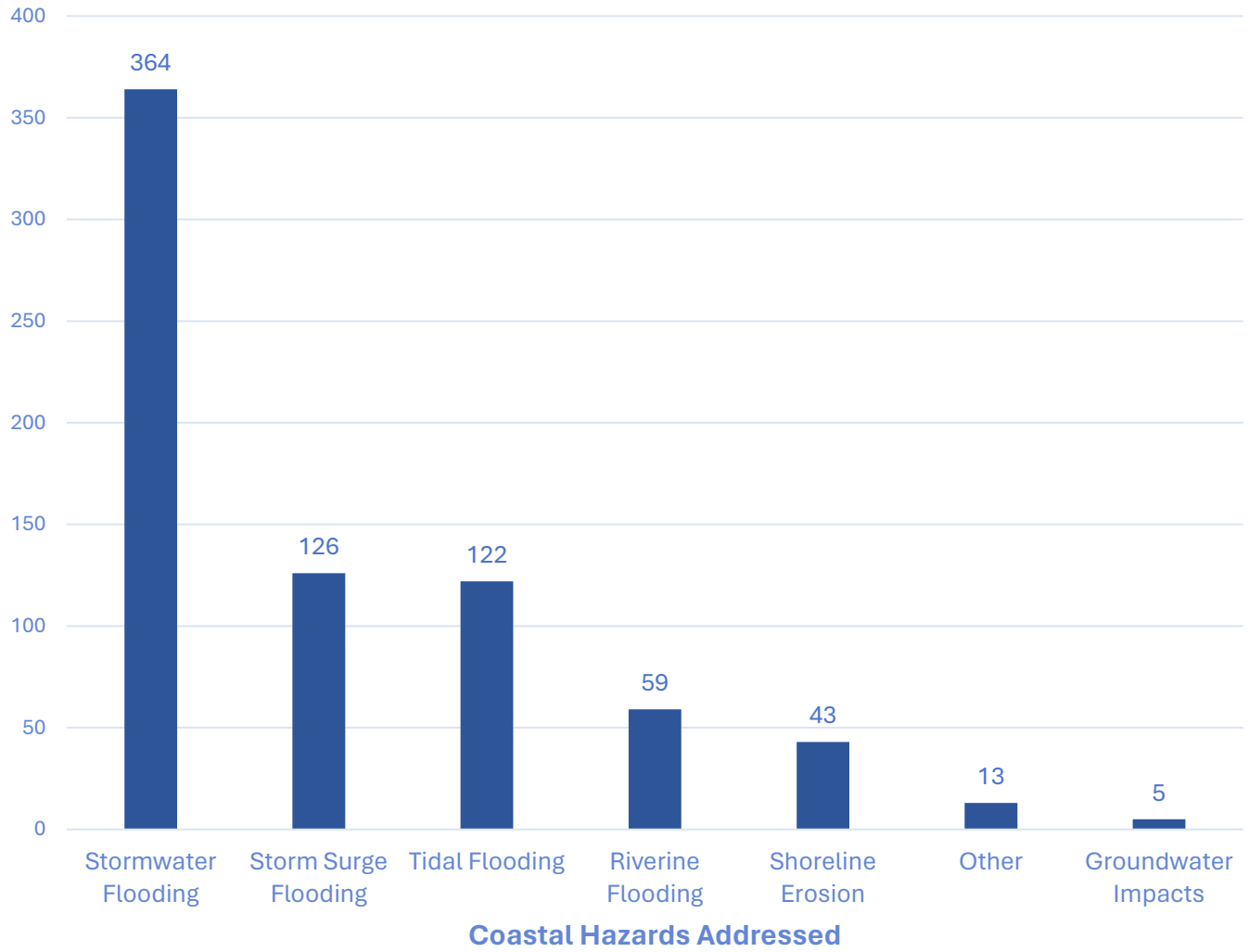


Subtype of Projects

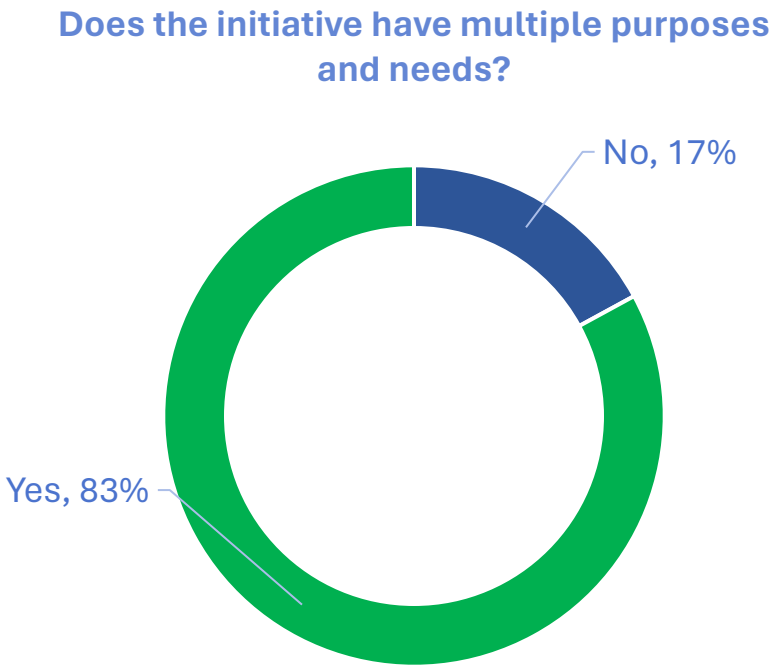


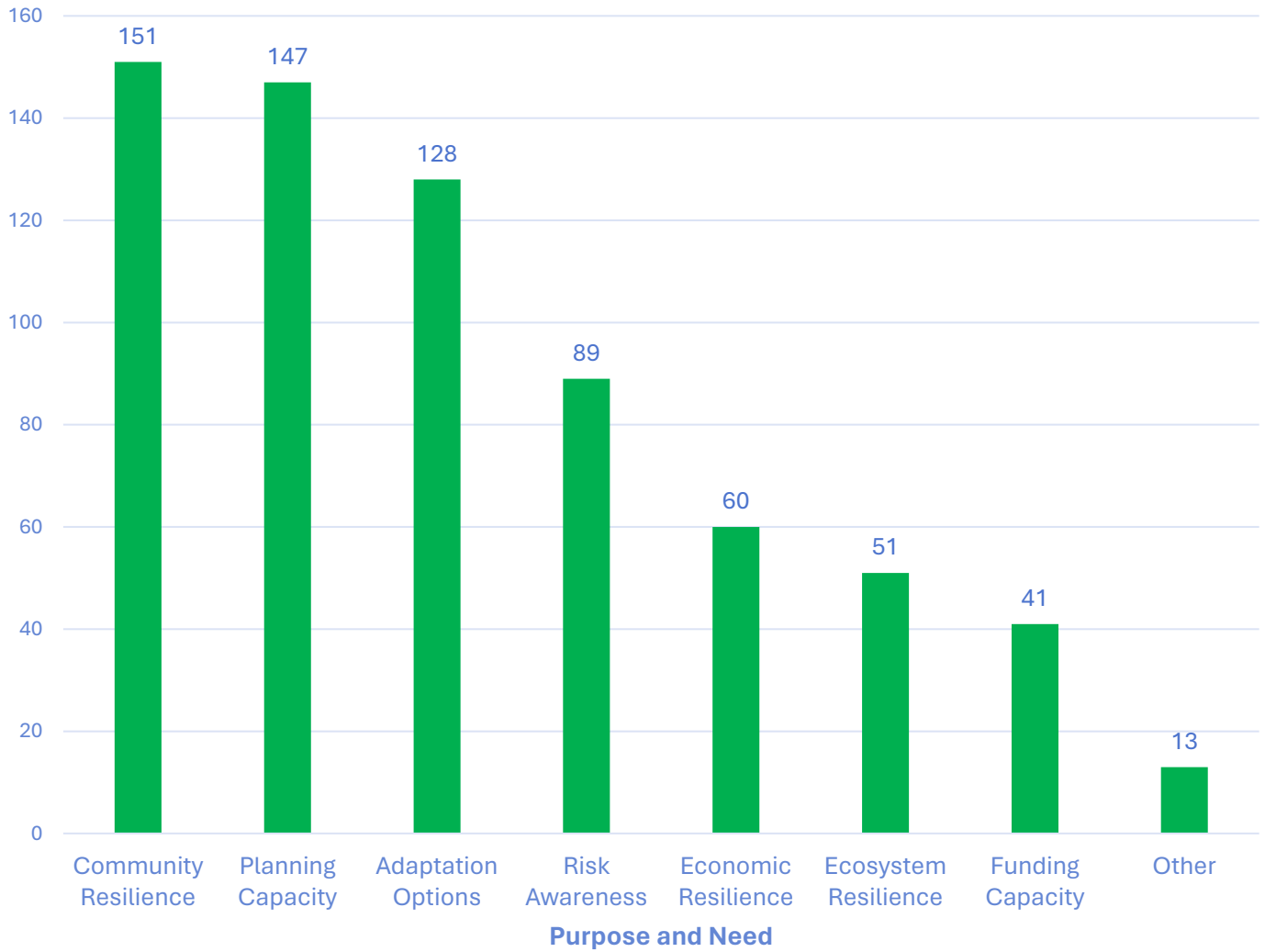
Coastal Hazards Addressed (Projects)



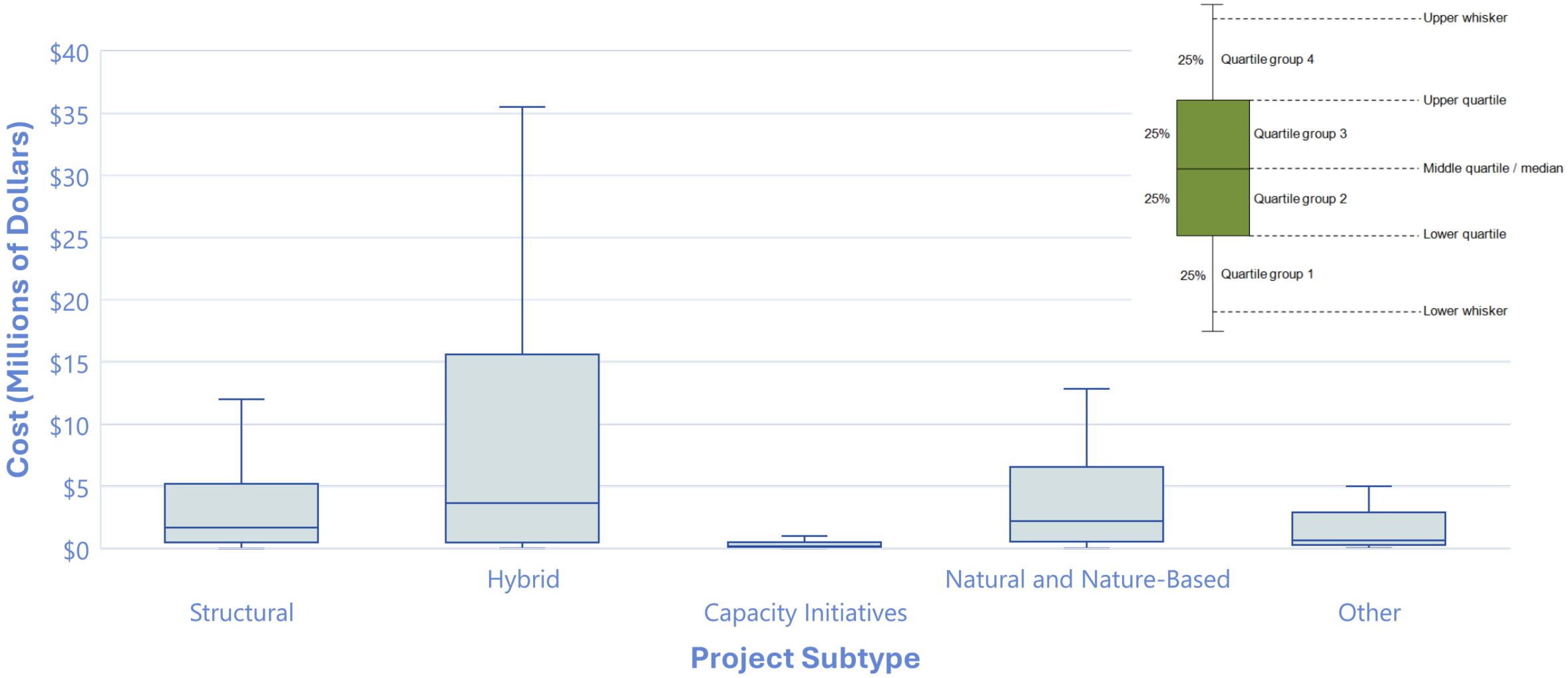


Purpose & Need (Initiatives)



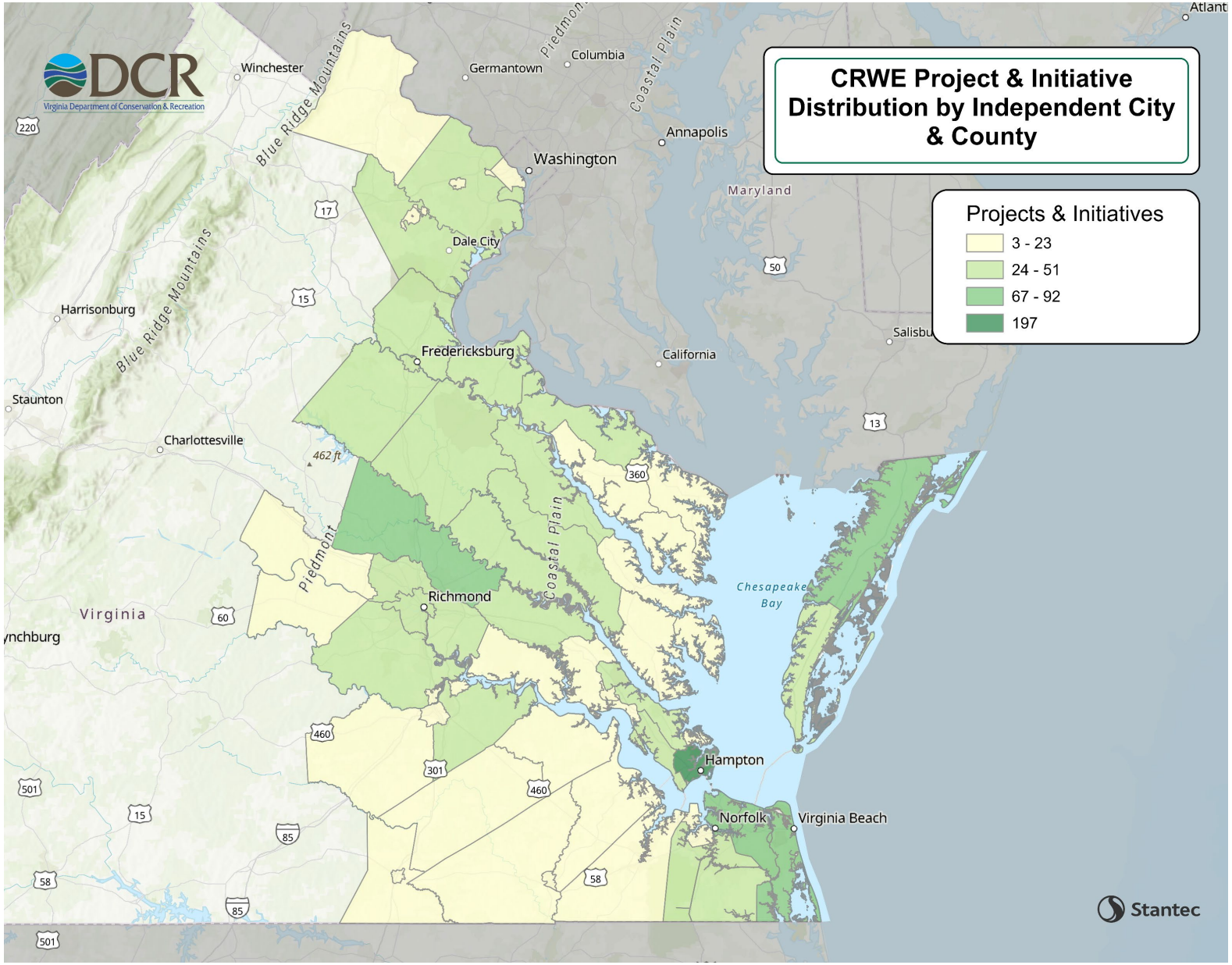


Costs By Project Subtype



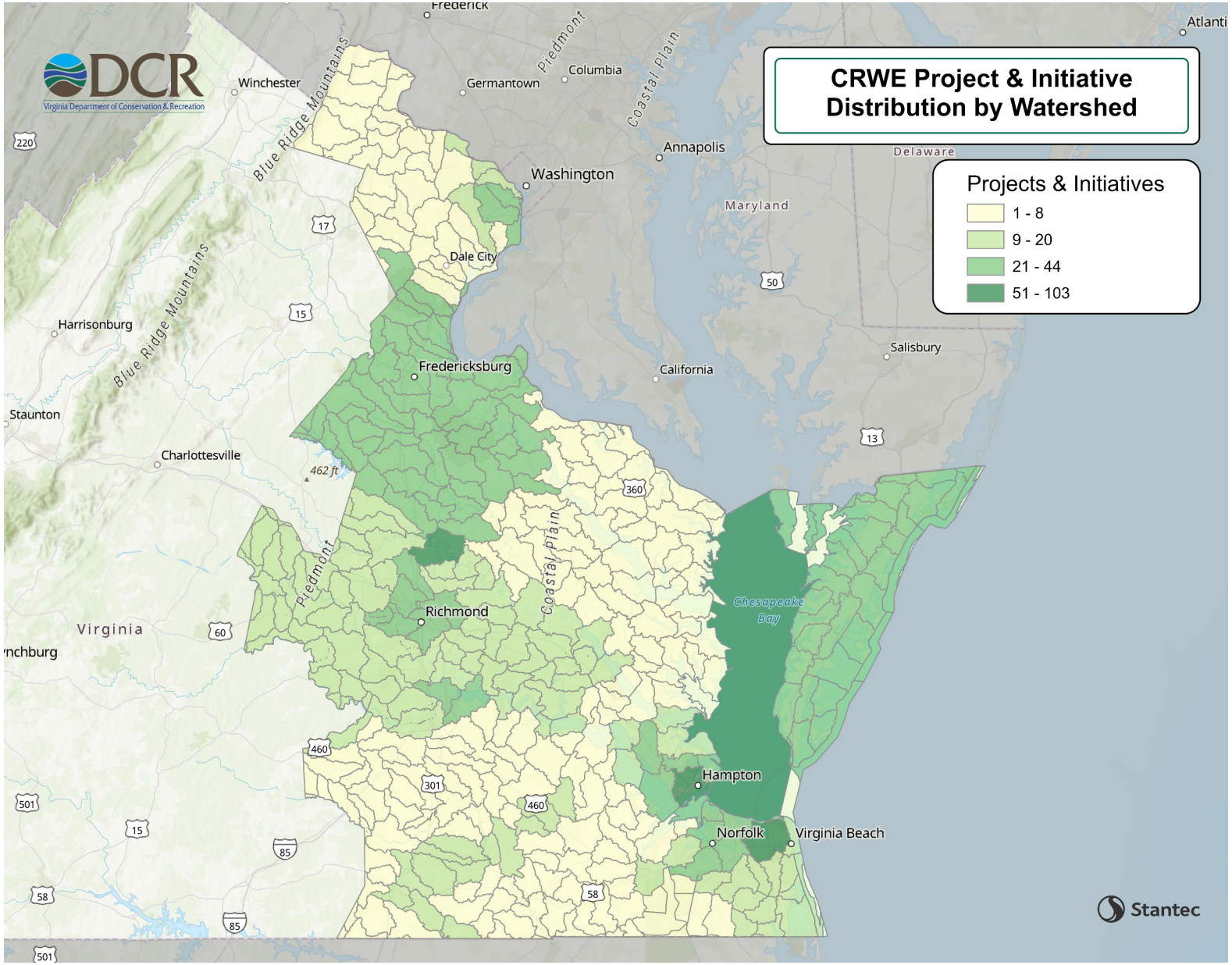
Project & Initiative Distribution by Locality

- High concentration in Hampton Roads/Eastern Shore area
- City of Hampton has the largest number of projects & initiatives with 197 total



Project & Initiative Distribution by Watershed

- Large concentration of projects & initiatives around the Chesapeake Bay and Eastern Shore area
- Low number of projects & initiatives between the Chesapeake Bay and Richmond area
- Distribution by watershed mirrors PDC boundaries in northwestern project area



High Risk Flood Areas with Low Project & Initiative Counts

- Projects & initiatives < 270,000 acres were compared to coastal flood data
- Considered high flood risk if in 2080 10% or greater annual exceedance
- Areas Identified:
  - High flood risk areas along rivers (James, York, Rappahannock, & Potomac River)
    - This may be a product of the Phase I plan focus on coastal hazards
  - Portsmouth has a low number of projects relative to neighboring Norfolk, despite having similar flood risks
  - Downtown West Point has no projects identified but has flood prone areas
  - Gloucester has no projects identified & Gloucester Point has 1 project identified but both have flood-prone areas
  - Poquoson has no projects identified but has flood-prone areas

Opportunities

Data Improvement

- Address missing cost data
  - Roughly 23% (25) of all owners have missing cost data
- Identify and remove duplicate projects
- Improve spatial data quality

Analysis

- Social vulnerability assessment
- Potential opportunities for project coordination
- Scale of Benefits assessment (e.g., begin with spot check for accuracy)

What's Next

- Address and incorporate DCR and TAC comments
- Finalize Data Quality Improvement Plan
- Conduct technical assistance and data improvement
  - Address requests for support
  - Leverage additional identified data sources
- Carry out additional analysis
- Produce summary report

Subcommittee Discussion

Planned Resilience Actions Analysis

VIRGINIA COASTAL RESILIENCE MASTER PLAN

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New Business

Recommendations Development

Subcommittee Recommendations

Purpose: Identify opportunities to improve mitigation of severe and repetitive flooding in the coastal region. This may include:

- Actions to implement prior to the next planning phase. (Next 1-4 years)
- Planning process improvements.

Audience: State government, PDCs, local governments, and others.

- Recommendations for implementation actions will identify the intended audience in general terms (ex., state agencies).

Aiming for 3-5 recommendations per subcommittee.

Presentation: A section of the final plan document, presented as recommendations of the public body.

Recommendations Development

- Collaborative process
  - Launch team will facilitate discussions.
- Informed by:
  - Prior TAC discussions
  - Phase I plan
  - Stakeholder engagement
  - TAC member surveys
- Final recommendations will be voted on by subcommittee members, followed by full TAC.
  - Subcommittees will report out status updates at Q2 and Q3 Full TAC meetings.

Background Materials and Information

- Phase I TAC Recommendations
- End-User Survey Results
- Subcommittee Objectives

Project Prioritization Subcommittee Recommendations

Draft Themes to inform Brainstorming

Driving toward Outcomes

- Developing a clear plan purpose, goals, implementation strategy, and measures of success

Supplying Actionable Impact Data

- Effectively assessing the potential impacts of flooding to support decision making

Identifying Flood Resilience Needs

- Establishing criteria to define where the greatest need for flood resilience actions exists.

Others?

Subcommittee Discussion

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Public Comment

If you seek to provide public comment, please sign up either in-person or virtually using the Chat window.

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Action Items, Scheduling

- Action Item Review
- Full TAC Meeting on June 18, 2024 (all virtual)
- Quarter 3 Subcommittee Meeting
  - Updates on Planned Resilience Actions Analysis and Impact Assessment
  - Recommendations for Future Planning

CONTRACT NO. E194-89627

VIRGINIA COASTAL RESILIENCE MASTER PLAN END USER SURVEY – RESULTS SUMMARY

Virginia Coastal Resilience Master Plan, Phase 2

JANUARY 22, 2024

Dewberry

SUBMITTED BY
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Document contains edits by DCR Office of Resilience Planning.

CONTENTS

Overview

This memorandum presents and interprets responses to the Virginia Coastal Resilience Master Plan (CRMP) End-User Survey that was conducted in December 2023 – January 2024. The purpose of the survey was to collect feedback from the plan's intended end users to inform development of the data and products created during the Phase II plan update, due December 2024. This memo presents a summary of survey respondents, responses and key findings disaggregated by organization type, and key takeaways for Phase II development.

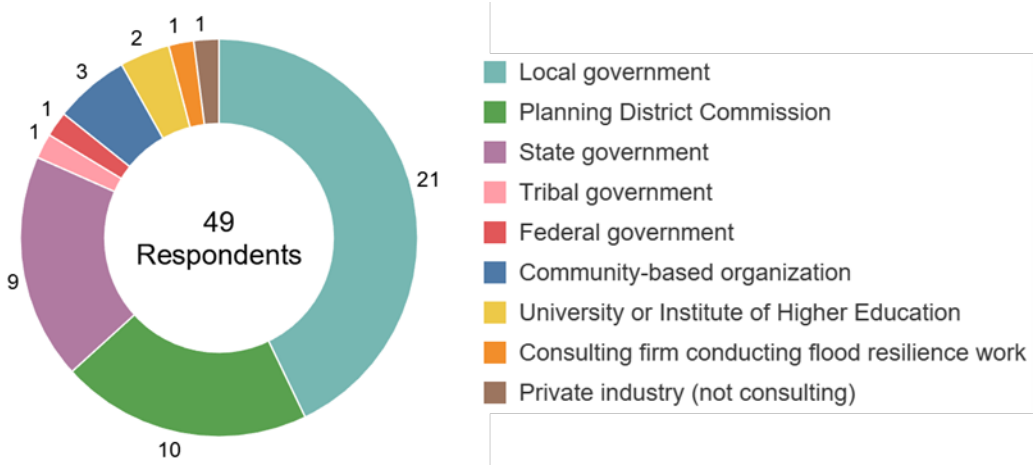
Survey Respondents

The survey had 49 total respondents, with the majority representing government agencies. Respondents represented:

- 18 Local governments
- 8 Planning District Commissions
- 8 State government agencies, departments, or divisions
- 9 other organizations, including tribal or federal governments, community-based organizations, universities, or private industry.

A summary of the respondents by organization type is provided below in Figure 1. A complete list of respondents by organization can be found at the end of this memorandum (Table 7, pages 18-19). Organization type is also used to classify responses to questions throughout the survey.

Figure 1. Count of survey respondents by employer type as indicated in the question "Please indicate which of the following best represents your employer's primary function."



Summary of Key Findings

Survey responses across all questions are consolidated into the below summary of key findings. This summary groups findings into feedback that is either: (1) relevant to the overall CRMP planning effort; (2) specific to the creation of the PDF document; (3) specific to the creation of the web-based services; or (4) funding-relevant findings relevant to work beyond the scope of the CRMP. Within each group, feedback is classified as either positive feedback, critique, or specific suggestion.

Overall Feedback

Of the 49 survey respondents, 40 (82%) reported actively using at least one of the CRMP products before filling out the survey.

Positive Feedback

- The CRMP products have previously been utilized for a wide variety of use cases, with the most popular being public education and awareness (11 responses), grant seeking (13), and plan development (12), and research (15).
- Products are helpful for providing an overview of resilience-related activities happening across the state, both top-down driven by the Commonwealth and bottom-up driven by communities.
- Products are useful for communicating to non-technical audiences, ranging from individual residents to elected officials.

Critiques

- The Phase I plan's focus on coastal flooding limits its applicability for communities that face significant interior flooding and leads to a potentially misleading narrative that more inland areas do not face flood risks.
- CRMP data products (including underlying sea-level rise scenarios and funding sources) can become outdated, and require regular update to ensure relevancy for use.
- Not all critical infrastructure (as identified by localities) and resilience-related projects are captured.

Specific Suggestions

- Incorporate revised sea level rise projections.
- Expand analysis and narrative to encompass other flooding types, including pluvial/rainfall-driven flooding, riverine flooding, and composite flood impacts.
- Conduct additional economic analysis to capture more impacts in terms of dollars. This will help communicate risks and importance of resilience investments to decision makers.
- Add contextual information about flood insurance coverage, and the insurance gap that needs to be addressed.
- Further integrate and align the plan with other state plans, including the HMP.
- Develop a scorecard and tracking on community outreach by localities and regions.
- Continue education and engagement efforts with localities to further resilience planning capacity.

Plan Document

32 survey respondents (65%) have used the PDF plan document.

Positive Feedback

- Clear communication and flow in the plan document, making it readable and easy to navigate.

Critiques

- Example projects are seemingly arbitrary and often do not address the most pressing regional resilience needs.
- Impacts are not framed in terms of economic losses, which would be more helpful for driving decisions.

Specific Suggestions

- Project sheets should be expanded and could be improved by including an icon to indicate project type and description or score to indicate population served.
- Include a narrative about coordination between state agencies and plans.
- Highlight case studies about how the plan and related products are being used.
- Expand content related to resilience-related economic development, job creation, and innovation.
- Place greater emphasis on natural infrastructure and incorporate biodiversity and ecological resilience.
- Include more specific actions to guide other state planning work.
- Improve tribal representation.

Web Explorer & Data Download

33 survey respondents (67%) have used the Web Explorer, while 16 (33%) have used the Portal Hub, and 4 (8%) have used the AWS data download options.

Positive Feedback

- Users found all elements of the web explorer useful, with the hazard information cited as being the most useful.

Critiques

- Web explorer can feel cluttered, hard to navigate, and overwhelming to users – there is almost too much information.
- Metadata and calculation methods are not clear in the web application, nor where to go to find that information.
- Not all data is available for download, and downloadable data can be hard to work with.

Specific Suggestions

- Include more context to explain the data, possibly through a pop-up function.
- Integrate more dynamic and user-friendly data download process, including:
  - Jurisdiction-specific impacts
  - Projects and initiatives
  - SLR models as a locally-storable raster rather than web service.
- Adding recommended citations in metadata would be helpful when referencing information in plans and grant applications.
- Improve and expand on the inventory of past, present, and future resilience work so that it is a more user-friendly and living database.

Funding & Financing

- Respondents have most experience seeking and winning federal and state grant funding sources.
- Barriers to engaging with funding include:
  - Lack of staff and staff capacity, both in terms of numbers and expertise.
  - Challenges related to funding caps and local match requirements.

- Competitive landscape and meeting requirements related to benefit-cost and environmental justice metrics.
- Gaps in data hindering project design and grant applications.
- Lack of awareness about relevant grant opportunities and timelines.
- Issues with slow administration and lack of coordination between state and localities/tribes.
- Limited political will and prioritization of resilience across competing interests.

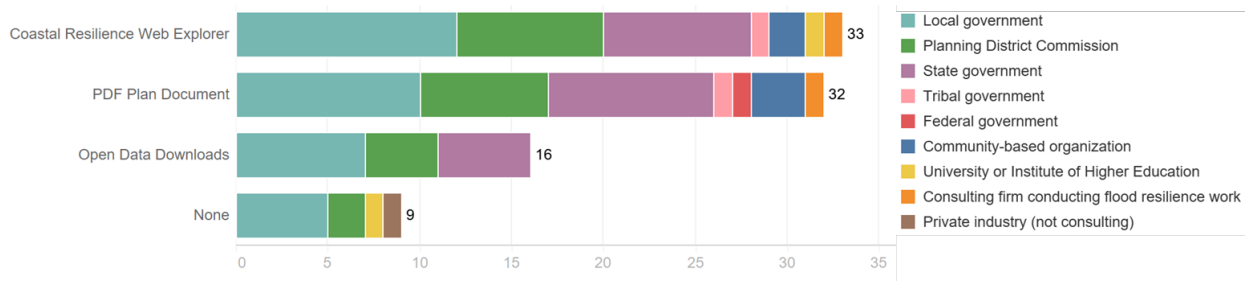
- There are many steps the Commonwealth can take to address these barriers. Most popular were offering training for local government staff, highlighting best practices and successful case studies, and offering resources for evaluating funding opportunities.

Detailed Survey Responses

Product Use

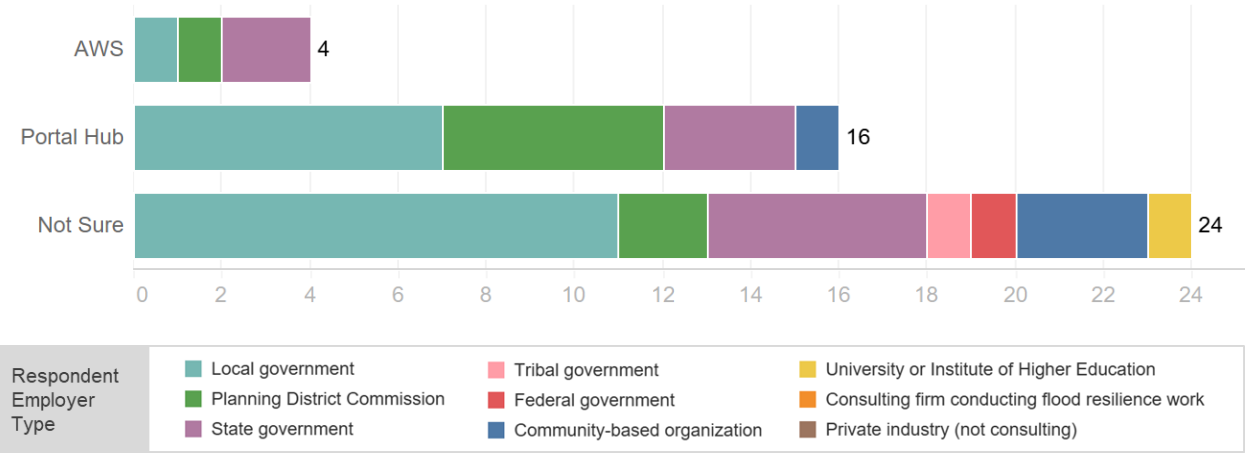
Respondents were asked which products they've used in their work, shown in Figure 2. 67% of respondents have used the Web Explorer while 65% of respondents have used the PDF Plan document. 18% of respondents had not yet used any of the Coastal Resilience Master Plan products in their work.

Figure 2. Responses to "Which of the Coastal Resilience Master Plan products have you used in your work?" broken down by organization type.



More specifically, respondents were asked if they had used the open data products through AWS or portal hub. Responses are shown in Figure 4.

Figure 3. Responses to "If you have downloaded open data, which of the two Coastal Resilience Open Data Portals have you used?" broken down by organization type.



Product Usefulness

When asked about the usefulness of each product, the majority of respondents said all three products were either somewhat or extremely useful, as shown in Figure 4. and Figure 5.

Figure 4. Responses to “Please rank the overall usefulness of the Coastal Resilience Master Plan products.”

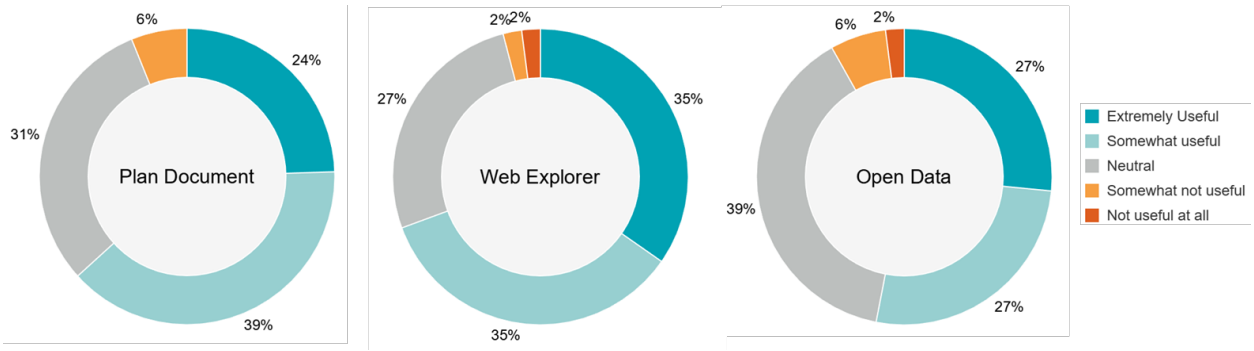
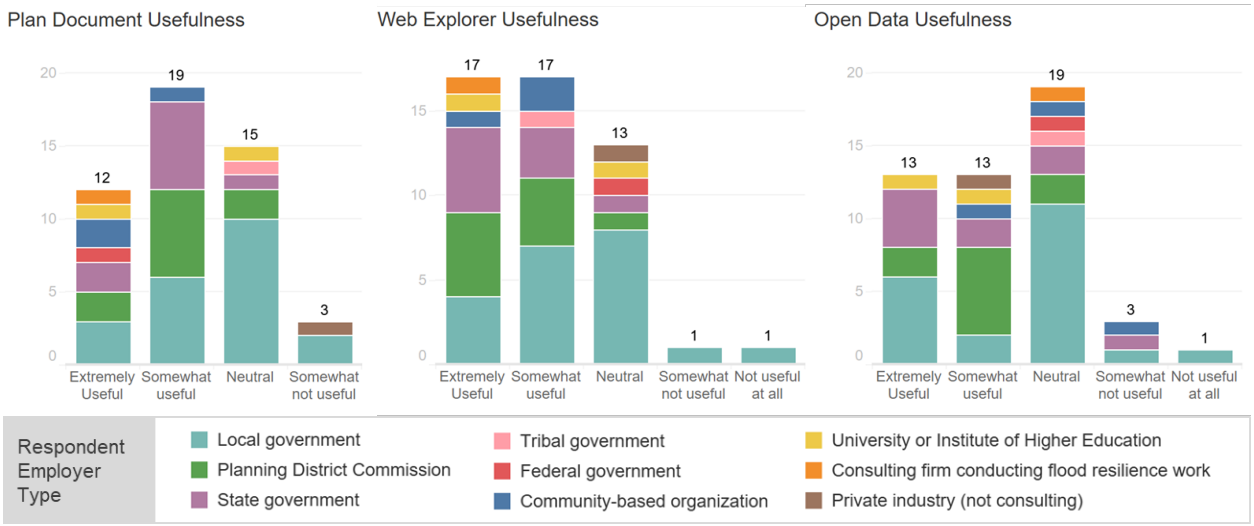


Figure 5. Responses to “Please rank the overall usefulness of the Coastal Resilience Master Plan products” broken down by organization type.



More specifically, respondents were asked to reflect on the usefulness of the Web Explorer tabs and responses are presented in Figure 6 and Figure 7.

Figure 6. Responses to "Please rank the usefulness of the Coastal Resilience Web Explorer tools."

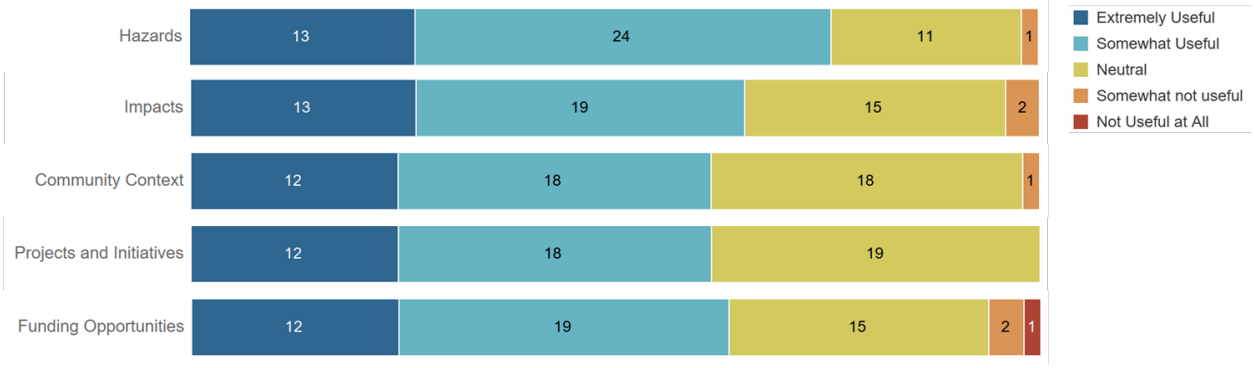
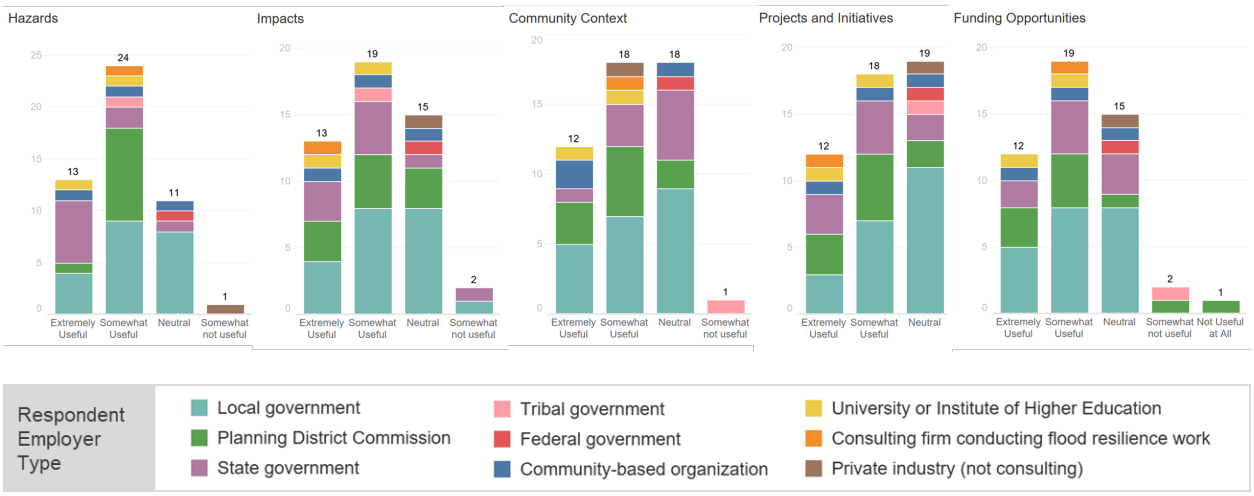


Figure 7. Responses to "Please rank the usefulness of the Coastal Resilience Web Explorer tools." broken down by organization type.



Respondents provided additional comments regarding product usefulness, described in Table 1.

Table 1. Responses to "Please provide any comments regarding the usefulness of the Coastal Resilience Master Plan products." Responses that were left blank or indicated a simple "no" or "not applicable" are excluded.

ORG TYPE	RESPONSE
Local government	The updated Energy and Climate Change Action Plan (May 2023) utilized the Coastal Resilience Master Plan: https://www.alexandriava.gov/energy/energy-and-climate-change-action-plan. The City plans to develop a Flood Resilience Plan in 2024 and will utilize all products as we discuss updates to policy and programs understanding what is happening across the state is incredibly valuable. I'm not sure how the products were or were not used for the City's Waterfront Mitigation Program.
	Current plan is too focused. As a coastal community we face many types of flooding.
	Articulated very clearly. Clear format and flow, very readable and easy to navigate to find everything I'm looking for.
	The social vulnerability index map has been useful when social vulnerability is a criteria for grants.

ORG TYPE	RESPONSE
	I am grateful for the staff that produced the Coastal Resilience Master Plan.
	These products should prove helpful
	Information from this plan will be utilized in PWC's upcoming development of a PWC Flood Resilience Plan.
	Southampton County is a considerable distance from the coast, so the usefulness of the Plan hasn't been determined.
	I really like the mapping products. As we implement our MS-4 program it will be good to know what areas of Spotsylvania are most at risk for climate impacts.
	I've used these products to discuss resilience resources and goals with elected officials.
	I don't know that I've had the need to use the coastal resilience master plan.
Planning District Commission	Coastal Resilience Web: Funding Opportunity update would be useful. Lack of downloadable Impact data. The data that is downloadable is difficult to parse and navigate. Most ESVA projects are initiated at the local town level - specific impacts on especially prone towns and jurisdictions would be useful. PDF Plan Document: Example projects are seemingly arbitrary and often do not address the most pressing regional resilience needs. Impacts on Community Resources, Critical Sectors, and Natural Infrastructure except Annual Structure Losses not put into dollar amounts - info that local stakeholders and decision-makers use to make determinations. Open Data Downloads: Dynamic Mapping would help with utilization.
	They are needed guidance in our own resilience planning.
	The primary benefit of the pdf is that it provides a solid overview of the context and history of the Commonwealth's planning efforts while also providing a narrative of what we are trying to accomplish. Static maps are nice and easy to read, but they can quickly become outdated. The web explorer is almost too much information. It's not clear how the "composite" impacts are calculated, and directing someone to the plan without a link is unhelpful. The project tab is very cluttered. The open data downloads are great to have, but the datasets themselves are not particularly useful.
	There are some nice graphics and statistics. But we don't come back to these products much.
	Its usefulness relates to either a public policy issue where we need context/data or if a grant funder requires certain data, maps, or narrative which the plan can assist with. We know the Master Plan is a good document, how we use it is driven by policy or $
	Since I am rather new to my position, I haven't had a lot of opportunities to utilize the CRMP products in any real-world scenarios. However, from what I have been able to see of the products, I can see how they would be of use in planning for resilience in our area. I think that it helps to see what areas are most at risk when planning ahead since it costs less to be proactive rather than reactive to potential risks.
	I found the print/PDF master plan product to be easily digestible. Having started my current position after the Master plan Phase I was completed, I thought it was really helpful to understand the foundations of resilience planning progress for the Commonwealth and to get a sense of the direction for future efforts.
State government	The future inundation products were very useful for assessing the resilience of natural heritage resources and protected lands in the coastal zone of Virginia.
	The products provide great historical data.
	The PDF was useful for someone who is new coming into this field. It gave a good lay of the landscape. The web explorer has been helpful for visualizing and exploring the data. Especially for someone new to all of

ORG TYPE	RESPONSE
	this. We've also used the map services in a mapping tool we've been using on the Eastern Shore to identify future impacted communities.
	In using the plan, data download, and tools for grant writing and other technical reporting, it would be great to have recommended citations for each. For example, DCR is using the 2080 SLR projections in our planning and related grant proposals. The data comes from NOAA, but it's housed in Open Data Downloads. Having a recommended citation in the metadata, or ArcGIS Online landing page, would alleviate some ambiguity, i.e., should NOAA be the citation for the SLR map service or is it DCR, another entity?
	PDF Plan Document lists TAC recommendations, needs for improvement, and other locality/regional information not provided elsewhere. CRWE provides tabular summary at the locality scale and very local mapping impacts
	At VDEM there is some commonalities in the FEMA required hazard mitigation plans (state and local). The PDF document provides the references - where we can incorporate those findings into future hazard identification and risk assessments. FEMA requires the best available data. The better integrated these planning processes, the more useful these products will be for grant making decisions at our agency. It is challenging to set funding priorities from two different planning efforts, so alignment is key. The Coastal Resilience Web Explorer is helpful to get a quick glance at flood hazards, and social vulnerabilities.
	Provides good insights to coastal flooding exposure of transportation infrastructure. Provides good information on planned transportation related resilience improvements.
	I have not used the web explorer hence the answer to #7. Most design effort at the port is handled by consulting services.
Tribal government	I know the document would be really useful and I have had a chance to read some of it, but because of limited capacity, I have not been able to dedicate time to reading the whole document, and so I have not been able to fully take advantage of all of the information it has to offer.
Other	Key core resource for developing crucial Coastal Community on-community Community Action Plans to implement and actualize positioning for funding opportunities that are direct Shoreline and unique Riverine based Communities.
	Used data tables from plan document to supplement sea level rise risk and vulnerability info in 2 regional hazard mitigation plans, as well as the State HMP.
	Data driven information useful for grant writing and assessment of integrated services to broker and deliver.

Use Cases

Respondents were asked how they have used or would apply the products to their work across nine potential use cases. Across all respondents, there was the greatest interest in using the products in the future for public education and awareness (31), grant seeking (26), and plan development (27). The top use cases for the products to date have been research (15), grant seeking (13), plan devleopment (12), and public education and awareness (11).

- **Localities and PDCs** are particularly interested in using for public education and awareness, plan development, and grant seeking.
- **State government respondents** were most interested in public education and awareness, program/operational decisions, and research.

A breakdown of responses is shown in Figure 8 and Figure 9.

Figure 8. Responses to “Consider the following potential use cases of the Coastal Resilience Master Plan products. Which of the following responses best reflect how you use the plan in your work?”

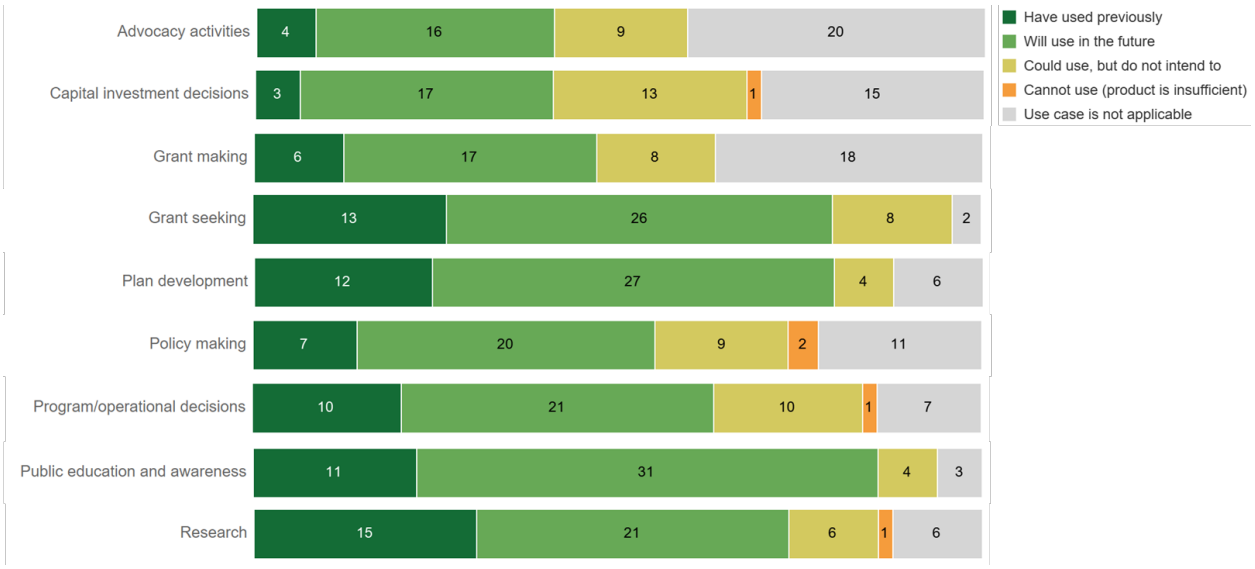
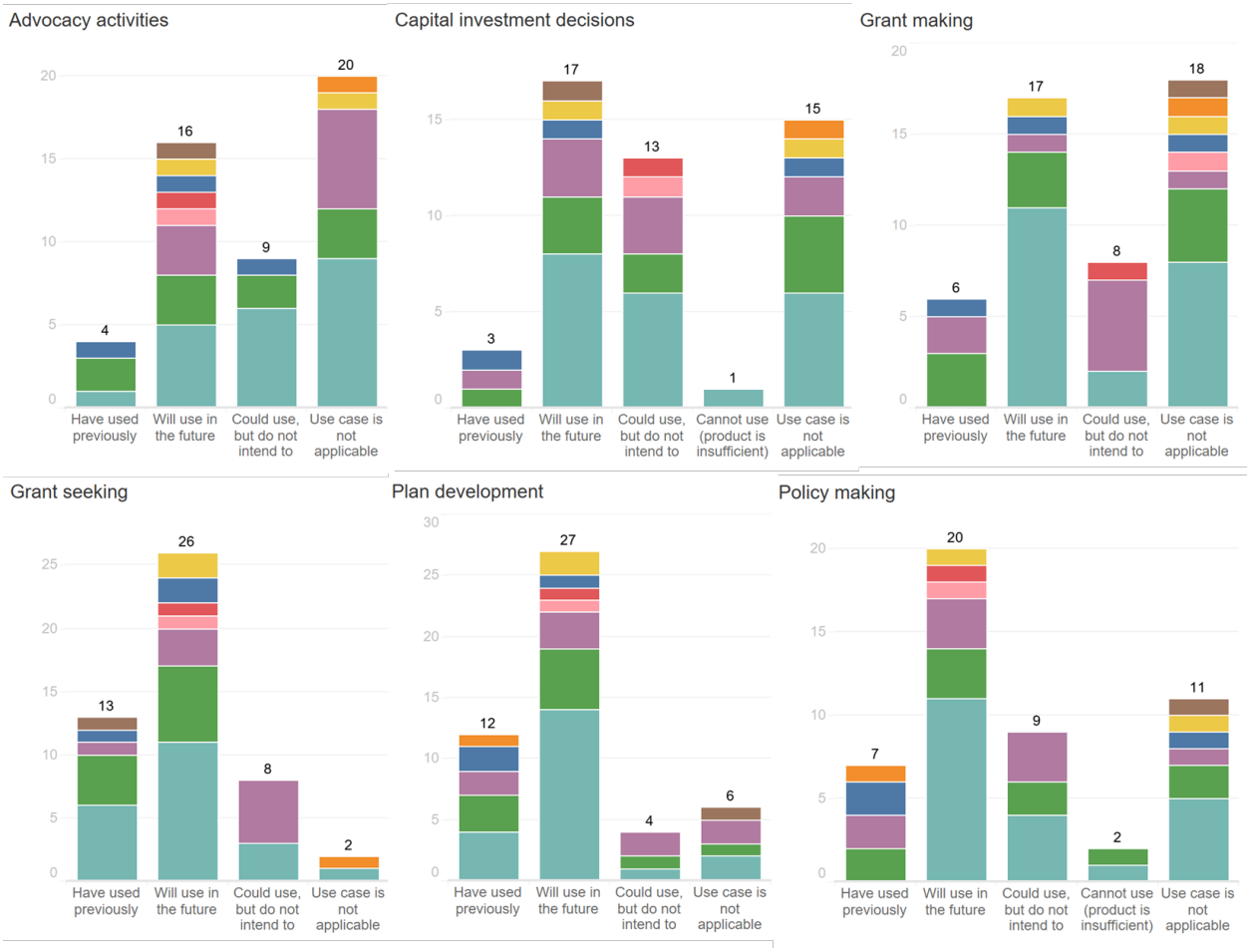
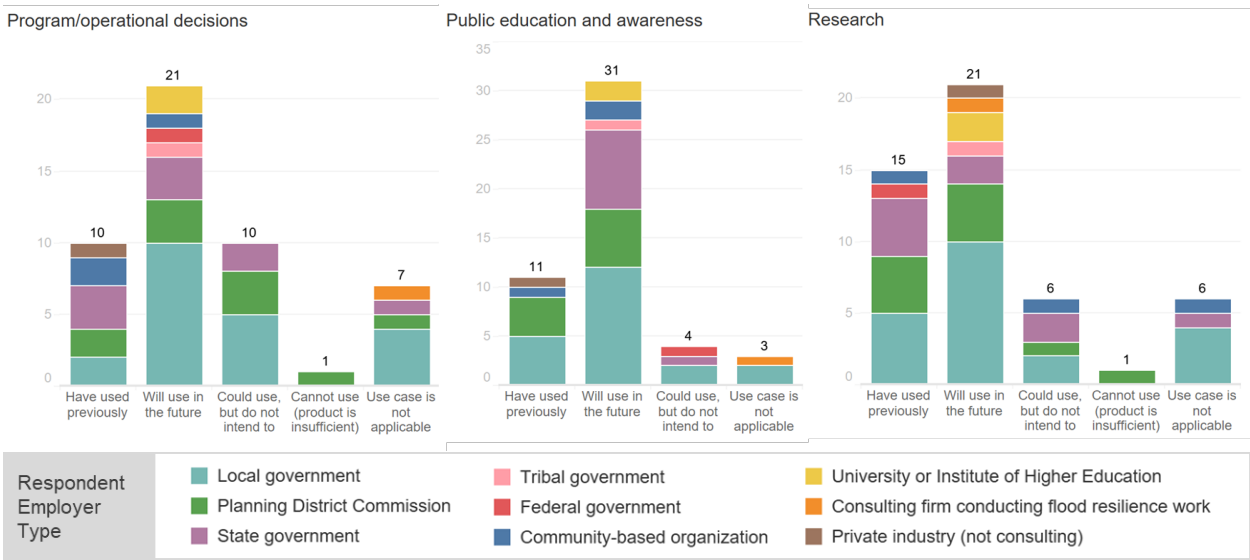


Figure 9. Responses to “Consider the following potential use cases of the Coastal Resilience Master Plan products. Which of the following responses best reflect how you use the plan in your work?” broken down by organization type.





To complement the nine use cases presented above, respondents were also asked if they had used the products in other ways. Through this open-ended question, respondents generally provided more detailed information on the ways they have used products for planning and grant application development.

Table 2. Responses to "Have you used the Coastal Resilience Master Plan products in other ways? If so, please describe the product and its applications." Responses that were left blank or indicated a simple "no" or "not applicable" are excluded.

ORG TYPE	RESPONSE
Local government	Our consultant has used the data for our own master planning effort.
	To build educational and outreach materials.
	We have used it to determine social vulnerability for grant applications.
	I have used it to inform property owners of potential for sea level rise at or near their property.
Planning District Commission	Used as a base or point of reference for other tools and products.
	I have embedded them in our website.
	We refer to the master plan when giving presentations or briefings, usually in the context of being consistent with our own regional policies.
	Its driven by the question and how best to answer such question either qualitative or quantitative
	I have used the CRMP products as a way to understand the region that I now work in and the potential risks that it faces. It has helped me to get a better idea of what issues I am working with and what areas may need the most focus for resilience projects.
State government	We used the future inundation products to assess the resilience of natural heritage resources and protected lands in the coastal zone of Virginia.
	Mentioned above, we used the map service from the data portal to identify future impacted communities. We are using that information to design a community project on the Eastern Shore around flooding impacts.
	None other than already mentioned, we look at grant projects that are funded by FEMA that were identified in the plan.
Other	Community Action Plan partnership

Limitations

Respondents were asked about the limitations they have encountered when using the CRMP materials and responses are presented in Table 3.

Table 1. Responses to “Have you encountered any limitations in the plan's products that have prevented you from using them how you would like? If so, please describe the product and its limitations” broken down by organization type. Responses that were left blank or indicated a simple “no” or “not applicable” are excluded.

ORG TYPE	RESPONSE
Local government	Focus is too limited for all the climate change/flooding issues localities face. In addition, we have developed our own City-specific and more focused materials and evaluations.
	The example project sheets need an icon or indicator for the project type (ex. for structural projects, is the example a flood risk reduction measure, a structural shoreline stabilization, or community infrastructure). See pg. 180-181.
	I have used them despite limitations and just have caveats added to my product.
	We have a small town, but we have critical infrastructure that will be inundated during a 100-yr flood event. Don't see this info on the map.
	Already answered that I have not used the products.
Planning District Commission	Coastal Resilience Web: Funding Opportunity update would be useful. Lack of downloadable Impact data. The data that is downloadable is difficult to parse and navigate. Most ESVA projects are initiated at the local town level - specific impacts on especially prone towns and jurisdictions would be useful. PDF Plan Document: Example projects are seemingly arbitrary and often do not address the most pressing regional resilience needs. Impacts on Community Resources, Critical Sectors, and Natural Infrastructure except Annual Structure Losses not put into dollar amounts - info that local stakeholders and decision-makers use to make determinations. Open Data Downloads: Dynamic Mapping would help with utilization.
	The Resilience Web Explorer is not linked everywhere it should be across State Agencies and so it can be difficult to find.
	It doesn't consider rain driven flooding and the associated stormwater projects. It doesn't layout enough implementation strategies to drive state budget discussions and priorities (compared to state programs other than resiliency).
	The scenarios for hazards do not really correspond to local or regional planning scenarios or timelines. (e.g. 2020/2040/etc. vs twenty-five years, thirty years).
	I have not encountered limitations in its use. However, as part of the project prioritization committee for phase II, we have discussed how more information/data could be useful.
	Any limitations are being addressed through phase 2, i.e. precipitation impacts as a key component to coastal resilience in the region.
	On the web explorer, I really want to click on map shading to see a popup that explains the underlying data. Also, the data available for the Projects and Initiatives is almost non-existent, making that page not so useful.
State government	Not really, but I/we've used them at a very high level.
	Much of my work with the plan and related data includes GIS analysis. The current format of the SLR models (web map service) limits our ability to analyze the spatial data. Having these data available as rasters that can be locally stored and analyzed with typical GIS processing abilities would improve efficiency and produce better results.

ORG TYPE	RESPONSE
	Limited to coastal flooding. We are looking at statewide flooding.
Other	Access/Awareness/Communication/Inclusion

Desired Plan Content

Respondents were asked to reflect more specifically on the PDF plan document and what content they would like to see in a future revision. Responses are presented in Table 4.

Table 2. Responses to "What content would you most like to see included in future PDF plan documents?" broken down by organization type. Responses that were left blank or indicated a simple "no" or "not applicable" are excluded.

ORG TYPE	RESPONSE
Local government	We would benefit by more in depth info on pluvial flooding in coastal zones. It sounds like this will be explored more in future versions.
	rainfall data, urban flooding issues
	More project sheets, with a EJ lens/score on sheet, plus population served/protected.
	I'm new here, so I really don't feel qualified to make a recommendation.
	I would like to see information about storm surge flooding
Planning District Commission	Specific impacts on especially prone towns and jurisdictions. Dollar amounts on flooding impacts.
	Drainage issues
	Revised sea level rise projections. Narrative about coordination between state agencies and plans. Case studies of how the plan is being used.
	Expand sections on water management economic development, job creation, innovation being developed in Virginia
	It may be helpful to know what percentage of homes and businesses have flood insurance within each area identified for coastal flood exposure. There are Land Acres Exposed and Buildings Exposed with High Tide and Extreme Flood for both 2020 and 2080 with the percent change, but knowing the extent of insurance and how many will need it would be nice.
State government	Greater emphasis on natural infrastructure.
	Data currency
	An inventory of past, present, and future resilience work in the Coastal Zone. It's too easy to reinvent the wheel and documenting this work somewhere that is searchable and living would be a huge value add.
	recommended citation and more specific actions for land conservation and conservation planning. Incorporation of biodiversity priorities and ecological resilience
	No recommendations, however I would like to request an overview of the plan and web based products to our agency. We have a wide range of divisions and programs that may find these products useful.
	Pluvial and fluvial impacts. Composite flooding impacts.
Tribal government	I would really like to see something mentioned about the Tribes in Virginia. I think it is important that a state-wide planning document have at least some reference to how Tribes experience coastal resilience issues in the larger context of the surrounding community, and the state in general.
Other	Scorecard on Community Outreach by Local and Regional levels

Funding & Financing Experience

Separate from the CRMP materials, respondents were also asked about their experience seeking and using funding and financing mechanisms to implement resilience activities. Responses are presented in Figure 10 and Figure 11.

Figure 10. Responses to "What types of financing have you *successfully used* to fund your flood resilience activities (projects, staffing, initiatives, planning, etc.)?" broken down by organization type.

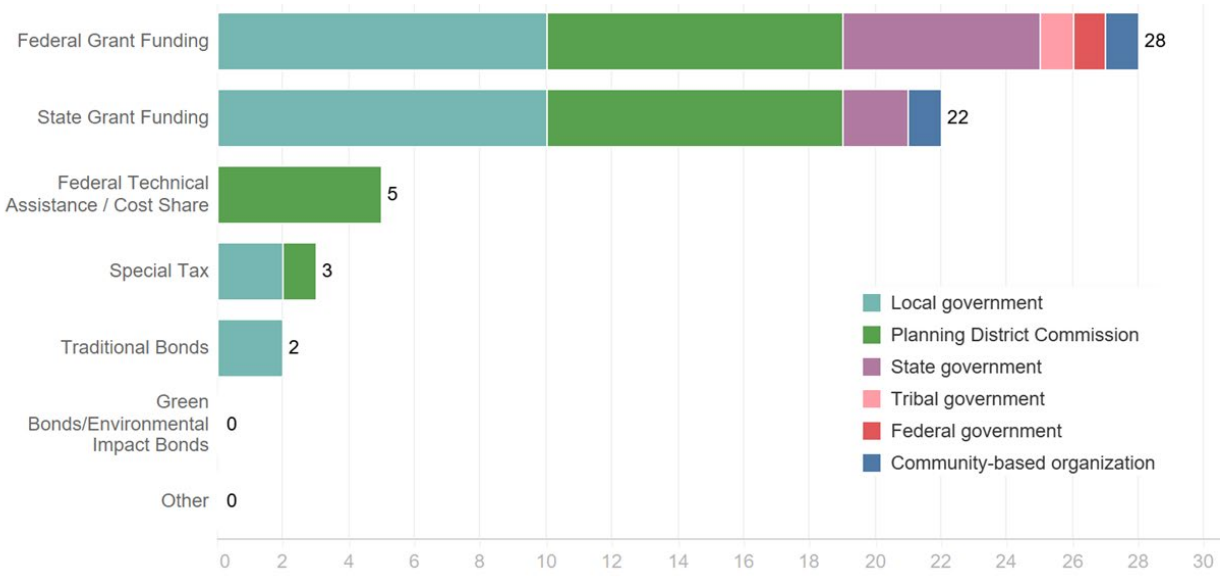
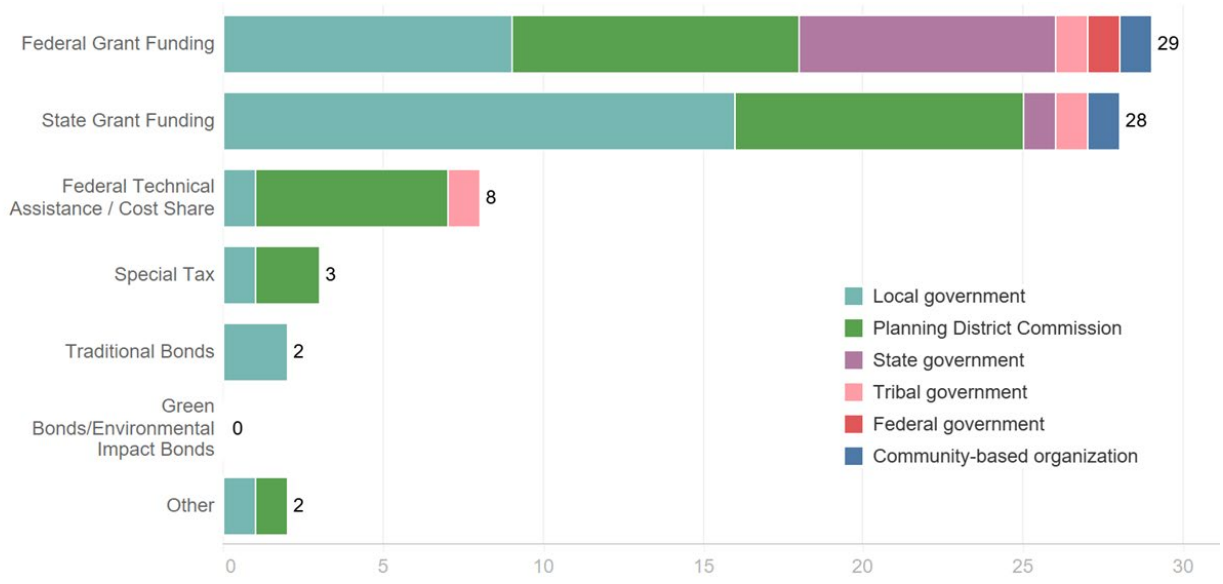


Figure 11. Responses to "What types of financing have you *sought* to fund your flood resilience activities (projects, staffing, initiatives, planning, etc.)?" broken down by organization type.



Funding Barriers

Additionally, respondents were asked about the barriers they face when seeking or accessing funding for resilience activities and responses to that are presented in Table 5.

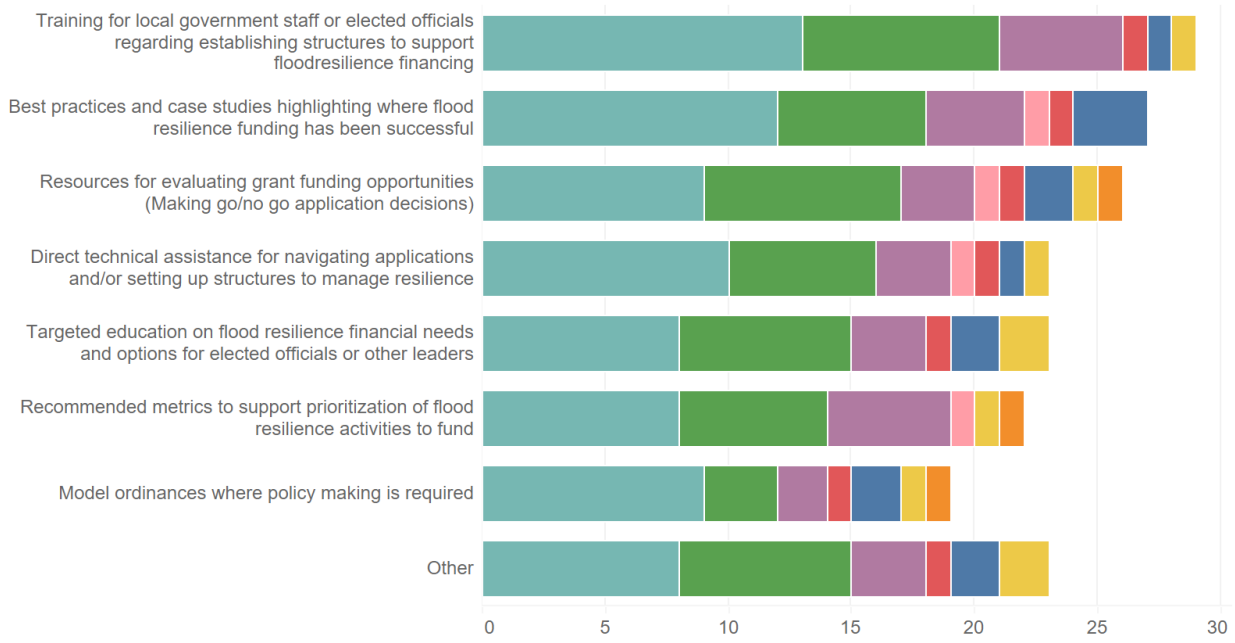
Table 3. Responses to “Are there any specific barriers that have prevented you from seeking or accessing funding for flood resilience activities?” broken down by organization type. Responses that were left blank or indicated a simple “no” or “not applicable” are excluded.

ORG TYPE	RESPONSE
Local government	Many funding sources require the project to be identified in a 'plan' so having all of our projects in this plan is expected to be beneficial as we look for future funding.
	The Grant application process has become extremely cumbersome and time consuming. We weigh the amount against how much we will need to spend just to put an application together which is getting ridiculous. Also many state grants are becoming difficult to get funds back in a timely manner, which means we are fronting the money for months or a year.
	CFPF maximum grant cap, state revolving loan max. cap, limited time between NOFO and grant deadline (need time for City Manager signature).
	Lack of staff to apply for grants is the biggest challenge for us. Also, better communication of grants that are available.
	I think our limited population size might have prevented us from obtaining BRIC funding. Not sure about that.
	insufficient staff
	lack of staff - Because the VA grants only cover the cost of hiring new employees and do not cover salaries of existing employees, we do not have the staff to execute any grants. In small areas like Northampton County, the cost of a CFM has historically been too much. Until the Phase one of the CFPF grant we did not have a CFM. Now the county is deciding whether or not they will continue to have a CFM because the funding for that position is gone.
	Local match required by state and federal grants.
	Just that I haven't decided yet how to approach grant application for project related to LiDAR or aerial drone imagery
	County Admin does not want to do anything that curbs the development community.
	Capacity
	General capacity to write the grants and apply for them.
	Staff time
	staffing/matching funding
	H & H analysis before addressing flooding issues, but no funds for the analysis
Planning District Commission	Agency and government capacity. Willingness of local decision-makers.
	Because flood resilience doesn't include more ancillary impacts (such as rates of septic failure and soil mapping), our region appears to not be impacted which can dissuade elected officials from acting and hurt our grant funding chances. There are also just more opportunities out there than we can possibly keep up with and we rarely have extra capacity to keep making "shovel ready" projects.
	Local contributions
	Limitations on how often one can apply (DSFPP five-year gap). Inability to use CFPF funds for existing staff or to include indirect costs. Staff capacity for developing proposals.

ORG TYPE	RESPONSE
	staff to manage new initiatives.
	Limitations are related to grant funder priorities.
	I'm honestly unsure since I haven't done anything with funding so far.
	Northern Virginia is often limited by environmental justice and/or marginalized community requirements within grant programming, especially in recent BIL/IRA programs. While this is important to ensure that marginalized communities have equitable access to funding, the screening tools can be limiting for communities in the region that are marginalized, but do not fit into the screening tools' programming.
	we need more data on Pluvial flooding before we can design resilience projects and apply for funding.
State government	Challenged to find grants that apply to specific needs
	Not sure/NA - Our program (CZM) is a pass through organization, so we're driven by the needs of our network.
	VDEM traditionally seeks funding on behalf of localities that are interested in applying. Barriers we have seen at the local level are cost share, and staffing.
	Seeking funding grants for resilience requires quite a bit of work. There is a limitation on staffing resources.
Tribal government	Limited staff capacity in terms of numbers and subject-matter expertise hinder out ability to apply for funding for a multitude of reasons, some of which amount to simply not having enough time to read a NOFO. At the state-level, some funding opportunities are not available to Tribes, and for those that are, the competition is so strong that it often is not worth the time and resources to apply for a grant that likely will not be awarded anyway. In general, I think Tribe-to-state funding and coordination processes are still very new, especially for the Federally recognized Tribes, so it's just uncharted territory for both sides.
Other	A lack of grant writing personnel
	Local match requirements
	NOAA/EPA Smart Growth for Coastal and Waterfront Communities (2009) not adopted locally by Locality, initially, no locality Certified Floodplain Manager, and deficient implementation of Planning for any but headwater area the Locality. Without administrative Implementation, Planning and incorporated language in State Statute required local "Plans" i.e. Official Map (Zoning) and Comprehensive Plan, the Administrative representation of Hazards is poor and poorly positions Community Action Plans in the most at risk communities. I
	Petersburg City Council
	We do not specifically engage in flood resilience advocacy, education or other activities. However, we are working with RAFT to see how we can empower business owners who seek to facilitate flood resilience for area residents.

When presented with a multiple-choice question about actions the Commonwealth could take to address funding barriers, the majority of respondents said that training for local staff, best practices and case studies, and resources for evaluating grant opportunities would be helpful. The distribution of responses are show in Figure 12.

Figure 12. Responses to “What could the Commonwealth do to help address barriers that prevent you from seeking or accessing funding for flood resilience activities?” broken down by organization type.



General Support Needs

Finally, respondents were asked for additional input on ways the Commonwealth could support their flood resilience needs. Responses are presented in Table 6.

Table 4. Responses to “Are there any other ways in which the Commonwealth could support your organization's flood resilience needs?” broken down by organization type. Responses that were left blank or indicated a simple “no” or “not applicable” are excluded.

ORG TYPE	RESPONSE
Local government	It is very valuable to understand what is happening across the state, especially in communities like ours - small and highly urban with older infrastructure being decimated with these very severe storm events that don't trigger a declaration of a NR disaster but they really negatively impact our community (cars are totaled, basements and first floors under water, driving is unsafe, pets get swept away, people are displaced, etc.). While we understand what is happening here in NoVA through those relationships and through our PDC, it would be great to learn from other cities facing these challenges! We are looking to learn as much as we can from our partners across the state so helping to facilitate that would be very valuable! Thank you!
	Climate Change issues are more than just sea level rise. Extreme rainfall and urban flooding in old drainage systems is a major issue. Unfortunately, in an effort to provide funding to coastal issues, other issues now have less priority.
	Create a model pathway for communities to obtain a state-match on large federal Coastal Storm Risk Management projects. Similar to NY/NYC.
	This falls into another Departments purview.
	Education classes and updates telling local government how to be involved.

ORG TYPE	RESPONSE
	You all are doing a wonderful job and I am grateful for your support thus far.
	Yes. Our county does not have the funds to hire a full time grant expert. At this time the CFM is also the grant writer. This person is not experienced in writing grants. The county would benefit from funding staff so that the employee can get acquainted with the job and the funding available.
	Continue to fund traditional grey infrastructure flood resilience projects (flood walls, elevation projects, etc.) and Dam Safety improvements/upgrades. While green infrastructure is important, it is not always feasible and limited in certain major flooding applications.
Planning District Commission	More capacity-building initiatives and opportunities. Supporting and scaling proven efforts, skill sharing. Developing and supporting more regional-wide approaches. Reaching out to local decision-makers and non-traditional partners. Monetizing future flood impacts.
	To be determined
	change the stormwater regulations to reflect projected rainfall, provide more grants even to low scoring CFPF applications, setup policy that guarantees state share of non-federal match for large construction projects, invest more state funding to address roadway flooding
	The waterfront along the Chesapeake Bay and tributaries are ~98% privately owned. Clearly declare that funding flooding problems on private property with public resources helps to protect the tax base of rural localities. There is a public nexus between spending public dollars on private property and protection of public health, safety, and welfare. If flooding decreases real-estate values, local govt can't fund essential services. If they raise taxes to cover the lost revenue, flooding becomes a regressive tax on the poor who don't live on the waterfront.
	Training on grant writing itself would be really helpful for myself. Also, more information on where to start for dam assessments either locally or on a regional scale. We have many that are not assessed and we know that there is funding. I'm just not sure where/who to start with.
	Continued communication and education opportunities with the PDCs to pass information on to the localities. At least in Northern Virginia, this has worked well through our workgroups and engagement with localities, but additional engagement opportunities for localities to participate and understand how they can utilize the plan and its tools would also be helpful. An example would be through the precipitation data/analyses through Phase II - having a workshop or training event for interested localities to understand how they could utilize/apply the data to their own planning and projects.
	Capacity is a major issue. Every community has flood resilience projects they want to see implemented, but who is going to design it, plan it, seek funding for it, manage the grant, and execute the project? Staff and nonprofits are mostly at capacity. Can the Commonwealth do anything to make flood resilience projects more accessible to neighborhoods?
State government	More certainties around how state funds will be tied to planning efforts. This may just take time to get to, but it's definitely an issue we hear about in our network a lot.
	Could DCR provide a presentation to VDEM staff on the CRMP products?
Tribal government	I really think more meaningful engagement and more frequent dialogue needs to happen between the state government and Tribal governments. I believe the state is making great strides to that end, but there is a lot of work left to do. For example, this survey did not have an option at the beginning for Tribal entity. It is vital to Tribal communities that they be actively consulted and that the results of those conversations are shown in spaces like this where DCR is seeking feedback from the different groups affected by sea-level rise and other coastal resilience issues. I do believe as conversations progress that incorporation of the Tribes will be easier and more evident so long as the conversation is continuous.
Other	Provide examples of completed projects with the details of the project. Include lessons learned and pitfalls encountered, if any.
	Public Outreach in mobilized communities. "See one do one" approach. Communication and technical guidance for positioning where Communities have provided feedback and engagement to DCR is key.

ORG TYPE	RESPONSE
	Hire someone who knows about these things to work for the city of Petersburg. We simply need more people in order to do the job.

Survey Respondents by Organization

Table 7. Number of survey respondents from each organization, classified by organization type.

ORG TYPE	ORGANIZATION	NUMBER OF RESPONDENTS
Local government	City of Alexandria	1
	City of Newport News	1
	City of Norfolk	1
	City of Portsmouth	1
	City of Richmond	1
	City of Suffolk	1
	King George County	1
	King William County	1
	Lancaster County	1
	Middlesex Department of Social Services	1
	Northampton County	2
	Prince William County	2
	Southampton County	1
	Spotsylvania County	1
	Stafford County	2
	Town of Ashland	1
	Town of Dumfries	1
	Town of West Point	1
Planning District Commission	Accomack-Northampton PDC	1
	Crater PDC	1
	George Washington RC	2
	Hampton Roads PDC	2
	MPPDC	1
	Northern Neck PDC	1
	Northern Virginia RC	1
	PlanRVA	1
State government	Department of Environmental Quality	1
	Department of Housing and Community Development	1

ORG TYPE	ORGANIZATION	NUMBER OF RESPONDENTS
	Virginia Coastal Zone Management Program; DEQ	1
	Virginia Department of Conservation & Recreation - Division of Natural Heritage	2
	Virginia Department of Conservation and Recreation	1
	Virginia Department of Emergency Management	1
	Virginia Department of Transportation	1
	Virginia Port Authority	1
Tribal government	Nansemond Indian Nation	1
Federal government	Marine Corps Base Quantico	1
Community-based organization	Bay Aging	1
	Crittenden, Eclipse and Hobson (CE&H) Heritage Civic League	1
	Northumberland Public Library	1
University or Institute of Higher Education	Virginia State University	2
Consulting firm conducting flood resilience work	Salter's Creek Consulting	1
Private industry (not consulting)	Communities In Schools of Petersburg, Inc.	1

Project Identification

The types of projects coming in should be reflective of the needs of the whole Commonwealth.

- 95% of waterfront property in the rural localities is privately owned, so publicly-owned projects cannot be the only ones included in the Master Plan.

Develop ways to encourage local governments to care about flood mitigation and tax base protection.

- Rural jurisdictions are lagging behind urban jurisdictions in this effort, largely due to issues of staff capacity.

Project Evaluation

- Project scoring is largely dependent on applicant characterizations of project type, extent, and benefits. Without objective and critical evaluation this can lead to significant over-valuation of projects.

- The scoring of projects tends to place a premium on those that address current flooding issues. This is not necessarily a strategic use of funds in building long-term resilience.

- There is no basis for evaluating project benefits for precipitation driven flooding in the absence of spatially explicit risk exposure information.

Natural and nature-based features should be considered critical infrastructure and projects that preserve ecosystem service capacity through coming decades should be ranked highly, regardless of proximity to developed landscapes.

As currently implemented, the project evaluation protocol is incapable of leading to a strategic increase in coastal flood resilience that reflects the CRMP guiding principles. The population of projects under evaluation is not the product of a comprehensive needs assessment but rather a compilation of independently identified local interests.

Even if the protocol was capable of reliable identification of the most impactful proposed projects, it cannot ensure critical needs across the entire coastal zone will be addressed. Absent some well-considered guidance regarding the type and location of projects which will advance the CRMP goals, current evaluation practices will simply result in creative project characterizations to gain funding for a hodgepodge of public works projects.

Federal Installation Partnerships

Following study of relationships, resources, and coastal resilience challenges in the shared locality, state, and federal Installation space, the Subcommittee identified the following:

1. Mutual benefit exists for localities and federal installations when they combine efforts for resilience solutions.

2. The best solutions will be locally driven, state supported, and federally shared. In this context, federal installations are regarded as local partners.

3. Wide awareness and relationship gaps exist between localities, state, and federal entities.

4. The state's primary CRMP value proposition is Locality support through information sharing, technical assistance, federal advocacy, and funding.

5. Tools and resources exist that can convey awareness, align relationships, and galvanize a locally driven, state supported, and federally shared approach to current and future resilience threats.

6. Localities and the state can help champion federal authorities to better serve local and federal installation resilience needs by advocating for policy changes at the Congressional level.

The Subcommittee recommends the following:

1. Develop formalized and sustained local and regional resilience networks that include local, state, and federal representatives-- and provide:

    a. Sustained resilience planning teams with an Executive Steering Committee and widely representative stakeholder pool.

    b. Well defined geographical areas of study.

    c. Sustained vulnerability and risk assessments that result in prioritized projects and implementation plans.

    d. Funding solutions.

2. Implement existing Compatible Use Study (formerly Joint Land Use Study) vulnerability/risk assessments, and associated plans and proposed projects.

    a. Include capacity building recommendations in the Coastal Resilience Master Plan (CRMP) [enclosure 1]

b. Encourage sustained Compatible Use or Military Installation Resilience (locality/federal installation shared) studies to be updated at least every 5 years.

c. Apply similar studies for non-Department of Defense federal installations.

3. Initiate and sustain a state campaign to support localities.

    a. Educate and advocate for federal and state supporting resources (funding, capacity, etc.)

    b. Build and incorporate a resources "roadmap", tied to state agency representatives, that closes the existing awareness and resource gaps among locality, state, and federal stakeholders. Include a "checklist" of suggested prerequisites localities should complete to increase eligibility and competitiveness for federal funding. Examples include an approved All hazards Mitigation Plan, Compatible Use or Military Installation Resilience study, and U.S. Army Corps of Engineers Vulnerability Assessment.

    c. Designate state funding sources to help localities meet match requirements for federal grants.

    d. Ensure every Defense Community in the CRMP study area is aware of the Association of Defense Communities— Advancing Resilience for Defense Communities - A Planning Framework. Although intended for Defense Communities, this publication is relevant for all communities contending with coastal resilience challenges and should be included in their resource libraries.

    e. Partner with bordering states for locally driven, state supported, and federally shared resilience solutions.

4. Support federal authorities that will provide local and state advantages. Specifically, support legislative changes at the Congressional level to enable the U.S. Army Corps of Engineers (USACE) to conduct feasibility studies that include Coastal Storm Risk Management (CSRM) project features on federal properties, and to construct such features, utilizing shared federal civil works appropriations and/or non-federal sponsor funds.

5. Seek to adapt existing wide-area infrastructure models (e.g. VDOT Smart Scale) to Coastal Resilience solutions.

Enclosure 1: Existing Compatible Use Study (Joint Land Use Study) Plan Capacity Building Actions

A. 2017 Virginia Regional JLUS

1. Adopt Statewide Military Compatible Land Use Planning Guidelines for Local Governments to Integrate into Regional and Local Planning and Zoning Documents (2017 Virginia Regional JLUS)

2. Establish Permanent Funding Sources for Military Compatibility Planning and Assistance for Local Governments and Other Agencies, (2017 Virginia Regional JLUS)

3. Virginia Leadership should consider working with the military and Maryland Leadership to formally establish a Virginia -Maryland Military Compatibility Working Group. If established, this group should consider being responsible for communication, coordination, and monitoring the implementation of actions needed to address compatibility issues that occur within the identified public resources used for military training. The primary focus for this group is broad military capabilities that can affect state installations that have operational or influence areas that span both states (such as Military Training Routes). (2017 Virginia Regional JLUS)

4. Virginia Leadership should consider working with the military and North Carolina Leadership to formally establish a Virginia -North Carolina Military Compatibility Working Group. It would helpful if this group would consider being responsible for communication, coordination, and monitoring the implementation of actions needed to address compatibility issues that occur within the identified public resources used for military training. The primary focus for this group is broad military capabilities that can affect state installations that have operational or influence areas that span both states (such as Military Training Routes). (2017 Virginia Regional JLUS)

B. 2019 Norfolk and Virginia Beach Joint Land Use Study

1. To address both installation and DoD personnel readiness, implement the applicable, climate resilience "Recommended JLUS Actions" found in Table 3-2 of the report. The top four, highest scoring actions are capacity building projects including (in order):

   Action 1: Hampton Boulevard Comprehensive Flood Mitigation and Stormwater Management Strategy

   Action 2: Shore Drive Comprehensive Flood Mitigation and Stormwater Management Strategy

   Action 3: JEB Little Creek Gate 1 - Amphibious Drive - Shore Drive Flooding Study

Action 4: East Amphibious Drive, Chubb Lake, and Lake Bradford Flood Mitigation and Stormwater Management Strategy

2. Implement "Coordination and Outreach Strategies" identified in Table 4-1 of the report, including:

    - Develop a stormwater systems maintenance MOU for each installation and respective locality to define ongoing roles and responsibilities for routine maintenance of ditches, culverts, and other drainage components that span locality/ Navy jurisdiction.

    - Establish coordination protocols between city floodplain managers and Navy support personnel to share information about flood risk, flood insurance, existing city programs, and floodplain development regulations.

    - Update the Military Commuter Survey (HRTPO) to address issues related to flooding and sea level rise and how these issues affect overall access to work and other services.

3. While the document's "Advocacy Strategies" regarding federal funding (DCIP) are discussed, new resilience funding resources available from the Commonwealth should also be recognized (REGGI auction funds, etc) and used to advance the recommendations of the JLUS)

C. 2018 Hampton-Langley JLUS Resilience Addendum

1. To address both installation and DoD personnel readiness, implement the climate resilience recommendations of the Addendum, including:

    - Determine which roadways are designated as high priorities for JBLE-Langley

    - Establish a plan to maintain access of key corridors

    - Establish support for strategic relocation to higher ground

    - Develop a stormwater management plan

    - Manage stormwater off the base in City owned land

    - Coordinate ecological improvements with base development

D. Fort Pickett JLUS

1. COM-3A: Establish a JLUS Implementation Coordination Committee Formalize through a resolution that the Fort Pickett JLUS Policy and Technical Committees will transition to a JLUS Coordination Committee and be responsible for monitoring the achievement of the recommended JLUS strategies and act as a forum for continued communication and sharing of information and current events associated with military compatibility. Jurisdictions should appoint a military liaison to be the point of contact to be on the committee who would be present at jurisdiction meetings. The resolution should outline such assigned responsibilities. (Partners: Nottoway County Brunswick County Dinwiddie County Town of Blackstone)

2. COM-8A: Review Existing Military Operations that Use Facilities / Resources Located Off Fort Pickett Fort Pickett should identify and review all existing military training operations that make use of facilities, equipment or other resources that belong to other organizations. A determination should be made if the training activities could be conducted in the future and may still require use of facilities, equipment or resources that do not belong to Fort Pickett. Those operations without current agreements (MOU / MOA) should be flagged. See COM-8B

3. DSS-2A: Ensure Affected Jurisdictions and Public are Notified of Wildland Fires Fort Pickett and the VAARNG should work closely with Dinwiddie County and other jurisdictions in the Study Area to ensure timely notifications when wildland fires are burning on the installation, particularly when there are off installation impacts such as smoke. To the extent possible, Fort Pickett should also provide notification to the public via their website and social media sites

   DSS-2B: Jurisdictions Need to Keep Community Informed of Wildland Fires Government departments in the local communities need to ensure they provide adequate information to members of the public when the potential exists for wildland fire impacts. Actual wildfire information should be provided including whether natural occurring fire or prescribed burn event. Jurisdictions should establish telephone (consider use of CodeRED type notification) and text message notifications to residents along with websites and social media sites to provide updates and status of wildland fire impacts such as smoke moving into communities.

4. LU-1B: Add a Fort Pickett element to Comprehensive Plans JLUS Partner jurisdictions should incorporate a Fort Pickett element into their comprehensive plans that looks into compatibility and encroachment issues with the installation.

5. RE-1: Stormwater on the airfield runways and taxiways. During heavy rain events there are instances where stormwater drainage backs up onto the Allen C. Perkinson Airport Blackstone AAF runway and taxiways. This can affect aircraft movements on taxiways and aircraft sorties (landing, take-offs, touch and goes, etc.) impacting training operations. (This was identified as an internal issue only – are there any off-base contributing factors? Town of Blackstone?) The recent construction of the State Department FASTC complex has added additional impervious surfaces to the south and east of the airfield. While new construction projects on Fort Pickett are required to comply with federal and state requirements for management of stormwater runoff, the increased impervious surface in combination with the existing impervious surface has the potential to increase stormwater runoff on and around the airfield. Over long periods of time stormwater runoff has the potential to affect the integrity of the runways, taxiways and ramps on the airfield due to soil erosion. (http://www.pickettlanduse.com/images/docs/fpmtc_final_backgroundreport.pdf Page 5-119)

6. RE-1B: Conduct Periodic Stormwater Infrastructure Maintenance Fort Pickett should ensure maintenance teams conduct periodic stormwater infrastructure preventative maintenance that is regularly scheduled. Maintenance should include clearing obstructions in manmade (e.g. culverts) and natural (e.g. waterways) infrastructure and correcting any identified deficiencies. Maintenance teams should also ensure locations where flooding occurs s are visited in advance of major weather events when flooding is predicted and take any necessary actions. (This was identified as an internal issue only – are there any off-base contributing factors? Town of Blackstone?)

7. RC-2: Concern with impacts to roadways in the Town of Blackstone. The Town of Blackstone is the closest jurisdiction to Fort Pickett. Some of the economic development commercial activities located within the boundary of the installation but located on non-military land (e.g. Pickett Park) cause impacts to roadways within the town. In addition, trucks supporting FASTC during construction have also caused some deterioration to town roads. These roadway impacts can cause issues for the town where limited road maintenance funds are available. Flooding not considered?

E. 2014 Marine Corps Base Quantico JLUS

1. Update the JLUS with an addendum that provides a new and more detailed assessment of climate vulnerabilities with the goal of identifying recommendations to eliminate or mitigate those threats. See:

    a. Recommendations CO.6 - Develop a regional dialogue towards mitigation of environmental impacts and resource conservation (on and off base) .

b. Recommendation EC.1 - Pursue conservation partnering opportunities through the Readiness and Environmental Protection Integration (REPI) under DoD and through state, local and private conservation efforts (in collaboration with conservation partners) to pursue suitable properties for conservation in JLUS Military Influence Area Zones 1.2, 1.3, 2.1, 2.4 , 3.1 and 5.1. (EC.2)

c. Recommendation EC.3 - Using the QRESC/QRPT structure, cooperatively work together on stormwater management and other water quality initiatives for shared watersheds (see Recommendation CO.6)

d. Recommendation EC.4 - Through coordination between Prince William County and MCB Quantico, pursue restoration projects along Little Creek to address erosion and flooding issues in this water body and the adjacent properties from Route 1 to the Potomac River. SEE ONGOING, MID-TERM, and LONG-TERM strategies.

F. Naval Weapon Station Yorktown – 2013 Encroachment Action Plan

1. Use the CUP process to update the NWSY 2013 Encroachment Action Plan and provide greater specificity than the 2017 Virginia Regional JLUS to address current resilience issues/needs. See the Regional JLUS, Goal 8, page 43 where it states:

    - There are several public waterways including the Appomattox, Potomac, James, and York Rivers that provide invaluable training assets and realistic training environments for the military; however, these public waterways are also utilized by the general public and commercial business. These waterways should be protected to support ongoing multiple uses.

G. Fort AP Hill

1. Use the CUP process to provide greater specificity than the 2017 Virginia Regional JLUS to address current resilience issues/needs.

H. 2021 Portsmouth & Chesapeake JLUS

1. To address both installation and DoD personnel readiness, including flooding impacts to infrastructure, access, rail and port operations at the Craney Island Fuel Depot, implement the applicable, climate resilience "JLUS Actions" found in Table 5.2 of the report. The top four, highest scoring actions (Tier 1) are capacity building projects including (in order):

Action 1: Effingham Street Comprehensive Flood Mitigation and Stormwater Management Strategy.

Action 2: George Washington Highway Comprehensive Flood Mitigation and Stormwater Management Strategy.

Action 3: Victory Boulevard Comprehensive Flood Mitigation and Stormwater Management Strategy

Action 4: Portsmouth Boulevard Comprehensive Flood Mitigation and Stormwater Management Strategy.

Other notable JLUS actions include:

Action 16: Work with VDOT to pursue a flood risk/ vulnerability assessment of highway interchanges (access ramps) that considers future SLR and future rainfall along with traffic generation patterns.

Action 17: Complete a future flood risk/vulnerability assessment of all public facilities and their associated access corridors.

I. Fort Lee

1. Use the CUP process to provide greater specificity than the 2017 Virginia Regional JLUS to address current resilience issues/needs.

J. NSF Dahlgren

1. Use the CUP process to provide greater specificity than the 2017 Virginia Regional JLUS to address current resilience issues/needs.

K. Installations in VA not covered by an existing JLUS (are these considered to be in the "coastal" area identified in the VCRMPF?):

- Army Reserve National Guard sites in VA
- Arlington & US Soldiers and Airmen's Home National Cemeteries
- Defense Supply Center Richmond
- NSA Washington – NSF Arlington
- WHS Pentagon
- AFETA Camp Peary

Aligning Economic Development

The Master Plan should include a definition of economic development, and contain a clear message of the economic impacts of increased flooding in the coastal zone. The subcommittee recommends that the Master Plan provide acknowledgement and support for industries that develop a resilience and adaptation economy in Virginia. The scale of impacts in coastal Virginia and across the state provide an opportunity for the Commonwealth to be a global market leader in solutions that enhance resilience.

We recommend that the General Assembly provide incentives for businesses to develop innovative resilience-enhancing products, technologies, designs, and services, to partner with universities to capitalize on their expertise, and to foster workforce development in building and implementing resilience solutions. These incentives could include such nonfinancial measures as expedited permitting so that innovative solutions like green infrastructure can be rapidly implemented. However, funded incentives — including tax breaks for related R&D and capital investment as well as grants and low-interest financing — will also be important.

As part of this effort, we recommend that the Commonwealth continue to support economic development investments in Virginia's resilience and adaptation economy, such as the recent GO Virginia grant to foster coastal resilience and an adaptation economy (Virginia Sea Grant). We further recommend that the state explore making financial and nonfinancial incentives available to smaller local jurisdictions to increase their ability to support business activities that further resilience, and enable them to address impacts such as overburdened septic systems and ditch networks that affect water quality.

Stakeholders need a better understanding of scientific topics to better understand how coastal resiliency efforts would impact economic development, and there is a need to educate elected officials who are in the business of economic development. The subcommittee compiled a list of economic outreach contacts and sought their feedback to a series of questions in order to guide the focus and priorities of the subcommittee. By working with our contacts in coastal Virginia, the subcommittee will be able to provide the CRMP with valuable feedback that aids stakeholders.

For future iterations of the CRMP, the subcommittee is committed to the following:

- Continuing to survey the capacity of its members and how they can contribute to the CRMP planning process.
- Representing all of coastal Virginia and restructuring the subcommittee if needed.
- Developing a list of Virginia Economic Development Partnership approved recommendations that will benefit the CRMP.

VIRGINIA COASTAL RESILIENCE MASTER PLAN – PHASE 2

Impact Assessment Methodology

APRIL 4, 2024

Dewberry

DRAFT

SUBMITTED BY
Dewberry Engineers Inc.
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Richmond, Virginia 23219

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Virginia Coastal Resilience Master Plan Phase 2 Impact Assessment Methodology

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Revision History

March 4, 2024	Initial Draft Document
March 21, 2024	Revised Draft Document
April 4, 2024	Final Draft Document

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Acronyms

AAD	Average Annualized Depth
AAL	Average Annualized Loss
ACS	U.S. Census Bureau's American Community Survey
ADT	Average Daily Traffic
AEP	Annual Exceedance Probability
ALF	Annual Likelihood of Flooding
BCAR	Benefit Cost Analysis Re-engineering
BCA	Benefit-Cost Analysis
C	Coastal
C-CAP	Coastal Change Analysis Program
CPFRA	Coastal Probabilistic Flood Risk Assessment
CRMP	Coastal Resilience Master Plan
DCR	Virginia Department of Recreation and Conservation
DDF	Depth-Damage Functions
E	Exposure
ES	Event-Specific
FEMA	Federal Emergency Management Agency
F	Fluvial
Hazus-MH	Hazus Multi-Hazard
HIFLD	Homeland Infrastructure Foundation-Level Data
HUC	Hydrologic Unit Code
MF	Multi-Frequency
MHW	mean high water
MHWS	mean high water spring
MLW	mean low water
MTR	mean tidal range
NFHL	National Flood Hazard Layer
NNBF	natural and nature-based features
NOAA	National Oceanic and Atmospheric Administration
OSM	OpenStreetMap
P	Pluvial
R	Risk
SACS	South Atlantic Coastal Study
SFHA	Special Flood Hazard Areas
SLR	sea level rise
SWEL	Stillwater Elevation
TAC	Technical Advisory Committee
TB	Threshold-Based
USACE	U.S. Army Corps of Engineers
V	Vulnerability

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VGIN	Virginia Geographic Information Network
VIMS	Virginia Institute of Marine Science

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1. Introduction

1.1 Document Objectives

The purpose of this document is to provide a technical overview of the approach and methods used to assess potential flooding impacts in Phase 2 of the Virginia Coastal Resilience Master Plan (CRMP). Phase 2 of the CRMP builds on the approach and methods of Phase 1 (Dewberry 2021), with an expanded set of flood hazards, updated asset data sources, and refined impact metric calculation methods. The impact assessment produces quantitative data that characterizes how Virginia's people and landscape will be affected by flood hazards, now and into the future, accounting for sea level rise (SLR) and shifting precipitation regimes. The impact assessment incorporates the hazard data from the Phase 1 Coastal Hazard Framework, the Phase 2 Pluvial Hazard Framework, and Federal Emergency Management Agency (FEMA) Special Flood Hazard Areas (SFHA). The impact assessment uses these sets of hazard data and results from the asset data gathering effort to produce information that can be leveraged by decision makers to address flood risk.

1.2 Background Information

The Virginia Department of Recreation and Conservation (DCR) published the first iteration (Phase 1) of the CRMP in 2021, with support from Dewberry. Phase 2 of the CRMP will build on and update the data, methods, and outputs from Phase 1. Key updates include expanding the suite of flood hazards considered to include fluvial (riverine) and pluvial (rainfall-driven) flood hazards, and an additional planning horizon for coastal flood hazard events. Coastal flood hazard data will be consistent with Phase 1 for 2020, 2040, 2060, and 2080 and expanded to include sea level rise projections for the 2100 time horizon. However, if appropriate based on best available SLR trends, Phase 2 may update how the SLR increments are associated with planning scenarios for analysis and presentation.

Pluvial and fluvial flood hazards are new to Phase 2, and this analysis will calculate impact metrics for these flood hazards based on hazard data availability. Pluvial flood hazard modeling will be conducted as part of the CRMP effort and include a range of precipitation intervals encompassing existing and future frequency ranges. As a result, this analysis will include event-specific and multi-frequency impact metric results for pluvial flood hazards.

Fluvial flood hazard data in this assessment will be based on the effective one-percent Annual Exceedance Probability (1% AEP) as depicted in FEMA's SFHA from the National Flood Hazard Layer (NFHL). This data has been processed to only show fluvial, not coastal, component of the SFHA. Note that due to the limited data available for fluvial flood hazard scenarios, this analysis will only calculate fluvial impact metrics based on the 1% AEP event. Additionally, unlike coastal and pluvial hazard data which include flood depths, fluvial impact metrics will only consider the extent of the SFHA and not flood depth of the event that it represents. Separate from this task, a case study will be performed in four select Hydrologic Unit Code (HUC) watersheds (Great Wicomico-Piankatank, Rapidan-Upper Rappahannock, Lower Rappahannock, and Mattaponi) using the full impact assessment methodology applied to multi-frequency fluvial data, as applicable, to understand the value that data may add to future iterations of the CRMP.

Phase 2 additionally builds upon the set of assets used in Phase 1, with some updates and adjustments to data types and sources (See Section 4). With the expanded suite of flood

hazards and updated asset data, the impact metrics this assessment will calculate include key metrics calculated in Phase 1, with broader range of flood hazard inputs, and additional metrics to support evaluating flood hazards impacts on newly included asset data types (see Section 2.3).

At this time, this document does not include details on the Phase 2 approach to re-classification of asset data, or methods for generating impacts metric summaries at a range of geographic scales. These aspects of the approach remain under evaluation and will be included in an updated version of this document.

2. Approach

2.1 Overview

The CRMP impact assessment employs a structured yet flexible mixed-methods framework for producing metrics to describe the level of impact flooding is expected to have across Virginia's coastal region. These quantitative metrics can be paired with qualitative analysis to strengthen findings, reduce uncertainties, and provide a more complete picture of current and evolving flood impacts. Using this framework, the impact assessment evaluates three types of data as inputs (hazards, assets, and context) to produce the three levels of progressively-detailed quantitative metrics: exposure, vulnerability, and risk.

The following sections overview the impact assessment approach through a presentation of proposed metrics and methods for calculating them. Each calculated metric is defined in Section 2.3 and their calculation methods are detailed in Section 3.2. Raw quantitative assessment results are captured in the Asset and Geometric Summarization Tables outlined in Section 3.4.

2.2 Data Inputs

Inputs to the impact assessment includes data related to hazards, assets, and context, described below:

Hazards – Hazards are the potential occurrence of a physical event or trend that may threaten our social, built, and ecological environments. The flood hazard data from the Coastal Flood Hazard Framework, Pluvial Flood Hazard Framework, and Fluvial FEMA SFHA are key inputs into the impact assessment. Resulting event-driven flood exposure and depth scenarios represent where and how often flooding may occur and how severe the flood hazard may be at a particular location.

Assets – Assets are physical components or resources of value that may be directly affected by the hazard. Assets considered for this assessment include buildings, roadways, and other built infrastructure, and land areas with cultural, recreational, agricultural, or ecological value. The location, characteristics, and value of a given asset inform our understanding of the types of consequences that may occur due to its flooding.

Context – Context informs our understanding of how flooding challenges differ by region, locality, neighborhood, and individual, and the varying capacity to address them. Qualitative and quantitative information relating to Virginia's coastal areas' history, demographics, and

community characteristics drive our understanding of how impacts may accrue amongst populations and communities across the Commonwealth.

Outputs of the assessment include quantitative asset-specific impacts, and impacts summarized over geographic areas of interest. Those output data can then be further manipulated for scoring, ranking, and comparative presentation.

2.3 Impact Metrics

2.3.1 Organizational Framework

This section presents a consolidated list of all of the quantitative metrics that will be produced in the impact assessment, summarized in Table 1 through Table 3.. To further understand and describe these metrics, they are classified by category, level, type, and hazard, as introduced below.

Category – Metrics in the impact assessment are organized into three overarching categories based on the concept behind the calculation performed: Binary Exposure, Depth of Flooding, and Area Inundation.

Level – The impact assessment approach enables a progressively detailed evaluation dependent on the availability and quality of data. As noted in **Error! Reference source not found.** below, three overarching levels of assessment will be executed: exposure, vulnerability, and risk.

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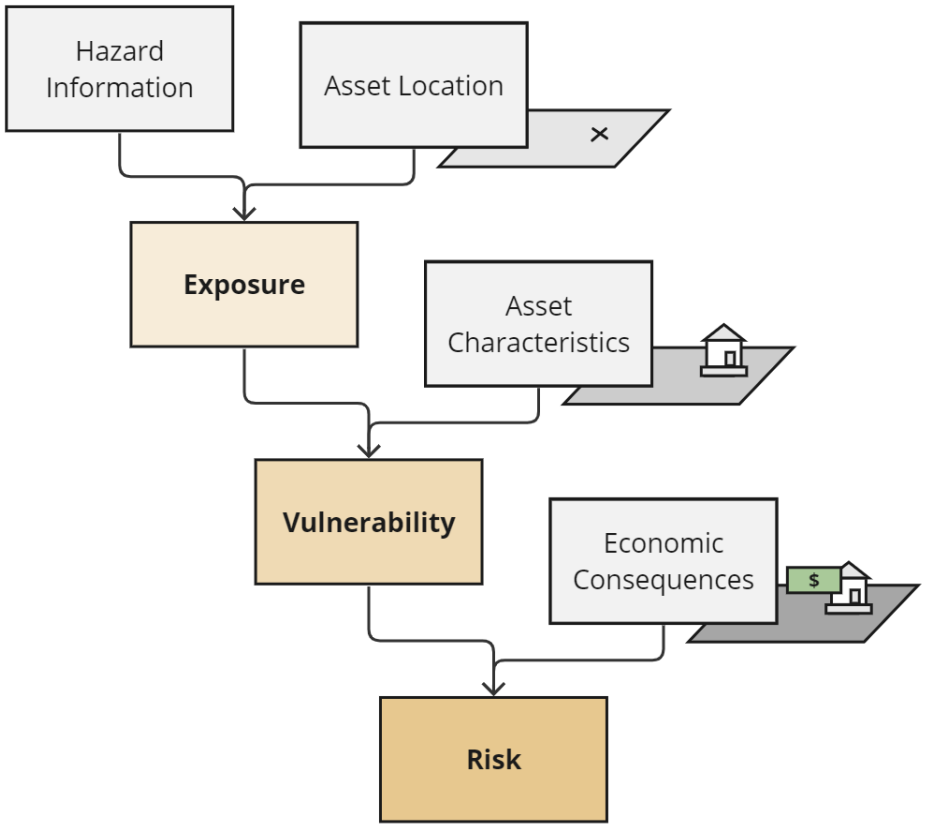
Figure 1. Asset information required to describe impacts with varying levels of detail.

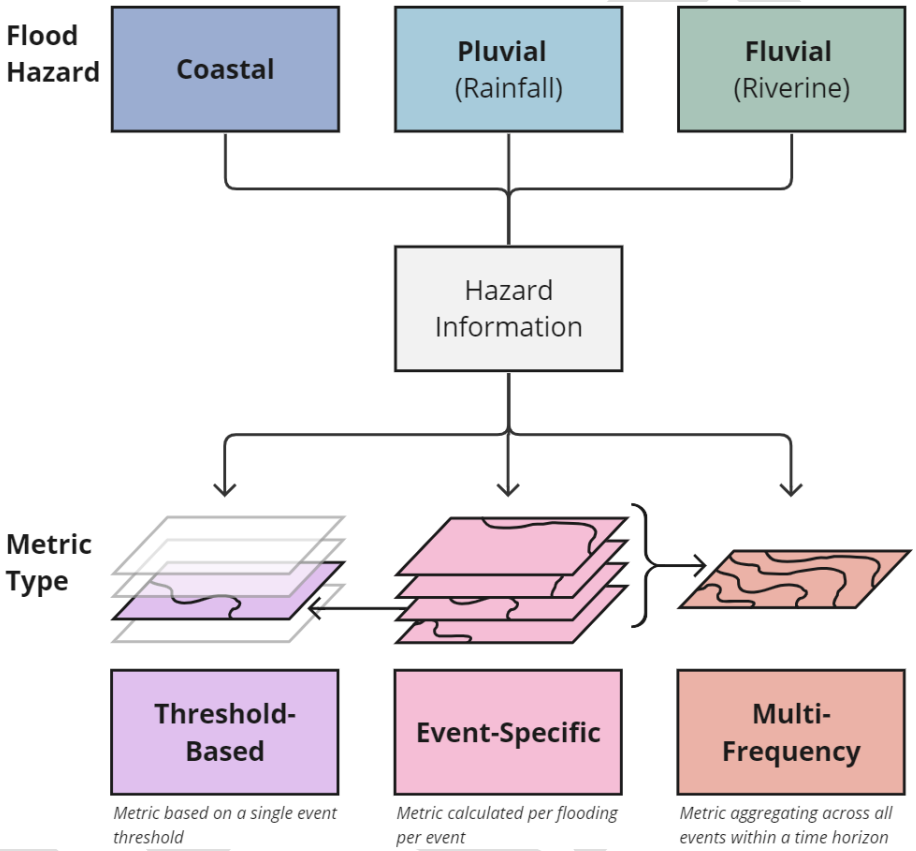


A quantitative estimate of risk is possible where accurate asset location, key characteristics related to asset sensitivity to flooding, and asset value data are available. Where no such information is available, the impacts may be described in narrative format. Thus, impact metric results are presented through a range of progressively data-intensive metrics introduced below and further described in Section 3.2. In the set of tables below, metric level is indicated as either Exposure (E), Vulnerability (V), or Risk (R).

- **Exposure** – The likelihood and degree (e.g., flood depth) to which an asset – or population or system associated with the asset – will be physically exposed to flooding. For this assessment, the flood exposure for a given asset is a factor of its location and the hazard present at that location.
- **Vulnerability** – A measure of the degree to which an asset – or population or system associated with the asset – is likely to be adversely affected by the hazard. For a vulnerability assessment, physical exposure is enhanced by understanding the asset's susceptibility, or sensitivity, and adaptive capacity. Sensitivity measures an asset's innate susceptibility to harm, and adaptive capacity captures the asset's ability to adjust to a new situation or cope with the consequences of a hazard event.
- **Risk** – The estimated value of direct and indirect consequences associated with the functional disruption of the asset – or population or system associated with the asset. For this assessment, the risk is quantified in economic terms. It incorporates probable losses associated with direct damages to the asset.

All impacts that revolve around discrete and identifiable assets will have exposure statistics, but the degree to which vulnerability and risk is quantified depends on asset-specific and hazard-specific data available. As shown in **Error! Reference source not found.** and described below, hazard-specific data varies based on whether the flood data is source is coastal, pluvial, or fluvial, and impact metrics produced may be based on individual events or aggregated across events.

Figure 2. Flood hazard information sources and impact metric types.



Hazard – Due to the varying nature of flood hazard information available, not all metrics will be calculated for all flood hazard types. Coastal flooding conditions considered for this analysis include the tidal boundaries of mean low water (MLW), mean high water (MHW), and 1.5 times mean tidal range (1.5xMTR); and coastal storm surge events with an AEP of 50%, 20% 10%, 4%, 2%, 1% and 0.2%. Coastal flood conditions are assessed across five SLR conditions, representing the current and future time horizons. Pluvial (rainfall-driven) flood conditions follow a similar framework as coastal flood events, but specific recurrence intervals are still being determined. Fluvial (riverine) flooding was not modeled for the CRMP, and so impacts related to this type of flooding are limited to an assessment of binary assessment of whether or not assets are within FEMA's present-day SFHA (data has been processed to only show fluvial, not coastal, component of the SFHA). In the tables below, which flood hazard type is relevant to each metric is indicated as either Coastal (C), Pluvial (P), and/or Fluvial (F).

Type – Some metrics are event-specific (e.g., depth of flooding per event), while others represent multi-frequency calculations that aggregate impacts across events with a given time

horizon (e.g., average annualized depth of flooding). Additionally, other metrics use a threshold (such as MHW) to estimate changes across time horizon (e.g., land lost). In the tables below, this metric type is indicated as either Event-Specific (ES), Multi-Frequency (MF), or Threshold-Based (TB).

This impact assessment will result in a set of asset-specific impact metrics that will be presented in Asset Impact Tables, as well as aggregated summaries of those impacts over designated areas of interest presented in Geographic Summary Tables. A breakdown of which metrics will appear in which tables and across which asset types is presented in Section 3.4.

2.3.2 Binary Exposure

Whether or not an asset is exposed to any amount of flood waters during a flood event provides the most foundational view of flood exposure. Seven metrics related to this binary (in or out) depiction of flood exposure are summarized in Table 1 below Figure 3 shows how these metrics build off each other. The process for calculating them are described in Section 3.2.1.

Figure 3. Binary exposure metrics calculation flow

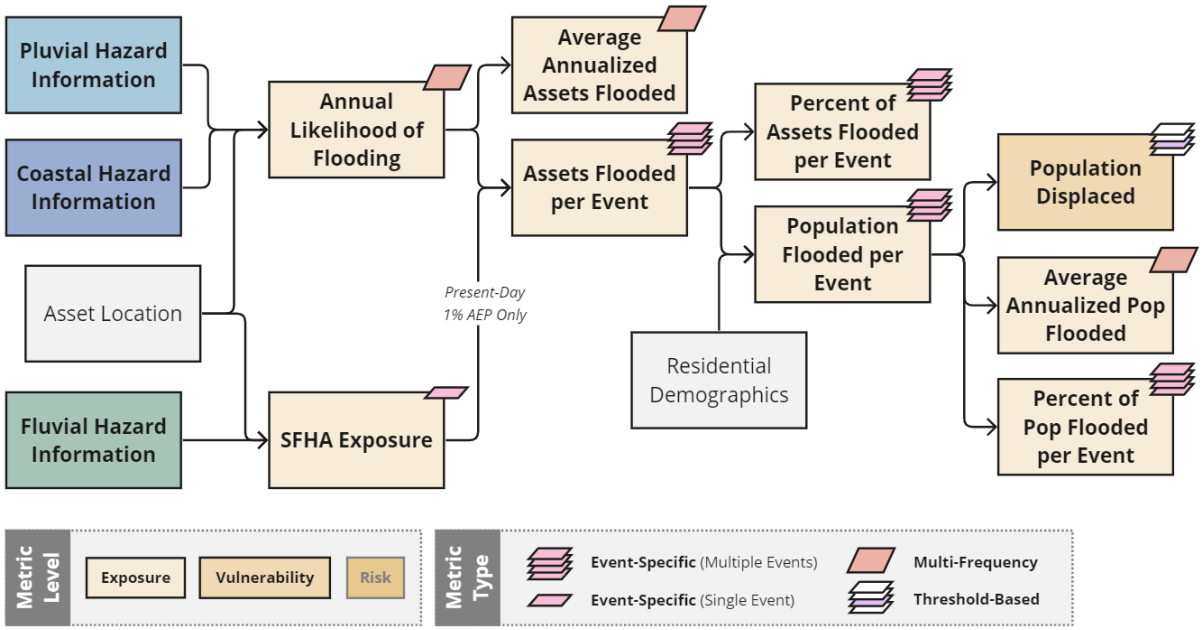


Table 1. Binary exposure metrics with relevant definition, units, level, type, and hazard.

Metric	Definition	Units	Level	Type	Hazard		
Annual Likelihood of Flooding	The probability that any amount of flooding will occur at a location in a given year for a given time horizon.	percent	E	MF	C	P	
SFHA Exposure	The binary determination of whether or not an asset is within FEMA's present-day SFHA.	Y/N	E	ES	F		
Assets Flooded Per Event	The number of assets of a certain type exposed to flooding for each modeled flood event within a given geography of interest.	asset count	E	ES	C	P	F*

Metric	Definition	Units	Level	Type	Hazard		
Percent of Assets Flooded per Event	The portion of assets of a certain type exposed to flooding for each modeled flood event within a given geography of interest.	percent	E	ES	C	P	F*
Average Annualized Assets Flooded	The probability-weighted average number of assets flooded in a given year across all events within a given time horizon and geography of interest.	asset count	E	MF	C		P
Population Flooded per Event	The estimated number of people living in flood-exposed residential buildings for each modeled flood event.	pop count	E	ES	C	P	F*
Percent of Population Flooded per Event	The estimated portion of people living in flood-exposed residential buildings for each modeled flood event.	percent	E	ES	C	P	F*
Population Displaced	The estimated number of people exposed to MHW for a given time horizon.	pop count	V	TB	C		
Average Annualized Population Flooded	The probability-weighted average people exposed to flooding in a given year across all events within a given time horizon.	pop count	E	MF	C		P

Levels: Exposure (E), Vulnerability (V), and Risk (R)
Types: Event-Specific (ES), Multi-Frequency (MF), and Threshold-Based (TB)
Hazards: Coastal (C), Pluvial (P), and Fluvial (F)

* Metric calculated for the present-day 1% AEP only.

2.3.3 Depth of Flooding

Flood depth is a component of asset exposure, but for assets where their sensitivity to impact can be directly tied to flood depth, this can lead to measurement of vulnerability and risk. Most notably, for building assets, damage and loss metrics reflect direct damages to the structures and contents of buildings from a flood event (calculated using assigned industry standard depth-damage functions). The six metrics related to depth of flooding are summarized in Table 2 below and

Figure *4*shows how these metrics build off each other. The process for calculating them are described in Section 3.2.2.

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Figure 4. Depth and damage metrics calculation flow.

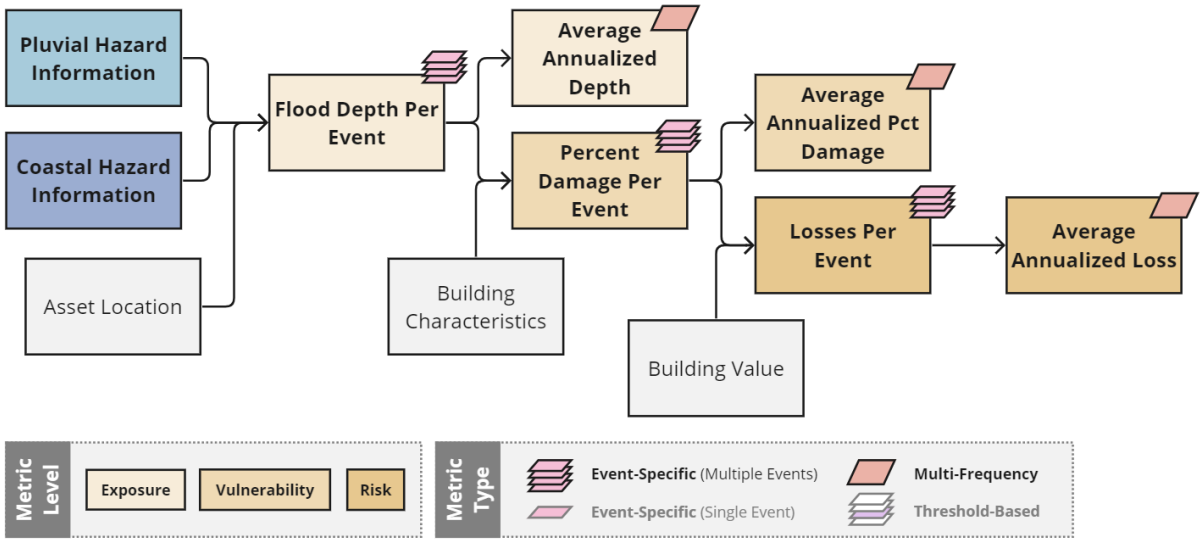

Table 2. Depth of flooding metrics with relevant definition, units, level, type, and hazard.

Metric	Definition	Units	Level		Type	Hazard	
Flood Depth per Event	The maximum depth of flooding an asset is exposed to for each modeled flood event.	feet	E	V	ES	C	P
Average Annualized Depth	The probability-weighted average of flood depth across all events within a given time horizon.	feet	E	V	MF	C	P
Percent Damage per Event	The estimated level of flood damage as a percent of building replacement value (both structure and contents), based on flood depth and building characteristics for each modeled flood event.	percent	V		ES	C	P
Average Annualized Percent Damage	The probability-weighted average of event-specific building percent damages (structure and content) across all events within a given time horizon.	percent	V		MF	C	P
Losses per Event	The estimated dollar value of losses due to flood damage (both structure and contents), based on flood depth and building characteristics for each modeled flood event.	dollars	R		ES	C	P
Average Annualized Loss	The probability-weighted average of event-specific building losses (structure and content) across all events within a given time horizon.	dollars	R		MF	C	P

Levels: Exposure (E), Vulnerability (V), and Risk (R)
Types: Event-Specific (ES), Multi-Frequency (MF), and Threshold-Based (TB)
Hazards: Coastal (C) and Pluvial (P)

2.3.4 Extent of Flooding

Although many assets considered in the CRMP are site-specific points, some assets are represented by lines, polygons, or gridded raster data where length or area flooded across various event conditions can be used to capture measures of exposure, vulnerability, and risk. This includes assets like roads, military facilities, tribally owned land, and natural infrastructure

including conserved lands and recreational areas. For these assets, the extent of flooding is used to estimate the damage and disruption likely to be caused by flood events. Note for non-raster data, metrics will be calculated at the level of individual assets (features), which can be summarized across asset types to calculate total lengths or areas exposed within an area of interest. This excludes select natural infrastructure polygon layers where individual assets are overlapping and will be dissolved into representative areas for analysis. Specific natural infrastructure layers where this applies are noted in section 3.2.3 Extent of Flooding.

Healthy ecosystems are resilient to major storm events, but likely to be impacted by long-term changes in tidal conditions due to rising sea levels. Examining changes in frequent and periodic flood conditions (MLW, MHW, and 1.5xMTR) can help determine natural areas most vulnerable to increased flooding from climate change. These natural areas provide ecosystem services (direct or indirect contributions that ecosystems make to the environment and human populations) which can be quantified in dollar values and used to estimate risk posed by SLR in these areas. Coastal hazard conditions will be used to calculate these metrics given the prominent influence of tidal conditions. Changing fluvial and pluvial hazard conditions will also likely affect existing natural infrastructure through processes such as increased erosion, changing salinity, and turbidity; however, quantifying fluvial and pluvial impacts on natural infrastructure is beyond the scope of this assessment.

Metrics related to length-based and area-based flood exposure, including impacts to natural areas that provide ecosystem services, are summarized in Table 3 below and **Error! Reference source not found.** shows how these metrics build off each other. The processes for calculating them are described in Section 3.2.3.

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Figure 5. Extent of flooding metrics calculation flow.

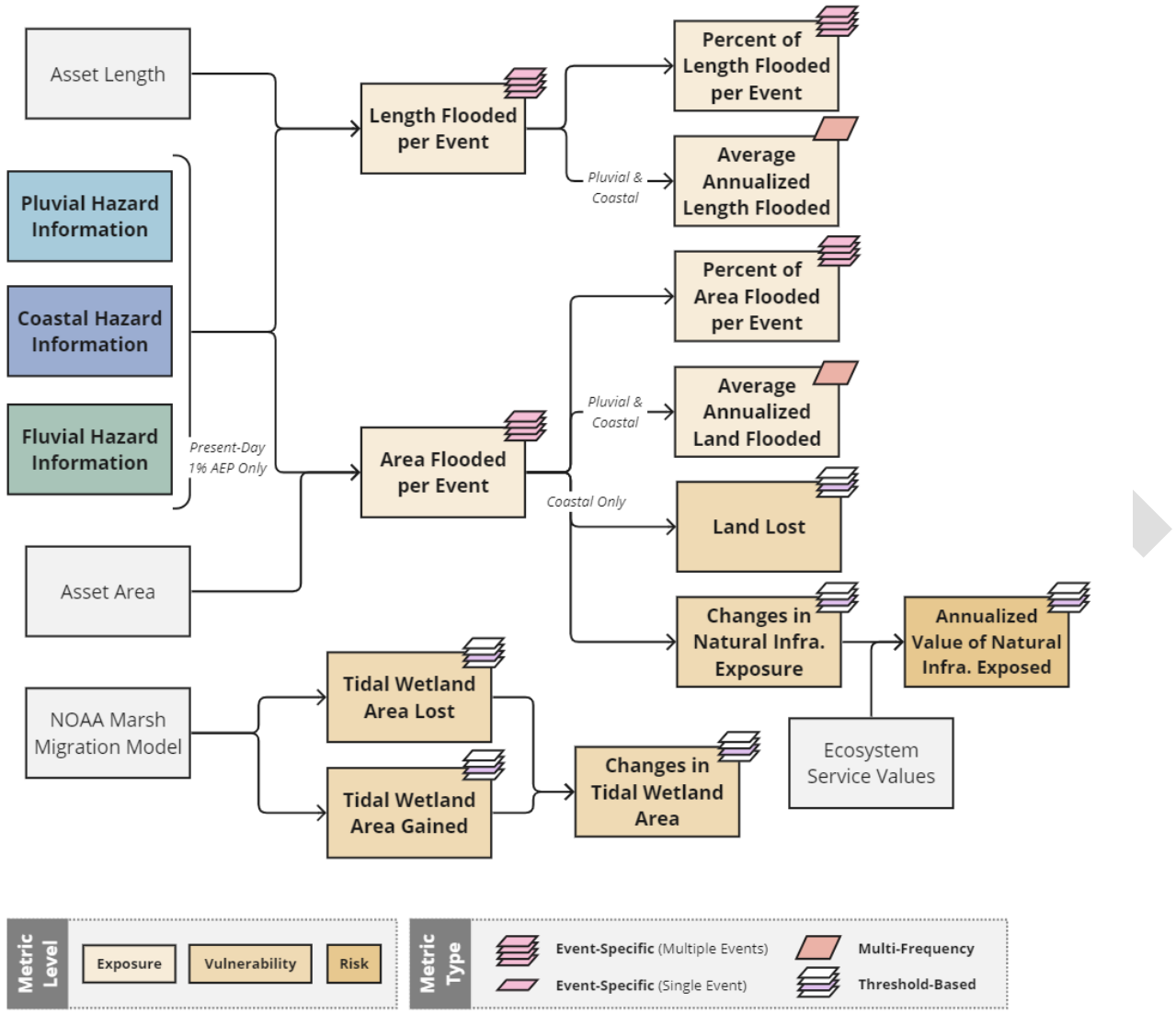

Table 3. Extent of flooding metrics with relevant definition, units, level, type, and hazard.

Metric	Definition	Units	Level	Type	Hazard
Length Flooded per Event	The length in feet of a linear-based asset that is covered by any depth of floodwaters for each modeled flood event.	feet	E	ES	C P F*
Percent of Length Flooded per Event	The portion of a linear-based asset that is covered by any depth of floodwaters for each modeled flood event.	percent	E	ES	C P F*
Average Annualized Length Flooded	The probability-weighted average of linear feet flooded across all events within a time horizon.	feet	E	MF	C P
Area Flooded per Event	The land area in acres of an area-based asset that is covered by any depth of floodwaters for each modeled flood event.	acres	E	ES	C P F*

Metric	Definition	Units	Level	Type	Hazard
Percent of Area Flooded per Event	The portion of a area-based asset that is covered by any depth of floodwaters for each modeled flood event.		E	ES	C P F*
Average Annualized Land Flooded	The probability-weighted average of land area flooded across all events within a time horizon.	acres	E	MF	C P
Land Lost	The projected changes in the acreage of area-based assets' land area for a given time horizon relative to 2020 MHW baseline.	acres	V	TB	C
Changes in Natural Infrastructure Flood Exposure	The projected changes in the acreage of all natural infrastructure areas for a given time horizon based on selected exposure zones using MLW, MHW, and 1.5xMTR thresholds.	acres	V	TB	C
Tidal Wetland Area Lost	The projected loss in tidal wetland acreage for a given time horizon within the extent of current wetland based on the NOAA Marsh Migration model thresholds for wetland class transitions.	acres	V	TB	C
Tidal Wetland Area Gained	The projected gain in tidal wetland acreage outside the extent of current wetland for a given time horizon based on the NOAA Marsh Migration model thresholds for wetland class transitions.	acres	V	TB	C
Total Change in Tidal Wetland Area	The projected total change in tidal wetland acreage for a given time horizon based on the NOAA Marsh Migration model thresholds for wetland class transitions. This accounts for tidal wetland loss and potential tidal wetland gain through wetland migration.	acres	V	TB	C
Annualized Value of Natural Infrastructure Exposed to Flooding	The dollar value of ecosystem services for natural infrastructure exposed to flooding based on selected exposure zones in a given year within a given time horizon.	dollars	R	TB	C

Levels: Exposure (E), Vulnerability (V), and Risk (R)
Types: Event-Specific (ES), Multi-Frequency (MF), and Threshold-Based (TB)
Hazards: Coastal (C), Pluvial (P), and Fluvial (F)

* Metric calculated for the present-day 1% AEP only.

3. Methods

3.1 Asset Data Preparation

Data is that is accurate and complete is essential foundation for executing a reliable analysis. The study team took multiple steps to prepare asset data for analysis, including a detailed source review, data cleaning, and merging.

3.1.1 Data Source Review

The project team consulted with numerous external experts to source and review asset data. Information on data sources and requests for feedback were presented to the Coastal Resilience Technical Advisory Committee and its Project Prioritization Subcommittee, the VDEM Critical Infrastructure Working Group, and the EPA Region III Regional Tribal Operations Committee. Additionally, the project team directly consulted with experts and data owners regarding their best available datasets. Entities that provided data and/or consulted on appropriate data sources and uses included:

- Department of Conservation and Recreation/Natural Heritage
- Department of Environmental Quality (DEQ)/Coastal Zone Management
- Department of General Services
- Department of Historic Resources
- Department of Housing and Community Development
- Department of Rail and Public Transit
- DEQ Office of Pollution Response & Emergency Preparedness
- US Navy Region Mid-Atlantic
- Virginia Department of Emergency Management
- Virginia Department of Health
- Virginia Department of Transportation
- Virginia Institute of Marine Science

Detailed evaluation of proposed asset data included documenting information related to the asset data source and considerations related to relevancy, quality, and database integration. Data reviewers used an online database form to input fields including date last updated, relevant attributes, potential overlap with other sources, and concerns to flag or discuss. Data from the forms are maintained in an online Airtable database that can be updated as new sources or information arises. Screenshots of the review survey are shown below in **Error! Reference source not found.**.

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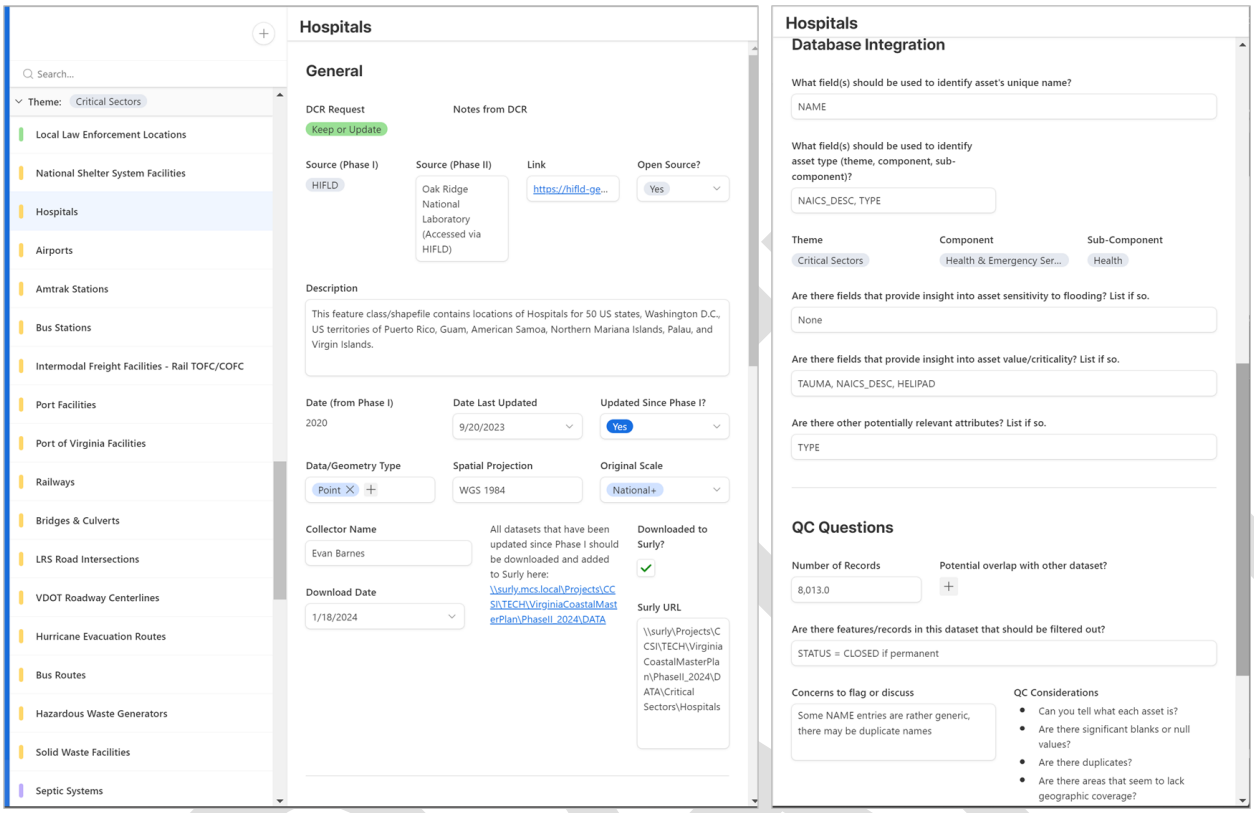
Figure 6. Screenshots of the online database form used by data review team to document data sources and flag analysis and quality concerns.



Reviewers were prompted to flag concerns including significant blanks, null values, duplications, and lack of geographic coverage. Additionally, datasets were cross-checked for overlap with other sources. Concerns were flagged and minor issues were addressed if feasible, but due to the timeline of this study, no base asset data was created or significantly improved. Large deficiencies in data were noted in the data documentation to aid the Commonwealth in future data improvement efforts.

3.1.2 General Asset Data Standardization and Cleaning

To bring data into a consistent format, information from individual data sources is extracted to identify unique asset identifiers, names, and typology information in a consistent and integrated format. To ensure both consistency in data formatting and traceability for the provenance of data in use, an automated process is used to reproject spatial information to a common analytical projection system and metadata concerning the initial download as well as the database transfer are collected and stored alongside the data. Additionally, the following steps are taken to support quality control processes:

- Assets exposed to MLW in 2020 are assumed to be water-based assets and flagged for potential exclusion.
- Assets suspected to be duplications across and within source datasets are flagged for further examination and potential exclusion.
- Asset source, name, and type information is retained so that sorting and rule-based exclusions can be applied at a later stage of the analysis. This includes the removal

of ancillary data that are not important to the assessment.

3.1.3 Roadway Asset Data Preparation

Linear roadway assets are broken up into segments, either as a factor of the input data, or by splitting at points of intersection. Each segment is then treated as a discrete asset. These linear features are also converted to a polygon by buffering based on the asset width (when available), or a default width of 40 feet, to capture a more realistic view of flood exposure for these assets. Roads will be assessed as both linear assets (providing length of roadway exposure in feet) as well as an area-based asset (providing area exposed to flooding) and a broader picture of potential impacts. To provide context to roadway segments, the following attributes will also be utilized:

- Category (i.e., Hurricane Evacuation Routes, Primary, Secondary, Street)
- Average Daily Traffic (ADT)

3.1.4 Building Dataset Creation

Additional steps are taken to prepare building dataset to maximize coverage and accuracy for risk assessment.

Refine Building Inventory – The building inventory is a combined dataset. The primary source of building footprint and parcel data for this effort is the Lightbox SmartParcels data (dated October 2024 and sourced through Homeland Infrastructure Foundation-Level Data (HIFLD) Secure). The latest Virginia Geographic Information Network (VGIN) building footprint data (last updated January 2024) is used to supplement build footprints with attribute data being provided from the Phase 1 dataset where available. Preliminary analysis identified about 79,000 buildings to be integrated into the LightBox SmartParcels data. For Phase 2, those 79,000 building footprints will be overlaid against the latest VGIN building footprint data to identify the additional buildings to be integrated. The attributes from the Phase 1 data will be transferred over to the latest VGIN data before integration. More information about Phase 1 building sources can be found in Section 3.1.2 of the Phase 1 Appendix E: Impact Assessment Methodology Report (Dewberry 2021).

From this combined dataset, the building footprints will be excluded from analysis for the following reasons:

- Occupancy type (vacant or undefined designations)
- Area (less than 500 square feet)
- Buildings in 2020 MLW floodplain

The combined building data represents a best available dataset. However, buildings are inevitably going to still be missing from this merged data set, particularly in areas with new development.

Attribute Relevant Data – In order to prepare structures for damage and loss assessments described in Section 3.2.2, several critical attributes must be assigned to each building: occupancy, foundation type, number of stories, building area, building replacement value, year of construction, and first floor height. First-floor height is the height, in feet, of the top of the first

floor above ground level. The building area is area of building footprint in square feet. The number of stories is the number of occupiable stories. Occupancy describes the building's use or function and is typically represented by general use classes defined in the Hazus Multi-Hazard (Hazus-MH) loss estimation model framework (FEMA 2020). Additionally, information on structure value is needed to translate building damages into economic losses.
Occupancy type, foundation type, number of stories, building area, and first floor height will be attributed to each building through the HIFLD Secure building, parcel, and associated tax assessment data. Building replacement value will be calculated using empirical relations between building area, occupancy type and cost per square feet associated with the occupancy type as defined by Hazus. Content replacement value will be calculated as a proportion of the calculated building replacement value using the default content percentage in Hazus. A list of occupancy types and valuation rates is included in Table 5 in Section 3.2.2. For additional information on the Hazus approach to utilizing replacement values to estimate damages from flood hazard events, please see the FEMA "Guidance for Flood Risk Analysis and Mapping" report (FEMA 2020).

Lowest adjacent grade (the lowest point of the ground level immediately next to a building) and highest adjacent grade (the highest natural elevation of the ground surface) will also be attributed to each structure.[1] That will be used to determine the lowest and highest points of the structures elevation to calculate flood depth in structure. If needed, to account for missing building information, Hazus defaults can be used to determine missing first floor height data.

Additional attribute data that can be utilized for analyzing and classification of the buildings in this dataset also include: Owner Occupied (Yes/No), Assessed Value ($), Improved Value ($), and Market Value ($).

3.1.5 Approximation of Household Demographics

Population and demographics from the US Census Bureau's American Community Survey (ACS) will be statistically attributed to individual residential building footprints (using 2020 block group boundaries and 5-year ACS estimates from 2021 TIGER data). This is an alternative approach to distributing population uniformly through a census block, and has the benefit of accounting for population distribution and density variations. Mapping the population to the

[1] Lightbox building data comes with ground_elevation_min_ft and ground_elevation_max_ft that will for lowest and highest adjacent grade for analysis. If that data is missing or not available, lowest and highest adjacent grades will be estimated using updated elevation data and ESRI Zonal Statistics.

building footprints facilitates geographic-specific population and demographic aggregation for working with geometries that do not coincide with census block boundaries (such as floodplains and project boundaries). While this process is highly useful for statistical modeling at an aggregated scale, these estimates should not be used to report impacts to individual structures and residents. It is recommended that the resulting raw values be shared and reported out at a minimum geographic scale of a census block group. The process to do this calculation is described below.

- **Source Data Aggregation** – Building-level data from multiple sources are combined to create a comprehensive building layer, as described above in Section 3.1.4.
  - **Land-Use Attribution** – Land-use information for the buildings is extracted from the parcel data.
  - **Type Classification** – Each building is categorized as residential or non-residential based on the land-use type of the parcel.
- **Demographic Attribution** – In order to use the ACS demographics data, each residential building footprint should be associated one-to-one with a census block group. The centroids of the residential buildings are intersected with census block groups. In Phase 1, the ACS demographics reported for each census block group were then proportionally allocated to the residential buildings using a simplified areametric (or area-weighted) approach. Using this approach, larger footprints received a bigger share of the census block group population. The proportioning method distributed demographic composition based on the living square footage reported in the parcel data. Where square footage was not available, the building footprint area was used. Care was taken to verify that the total population allocated to buildings matched with the total reported in ACS. One of the main challenges in this process is to exclude secondary residential structures such as garages, sheds and barns from receiving a share of the population. This challenge was partially overcome by setting a minimum area threshold of 500 square feet to consider a footprint as a primary residential structure. Another drawback was that the multi-family and apartment type dwellings were managed like single family dwellings as the population was area based. In Phase 2, we propose a simplified volumetric approach (Murayama 2009, Pajares, et al. 2021) using the number of stories multiplied by footprint area for population allocation which will alleviate this issue to a larger extent. In order to account for every person in the census block group, a set of rules was devised based on the data available in each census block group. These rules are incrementally applied in each census block in the order shown in the list below.
  - Only residential buildings are identified as the primary areas of population in each census block group. Residential buildings are identified as anything with a residential-based land use type.
  - In populated census block groups with no residential buildings or parcels available, the population is distributed to all the buildings in the census block group, regardless of occupancy type. An example for this case would be prisons. Generally, prisons are the only buildings in a census block reporting population. Since prisons are considered Government or Tax-exempt occupancy buildings, they are not included in population distribution. In such blocks, population is distributed to all the buildings regardless of occupancy type.
  - In populated census block groups where no building footprints are available, the

parcel centroids are used as representative points to be considered for the population. Each building in the parcel area is assumed to be 2,000 square feet. An example of these would be block groups with new development where the geospatial dataset is not updated to reflect them.

In addition to population counts, demographic information related to social vulnerability (e.g., race, income, education, employment, etc.) will be pulled directly from ACS at the block group level and pairable with all residential building footprints. Demographic variables referenced in the CRMP are listed in Table 4.

Table 4. Demographic ACS Variables that align with the CDC's 23 SVI components. (Centers for Disease Control and Prevention and Agency for Toxic Substances and Disease Registry 2022)

SVI Theme	SVI Variable	ACS Table	ACS Variables
Socioeconomic	No Health Insurance	S2701	S2701_C04_001E
Socioeconomic	Civilian Unemployment	DP03	DP03_0005E
Socioeconomic	Below 150% Poverty	S1701	S1701_C01_040E
Socioeconomic	No High School Diploma	B06009	B06009_002E
Socioeconomic	Housing Cost Burden	S2503	S2503_C01_028E + S2503_C01_032E + S2503_C01_036E + S2503_C01_040E
Household	Single-Parent Households	B11012	B11012_010E + B11012_015E
Household	Limited English Language Proficiency	B16005	B16005_007E + B16005_008E + B16005_012E + B16005_013E + B16005_017E + B16005_018E + B16005_022E + B16005_023E + B16005_029E + B16005_030E + B16005_034E + B16005_035E + B16005_039E + B16005_040E + B16005_044E + B16005_045E
Household	Civilian with a Disability	DP02	DP02_0072E
Household	Aged 65 and older	S0101	S0101_C01_030E
Household	Aged 17 and younger	B09001	B09001_001E
Racial & Ethnic	Two or More Races	DP05	DP05_0083E
Racial & Ethnic	Other Races	DP05	DP05_0082E
Racial & Ethnic	Native Hawaiian or Pacific Islander	DP05	DP05_0081E
Racial & Ethnic	Total Minority	DP05	DP05_0071E + DP05_0078E + DP05_0079E + DP05_0080E + DP05_0081E + DP05_0082E + DP05_0083E
Racial & Ethnic	Hispanic or Latino	DP05	DP05_0071E
Racial & Ethnic	Asian	DP05	DP05_0080E
Racial & Ethnic	American Indian or Alaska Native	DP05	DP05_0079E

SVI Theme	SVI Variable	ACS Table	ACS Variables
Housing	No Vehicle	DP04	DP04_0058E
Housing	Multi-Unit Structures	DP04	DP04_0012E + DP04_0013E
Housing	Mobile Homes	DP04	DP04_0014E
Housing	Group Quarters	B26001	B26001_001E
Housing	Crowding	DP04	DP04_0078E + DP04_0079E

3.2 Key Metric Calculations and Processes

The following sections provide more details on the calculation methods and processes behind the impact metrics introduced in Section 2.3.

3.2.1 Binary Exposure

Annual Likelihood of Flooding (ALF) – When multi-frequency hazard data is available (coastal and pluvial hazards), ALF describes the probability that any amount of flooding will occur at a location in a given year for a given time horizon. ALF considers the annual probability of an event occurring and the extent of the floodplain associated with that event. This calculation includes the following steps:

1. **Asset-Floodplain Intersection** – All discrete assets from all sources are intersected with all the extents of the modeled flood events to identify whether or not the asset is inside or outside of the floodplain for each event frequency and time horizon. If a building footprint, area-based asset, or linear asset is partially in the floodplain, it is considered exposed by this metric.
2. **Impact Threshold Frequency** – For each time horizon, the highest frequency flood (the flood with the lowest return interval and highest AEP) that intersects with the asset is identified. This event is considered the threshold for the asset experiencing flooding. Assets exposed to tidal flooding (MHW) are assumed to have a 100% ALF.
3. **Annual Likelihood of Flooding** – The AEP of the identified most-frequent flood event is used to estimate the ALF for a given structure. For example, if a structure is in the 20% AEP floodplain (and by default the floodplains of all less-frequent flood events) but not the 50% AEP floodplain, it is estimated to have an 20% ALF.

SFHA Exposure – The SFHA data used in this impact assessment is a spatial extent reflecting the extent of the present day 1% AEP fluvial (riverine) flood. Similar to the process described in calculating ALF, all buildings, point-based assets, and linear assets are compared to this extent to determine whether they or inside or outside of the SFHA.

Assets Flooded per Event – For coastal and pluvial hazards, asset ALF will be used to extract the number of assets exposed to flooding for any given event frequency. Since all assets are flooded in an event with the same or lower frequency as their ALF, then a count of all assets exposed during a given flood condition can be extracted by counting all assets of the same type within a geography of interest where event AEP is greater than or equal to asset ALF. For

example, to calculate the assets exposed in a 10% AEP event, one would take a count of all assets with an ALF of 100%, 50%, 20%, and 10%.

For fluvial, SFHA-exposed assets of the same type will be counted to summarize the number of assets in the SFHA within a given geography of interest.

Note if a linear or area-based asset is partially flooded, this exposure would not be reported in terms of length of area. For example, if a 1,000 ft roadway is partially exposed (10 feet of exposure), reporting 1,000 ft of roadway infrastructure exposure is not appropriate. Instead, it would be appropriate to report that 1,000 ft of roadway service is impacted due to partial roadway infrastructure flooding.

Percent of Assets Flooded per Event – The count of flooded assets will be compared to the total number of assets of the same type within a geography of interest in order to develop a percent of assets flooded for any given event frequency.

Average Annualized Assets Flooded – ALF can be summed across assets to summarize total hazard exposure of an asset type across a geography of interest for a given time horizon. Mathematically, this is the same as taking the metric average across all assets and multiplying it by the number of assets in a given geographic boundary. The resultant value is the average annualized number of flooded assets or the expected number of assets flooded each year.

Population Flooded per Event – This metric provides an estimate of the number of people living in flood-exposed residential buildings for each modeled flood event. Population estimates are attributed to each residential building footprint using the method described in Section 3.1.5 and exposure is derived from the building's calculated ALF. While the population exposure impact metric focuses on population counts and is unrelated to demographic characteristics, population exposure can also be broken down by race/ethnicity or other relevant categories in subsequent analyses.

Percent of Population Flooded per Event – The estimated number of residents exposed to flooding will be compared to the total number of residents within a geography of interest in order to develop a percent of population flooded for any given event frequency.

Population Displaced – For this assessment, buildings that fall within the MHW floodplain are considered uninhabitable and so this metric captures an estimated count of residents living in buildings with an ALF of 100%. This metric is an approximation of a much more complex process that involves individual decision-making about what level of flooding would trigger decisions to relocate—while others are studying these triggers, a more detailed analysis is outside of the scope of this plan. It also does not consider population growth for future time horizons or that some coastal residential buildings are secondary homes or vacation rental properties.

Average Annualized Population Flooded – When summarizing population exposure to a geography of interest, the ALF at a residential structure was used as a weight applied to each resident. Mathematically, this is the same as taking the average ALF across all residents and multiplying it by the number of residents. The resultant value is the average annualized number

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of people experiencing flooding, or the statistically expected number of people whose homes are flooded in a given year.

3.2.2 Depth of Flooding

Flood Depth per Event – The depth of flooding is the difference between water surface elevation and ground elevation at the location of the asset, measured in feet. For linear- or polygon-based assets, this metric focuses on the maximum flood depth experienced across the length or perimeter of the asset during any given flood event and time horizon. First floor height will be added to ground elevation to determine depth in structure for buildings. Flood depth is only calculated for coastal and pluvial flood hazards. When summarizing across a geographic area, counts of assets by bucketed flood depths (e.g., Assets Flooded 0 to 1 ft, Assets Flooded 1to 2 ft, etc.) could be a useful future analysis for certain asset type.

Average Annualized Depth (AAD) – The probability-weighted average of flood depth for a given asset across events is calculated by computing the sum product of the maximum flood depth and probability weights assigned to each modeled flood event within a time horizon. Probability weights for each modeled event AEP is calculated using the following equation:

$$Weight_n = AEP_n – AEP_{n+1}$$

If summarizing AAD to a geography of interest, the resultant value would be the expected cumulative depth of flooding across all assets for a given year. This metric can be challenging to communicate but can help to account for the relative variation in hazard exposure between assets in flood-prone areas.

Percent Damage per Event – The level of damage a building (both structure and contents) is likely to experience can be estimated based on modeled relationships between flood depth and building damage, using best-available information about a building's characteristics. Building damages are calculated using the U.S. Army Corps of Engineers' (USACE) Go-Consequences, a flood loss estimation software written and optimized for use in a cloud computing environment to estimate flood loss over large geographies and/or flood conditions. Go-Consequences calculates structural and contents loss based on building occupancy types and their respective depth-damage functions (DDFs). While selecting the appropriate DDF for loss analysis of each building occupancy type can be informed by various factors, it is largely informed by expert judgment.

Building DDFs relate the flood depth above the first floor of a building to structural and contents damages and expected economic loss. The relationship between flood depth and damage is dependent on several factors, particularly the building use or functionality (occupancy) and the building design (foundation type, number of stories, height of first floor above ground). Often, building design is inferred by occupancy type and no other information is needed to assign a DDF. However, in single and multi-family residential buildings, which represent a large variety of building designs in a variety of environments, other building attributes can be incorporated into the DDF assignment process to provide a DDF better tailored to building design.

The USACE and FEMA have developed a wide variety of DDFs for different building types, different geographic regions, and different types of flood hazards (freshwater, saltwater, waves,

etc.). The USACE Go-Consequences software provides a default suite of DDFs sourced from the USACE Galveston DDF library for all Hazus occupancy types. The library provides multiple possible curves for a given occupancy, in such cases, the software adopts the average of the curves. Where multiple curves are not assigned, the library provides a single curve for a given occupancy, and the software adopts the curve. The following describes the DDFs used for each structure type.

- **Single Family Structures** – FEMA has recently developed an improved suite of DDFs as part of ongoing research and development for Coastal Probabilistic Flood Risk Assessment (CPFRA). Following the methodology employed in Phase I, the FEMA CPFRA curves will be applied again in Phase 2.
- **Mobile Homes and Multi-Family Residential Structures –** The Go-Consequences software default DDFs are used for both inland (including pluvial) conditions and coastal conditions when breaking wave conditions are less than 1.5 feet. However, when breaking wave conditions exceed 1.5 feet (i.e., the area of moderate wave action, or coastal high hazard zone, as defined by FEMA), the FEMA Benefit Cost Analysis Re-engineering (BCAR) DDF library is used, which appropriately considers the enhanced damage effects caused by large waves.
- **All Other Building Occupancy Classes –** Default DDFs in Go-Consequences were used for buildings with occupancy classes other than single family, mobile homes, and multi-family residential for both inland and coastal conditions. These pre-selected DDFs were reviewed by a subject matter expert in loss analysis and post-disaster damage assessments and were deemed appropriate for use in coastal Virginia. It should be noted that the USACE is currently applying Go-Consequences with an adaptation of the DDF library developed by FEMA for coastal damages across the southeastern coast as part of the South Atlantic Coastal Study (SACS) (Will Lehman, USACE, per comm.). Go-Consequences provided multiple DDFs for all structure types, as noted in Table 5, except for *Group Housing*, *Nursing Homes*, *Banks*, *Hospitals*, *Parking Garages*, *Industrial High Technology Factories*, *Churches/Non-profit*, and *College/University* occupancy types.

For *Single Family*, *Mobile Homes*, and *Multi-Family* residential structures occupancy types, additional DDF libraries provide a more nuanced view of the relationship between flood depth and damage based on details of building design and specific hazard conditions not considered by the Go-Consequences default DDF library.

This graduated approach is especially applicable to the CRMP. It better reflects changing risk and loss to residential structures as SLR increases flood depths and allows for greater wave heights and increased inland propagation of wave action. Used as a package, these DDFs represent a range of similar building designs and hazard variables for single-family homes and are deemed suitable by FEMA for planning purposes. Despite their developmental status, these DDFs are derived from existing data and are considered the best available product for single-family coastal buildings. The Go-Consequences code was modified to assign the correct DDF to each building for each hazard type (inland and coastal), and for each flood level, based on building attributes such as the number of stories and foundation type, as well as breaking wave height. Damages to building contents are determined using a separate set of *Contents* DDFs that are paired with the building DDFs.

Flood damages for an individual building are calculated for each event AEP, based on the event's associated flood hazard type, flood depth and possible wave height, and structure attributes. For each event, the *Total Flood Depth* and, in coastal conditions, *Wave Height Above Stillwater Elevation (SWEL)* is extracted at each building. In riverine or pluvial conditions, wave height is set to 0, while in coastal conditions, each *Wave Height Above SWEL* is translated into a *Breaking Wave Height* as,

Breaking Wave Height = Wave Height Above SWEL / 0.7,

and each *Total Flood Depth* is translated to *Depths Above First Floor* by subtracting the building's *First Floor Height* from each *Total Flood Depth* as,

Depth Above First Floor = Total Flood Depth – First Floor Height.

For each different hazard, every building is assigned a *Building* and *Contents* DDF based on the building occupancy or other building attributes, including *Breaking Wave Height* in applicable coastal situations. Each building will then have event-specific *Breaking Wave Heights*, *Depths Above First Floor*, and DDFs corresponding to the AEP hazards. The Go-Consequences software will then relate each *Depth Above First Floor* to a *Building Percent Damage* using the defined DDF to provide event-specific damage calculations for each building. Estimated damages to a building's structure and contents are calculated separately but can be combined for simplicity in presentation.

Losses per Event – Monetary loss for both building and contents are calculated for each hazard and building as:

$$Buildings\ Loss_{hazard} = building\ damage_{hazard} * building\ replacement\ value, \text{ and}$$

$$Contents\ Loss_{hazard} = contents\ damage_{hazard} * contents\ value.$$

Total Loss is the sum of building and contents losses for each event and building,

$$Total\ Loss_{hazard} = Buildings\ Loss_{hazard} + Contents\ Loss_{hazard}.$$

Building replacement value is calculated a factor of building square footage. Table 5 details how occupancy types are aligned with values and DDFs.

Other, indirect losses can be incurred from the displacement of people from the structures and broader economic impacts of the damage and disruption but those are not captured in this effort.

Table 5. Structure occupancy type and cost classifications from FEMA/Hazus used for coastal damage calculations.

Occupancy	Cost/ft^2	Description	Multiple or single DDFs provided by go-consequences	DDF used by CRMP
Res 1- Stories 1	150.09	Single-Family Dwelling	Multiple	FEMA

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RES 1- STORIES 2	156.24			CPFRA
RES 1- STORIES 3	160.53			
RES 1- STORIES 4	145.42			
RES2	52.39	Mobile Home	Multiple	Default when breaking wave < 1.5 feet FEMA BCAR when breaking wave > 1.5 feet
RES3A	141.95	Multi-Family Dwelling - Duplex	Multiple	
RES3B	124.79	Multi-Family Dwelling - 3 to 4 Units	Multiple	
RES3C	224.08	Multi-Family Dwelling - 5 to 9 Units	Multiple	
RES3D	210.75	Multi-Family Dwelling - 10 to 19 Units	Multiple	
RES3E	230.45	Multi-Family Dwelling - 20 to 49 Units	Multiple	
RES3F	217.03	Multi-Family Dwelling > 50+ Units	Multiple	
COM1	136.83	Retail Trade	Multiple	Default
COM2	132.88	Wholesale Trade	Multiple	
COM3	161.37	Personal and Repairs Services	Multiple	
COM4	218.79	Business/Professional/Technical Services	Multiple	
COM5	317.05	Depository Institutions	Single	
COM6	419.08	Hospital	Single	
COM7	301.27	Medical Office/Clinic	Multiple	
COM8	279.64	Entertainment & Recreation	Multiple	
COM9	209.73	Theaters	Multiple	
COM10	95.15	Parking Garages (Not Parking Lots)	Single	
IND1	162.76	Heavy Industrial	Multiple	
IND2	132.88	Light Industrial	Multiple	
IND3	258.12	Food/Drugs/Chemicals	Multiple	
IND4	258.12	Metal/Minerals Processing	Multiple	
IND5	258.12	High Technology	Single	
IND6	132.88	Construction (Facilities and Offices)	Multiple	
RES4	236.49	Temporary Lodging	Multiple	
RES5	254.52	Institutional Dormitory	Single	
RES6	258.46	Nursing Home	Single	
AGR1	132.88	Agriculture	Multiple	
REL1	223.92	Church/Membership Organizations	Single	
GOV1	171.68	Government, General Services	Multiple	
GOV2	291.91	Government, Emergency Response	Multiple	
EDU1	217.09	K-12 Schools/Libraries	Multiple	

EDU2	241.74	Colleges/Universities	Single	

Average Annualized Loss (AAL) – AAL is a risk metric that captures the expected flood loss for any given year over a broad period of time, based on an individual structure's exposure to a range of flood elevations and their associated annual probabilities. AAL is a flood loss industry standard for evaluating flood risk, employed by FEMA, USACE, and the flood insurance industry, among others. AAL is expressed in dollars and can be particularly helpful for comparing the costs and benefits of risk mitigation actions.

After losses are calculated for each hazard, the building AAL can be calculated following the Hazus-MH method. The hazard frequencies are paired with the consequent building losses sorted by frequency (ascending) to determine AAL.

From each sorted pair, *i*, the structure's AAL is calculated as,

$$AAL = \sum_{i=1}^{n-1}\left((F_i - F_{i+1}) * \frac{(L_i + L_{i+1})}{2}\right) + (F_n * L_n)$$

where **n**=number of Hazards, **Fi** = i^{th} Frequency, and **Li** = i^{th} Loss.

Average Annualized Percent Damage – When aggregating across event conditions within a given time horizon, event-specific percent damages will be translated into *Average Annualized Percent Damages*. This metric represents the probability-weighted average across event-specific building damages (structure and content) across all events within a given time horizon. This can be derived by applying the probability weighting function (described above) to event-specific damages, similar to the AAD or AAL calculations. It is also the same as dividing a building's AAL by its value (or total AAL in a geography of interest by the total value of buildings exposed) in order to get a normalized perception of vulnerability and risk that is based on structure values. Using damages (rather than losses) to visualize or evaluate flood risks can help to serve equity objectives and counteract the tendency to see higher-value buildings as presenting greater risk than lower-value buildings.

3.2.3 Extent of Flooding

Length Flooded per Event – For linear assets, the extent of their exposure is calculated as the length in linear feet that intersect with the floodplain extents for each event condition. For fluvial (riverine) flood hazards, length exposed will be calculated only to the present-day 1% AEP.

Percent of Length Flooded per Event – Length in feet of flood exposure will be translated into a percent value based on the total length of the asset, to convey the portion of the asset that intersects with a given floodplain for any given event frequency.

Average Annualized Length Flooded – The probability-weighted average of linear flood extents per asset feature across events is calculated by computing the sum product of flooded lengths and probability weights assigned to each modeled flood event within a time horizon.

This leverages the probability weight function described above and resultants in the statistically expected cumulative extent of flooding across all assets for a given year.

Area Flooded per Event – For assets that cover a significant amount of land area (i.e., a raster or non-building polygon), exposure is calculated as the area that intersects with the floodplain extents for each event condition. To account for area-based assets that cross over bodies of water, all flood inundation is considered relative to a 2020 MHW baseline.

For fluvial (riverine) flood hazard, flood exposure to the present-day 1% AEP event is calculated as the area that intersects with the SFHA boundary.

Percent of Area Flooded per Event – Area in acres of flood exposure will be translated into a percent value based on the total area of the asset, to convey the portion of the asset that intersects with a given floodplain for any given event frequency. Percent values will also be calculated within a geography of interest, based on the total area exposure of a certain asset type.

Average Annualized Land Flooded – The probability-weighted average of area-based flood extents per asset feature across events is calculated by computing the sum product of flooded acres and probability weights assigned to each modeled flood event within a time horizon. This leverages the probability weight function described above and resultants in the statistically expected cumulative extent of flooding across all assets for a given year.

Land Lost – For this assessment, the land is considered fully inundated and therefore effectively "lost" if it falls within the MHW floodplain. As sea levels rise, the MHW floodplains expand and areas newly covered by this tidal condition will be considered lost to permanent daily inundation. Change in land area, calculated in acres, is found by subtracting the non-inundated land area associated with a given time horizon from the baseline condition land area (landward of 2020 MHW) in the geography of interest. Because tidal inundation is specific to coastal flooding, this metric is only calculated for coastal flood hazard.

Changes in Natural Infrastructure Flood Exposure – The natural infrastructure analysis will enhance the framework from Phase 1 by incorporating new data sources and new metrics of natural infrastructure vulnerability and risk. Similar to the analytic approach for calculating loss of land, change in natural infrastructure flood exposure is a threshold-based metric calculated only for coastal flood hazard. While MHW is used as the threshold for loss of land, MLW is used as the loss threshold for the natural infrastructure asset types shown in Table 6. By using the MLW threshold, it is assumed natural infrastructure is lost through conversion to open water. The MHW threshold is not used to define natural infrastructure loss to reflect natural coastal assets' tolerance for periodic tidal inundation.

As noted in Section 2.3.4 Extent of Flooding, for non-raster data, metrics will be calculated at the level of individual assets (features) with the exception of select natural infrastructure polygon layers where individual assets are overlapping. Conservation Land metrics will be calculated at the individual asset level given the unique names of conserved lands. The Virginia Institute of Marine Sciences Natural and Nature-Based Feature (NNBF) data and the Agricultural and Forested Conservation Priority Area polygons will be dissolved by natural feature type. Given

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the highly fragmented nature of these polygon features, this will support a streamlined analysis while allowing for total area summaries by NNBF type to be produced for geographies of interest (i.e. acres of beach exposed to future MLW within a given watershed). For natural infrastructure layers that do not contain attributes for specific natural feature types, all polygons will be dissolved to represent generalized areas. This includes the Predicted Suitable Habitat for Sensitive Species, Natural Habitat and Ecosystem Diversity Conservation Priority Areas, and Protected Landscapes Resilience Conservation Priority Areas data. Summaries of area flood exposure will be produced for geographies of interest (i.e. acres of predicted suitable habitat for sensitive species exposed to future MLW within a given watershed).

Table 6. Natural infrastructure assets and supporting data sources.

Natural Infrastructure Assets	Data Source
Beaches, Breakwater, Dune, Emergent Wetland, Forested Wetland, Marsh Sill, Oyster Sill, Scrub-Shrub, Scrub-Shrub Wetland, Tidal Marsh, and Wooded	Virginia Institute of Marine Sciences NNBF
Land Use/Land Cover (upland forest, scrub-shrub, non-tidal wetlands, cropland, etc.)	Chesapeake Conservancy Land Use/Land Cover Data
Tidal wetlands*	NOAA Marsh Migration Model
Conservation Lands	DCR
Predicted Suitable Habitat for Sensitive Species	DCR
Natural Habitat and Ecosystem Diversity Conservation Priority Areas	ConserveVirginia
Protected Landscapes Resilience Conservation Priority Areas	ConserveVirginia
Agricultural and Forested Conservation Priority Areas	ConserveVirginia

*Changes in tidal wetland area will be calculated using the NOAA Marsh Migration model thresholds.

As sea levels rise relative to the landscape, today's upland areas will become more frequently inundated. These areas will be subject to changing environmental conditions associated with this tidal inundation, resulting in alterations to asset characteristics as natural ecosystems respond. For example, this changes in natural infrastructure flood exposure metric may be useful for anticipating locations of potential species or crop loss due to saltwater intrusion. The acreage of natural infrastructure within different flood exposure zones will be calculated under present and future conditions. The flood exposure zones represent areas that are projected to be lost to flooding (MLW) or experience daily (MHW) to periodic (1.5xMTR) flood exposure. The boundary of 1.5xMTR was selected for alignment with Virginia's legal boundaries for the extent of tidal wetlands, which is defined as those areas between MLW and 1.5xMTR. These discrete calculations, as shown in Table 7, will allow for different combinations of flood exposure to be assessed based on the threshold and relative baseline of interest. In the context of Table 7, upland refers to area landward of the MLW to 1.5xMTR flood extent. For example, the following calculations could be completed for natural infrastructure:

- Total area of natural infrastructure lost to future MLW
- Total area of natural infrastructure exposed to future MHW
- Total area of natural infrastructure exposed to future 1.5xMTR

Table 7. Exposure zone conversion calculations for natural infrastructure analysis

Exposure Zones	Exposure Zone Conversion Calculations
Exposed to future MLW	Current MLW area exposed to future MLW
	Current MHW area exposed to future MLW
	Current 1.5xMTR area exposed to future MLW
	Current upland area exposed to future MLW
Exposed to future MHW	Current MHW area exposed to future MHW
	Current 1.5xMTR area exposed to future MHW
	Current upland area exposed to future MHW
Exposed to future 1.5xMTR	Current 1.5xMTR area exposed to future 1.5xMTR
	Current upland area exposed to future 1.5xMTR
Not exposed to future MLW, MHW, or 1.5xMTR	Current upland area remaining as upland

It is important to note that tidal wetlands are not included in the changes in natural infrastructure flood exposure metric due to complex factors, including coastal geomorphology and development pressures. The following section describes the approach used to calculate changes in tidal wetland area.

Tidal Wetland Area Lost – Changes in tidal wetland area will be calculated using National Oceanic and Atmospheric Administration (NOAA) Marsh Migration data created in 2016. NOAA's marsh migration mapping was selected because it was the only readily available statewide coverage of a coastal land cover change model that aligned with the CRMP SLR scenarios. This data source was also used to calculate loss of tidal wetland habitat in Phase 1. The NOAA analysis classifies wetlands based on NOAA's Coastal Change Analysis Program (C-CAP), which provides inventories of coastal intertidal areas, wetlands, and adjacent uplands. The NOAA marsh migration analysis land cover classes have a 10-meter resolution and are based on the C-CAP data that reflects conditions mapped in the 2005 to 2006 timeframe. While NOAA is currently phasing in the next generation of high-resolution land cover data for the nation's coastal areas at 1-meter resolution, the initial next generation NOAA C-CAP Phase 1 data products will only include impervious, canopy, and water classifications, and will not provide sufficient details for a tidal wetland acreage loss analysis.

The NOAA methodology assumes that specific wetland types exist within an established tidal elevation range based on an accepted understanding of what types of vegetation can exist given varying frequency and time of inundation, as well as salinity impacts from such inundation (NOAA Office for Coastal Management 2017). The NOAA methodology assumes areas between Mean Tide Level and MHW as suitable for salt marsh, and areas between MHW and mean high water spring (MHWS) tide as suitable for brackish/transitional marsh. MHWS represents an upward shift in the MHW based on the highest tide levels in the spring. The marsh mapping results are available in half-foot increments of net sea level change from 0 to 10 feet. To calculate changes in tidal wetland area, representative water levels that align with the 0.5-foot increment data from NOAA must be selected. As shown in Table 8, water values can be selected for alignment with the CRMP scenario water level ranges.

Table 8. CRMP scenario alignment with NOAA marsh migration mapping outputs

Year	CRMP Scenario Ranges (ft)	Nearest 0.5-foot Increment from NOAA (ft)
2040	1.6 to 1.8	1.5
2060	2.8 to 3.0	3.0
2080	4.4 to 4.8	4.5

In addition to marsh migration landward, marshes also can experience vertical accretion through the buildup of organic and inorganic matter. While the NOAA Marsh Migration data is relatable to different water levels based on specific marsh accretion rates, marsh accretion is not directly included in the marsh model response. Accretion rate data is limited and highly variable between marshes in coastal Virginia, presenting challenges in selecting a single marsh accretion rate value for the coastal zone. Therefore, marsh accretion is not included in the marsh migration analysis. It is important to note this may result in an overestimation of marsh loss given that some marshes may persist longer.

To calculate tidal wetland area lost, current marsh extent will be compared with future open water conditions and the area of existing marsh converted to open water will be calculated. For example, an area designated as salt marsh under present day conditions that is represented as open water under 1.5ft sea level rise conditions would be considered tidal wetland area lost.

Tidal Wetland Area Gained – Tidal wetland area gained will be calculated as the projected acreage of tidal wetland under future conditions that is outside of the extent of current tidal wetlands. For example, an area designated as upland under present day conditions that is represented as saltwater marsh under 1.5ft sea level rise conditions would be considered wetland area gained.

Total Change in Tidal Wetland Area – The total change in tidal wetland area will use the tidal wetland area gained and tidal wetland are lost calculations above as follows:

Total Change in Tidal Wetland Acreage = Total Tidal Wetland Area Gained - Total Acres of Tidal Wetland Lost.

Annualized Value of Natural Infrastructure Exposed to Flooding – The benefits provided by natural infrastructure, known as ecosystem services, can be appraised in dollars and used to translate potential loss into risk values for communication and comparison. Current FEMA Benefit-Cost Analysis (BCA) Guidance provides FEMA ecosystem services values, as shown in Table 9.

Table 9. FEMA BCA Guidance ecosystem service values

2022 Proposed Values	
LAND COVER CATEGORY	**VALUE (2021 USD/ACRE/YEAR)**
FOREST	**12,589**

Urban Green Open Space	15,541
Rural Green Open Space	10,632
Riparian	37,199
Coastal Wetland	8,955
Inland Wetland	8,171
Coral Reefs	7,120
Shellfish Reefs	2,757
Beaches and Dunes	300,649

To determine the value of ecosystem services, the natural infrastructure data sources to be used in the CRMP Phase 2 analysis were cross-walked with the 2022 proposed FEMA BCA guidance ecosystem service categories, as shown in Table 10, Table 11, and Table 12. The value calculations will be based on the area calculations derived from the changes in natural infrastructure metric. Natural infrastructure features exposed to MLW will be considered areas where ecosystem services are lost. Natural infrastructure features within other exposure zones landward of MLW will be considered areas where ecosystem services could be threatened by daily or periodic tidal flooding. Natural infrastructure areas in the selected exposure zones will be multiplied by the FEMA BCA ecosystem service value to estimate the annualized value of ecosystem services. The Conservation Lands, Predicted Suitable Habitat for Sensitive Species, Natural Habitat and Ecosystem Diversity, and Protected Landscapes datasets are not included in the annualized value of natural infrastructure exposed to flooding analysis because there are no natural feature assets within these datasets that can be directly aligned with FEMA BCA ecosystem service classifications.

The Chesapeake Conservancy land use/land cover data will be used for the forest, urban green open space, rural green open space, and inland wetland categorizations, as shown in Table 10. *Forest* and *Tree Canopy, Other,* can all be cross-walked to *Forest* from the BCA guidance. While *Tree Canopy over Impervious* are at times on the outer rims of forest tree canopies, there is mostly overlap with impervious surfaces themselves. Therefore, they are excluded from this analysis as they would capture impervious surfaces. *Harvested Forest, Cropland, and Pasture/Hay* can be classified as *Rural Green Open Space*. *Natural Succession* can be classified as *Forest, Rural or Urban Green Open Space.* To distinguish the *Forest* classification, the detailed land use classification of *Natural Succession Scrub/Shrub* can be used. The detailed land use classification of *Natural Succession Herbaceous* aligns with *Rural or Urban Green Open Space*. The FEMA BCA Guidance defines urban based on the criteria specified in the U.S. Census Bureau's 2010 Census Urban and Rural Classification and Urban Area Criteria. The Census criteria for defining Urban Areas was updated as part of the 2020 Census data, and therefore the 2020 Census Urban Areas data will be used to distinguish areas as rural or urban for corresponding classification as *Rural or Urban Green Space. Turf Grass* can also be classified as *Rural or Urban Green Open Space* and will use the 2020 Census Urban Area data to distinguish between rural or urban areas. *Pervious Developed, Other* and *Extractive* contain non-natural infrastructure and will not be used. *Impervious Structures*, *Impervious Roads*, and *Other Impervious*, are not natural infrastructure and will not be used. (Chesapeake Conservancy 2022)

The Virginia Institute of Marine Science (VIMS) NNBF data is better suited for beach and dune analysis given there is not a direct land use/land cover category that correlates with this natural infrastructure type. Within the VIMS NNBF dataset, *Beach* and *Dune* are separated into two different categories that can be combined to crosswalk with the *Beaches and Dunes* BCA classification.

Table 10. Alignment of Chesapeake Conservancy land use/land cover classification with FEMA BCA ecosystem services classification

Chesapeake Conservancy Land Use/ Land Cover Classification	BCA Ecosystem Services Classification	Value (USD/acre/year)
Water	n/a	n/a
Wetlands, Tidal Marsh Non-forested	n/a*	$8,955/acre/year
Wetlands, Riverine Non-forested	Inland Wetland	$8,171/acre/year
Wetlands, Terrene Non-forested	Inland Wetland	$8,171/acre/year
Forest	Forest	$12,589/acre/year
Tree Canopy, Other	Forest	$12,589/acre/year
Tree Canopy, Over Turf Grass	Forest	$12,589/acre/year
Turf Grass	Rural Green Open Space	$10,632/acre/year
	Urban Green Open Space	$15,541/acre/year
Harvested Forest	Rural Green Open Space	$10,632/acre/year
Natural Succession Herbaceous	Rural Green Open Space	$10,632/acre/year
	Urban Green Open Space	$15,541/acre/year
Natural Succession Scrub/Shrub	Forest	$12,589/acre/year
Cropland	Rural Green Open Space	$10,632/acre/year
Pasture/Hay	Rural Green Open Space	$10,632/acre/year
Extractive	n/a	n/a
Pervious Developed, Other	n/a	n/a
Tree Canopy over Impervious	n/a	n/a
Impervious Structures	n/a	n/a
Impervious Roads	n/a	n/a
Impervious, Other	n/a	n/a

**In the Chesapeake Conservancy Land Use/Land Cover Data, Wetlands, Tidal Marsh Non-forested covers tidal wetlands. The NOAA Marsh Migration data will be used for coastal wetland classification.*

The changes in tidal wetland area calculated based on the NOAA Marsh Migration data will be used to estimate the value ecosystem services for tidal wetlands. The values representing tidal wetlands from the NOAA Marsh Migration Classification can be cross-walked with the BCA

ecosystem service classification values as shown in Table 11. The area of tidal wetland lost will be used to calculate the potential loss of ecosystem services, while the area of tidal wetland gained will be used to calculate the value of the ecosystem services of new marsh. The total change in tidal wetland area will be used to assess changes in the total value of tidal wetland ecosystem services between different sea level rise scenarios.

Table 11. Alignment of NOAA marsh migration classification with FEMA BCA ecosystem services classification

NOAA Marsh Migration Classification	BCA Ecosystem Services Classification	Value (USD/acre/year)
Salt Marsh	Coastal Wetland	$8,955/acre/year
Brackish/Transitional Marsh	Coastal Wetland	$8,955/acre/year
Open Water	n/a	n/a

The ConserveVA datasets include only high priority unprotected lands. While natural infrastructure classifications in the Agriculture and Forestry ConserveVA data layer can be cross walked with the FEMA BCA ecosystem service categories, it is important to note that the resulting values will be presented as value of high priority unprotected lands, rather than as a complete representation of these natural infrastructure categories. These values will be provided in addition to the ecosystem services values calculated based on the land cover, beaches and dunes, and tidal wetlands.

In the ConserveVA datasets, *Agriculture and Forestry* is broken down into two classifications as shown in Table 12. *Forest* can be easily cross-walked to the BCA classification of *Forest*. *Agriculture* is, for the most part, open space in rural areas, and can be cross-walked to *Rural Green Open Space*. The Natural Habitat and Ecosystem Diversity dataset and Protected Landscape Resilience dataset cannot be directly used for this analysis as there are no natural feature classification within the dataset.

Table 12. Alignment of ConserveVA classifications with FEMA BCA ecosystem services classification.

ConserveVA Classification	BCA Ecosystem Services Classification	Value (USD/acre/year)
Agriculture and Forestry: Forest	Forest	$12,589/acre/year
Agriculture and Forestry: Agriculture	Rural Green Open Space	$10,632/acre/year
Natural Habitat and Ecosystem Diversity	n/a	n/a
Protected Landscapes Resilience	n/a	n/a

3.3 Integrating Contextual Data

To complement asset data and metrics, contextual datasets will be integrated into the database alongside asset information and summarized across geographic areas of interest (reference grid cells, census block groups, and HUC12s). Contextual data is all data that does not describe

discrete assets of value (such as complementary modeled indices), even if the subject of the dataset it aligns with a specific asset-based theme.

In Phase 1 this focused on social vulnerability and community capacity. In Phase 2, demographic data relating to social vulnerability will be pulled directly from ACS using Census's API (described in Section 3.1.5), but in order to ensure alignment with CFPF and other statewide efforts, the social vulnerability theme scores from DCR's Virginia Social Vulnerability Block Groups 2020 (Virginia DCR 2023) will be leveraged directly for this effort, rather re-calculating these values independently as done in Phase 1. The demographic estimates and block group social vulnerability scores will be attributed to residential footprints for summarization across different geographies of interest as described in 3.1.5.

In Phase 2, the suite of contextual datasets integrated into the database and analysis will expand and include Conservation Vision's watershed impact model, development vulnerability model, and recreational access needs model. These indices cover the entirety of the study area, and the average value will be applied to each geographic area of interest used to summarize asset-specific impacts (as described in Section 3.4.2). This data can then used for multi-variant analyses and visualizations within geographic areas of interest. For example, in Phase 1, a combined view of social vulnerability and Average Annualized Land Inundated for each populated reference grid cell was presented using bi-variant mapping (using a two dimensional axis) to highlight areas with both high social vulnerability and high flood exposure.

3.4 Structure of Results

Data ingested and produced will be stored in multiple sets of tables outlined in this section and illustrated in **Error! Reference source not found.**. Tables pertaining to the same asset or geography will be linkable through unique identifiers.

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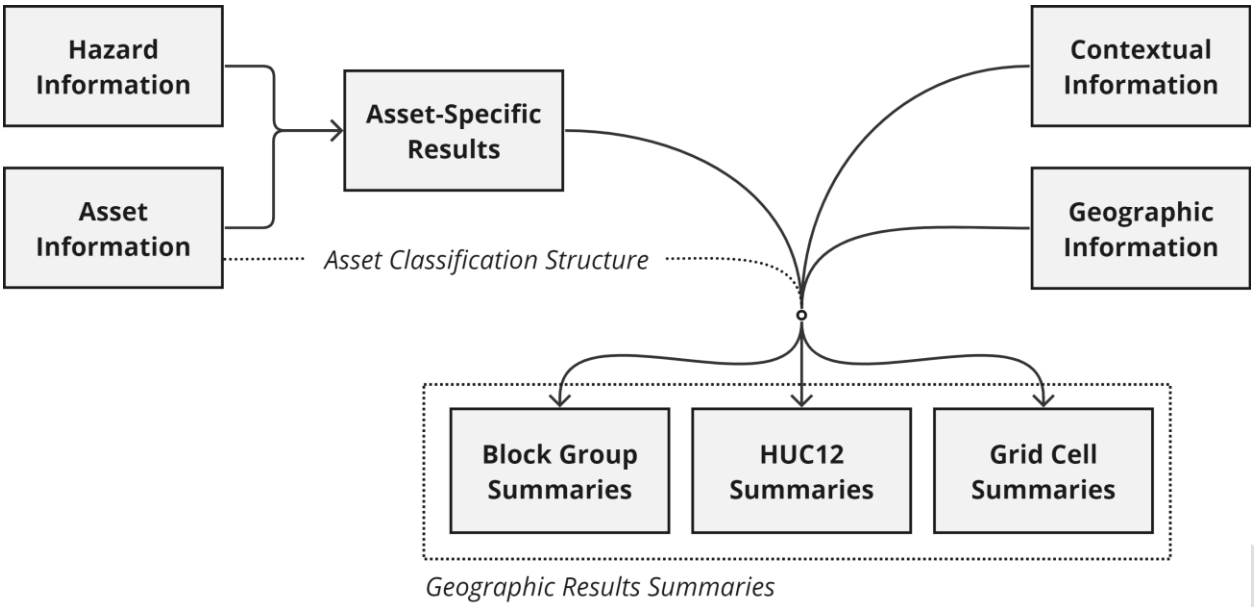
Figure 7. Simplified representation of the types of tables stored in the CRMP database and how they connect.



3.4.1 Asset Tables

As described in the calculation processes of Section 3.2, hazard and asset information are leveraged for asset-specific impact metrics, which will be stored in a set of asset-level impact results tables organized by asset and analysis type. There will also be linkable asset detail tables with contextual information related to asset name and type for use in categorization, outlined in Table 13 (these will include all assets, not just ones with flood exposure). Organization structure and key table attributes (i.e., columns) for all produced asset-specific results tables are outlined in Table 14. Same as in Section 2.3, the results tables below indicate metric type as either Event-Specific (ES), Multi-Frequency (MF), or Threshold-Based (TB). Additionally, separate tables will be produced for impacts related to different flood hazards, and which flood hazard type is relevant to each metric is indicated as either Coastal (C), Pluvial (P), and/or Fluvial (F).

Table 13. Organization of asset detail tables and attributes.

Asset Data	Table Attributes/Columns
Building Footprints	Building ID, Source, Occupancy Type, Owner Occupied, Foundation Type, Number of Stories, First Floor Elevation, Square Footage, Year of Construction, Assessed Land Value, Assessed Improvement Value, Building Replacement Value, Content Replacement Value, Lowest Adjacent Grade, Highest Adjacent Grade, Building Area, Population, Demographics, Land Ownership (Tribal and Federal), Grid ID, CBG ID, HUC12 ID
Point Assets	Asset ID, Name, Type, Sub-Type, Source, Source ID, Grid ID, CBG ID, HUC12 ID, Additional Type Field(s)
Area-Based Assets	Asset ID, Name, Type, Sub-Type, Source, Source ID, Area, Ecosystem Service Value, Grid ID, CBG ID, HUC12 ID, Additional Type Field(s)
Linear Assets	Asset ID, Name, Type, Sub-Type, Source, Source ID, Length, Grid ID, CBG ID, HUC12 ID, Additional Type Field(s)

Table 14. Organization of asset-specific impact tables and attributes.

Asset Data	Type	Table Attributes/Columns	C	P	F
Building Footprints	ES	Building ID, Time Horizon, Event AEP, Flood Depth per Event, Structure Percent Damage per Event, Content Percent Damage per Event, Structure Losses per Event, Content Losses per Event	✓	✓	
	MF	Building ID, Time Horizon, Annual Likelihood of Flood, Content Average Annualized Percent Damage, Structure Average Annualized Percent Damage, Content Average Annualized Loss, Structure Average Annualized Loss	✓	✓	
	ES	Building ID, SFHA Exposure			✓
Point-Based Assets	ES	Asset ID, Time Horizon, Event AEP, Maximum Flood Depth	✓	✓	
	MF	Asset ID, Time Horizon, Annual Likelihood of Flooding, Average Annualized Depth	✓	✓	
	ES	Asset ID, SFHA Exposure			✓
Linear Assets	ES	Asset ID, Time Horizon, Event AEP, Maximum Flood Depth, Length Flooded per Event, Percent of Length Flooded per Event	✓	✓	
	MF	Asset ID, Time Horizon, Annual Likelihood of Flooding, Average Annualized Length Flooded, Average Annualized Depth	✓	✓	
	ES	Asset ID, SFHA Exposure, Length Flooded per Event, Percent of Length Flooded per Event			✓
Area-Based Assets	ES	Asset ID, Time Horizon, Event AEP, Area Flooded per Event, Percent of Area Flooded per Event	✓	✓	
	MF	Asset ID, Time Horizon, Annual Likelihood of Flooding, Average Annualized Land Flooded	✓	✓	
	TB	Asset ID, Time Horizon, Land Lost, Changes in Natural Infrastructure Flood Exposure*	✓		
	ES	Asset ID, Area in SFHA			✓

**The Changes in Natural Infrastructure Flood Exposure metric will only be calculated on the asset-specific scale for Conserved Lands.*

Raster data, such as land cover data, describes the location of critical natural infrastructure and other relevant features but is not classified as discrete assets. The results of raster-based analyses will be presented in the geographic summary tables described below, but not in an asset-specific format.

3.4.2 Geographic Summarization Tables

Asset impact data will also be geographically aggregated across pre-determined geographies of interest to support mapping, comparison, and additional analysis. Impact results data across designated impact types or themes (i.e., all hospitals or commercial structures) will be aggregated and summarized across three main geographic units:

- **Census-designated boundaries** – Census block groups, which can be rolled-up into Census tracts, localities and planning districts.
- **Town boundaries –** Virginia town boundaries, which do not neatly align with census block group boundaries.
- **Watershed Hydrologic Unit Codes (HUCs)** – HUC 12s, which can be rolled-up into HUC 10s and HUC 8s.

- **Reference Grid Cells** – A custom reference grid with a tiling schema of 1,375 ft x 1,375 ft (43.4 acres), which creates a mesh of 290,000 grid cells to cover the study area.[2]

Note some metrics are not suitable for all summarization scales. Historic resources data is sensitive and will not be shown publicly at the reference grid cell or other geography less than ~250 acres. Specific population and demographic estimates are also less likely to be accurate at the sub-block group level.

The varying geographic size of census-based or HUC-based boundaries can make aggregation across those geography types harder for comparison, and so data can be normalized by a consistent total if used for comparison (i.e., divide raw values by land area or asset count, producing metrics like average annualized assets flooded per acre or average annualized percent of assets flooded). Alternatively, the grid cells with a consistent geographic size present a standard unit for accurate cross-jurisdictional analysis and comparison.

There will also be linkable geography detail tables with contextual information related to geography name and basic flood exposure information, outlined in Table 15. Organization structure and key table attributes (i.e., columns) for all produced geographic summary tables are outlined in Table 16. Note that in order to aggregate results across assets, a classification structure will have to be developed to group assets of the same type. Contextual data will also be summarized at each of the geographic units to facilitate integrated application and comparison as described in Section Integrating Contextual Data3.3.

Table 15. Organization of geography of interest detail tables and attributes.

Geography of Interest	Table Attributes/Columns
Reference Grid Cells	Grid ID, Total Area, Land Area, Average Annualized Land Flooded
Census Block Group	CBG ID, Locality, PDC, Area, Total Land Area, Average Annualized Land Flooded
HUC12	HUC12 ID, Total Area, Land Area, Average Annualized Land Flooded
Towns	Town ID, Town Name, Total Area, Land Area, Average Annualized Land Flooded

[2] The flood hazard model has a tiling schema that is 55,000 ft x 55,000 ft, and so the reference grid cells were designed as fractions of those tiles. In the Phase 1 assessment, four alternative reference grid cell sizes were explored but only the 1,375 ft x 1,375 ft one (the smallest option) was found most useful and is therefore the sole focus of Phase 2.

Table 16. Organization of geographic summary impact tables and attributes.

Asset Data	Type	Units	C	P	F
Building Footprints	ES	AOI ID, Building Type, Time Horizon, Event AEP, Structures Flooded per Event, Percent of Structures Flooded per Event, Structure Percent Damage per Event, Content Percent Damage per Event, Structure Losses per Event, Content Losses per Event, Population Exposed per Event, Percent of Population Exposed per Event, Structure Value Exposed per Event, Content Value Exposed per Event	✓	✓	
	MF	AOI ID, Building Type, Time Horizon, Annualized Structures Flooded, Average Annualized Percent Damage, Average Annualized Loss, Average Annualized Population Exposed	✓	✓	
	ES	AOI ID, Building Type, Structures in SFHA			✓
Point-Based Assets	ES	AOI ID, Asset Type, Time Horizon, Event AEP, Assets Flooded per Event,	✓	✓	
	MF	AOI ID, Asset Type, Time Horizon, Annualized Assets Flooded, Average Annualized Depth	✓	✓	
	ES	AOI ID, Asset Type, Assets in SFHA			✓
Linear Assets	ES	AOI ID, Asset Type, Time Horizon, Event AEP, Assets Flooded per Event, Percent of Assets Flooded per Event, Length Flooded per Event, Percent of Length Flooded per Event	✓	✓	
	MF	AOI ID, Asset Type, Time Horizon, Annualized Assets Flooded, Average Annualized Length Flooded, Average Annualized Depth	✓	✓	
	ES	AOI ID, Asset Type, Assets in SFHA, Length in SFHA, Percent of Length in SFHA			✓
Area-Based Assets	ES	AOI ID, Asset Type, Time Horizon, Event AEP, Assets Flooded Per Event, Area Flooded per Event, Percent of Area Flooded per Event	✓	✓	
	MF	AOI ID, Asset Type, Time Horizon, Average Annualized Area Flooded	✓	✓	
	TB	AOI ID, Asset Type, Time Horizon, Land Lost, Changes in Natural Infrastructure Flood Exposure, Tidal Wetland Area Lost, Tidal Wetland Area Gained, Total Change in Tidal Wetland Area, Annualized Value of Natural Infrastructure Exposed to Flooding	✓		
	ES	AOI ID, Asset Type, Assets in SFHA, Area in SFHA, Percent of Area in SFHA			✓

3.5 Quality Control Checks

Results data will be reviewed by various members of the CRMP team and rule-based methods for additional data sorting and cleaning as described in Section 3.1.2 can be applied as needed.

Additionally, produced metrics will be run through a monotonicity check, which is a test to ensure that impact metric values are increasing as hazard conditions increase, both over specific events and time horizons. If any results are found that don't follow this pattern, it is an indication that there is something awry about the hazard data or functions and steps will be taken to correct any errors.

3.6 Aggregation and Scoring Options

Each asset type's impact and context metrics vary in units, scale, and calculation method. To facilitate impact aggregation and comparison across impact types, all aggregated metrics used in the summarization layers can be converted to scores on any scale, such as 0-10. This conversion involves normalizing cumulative impact values for a specific asset type or category

relative to all other geographic areas of interest. These asset-specific impact scores can then be combined to generate impact scores by impact type and theme for use in various applications.

For each unit summarization for scoring (i.e., asset-level, grid cell, census tract, locality, HUC 12), scores would be calculated using the following process:

- **Convert to Impact Type Scores** – Starting with raw asset-level or summarized impact metrics (described above), values can be normalized to a standard range. This redistribution of values leads to a single impact type score for each impact type, regardless of metric units and scale. Normalization of raw values ranging from *Range_min* to *Range_max* can be calculated using the following formula:

  X' = 10 * [(X – Range_min) / (Range_max – Range_min)]

  Ranges should consider raw values across all time horizons. When components have multiple sub-components with scores calculated using different methods (e.g., transportation roadways and facilities), the component score can be calculated through averaging across components.

- **Generate Impact Theme Scores** – Average impact type scores across themes for each geographic unit of interest and time horizon, applying weighting criteria across impact types or components if desired.

- **Calculate Relative Ranking** – The range and distribution of raw scores will vary between categories, which can make it difficult to use raw scores alone for mapping and prioritization. To avoid the undue influence of outliers, raw scores can be converted relative rankings based on a variety of potential methods, including percentile, quintile, and k-means clustering.

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4. Data Catalog

Below is a list of data sources leveraged for this analysis, including their source and date last updated. More details about sources reviewed and assessed are provided separately.

Table 17. List of data sources used in the analysis.

INPUT DATASET	SOURCE	DATE
Assets		
Above Ground LNG Storage Facilities	Homeland Infrastructure Foundation-Level Database (HIFLD), original source unclear	12/15/2022
Airports	United States Department of Transportation, Federal Aviation Administration-Aeronautical Information Services (Accessed via ArcGIS Hub)	11/30/2023
AM Transmissions Towers	Federal Communications Commission Licensing Database (accessed via HIFLD)	5/7/2022
Amtrak Stations	Virginia Department of Rail & Public Transportation (DRPT)	
Bridges & Culverts	Virginia Department of Transportation (VDOT)	1/19/2024
Broadband Radio Service and Educational Broadband Service Transmitters	Federal Communications Commission (accessed via HIFLD)	11/23/2021
Bus Routes	Virginia Department of Rail & Public Transportation (DRPT)	3/1/2024
Bus Stations	Virginia Department of Rail & Public Transportation (DRPT)	3/1/2024
Cellular Towers	Federal Communications Commission (accessed via HIFLD)	6/1/2022
Child Care Facilities	Virginia Department of Social Services (accessed via HIFLD)	12/8/2022
Conservation Lands	Virginia Department of Conservation and Recreation (DCR)	11/1/2023
Conservation Priority Area: Agriculture and Forestry	DCR Agriculture and Forestry (ConserveVA)	11/18/2021
Conservation Priority Area: Natural Habitat and Ecosystem Diversity	Natural Habitat and Ecosystem Diversity Exposure (ConserveVA); Virginia Department of Conservation and Recreation (DCR)	11/18/2021
Conservation Priority Areas: Protected Landscapes Resilience	DCR Protected Landscapes Resilience (ConserveVA)	11/18/2021
Dams	Virginia Department of Conservation and Recreation (DCR)	2/12/2024
Emergency Medical Service Stations	Homeland Infrastructure Foundation-Level Database (HIFLD), original source unclear	6/1/2022
Emergency Operations Centers	Virginia Department of Emergency Management (VDEM)	10/1/2023
EPA Toxic Substance Control Act Facilities	United States Environmental Protection Agency (EPA)	3/11/2024
FDIC Insured Banks	Federal Deposit Insurance Corporation (accessed via HIFLD)	5/17/2022
Federal Real Property Public Dataset	U.S. General Services Administration	10/25/2023

Federally-Owned Land (Chesapeake Bay Program's Federal Facilities Workgroup)	Chesapeake Bay Program's Federal Facilities Workgroup	1/1/2017
Federally-Owned Land (ESRI)	BLM, DoD, USFS, USFWS, NPS, PADUS 2.1 (accessed via ESRI)	7/7/2023
Fire Stations	U.S. Geological Survey, National Geospatial Technical Operations Center (Accessed via HIFLD)	10/22/2023
FM Transmissions Towers	Federal Communications Commission (accessed via HIFLD)	9/18/2018
General Manufacturing Facilities	Industrial PinPointer database of manufacturing companies (accessed via HIFLD)	7/3/2023
Hazardous Waste Generators	U.S. Environmental Protection Agency (EPA) (accessed via VGIN)	11/18/2020
Higher Education Facilities	National Center for Education Statistics (accessed via HIFLD)	12/7/2022
Historic Resources		
Hospitals	Oak Ridge National Laboratory (Accessed via HIFLD)	9/20/2023
Hurricane Evacuation Routes	Virginia Department of Transportation (VDOT)	9/20/2023
Industry-Specific Manufacturing	HIFLD Secure	3/15/2024
Land Cover Data	Chesapeake Conservancy and Virginia State	1/1/2018
Land Mobile Broadcast Towers	Federal Communications Commission (accessed via HIFLD)	9/18/2021
Land Mobile Commercial Transmission Towers	Federal Communications Commission Licensing Database (accessed via HIFLD)	11/23/2021
Land Use Data	Chesapeake Conservancy	1/1/2018
Local Law Enforcement Facilities	Oak Ridge National Laboratory (Accessed via HIFLD)	2/1/2021
Major State Government Buildings	Technigraphics Inc. (accessed via HIFLD)	10/19/2021
Microwave Service Towers	Federal Communications Commission (accessed via HIFLD)	8/23/2022
National Shelter System Facilities	Federal Emergency Management Agency (FEMA) (accessed via HIFLD)	7/3/2023
Natural and Nature-Based Features	Virginia Institute of Marine Science (VIMS)	1/1/2021
Natural Gas Receipt Delivery Points	Oak Ridge National Laboratory (accessed via HIFLD)	12/11/2023
NOAA Marsh Migration		5/30/2023
Paging Transmission Towers	Federal Communications Commission Licensing Database (accessed via HIFLD)	9/18/2021
Petroleum Ports	Federal Communications Commission (accessed via HIFLD)	1/8/2022
Petroleum Registered Tank Facilities	Virginia Department of Environmental Quality (DEQ)	1/9/2024
Petroleum Terminals	Federal Communications Commission (accessed via HIFLD)	4/5/2022
Port of Virginia Facilities	Virginia Economic Development Partnership (VEDP)	10/22/2022
Power Plants	Oak Ridge National Laboratory (accessed via HIFLD)	9/21/2023

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Predicted Suitable Habitat for Sensitive Species	High-resolution Predicted Suitable Habitat Summary (non-public dataset); Virginia Department of Conservation and Recreation (DCR)	12/5/2023
Private Schools	National Center for Education Statistics (accessed via HIFLD)	10/4/2023
Public Refrigerated Warehouses	The International Association of Refrigerated Warehouses (accessed via HIFLD)	7/5/2023
Public Schools	National Center for Education Statistics (accessed via HIFLD)	12/7/2022
Public Water Supply	Virginia Department of Health (VDH)	
Railroad Crossings	Virginia Department of Rail and Public Transportation (DRPT)	5/1/2020
Railways	Virginia Department of Rail & Public Transportation (DRPT)	
Road Intersections	Virginia Department of Transportation (VDOT)	3/22/2023
Roadway Centerlines	Virginia Geographic Information Network (VGIN); Virginia Department of Transportation (VDOT)	1/12/2024
Septic Systems	Virginia Department of Health (VDH)	
Solid Waste Facilities	Virginia Department of Environmental Quality (DEQ)	7/12/2023
State Building Inventory	Virginia Department of General Services (DGS)	
Structures (Lightbox/HIFLD)	Lightbox/HSIN (accessed via HIFLD Secure)	7/15/2023
Structures (Phase I Supplemental)	Composite from CRMP Phase I (Sources including ODU, USACE, HRPDC, OSM, CityGML, and Dewberry)	
Substations	HIFLD Secure	7/20/2023
Supplemental Colleges	National Center for Education Statistics (accessed via HIFLD)	12/7/2022
TV Analog Transmitters	Federal Communications Commission (accessed via HIFLD)	12/16/2021
U.S. Army Corps of Engineers (USACE) Offices	USACE (accessed via HIFLD)	12/18/2023
VDOT Average Daily Traffic (ADT)	Virginia Department of Transportation (VDOT)	2/3/2024
VDOT LRS Map Package	Virginia Department of Transportation (VDOT)	3/11/2024
VGIN Building Footprint Data (Phase I)	Virginia Geographic Information Network	
Wastewater Treatment Facilities	United States Environmental Protection Agency (EPA) (accessed via HIFLD)	4/17/2022
Context		
Development Vulnerability Model	Virginia Department of Conservation and Recreation (DCR)	6/16/2022
Nature Based Recreational Access Model	Virginia Department of Conservation and Recreation (DCR)	7/1/2021
Population Demographics	American Community Survey (ACS), Census Bureau (from 2021 TIGER data)	7/20/2023
Social Vulnerability Index	Virginia Department of Conservation and Recreation (DCR)	10/18/2023
Watershed Impact Model	Virginia Department of Conservation and Recreation (DCR)	6/7/2022
Hazards		
Coastal Flood Events	Dewberry	

Pluvial Flood Events	Dewberry	
Riverine SFHA	Federal Emergency Management Agency (FEMA)	
Geographies		
Census Block Groups	American Community Survey (ACS)	10/12/2021
Census Urban Areas	2020 Census	1/1/2023
HUC12 Boundaries	United States Geological Survey (USGS)	12/27/2023
Reference Grid Cells	Dewberry	
Towns	Virginia Administration Boundaries Workshop community (via VGIN)	1/12/2024

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