SCCRTC CAVA Project Framework

Executive Summary

Introduction

A Climate Adaptation Vulnerability Assessment and Priorities Report (CAVA) is being developed for roads, rail lines, bridges, culverts, and other transportation assets owned by Santa Cruz County and the Santa Cruz County Regional Transportation Commission. The CAVA will assess how climate-related hazards are projected to affect the transportation system and will prioritize assets to identify the order in which they will undergo further actions to enhance resilience.

Driving Factors for the Framework:

- Created to align with best practices and grant funding criteria
- Informed by data availability
- Modified to align with community priorities

The project framework describes the methodology for conducting the CAVA. The goal of the CAVA report is to identify which transportation assets are likely to be most vulnerable to climate change and the priority order in which these assets need to be addressed for either operational or capital improvements to enhance their resilience. This project will not identify preferred resilience solutions, but rather the order in which that work should be completed. A comprehensive and prioritized list of transportation assets requiring further analysis for climate adaptation better positions Santa Cruz County to pursue local, State and Federal climate resiliency funding for climate adaptation measures. It will also support integration into other local planning efforts such as the County's Hazard Mitigation Plan (HMP) and Capital Improvements Plan (CIP).

The project framework was developed based on several driving factors. It was created to align with industry best practices and grant funding criteria for resilience-related transportation projects. It was also informed by data and information availability. Furthermore, it was modified to align with community feedback and priorities.

Hazard and Assets

The CAVA includes the following climate change-intensified natural hazards, selected based on their high potential to negatively impact transportation infrastructure in the County, their links to climate change, and the availability of sufficient data:

- Riverine and other inland flooding (driven by heavy precipitation and, in some cases, wildfire)
- Debris flows (driven by heavy precipitation and post-wildfire burn scar conditions)
- Landslides/slope failures (driven by heavy precipitation)
- Wildfire direct impacts
- High winds
- Coastal flooding (including both storm surge and tidal flooding exacerbated by sea level rise (SLR))
- Coastal erosion (including both cliff retreat and shoreline erosion exacerbated by SLR)

These hazards are expected to be exacerbated by climate change, and this study will incorporate the best available projections of how these hazards change over time into the analysis.

In terms of transportation assets, the focus of the CAVA is the County unincorporated roads and the Santa Cruz Branch Rail Line (SCBRL). The analysis includes the roadways and railways themselves, as well as bridges and culverts along them. These generally correspond to where most of the damage has occurred to transportation systems in the past. The presence of bicycle facilities along County roadways and the presence of existing or planned trails along the Branch Rail Line are also included in the analysis.

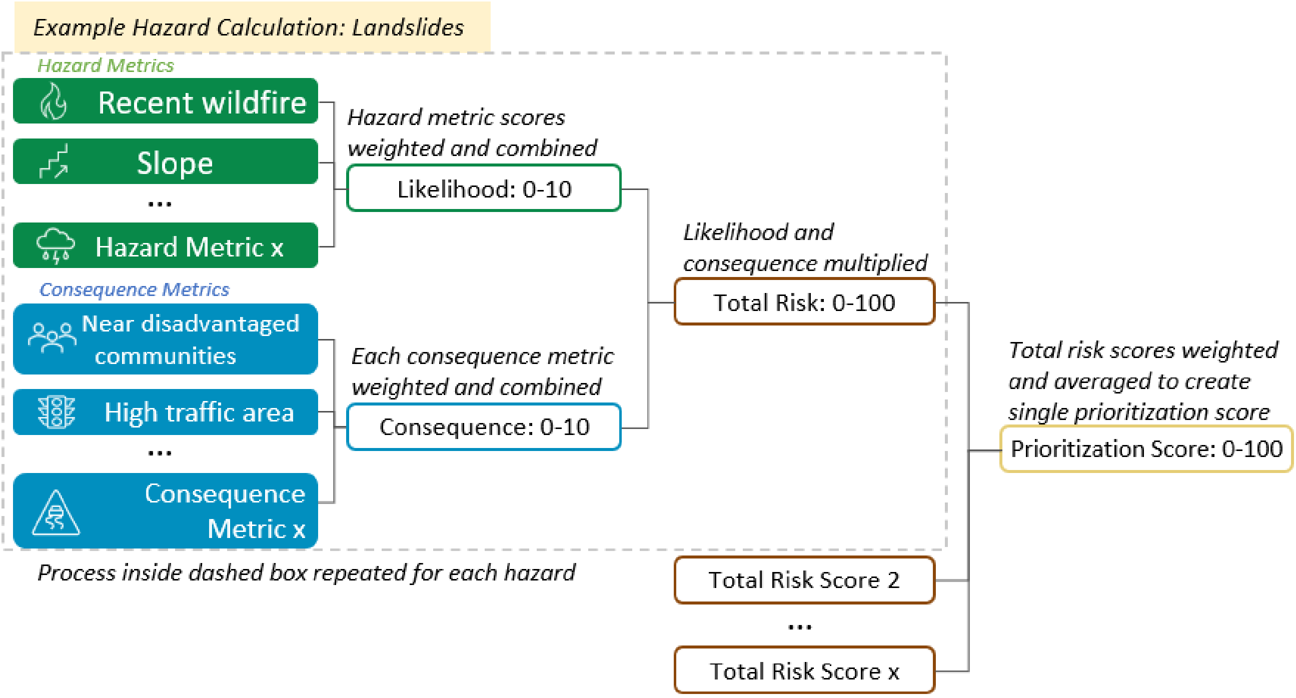
Asset Prioritization

The prioritization process will incorporate data related to hazard likelihood and consequence. For the purposes of the CAVA, hazard *likelihood* is defined as the relative probability of an asset being adversely affected by a hazard, and *consequence* defined as the degree to which an asset is being adversely affected in turn impacts the overall transportation system and its users.

Prioritization scores will be created based on a set of metrics that capture relevant data on hazard likelihood and degree of consequence. The specific metrics to be included are described in more detail in the main body of the report. The prioritization scores are intended to capture relative risk – a function of both likelihood and consequence – posed by the hazards to the different assets.

Figure ES-1 depicts how the prioritization scores are developed from the metrics for each asset for an example hazard. For each hazard, a set of hazard likelihood metrics are placed on scales from 0 to 10 and then weighted and combined into a hazard likelihood score, also ranging from 0 to 10. Similarly, a set of consequence metrics are scaled and weighted together into a consequence score ranging from 0 to 10. The hazard likelihood and consequence scores are multiplied into a hazard risk score ranging from 0 to 100. Hazard risk scores are developed for each hazard. Finally, an asset's hazard risk scores are averaged together to produce a single prioritization score.

Figure ES-1. Process for Assigning Prioritization Scores to an Asset



The results of the scoring will be presented in a series of maps and tables, as well as a written narrative synthesizing results across the different asset classes. The final output will be a clear set of priorities for project-level adaptation analysis, established based on best practices and best available data, and structured in a way that enables priority assets to compete for resilience funding.

Introduction

A Climate Adaptation Vulnerability Assessment and Priorities Report (CAVA) is being developed for unincorporated Santa Cruz County and the Santa Cruz Branch Rail Line (SCBRL). The CAVA will assess how climate-related hazards are projected to affect the transportation system and will prioritize assets for further action to enhance resilience.

Climate Adaptation Framework

The Climate Adaptation Framework for unincorporated Santa Cruz County and the SCBRL follows the Caltrans Adaptation Framework (https://dot.ca.gov/-/media/dot-media/programs/transportation-planning/documents/caltrans-climate-change-adaptation-strategy-report-2020-a11y.pdf).

Step 1 – Understand the Hazards and Impacts and Determine Vulnerability and Prioritization

This step identifies the assets exposed to various climate hazards, the timing of that impact, and the consequences of that impact on the transportation network. Assets are prioritized for more detailed assessments in Step 2. The CAVA project is developing this step of the process.

Step 2 – Identify Actions to Enhance Resiliency

This step will identify what type of improvements are needed to enhance resiliency.

Operational improvements include-

- Assessing strategies for enhancing emergency response capabilities
- Identifying enhancements to operations and maintenance activities

Capital Improvements include undertaking detailed assessments of vulnerable assets to determine the best approach to climate resiliency with consideration for the following approaches - protect, accommodate, or retreat.

Step 3 – Fund and implement Resilience Measures

Once the priority projects are identified and the best climate resilient action is determined, the measure can be implemented.

CAVA and Project Framework

The project framework describes the methodology for conducting the CAVA or Step 1 of the overarching Climate Adaptation Framework. It discusses what hazards will be evaluated and what transportation assets are being considered. The framework describes how these assets will be prioritized based on a set of metrics that assess both how sensitive they may be to damage from climate hazards and how critical they are to the function of the transportation network and the communities they serve.

The goal of the CAVA report is to identify which transportation assets are likely to be most vulnerable to climate change and the priority order in which these assets need to be addressed for either operational or capital improvements to enhance their resilience. A comprehensive and prioritized list of discrete transportation assets better positions Santa Cruz County to pursue local, State and Federal climate resiliency funding for climate adaptation measures.

The project framework was developed based on several driving factors. It was created to align with industry best practices and grant funding criteria for resilience-related transportation projects. It was also informed by data and information availability. Furthermore, it was modified to align with community feedback and priorities.

Hazards

The hazards included in the analyses were selected based on several criteria:

- High potential to negatively impact transportation infrastructure in the County
- Linked to climate change (whether directly or indirectly)
- Sufficient analytical data, from climate models or other sources, that can be used to measure the hazard and its potential for occurrence by location

In no particular order, the hazards that best met these criteria were:

- Riverine and other inland flooding (driven by heavy precipitation and, in some cases, wildfire)
- Debris flows (driven by heavy precipitation and post-wildfire burn scar conditions)
- Landslides/slope failures (driven by heavy precipitation)
- Wildfire direct impacts
- High winds
- Coastal flooding (including both storm surge and tidal flooding exacerbated by sea level rise (SLR))
- Coastal erosion (including both cliff retreat and shoreline erosion exacerbated by SLR)

Therefore, the prioritization process focuses on the above hazards.[1] These hazards are expected to be exacerbated by climate change, and this study will incorporate the best available projections of how these hazards change over time into the analysis.

Other notable hazards include:

- Extreme heat. This may have some impacts to the assets in the study, but likely a lower impact than other hazards. Impacts may be secondary in terms of impacting tree mortality adjacent to the road network that could have impacts later on. Arguably more relevant is its health and comfort impact on transit riders and active transportation users. While extreme heat is included in the hazard mapping, it is not considered in the prioritization.
- Seismic hazards. Seismic hazards, while a serious natural hazard concern that impacts the transportation system, are not climate related and were therefore excluded from the prioritization.

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[1] Note that there is some potential overlap between the different hazard types. For instance, riverine flooding can contain varying degrees of sediment concentration, with heavier concentrations often described as debris flow. Likewise, debris flows can be defined as a fast-moving form of landslide (https://www.usgs.gov/faqs/what-debris-flow#:~:text=Debris%20flows%20are%20fast%2Dmoving,50%20states%20and%20U.S.%20Territories).

Transportation Assets

In terms of transportation assets, the primary focus of the CAVA is the County unincorporated roads and the Santa Cruz Branch Rail Line (SCBRL).

The project framework will be applied to the following asset classes. These asset classes were selected based on (1) having relatively comprehensive representation in GIS format, and (2) having high potential direct impacts from climate hazards. The asset classes are:

- County roadway segments (from County's 'County_Maintained_Roads' GIS feature class)
- County bridges (from County's 'Bridges' GIS feature class where "STRUCTURE" equals 'Bridge')
- County large culverts (from County's 'Bridges' GIS feature class where "STRUCTURE" equals 'Culvert')
- County small culverts (from County's 'Stormwater_Culverts' GIS feature class)
- Branch Rail Line railway segments (from Regional Transportation Commission's (RTC's) 'Railroads' GIS feature class)
- Branch Rail Line bridges (from RTC's 'Bridges' GIS feature class)
- Branch Rail Line culverts (from RTC's 'Culverts' GIS feature class)

These generally correspond to where most of the damage has occurred to transportation systems in the past.

The presence of bicycle facilities along County roadway segments in addition to the presence of existing or planned trails along the Branch Rail Line are included as metrics in the prioritization, as discussed later in this chapter. Unfortunately, existing pedestrian facilities cannot be considered here as the data is not available in a GIS format.

More information on the units of analysis for the transportation assets can be found in the appendix.

Prioritization Methodology

Overall Structure

The prioritization will consist of metrics related to hazard likelihood and consequence. For the purposes of the CAVA, hazard likelihood is defined as the relative probability of an asset being adversely affected by a hazard, and consequence defined as the degree to which an asset being adversely affected impacts the overall transportation system and its users.

The following table shows the combinations of hazard groups and asset classes included in the prioritization.

Table 1. Asset-Hazard Combinations to be Assessed

	Riverine Flooding	Debris Flow	Landslides	Coastal Flooding	Coastal Erosion	Wildfire Direct Impacts	Wind
Roadway segments	X	X	X	X	X	X	X
Road bridges	X	X	X	X	X		
Road large culverts	X	X	X	X	X		
Road small culverts	X	X	X	X	X		
Railway segments	X	X	X	X	X	X	X
Rail bridges	X	X	X	X	X		
Rail culverts	X	X	X	X	X		

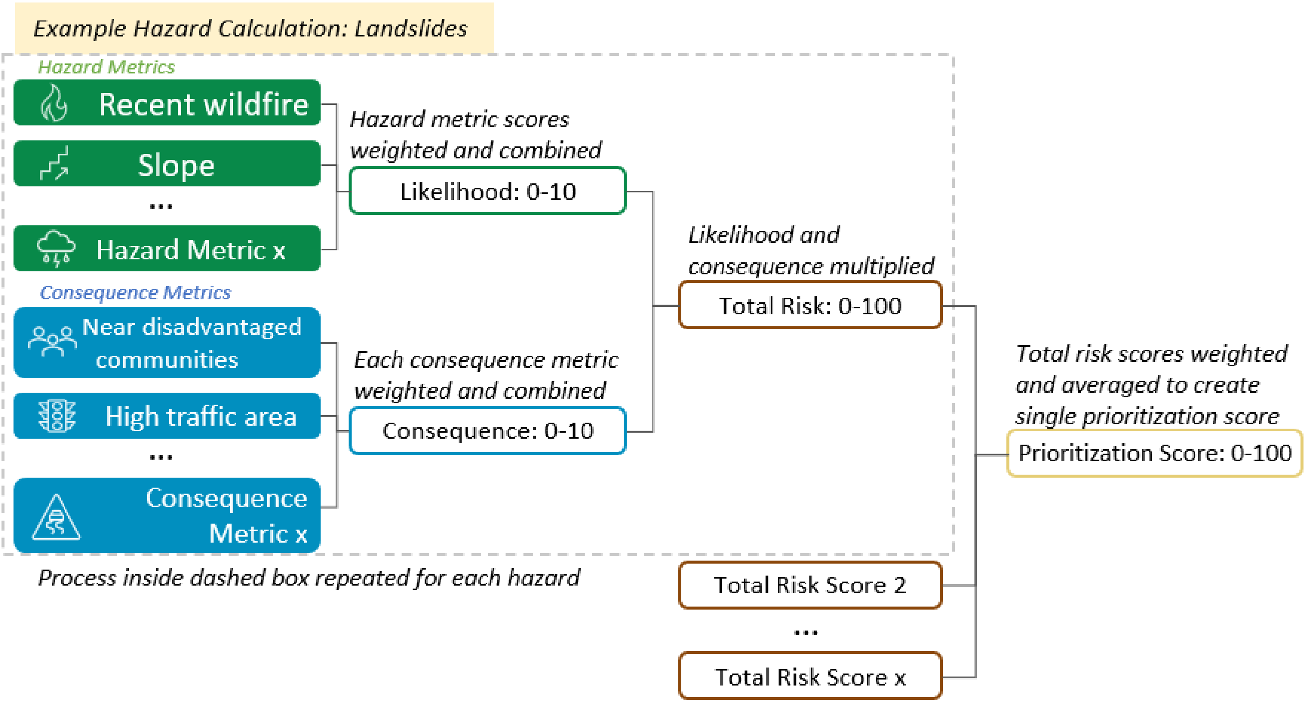
Scoring

Prioritization scores will be organized by asset class and assigned to each asset within each asset class. Each asset's prioritization score will be a composite of the hazard risk scores assigned for each hazard marked with an 'X' in for the relevant row in Table 1. The prioritization scores are intended to capture relative risk – a function of both likelihood and consequence – posed by the hazards to the different assets.

Each hazard risk score will be comprised of two components. One is a hazard likelihood score, which is a composite of an asset's hazard likelihood metrics. The other is a consequence score, which is a composite of an asset's consequence metrics. The consequence scores are consistent across the different hazards.

Each hazard risk score will be a unitless number ranging from 0 to 100, with 0 being relatively low priority and 100 being relatively high priority. Each asset's hazard risk score will be a product of its hazard likelihood score multiplied by its consequence score. Each asset's prioritization score is an average of its hazard risk scores. Figure 1 depicts this process of creating prioritization scores for an asset for an example hazard.

Figure 1. Process for Assigning Prioritization Scores to an Asset



Hazard Likelihood Scores

Each asset's hazard likelihood score will range from 0 to 10, with 0 being least vulnerable and 10 being most vulnerable. These scores will be calculated by scaling each hazard likelihood metric from 0 to 10, weighting each metric by its relative importance to overall hazard likelihood, and adding the weighted scores together.

While

Table 2 describes some of the nuances of the creation of the individual metrics, developing the hazard metrics will typically be done in the following manner. The first step involves obtaining the raw data used to create the metric in a GIS format where it can be mapped and analyzed. For some data sources, particularly those relying on historical climate events such as Cal Fire Fire Hazard Severity Zones or FEMA Flood Zones, this step simply involves gathering existing GIS data. But for other data sources, such as modeled future wildfire burn projections or heavy precipitation projections, there is more data processing required to produce the raw hazard data. Once the raw data is created, it can be mapped. These hazard maps will be an intermediate product of the analysis.

After a hazard dataset is mapped, it is ‘scaled’ by converting it from its raw format to a number ranging from a minimum of 0 to a maximum of 10. For some categorical data, like Fire Hazard Severity Zones of ‘Very High’, ‘High’, and ‘Medium’, this requires converting each category into a number; ‘Very High’ might receive a 10 as it corresponds to the highest likelihood of wildfire burn. Then ‘High’ might receive an 8, ‘Medium’ a 6, and all other areas a 0. For numerical data, this scaling is typically done mathematically using a technique like min-max normalization.

After the hazard data is scaled, it is overlaid with the appropriate asset data in GIS.[2] Each asset receives a score for that metric depending on which portion of the hazard data it overlaps with. If it overlaps with a hazard dataset with a scaled score of 10, then the asset receives a 10 for that metric. If it overlaps with a hazard dataset with a scaled score of 9, it receives a 9, and so on and so forth.

Climate Projection Details

In the hazard mapping and prioritization process, climate projections will typically be shown for three timeframes: historical conditions, an averaged projection year of 2040, and an averaged projection year of 2070. Climate metrics will be calculated for these horizon years aggregated across 30-year time spans centered around each analysis year. The 30-year baseline that will be used for most of the climate projections is also a 30-year period spanning from 1985-2014. The use of 30-year time spans helps account for interannual variability and better capture long-term trends.

The metrics discussed later in this chapter will typically be aggregated across climate scenarios by showing a middling projection (50th percentile) and high-end projection (90th percentile). These percentiles will typically be calculated by aggregating across Global Climate Models (GCMs) from three emissions scenarios: Shared Socioeconomic Pathway (SSP) 2-4.5 (moderate greenhouse gas emissions), SSP 3-7.0 (high greenhouse gas emissions), and SSP 5-8.5 (very high greenhouse gas emissions). These scenarios consider not only greenhouse gas emissions but social dynamics and inequalities as well. The moderate emissions scenario is a ‘middle of the road’ outcome in which some mitigation and adaptation measures are taken globally, there is some level of cooperation between countries, and global population growth levels off in the second half of the century. The high emissions scenario assumes greater levels of coal use, social inequality, population growth, nationalism, and regional conflicts and security concerns with decreasing investments in technological development, leading to drastic environmental damage. The very high emissions scenario is based on continued and increasing use of fossil fuels continuing throughout the coming century reaching levels of around double the current

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[2] This is the typical case. For a few of the metrics, particularly condition information for bridges and culverts, the data was already associated with the assets, so the overlays are not needed.

consumption level. Based on developments in recent years, this scenario is now considered an unlikely and worst-case outcome.

Consequence Scores

Like the hazard likelihood scores, the consequence scores will also be unitless numbers ranging from 0 to 10, with 0 being lowest consequence and 10 being highest consequence. These scores will be calculated by scaling each consequence metric from 0 to 10, weighting each metric by its relative importance to overall consequence, and adding the weighted scores together.

The consequence metrics will be developed in a similar manner to the way the hazard metrics were developed. The raw data for each metric is developed, the raw data is then scaled from 0 to 10, and then that scaled data is combined with the assets to produce the score for each metric.

The selection of consequence metrics was informed by input from the project team, key stakeholders, and the public; availability of data; and metrics used in similar studies. The consequence metrics stay consistent across the hazard types. One set of consequence metrics will be used for all roadway asset classes, and another set will be used for rail asset classes. For roadways, metrics include travel volume (expressed as Average Annual Daily Traffic (AADT)), location within or nearby disadvantaged communities, whether an asset has a viable detour (and if so, its detour time), whether the asset enables access to a critical facility,[3] and whether the asset includes bicycle facilities. For rail, metrics include whether the asset is located on a higher priority section of the line, location within or nearby disadvantaged communities, and whether the asset includes or will soon include trails.

The weighting of the consequence metrics will be based in part on the feedback from stakeholder and community outreach. Based on that feedback, the following metrics seemed to be the most important: travel volume, whether a detour exists (i.e., whether it's a one-way in/out road), and the length of the detour. Therefore, these metrics will receive relatively high weights in the scoring.

Impacts to disadvantaged communities are a key emphasis of the CAVA to help improve public health, quality of life, and economic opportunity as these communities generally have less capacity to adapt to challenges of climate change. Therefore, location within or near a disadvantaged community will also receive a high relative weight in the scoring.

Metrics by Asset and Hazard

The following figure and table show each metric to be included in the hazard likelihood and consequence scores. The table describes each metric; the rationale for its inclusion; the original data source(s) and work needed to develop the metric from those data; what asset(s) the metric applies to; what hazard group(s) the metric applies to; and the type of metric (i.e., whether the metric is a hazard likelihood or consequence metric).

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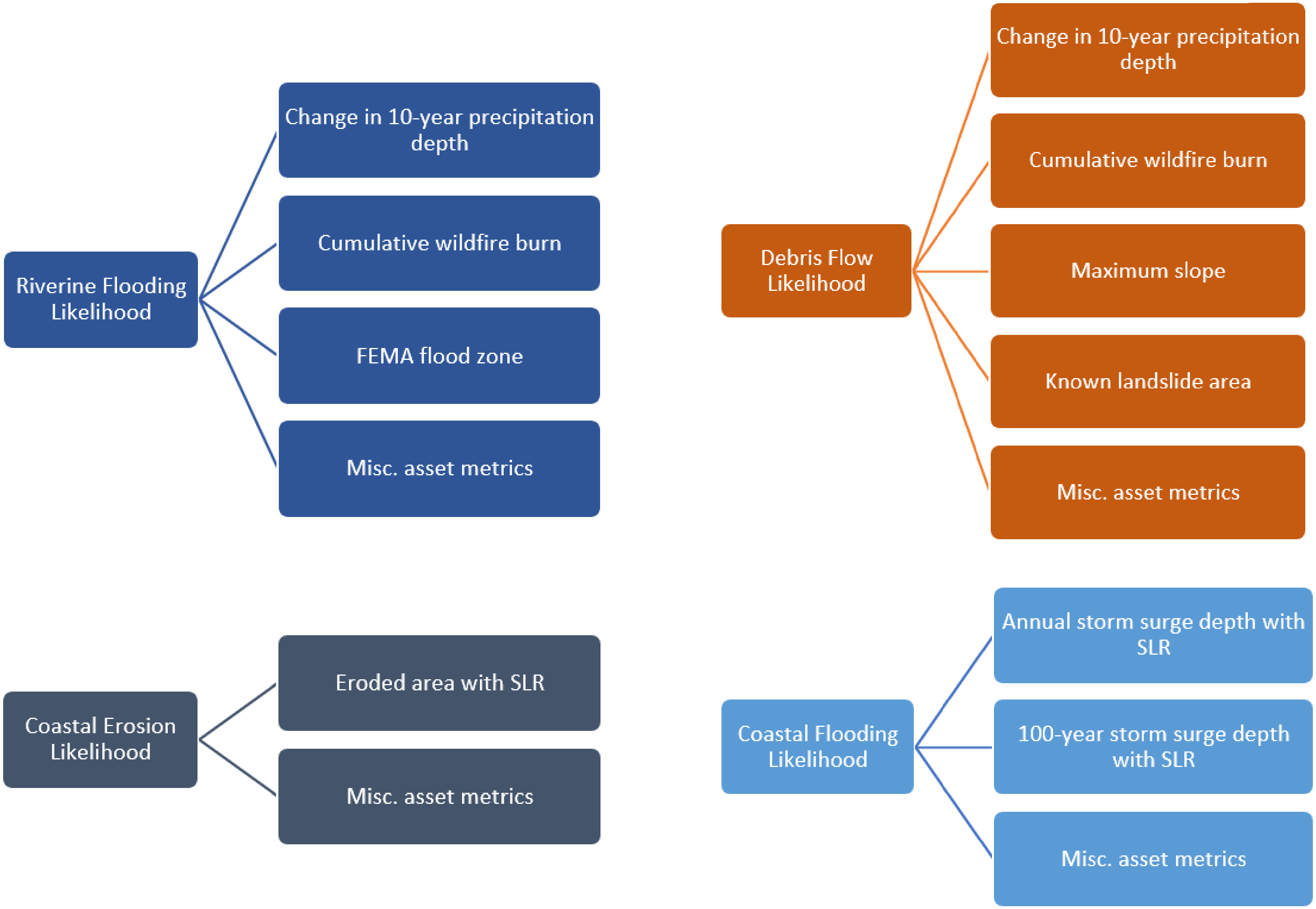
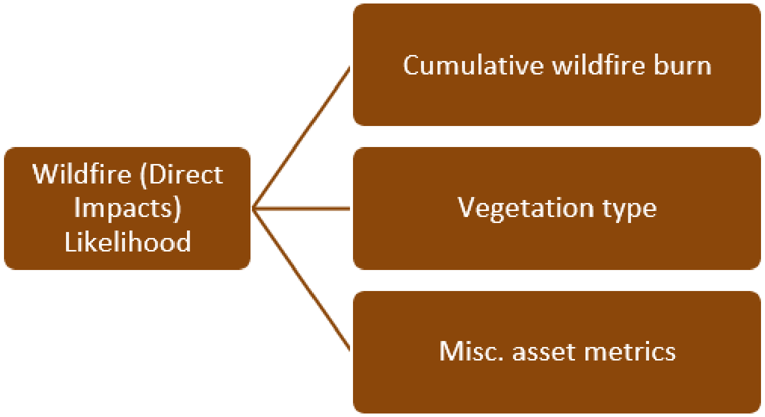
[3] Critical facilities are defined by the County and include hospitals, fire stations, police and sheriff stations, Emergency Operations Centers (EOCs), County-owned buildings, medical clinics, nursing homes, schools, libraries, churches, and camp/recreation facilities.

Figure 2. Hazards and hazard metrics. Metrics are applied differently based on asset class/type. Misc. asset metrics relate to asset class-specific susceptibility metrics like bridge scour susceptibility.




Wind Likelihood
Vegetation type (i.e. proximity of trees to roadways)


Wildfire (Direct Impacts) Likelihood
Cumulative wildfire burn
Vegetation type
Misc. asset metrics

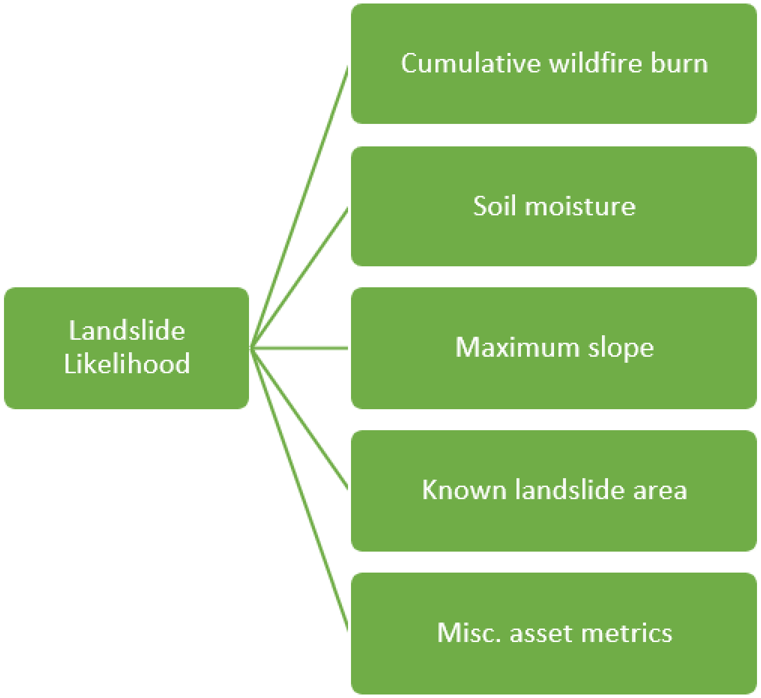

Landslide Likelihood
Cumulative wildfire burn
Soil moisture
Maximum slope
Known landslide area
Misc. asset metrics

Table 2. Prioritization Metrics

Description	Rationale	Data Sources and Development	Asset(s)	Hazard Group(s)	Type
Soil moisture	Areas with higher soil moisture and groundwater levels and are thus more susceptible to erosion/slope failure	LOCA2 projections for projected future precipitation; 30-day cumulative precipitation total used as a proxy for soil moisture. Some data processing required to manage large datasets, and query and aggregate to calculate metric. Alternatively, could use LOCA2 projected future soil moisture, if data quality is deemed adequate.	All	Landslide	Hazard likelihood
Maximum slope nearby road	Areas with steeper slopes tend to be more prone to debris flows and landslides	Pacific Veg Map slope dataset. Assets will be buffered before overlaying with slope data.	All	Debris flow, Landslide	Hazard likelihood
Known Landslide Area	Areas with known landslides more prone to future landslides and debris flows	County “Cooper_Clark_Landslide_Map” and “Mapped Small Landslides and Debris Flow”. Assets will be buffered before overlaying with landslide data.	All	Debris flow, Landslide	Hazard likelihood
Vegetation type and density nearby road	Areas with less vegetation tend to be more prone to landslides	USGS Normalized Difference Vegetation Index (NDVI). Assets will be buffered before overlaying with NDVI.	Roadway segments, Rail segments	Wind, Wildfire direct	Hazard likelihood

Description	Rationale	Data Sources and Development	Asset(s)	Hazard Group(s)	Type
Known culvert issue	Culverts and roadways and railways containing culverts with known issues tend to be more susceptible to flooding and erosion hazards	For road culverts and segments: County “Stormwater_Culverts” feature class; whether issue is flagged via “STATUS” or “RECOMMENDA” field. For rail culverts: RTC ‘Rail Culverts’ feature class; whether asset has an issue flagged in “Condition2020” field and also its age, inferred from “Year” column. For both road and rail culverts, some manual categorization required.	Roadway segments, Road small culverts, Rail segments, Rail culverts	Riverine flooding, Debris flow, Landslide, Coastal flooding, Coastal erosion	Hazard likelihood
Distance from stream centerline	Linear assets closer to streams may be more exposed to flood, debris flows, and landslides	USGS National Hydrography Dataset (NHD). Distance to nearest centerline will be calculated.	Roadway segments, Rail segments	Riverine flooding, Debris flow, Landslide	Hazard likelihood
FEMA Flood Zone Rating	Assets within FEMA flood zones may be more exposed to flooding	FEMA Flood Zones. Simple overlay.	Roadway segments, Rail segments	Riverine flooding	Hazard likelihood
Annual storm surge inundation depth (2 metrics: current conditions and 2075 medium-high risk aversion SLR)	Assets with higher regular flood depths should be prioritized	USGS CoSMoS flood depth datasets. CA OPC SLR projections used for crosswalk to CoSMoS. Some data processing required to manage large datasets, and query, aggregate, and combine datasets to calculate metric.	All	Coastal flooding	Hazard likelihood

Description	Rationale	Data Sources and Development	Asset(s)	Hazard Group(s)	Type
100-year storm surge inundation depth (2 metrics: current conditions and 2075 medium-high risk aversion SLR)	Assets with higher extreme flood depths should be prioritized	USGS CoSMoS flood depth datasets. CA OPC SLR projections used for crosswalk to CoSMoS. Some data processing required to manage large datasets, and query, aggregate, and combine datasets to calculate metric.	All	Coastal flooding	Hazard likelihood
Sea Level Rise increment associated with coastal erosion	Assets exposed to coastal erosion sooner should be prioritized	USGS CoSMoS shoreline change datasets. Some GIS cleanup required to QC linework, convert to polygon, and then perform overlays.	All	Coastal erosion	Hazard likelihood
Watershed percent change in 10-year 24-hour precipitation (or potentially peak flow) compared to historical conditions (4 metrics: 2025 50th percentile scenario, 2025 90th percentile scenario, 2075 50th percentile scenario, 2075 90th percentile scenario)	Assets experiencing larger changes in heavy precipitation or flow may be more exposed to flood or debris flow damage	LOCA2 projections for precipitation. USGS StreamStats for watershed polygons and peak flows. Initial processing needed to snap assets to stream grid, query StreamStats, and ingest results. Climate model processing required to manage large datasets, and query and aggregate to calculate metric.	Road bridges, Road large culverts, Rail bridges	Riverine flooding, Debris flow	Hazard likelihood

Description	Rationale	Data Sources and Development	Asset(s)	Hazard Group(s)	Type
Watershed cumulative percent burned over 30 years (4 metrics: 2025 50th percentile scenario, 2025 90th percentile scenario, 2075 50th percentile scenario, 2075 90th percentile scenario)	Assets with more wildfires are more likely to experience heavier flood and debris flows	LOCA1 UC Merced wildfire projections (or LOCA2 Pyregence wildfire projections if available) for projected future wildfire. To help increase spatial resolution of wildfire projections, Cal Fire Fire Hazard Severity Zones will be used. USGS StreamStats for watershed polygons. Same initial processing steps as watershed change in precipitation. Climate model processing required to manage large datasets, and query and aggregate to calculate metric.	Road bridges, Road large culverts, Rail bridges	Riverine flooding, Debris flow	Hazard likelihood
Percent change in 10-year 24-hour precipitation compared to historical conditions (4 metrics: 2025 50th percentile scenario, 2025 90th percentile scenario, 2075 50th percentile scenario, 2075 90th percentile scenario)	Assets experiencing larger changes in heavy precipitation may be more exposed to flood or debris flow damage	LOCA2 projections for precipitation. Climate model processing required to manage large datasets, and query and aggregate to calculate metric.	Road segments, Road small culverts, Rail segments, Rail culverts	Riverine flooding, Debris flow	Hazard likelihood
Cumulative percent burned over 30 years (4 metrics: 2025 50th percentile scenario, 2025 90th percentile scenario, 2075 50th percentile scenario, 2075 90th percentile scenario)	Assets with more wildfires are more likely to experience heavier flooding and erosion	LOCA1 UC Merced wildfire projections (or LOCA2 Pyregence wildfire projections if available) for projected future wildfire. To help increase spatial resolution of wildfire projections, Cal Fire Fire Hazard Severity Zones used. Climate model processing required to manage large datasets, and query and aggregate to calculate metric.	Road segments, Road small culverts, Rail segments, Rail culverts for Riverine flooding and Debris flow; All for Landslides	Riverine flooding, Debris flow, Landslides	Hazard likelihood

Description	Rationale	Data Sources and Development	Asset(s)	Hazard Group(s)	Type
NBI Scour Critical Rating	Bridges with higher scour critical ratings are more susceptible to damage	NBI. Some gap filling needed for bridges that did not join to NBI.	Road bridges	Coastal flooding, Coastal erosion, Riverine flooding, Debris flows, Landslide	Hazard likelihood
NBI Bridge Substructure Condition Rating	Bridges with substructures in worse condition are more susceptible to damage	NBI. Some gap filling needed for bridges that did not join to NBI.	Road bridges	Coastal flooding, Coastal erosion, Riverine flooding, Debris flows, Landslide	Hazard likelihood
NBI Waterway Adequacy Rating	Bridges with less clearance over floodways are more exposed to flooding	NBI. Some gap filling needed for bridges that did not join to NBI.	Road bridges	Coastal flooding, Coastal erosion, Riverine flooding, Debris flows	Hazard likelihood
Culvert capacity	Culverts with less capacity are more likely to experience flooding and erosion damage	County 'Bridges' feature class. Some minor gap filling required. Calculated using diameter or length and width. Overall inland hazard likelihood metric will likely combine this with information on changes in flow as a ratio, e.g., change in flow divided by culvert capacity.	Road large culverts	Coastal flooding, Coastal erosion, Riverine flooding, Debris flows, Landslide	Hazard likelihood
Rail Bridge Evaluation Report Priority	Rail bridges with known issues are more likely to be susceptible to hazards	RTC Bridge Evaluation Report. Priority levels to be manually added to GIS file.	Rail bridges	Coastal flooding, Coastal erosion, Riverine flooding, Debris flows, Landslide	Hazard likelihood

Description	Rationale	Data Sources and Development	Asset(s)	Hazard Group(s)	Type
Average Annual Daily Traffic (AADT)	Roads used by more people should be prioritized	RTC AADT data in line format. Average AADT by functional class assumptions applied. Brief manual editing of AADT on high-volume roads for which AADT is available and that deviate heavily from functional class average.	All Roadway Assets	All	Consequence
Location within/nearby SCCRTC-defined disadvantaged communities	Assets serving disadvantaged communities should be prioritized	RTC definition of disadvantaged communities (pending). Assets overlaid with polygons. Some roadway segments located outside of polygons that serve these communities can be flagged based on discussions with the Project team.	All	All	Consequence
Whether detour is available and typical incremental detour time	Roads with no detour or long detours should be prioritized	Google Maps. Manual detours using Google Maps calculated for all roads outside of urbanized areas that appear to have incremental detour times >2 minutes (lots of very short segments or segments in urbanized blocks were detour will be less than that and not worth measuring manually). Metric will capture detour around segment of interest and account for detour time minus no-detour time for typical Wednesday at 8am. One way in/out roads without detours will receive highest priority under this metric.	All Roadway Assets	All	Consequence

Description	Rationale	Data Sources and Development	Asset(s)	Hazard Group(s)	Type
Whether critical facility is located along asset (or whether asset is required to access critical facility)	Roads providing access to a critical facility should be prioritized	County Critical Facilities[4] feature class. Roads with critical facilities within certain distance flagged. Brief manual review to flag roads that appear essential to serving critical facilities farther away from the road itself.	All Roadway Assets	All	Consequence
Presence of bike facility along asset	Roads with bicycle facilities should be prioritized	County Bicycle Facilities feature class. Bicycle facility features snapped to nearby road segments sharing similar names.	All Roadway Assets	All	Consequence
Presence of transmission line along asset (potential metric)	Roads serving transmission lines should be prioritized	Unknown. Roads buffered and overlaid with transmission lines to detect intersection.	All Roadway Assets	All	Consequence
Whether rail segment is located on higher priority portion of the corridor	Higher priority portion of corridor should be prioritized for this study	RTC provided. Segment between Watsonville and the wye in Santa Cruz flagged as higher priority. This will be further refined by RTC based on estimated ridership for different segments	All Rail Assets	All	Consequence
Whether rail segment coincides with rail trails (existing, in construction, or planned)	Segments that already or will include trails in addition to rail should be prioritized	Trails currently exist, are in construction, or are planned for the entire corridor, so all segments will be flagged.	All Rail Assets	All	Consequence

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[4] This dataset includes the following types of critical facilities:

Figure 3. Consequence metrics for roadways and railways.

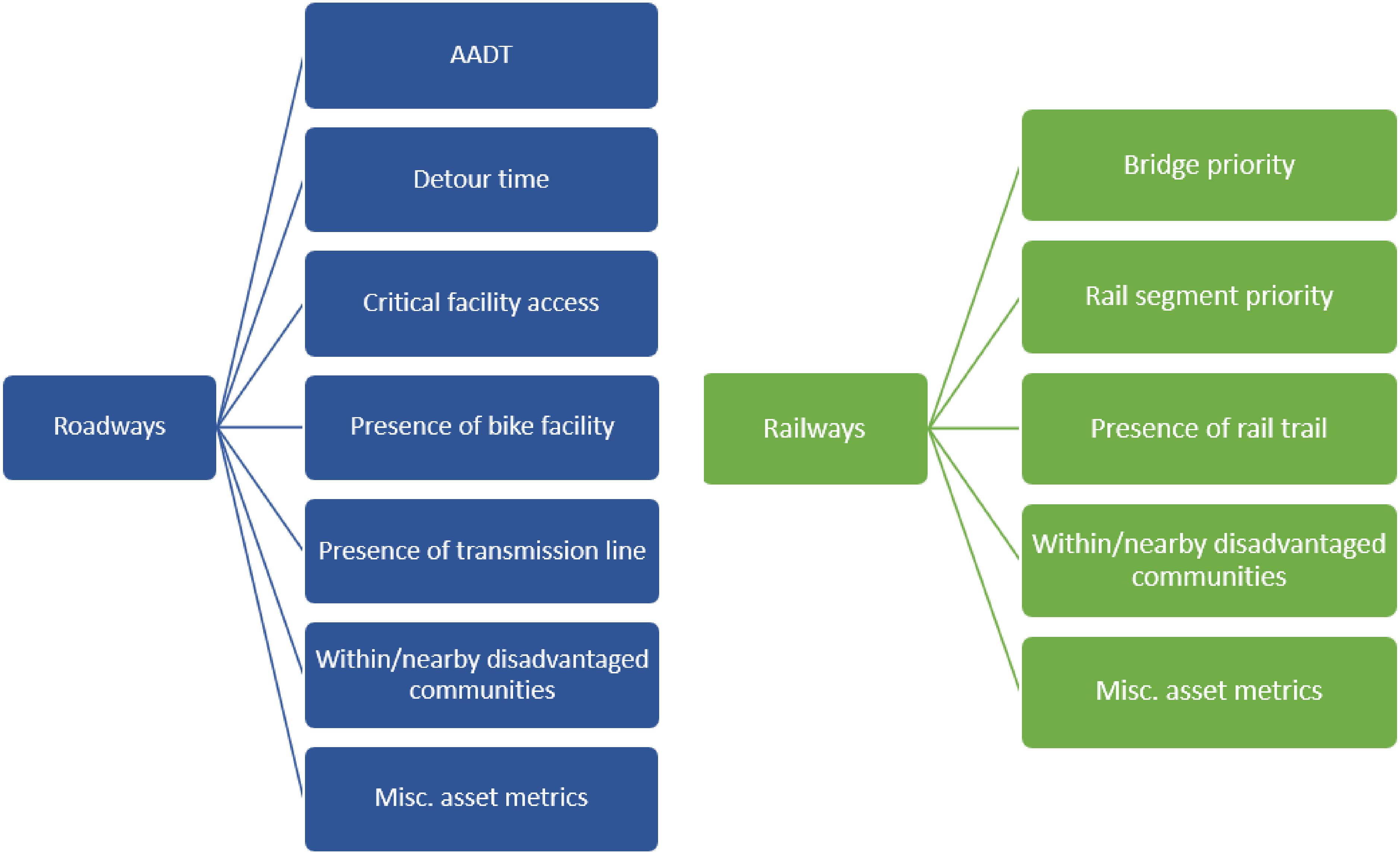

Table 3 indicates which metrics are included for each combination of hazard group and asset class. This information is captured in the preceding table as well, but Table 3 serves as a summary.

Table 3. Metric Summary by Hazard Group and Asset Class

	Coastal Flooding							**Coastal Erosion**						
Metric	**Road Seg.**	**Road Bridge**	**Road Large Culv.**	**Road Small Culv.**	**Rail Seg.**	**Rail Bridge**	**Rail Culv.**	**Road Seg.**	**Road Bridge**	**Road Large Culv.**	**Road Small Culv.**	**Rail Seg.**	**Rail Bridge**	**Rail Culv.**
Annual surge depth	X	X	X	X	X	X	X							
100-year surge depth	X	X	X	X	X	X	X							
SLR inc. for coastal erosion								X	X	X	X	X	X	X
NBI Scour Critical Rating		X							X					
NBI Bridge Sub. Condition Rating		X							X					
NBI Waterway Adequacy Rating		X							X					
Known culvert issue	X			X	X		X	X			X	X		X
Culvert capacity			X							X				
Rail Bridge Priority						X							X	
AADT	X	X	X	X				X	X	X	X			
Within/nearby disadvantaged communities	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Detour time	X	X	X	X				X	X	X	X			
Critical Facility Access	X	X	X	X				X	X	X	X			
Presence of bike facility	X	X	X	X				X	X	X	X			
Presence of transmission line	X	X	X	X				X	X	X	X			
Proposed passenger rail segment					X	X	X					X	X	X
Presence of rail trail					X	X	X					X	X	X

	Riverine Flooding							**Debris Flow**						
Metric	**Road Seg.**	**Road Bridge**	**Road Large Culv.**	**Road Small Culv.**	**Rail Seg.**	**Rail Bridge**	**Rail Culv.**	**Road Seg.**	**Road Bridge**	**Road Large Culv.**	**Road Small Culv.**	**Rail Seg.**	**Rail Bridge**	**Rail Culv.**
Watershed change in 10-year precip.		X	X			X			X	X			X	
Watershed cum. burn		X	X			X			X	X			X	
Change in 10-year precip.	X			X	X		X	X			X	X		X
Cum. burn	X			X	X		X	X			X	X		X
Max. slope								X	X	X	X	X	X	X
Known Landslide Area								X	X	X	X	X	X	X
Dist. from stream	X				X			X				X		
FEMA Flood Zone	X				X									
NBI Scour Critical Rating		X							X					
NBI Bridge Sub. Condition Rating		X							X					
NBI Waterway Adequacy Rating		X							X					
Known culvert issue	X			X	X		X	X			X	X		X
Culvert capacity			X							X				
Rail Bridge Priority						X							X	
AADT	X	X	X	X				X	X	X	X			
Within/nearby disadvantaged communities	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Detour time	X	X	X	X				X	X	X	X			
Critical Facility Access	X	X	X	X				X	X	X	X			
Presence of bike facility	X	X	X	X				X	X	X	X			
Presence of transmission line	X	X	X	X				X	X	X	X			
Proposed passenger rail segment					X	X	X					X	X	X
Presence of rail trail					X	X	X					X	X	X

	Landslide							Wildfire Direct Impacts		Wind	
Metric	Road Seg.	Road Bridge	Road Large Culv.	Road Small Culv.	Rail Seg.	Rail Bridge	Rail Culv.	Road Seg.	Rail Seg.	Road Seg.	Rail Seg.
Watershed cum. burn		X	X			X					
Cum. burn		X	X	X	X	X	X	X	X		
Soil moisture	X	X	X	X	X	X	X				
Max. slope	X	X	X	X	X	X	X				
Known Landslide Area	X	X	X	X	X	X	X				
Veg. type								X	X	X	X
Dist. from stream	X				X						
NBI Scour Critical Rating		X									
NBI Bridge Sub. Condition Rating		X									
Known culvert issue	X			X	X		X				
Culvert capacity			X								
Rail Bridge Priority						X					
AADT	X	X	X	X				X		X	
Within/nearby disadvantaged communities	X	X	X	X	X	X	X	X	X	X	X
Detour time	X	X	X	X				X		X	
Critical Facility Access	X	X	X	X				X		X	
Presence of bike facility	X	X	X	X				X		X	
Presence of transmission line	X	X	X	X				X		X	
Proposed passenger rail segment					X	X	X		X		X
Presence of rail trail					X	X	X		X		X

Combining Scores and Synthesizing Results

After hazard risk scores are calculated for each hazard-asset class combination, these scores will be combined into a prioritization score for each asset class as illustrated in Figure 4. The prioritization scores will be calculated by taking the average of an asset's hazard risk score for each hazard. Thus, the prioritization scores will also range from 0 to 100.

The results of the scoring will be presented in map and table formats. The final report will contain several paragraphs synthesizing results from the different asset classes in narrative format. This will help highlight the highest priority assets based on the framework.

Example Format

For discussion purposes, the following tables serve as an example of how the prioritization results could be formatted for different asset classes.

The first shows an example for Roadway Segments, and the second table shows an example for Rail Bridges. A consequence score is also shown, as are some of the raw metrics that make up that score. The disaggregated raw consequence metrics (e.g., AADT, detour time) are shown for context and since these metrics are often easier to interpret.

Figure 4. Prioritization score and hazard risk score. This process is repeated for each asset type.

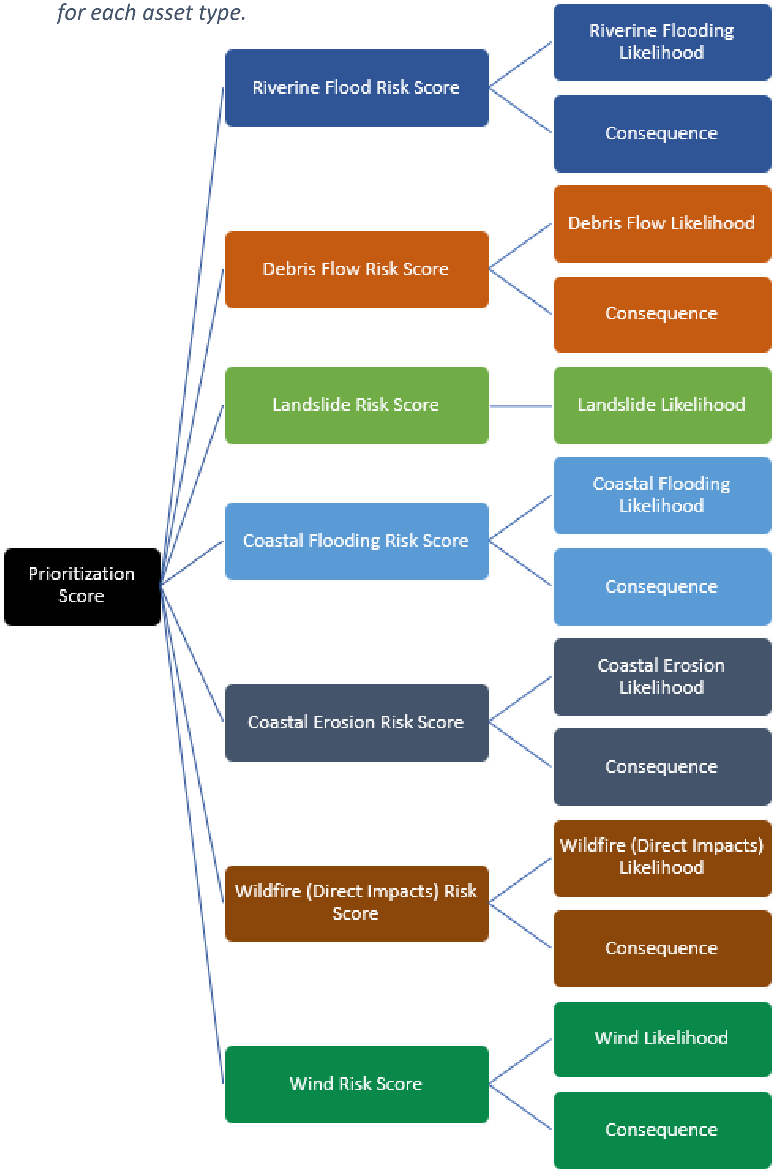

Table 4. Example Format of Prioritization Results Table – Roadway Segments

Asset ID	Street Name	Prioritization Score (0-100)	Consequence Score (0-10)	AADT	Within/nearby disadvantaged communities	Incremental Detour time	Critical Facility Access
735	L Street	72	9	12,000	Yes	One way in/out	Yes
839	C Street	50	5	9,000	No	5 mins.	Yes
135	C Street	35	5	8,500	No	4 mins.	Yes
902	J Street	28	4	8,750	No	<2 mins	No
…	…	…	…	…	…	…	…

Table 5. Example Format of Prioritization Results Table – Rail Segments

Asset ID	Milepost	Prioritization Score (0-100)	Consequence Score (0-10)	Within/nearby disadvantaged communities	Proposed passenger rail segment	Rail Segment Includes Trail
10945	123.5	100	10	Yes	Yes	Yes
10435	113.1	40	4	No	No	Yes
10113	124.5	36	4	No	Yes	No
10678	107.4	9	1	No	No	No
…	…	…	…	…	…	…

Appendix

Transportation Asset Units of Analysis

For the linear asset classes described in the list above – roadway and railway segments – units of analysis need to be established.

For the County roads, longer features will be broken up into intersection-to-intersection segments. Intersection-to-intersection segments are logical units of analysis for consequence metrics like detour lengths. The process of creating intersection-to-intersection segments, often referred to as planarization, will be done by splitting County roads features where lines intersected.[5] For Branch Rail Line segments, features will also be broken up into intersection-to-intersection segments, with both rail segments and County road segments used for planarization.

Roadway and rail bridges and culverts will be associated with roadway and rail intersection-to-intersection segments, respectively. This will be done using a snapping routine that prioritizes snapping to closer features and, for roads, snapping to features that share similar street names.

For all asset classes, including linear point features (i.e., the various bridges and culverts), a unique identifier (ID) will be added for tracking purposes. This unique ID will be in integer format and added to a field called 'CAVA_ID' for each feature class.

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[5] The planarization will not use features managed by other jurisdictions, since those features are represented in a different dataset with different (and less accurate) georeferencing.