Sustainable Development Verified Impact Standard

METHODOLOGY FOR COASTAL RESILIENCE BENEFITS FROM RESTORATION AND PROTECTION OF TIDAL WETLANDS

Document Prepared by:

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Relationship to Approved or Pending Methodologies

Approved and pending methodologies under the SD VISta Program and other programs, that prescribe similar project activities or aim to achieve similar sustainable development benefits were reviewed to determine whether an existing methodology could be reasonably revised to meet the objective of this proposed methodology. There are no approved or pending methodologies under the SD VISta program that fall under the sectoral scope of climate action.

The methodology will utilize procedures related to establishing project boundaries, demonstrating additionality, and projecting baseline land use changes that are contained in approved and pending VCS methodologies for tidal wetlands and seagrass meadows. These two methodologies are set out in Table 1 below.

Table 1: Similar Methodologies

Methodology	Title	Program	Comments
VM0033	Methodology for Tidal Wetland and Seagrass Restoration, v1.0	VCS	Quantifies the GHG benefits of restoring marsh, mangroves, and seagrass meadows, globally applicable.
VM007	REDD+ Methodology, v6.0 (in second validation)	VCS	Quantifies the GHG benefits of protecting and restoring marsh, mangroves, and seagrass meadows, globally applicable, <in second validation.>

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1 SOURCES

This methodology incorporates elements of the following methodologies:

- VM0033 Methodology for Tidal Wetland and Seagrass Restoration, v1.0
- VM0007 REDD+ Methodology Framework (REDD+ MF), v1.6

The following have also informed the development of the methodology:

- World Bank. 2016. Managing Coasts with Natural Solutions: Guidelines for Measuring and Valuing the Coastal Protection Services of Mangroves and Coral Reefs. M.W. Beck & G-M. Lange, editors, World Bank, Washington, DC.
- Beck, M. W., S. Narayan, I. J. Losada, A. Espejo, S. Torres. 2019. The Flood Protection Benefits and Restoration Costs for Mangroves in Jamaica, In Castaño-Isaza, J., Lee, S., Dani, S. (eds.). Forces of nature: assessment and economic valuation of coastal protection services provided by mangroves in Jamaica. World Bank, Washington.
- Menéndez, P., Losada, I. J., S. Torres-Ortega, S. Narayan, M. W. Beck. 2020. Global flood protection benefits of mangroves. Scientific Reports 10:4404.
- Menéndez, P., Losada, I. J., M. W. Beck, S. Torres-Ortega, A. Espejo, S. Narayan, P. Díaz-Simal, GM Lange. 2018. Valuing the protection services of mangroves at national scale: The Philippines. Ecosystem Services 34:24-36.
- Beck, M. W., I. Losada, P. Menendez, Reguero, B.G., P. Diaz Simal, F. Fernandez. 2018. The global flood protection savings provided by coral reefs. Nature Communications 9:2186.

This methodology uses the latest versions of the following Verified Carbon Standard (VCS) modules and tools:

- VMD0006 Estimation of baseline carbon stock changes and greenhouse gas emissions from planned deforestation and planned degradation (BL-PL)
- VMD007 Estimation of Baseline Carbon Stock Changes and Greenhouse Gas Emissions from Unplanned Deforestation and Unplanned Wetland Degradation (BL-UP)
- VMD0052 Demonstration of Additionality of tidal wetland restoration and conservation project activities (ADD-AM)

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

2.1 Methodology Description

Coastal ecosystems provide communities with protection against the impacts of climate-related hazards and natural disasters by reducing erosion and flooding from storms and stabilizing and raising shorelines in the face of sea-level rise.

Restoring and protecting coastal ecosystems contributes to the United Nations' *Sustainable Development Goal 13: Taking urgent action to combat climate change and its impacts*, and *Target 13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries*. This methodology provides a deemed estimate approach and a scenario approach to quantify the annual flood risk reduction (i.e., resilience) benefits of coastal ecosystems to people [Indicator 13.1.1]. SD VISta assets quantified using this methodology are not to be used for purposes of offsetting negative impacts of activities which may increase the number of persons affected by coastal flooding events.

This methodology currently applies to the restoration and protection of coastal wetlands including tidal marshes and mangroves and may be expanded to cover the restoration or protection of other coastal habitats such as coral reefs and oyster reefs.

2.2 Asset Description

Table 1: Asset(s) That Would Be Created by Projects Using the Proposed Methodology

Asset Title: Coastal Resilience Credit	
Asset Description	*Coastal flood reduction benefits*
Unit	*Reduced number of people at risk of coastal flooding each year (in persons)*
Sustainable Development Goal(s)	*SDG 13: Climate Change*
Additionality	Optional

Crediting Baseline	*Project method*
Offset optionality	No
Comments	*NA*

2.3 Asset Crediting

Projects utilizing this methodology can select a crediting period that is a minimum of 10 years and a maximum of 50 years. Crediting periods may be renewed following SD VISta rules and requirements at the relevant renewal date; however, the maximum total crediting period for a project may not exceed 50 years in line with the requirements of the SD VISta program rules and requirements.

The crediting baseline will be determined using a project method and must be reassessed at least every 10 years.

3 DEFINITIONS

Degraded wetland
A wetland which has been altered by human or natural impact through the impairment of physical, chemical and/or biological properties, and in which the alteration has resulted in a reduction of the diversity of wetland-associated species, soil carbon or the complexity of other ecosystem functions which previously existed in the wetland.

Historical Reference Period
The historical period prior to the project start date that serves as the source of data for defining the baseline.

Impounded Water
A pool of water formed by a dam or pit.

Marsh
A subset of wetlands characterized by emergent soft-stemmed vegetation adapted to saturated soil conditions.

Mangrove
A subset of tidal wetlands in subtropical and tropical coastal ecosystems dominated by halophytic trees, shrubs, and other plants growing in brackish to saline tidal waters.

Mudflat
A subset of tidal wetlands consisting of soft substrate not supporting emergent vegetation.

Open Water
An area in which water levels do not fall to an elevation that exposes the underlying substrate.

Tidal Marsh
A subset of marshes consisting of salt-tolerant and dwarf brushwood vegetation overlying mineral or organic soils.

Tidal Wetland
Vegetated habitats under the influence of the wetting and drying cycles of the tides (e.g., marshes, some seagrass meadows, tidal forested wetlands and mangroves). The scope of this methodology includes mangroves, tidal marshes and salt marshes.

Tidal wetland restoration
Restoration of degraded tidal wetlands in which establishment of prior ecological conditions is not expected to occur in the absence of the project activity. For the purpose of this methodology, this definition also includes activities that create wetland ecological conditions on mudflats or within open or impounded water.

Wetland
An area that meets an internationally accepted definition of wetland, such as from the IPCC, Ramsar Convention on Wetlands, those established by law or national policy, or those with broad agreement in the peer-reviewed scientific literature for specific countries or types of wetlands. Common wetland types include peatland, salt marsh, tidal freshwater marsh, mangroves, wet floodplain forests, prairie potholes and seagrass meadows.

4 APPLICABILITY CONDITIONS

This methodology currently applies to project activities that restore or protect tidal wetlands including mangroves and tidal marshes. More specifically the assessment of flood reduction benefits and resilience credits is focused on activities that increase or maintain the **area** of tidal wetland compared to the baseline scenario. Future revisions to this methodology based on peer reviewed science can be added to expand the applicability conditions to the restoration or protection of other coastal habitats such as coral reefs.

Project activities that restore and increase the area of mangroves or tidal marshes may include any of the following:

- Creating, restoring and/or managing hydrological conditions (e.g., removing tidal barriers, improving hydrological connectivity, restoring tidal flow to wetlands or lowering water levels on impounded wetlands); These activities can include the use of structures such as temporary coastal structures, for example to reduce wave energy in the initial stages of restoration, that are either later removed or naturally degrade.

- Altering sediment supply (e.g., beneficial use of dredge material or diverting river sediments to sediment-starved areas);
- Changing salinity characteristics (e.g., restoring tidal flow to tidally restricted areas);
- Improving water quality (e.g., recovering tidal and other hydrologic flushing and exchange or reducing nutrient residence time);
- Re-introducing native plant communities (e.g., reseeding or replanting);
- Improving management practice(s) (e.g., removing invasive species, reduced grazing);
- The prescribed burning of herbaceous and shrub aboveground biomass (cover burns) as a project activity may occur.

Project activities that protect and maintain the area of mangroves and tidal marshes may include any of the following, or combination of the following:

- Protecting at-risk wetlands (e.g., establishing conservation easements, establishing community supported management agreements, establishing protective government regulations, and preventing disruption of water and/ or sediment supply to wetland areas)
- Recharging sediment to avoid drowning of coastal wetlands
- Creating accommodation space for wetlands migrating with sea-level rise
- Avoiding degradation from alterations in the hydrology of the project area (involving drainage, interrupted sediment supply, or both)

5 PROJECT BOUNDARY

The project boundaries for all projects shall include the project area (i.e. all areas monitored for restored wetland extents) and the project impact area (i.e. all areas that could be impacted in terms of flood risk reduction by restoration activities).

The **project area** refers to the area of tidal wetlands that will be maintained or restored due to project activities. All restored areas are included the project area. The project proponent must define the spatial boundaries of the project area at the beginning of project activities. The project proponent must provide the geographic coordinates of lands included in the project area to facilitate accurate delineation of the project area. Remotely sensed data, published topographic maps and data, land administration and tenure records and/or other official documentation that facilitates clear delineation of the project area must be used.

The **project impact area** refers to all areas where flooding may be affected by the project activity. To identify the area to be assessed for flood reduction purposes, the project impact area is bounded up to the 10 m elevation contour and an alongshore width comprising the project area where additionally is considered at least 2x the alongshore width of the project area. This area can be delineated using topography data from digital or print elevation data or maps. The source of shoreline definition data for the project impact area should be identical to the source of the shoreline definition data used to delineate the project site.

The project area and project impact area may contain more than one discrete area of land. Each discrete area of land must have a unique geographical identification. When describing physical project boundaries, the following information must be provided for each discrete area:

- Name of the project area (including compartment numbers, local name (if any),
- Unique identifier for each discrete parcel of land,
- Map(s) of the area (preferably in digital format),
- The project area must be geo-referenced for location and extent and provided in digital format in accordance with SD VISta rules,
- Total area.,
- And details of land rights holder and user rights.

For protection projects, additional spatial boundaries for the reference region for conversion rate and reference regions for location to derive baseline rates and locations of conversion shall be defined in accordance with the latest VCS VM0007 modules BL-PL and BL-UP, or by other methodologies approved by Verra or the host country that are applicable to the project activity.

The impacts and subjects included in the project boundary are shown in **Table 2** below.

Table 2: Impacts and entities included in the Project Boundary

Impact	Entity	Primary or Secondary impact	Intended or Unintended	Required or Optional	Justification
Reduced area and depth of flooding in the project impact area	People and property assets in areas subject to coastal flooding events	Primary	Intended	Required	A key impact to assess for asset quantification The key social and economic benefits to be assessed.
Increased vegetative cover (ha) in the project area	Tidal marshes and mangroves	Primary	Intended	Required	The increase in vegetative cover is the primary variable that reduces wave energy, stabilizes shorelines (reducing erosion and building elevation), increases water storage capacity and ultimately reduces inland flooding.

6 BASELINE SCENARIO

For mangrove and tidal marsh restoration projects:

At the project start date, the most plausible baseline scenario for tidal wetland restoration projects must be identified as degraded tidal wetlands, mudflats, or shallow open water in which establishment of wetlands is not expected to occur in the absence of the project activity.

For mangrove and tidal marsh protection projects:

At the project start date, the most plausible baseline scenario for mangrove and tidal marsh protection projects must be identified as the conversion of existing mangrove or tidal marsh to another land use in which the loss of wetland flood reduction benefits is expected to occur in the absence of the project activity. The amount of mangroves or tidal marshes converted during the baseline period in the project impact area shall be determined by applying the BL-PL or BL-UP of VM0007 as applicable, or by using another defensible methodological approach that observes the principles of relevance, completeness, consistency, transparency and conservativeness and that has been approved by Verra or by the host country of the project and that are applicable to the project activity. Where the modules refer to project area, it should be understood as referring to the project impact area.

Project baselines for mangrove and tidal marsh protection projects must be revised at least every 10 years. The date of the next scheduled revision must be specified. Project baseline flood estimates will be based on the mangrove or tidal marsh area at the beginning of the baseline period. Projections for each baseline revision will be subject to independent verification. Reassessments must capture changes in the drivers and/or behavior of agents that cause the change in land use and/or land management practices and changes in coastal resiliency. This baseline reassessment must include the evaluation of the validity of proxies used in BL-PL or BL-UP to estimate future reduction in tidal wetland areas in the baseline scenario.

7 ADDITIONALITY

Offsetting
Assets generated from this methodology may not be used for offsetting.

Demonstration of additionality is optional under this methodology because assets generated by projects using this methodology cannot be used be for offsetting emissions. However, additionality demonstration is possible should projects choose to do so.

To demonstrate additionality, projects must demonstrate that the project activity is not required by law or regulation (Step 1) and project activities face barriers to implementation. This methodology uses a positive list to demonstrate the barriers to implementation for restoration and protection activities (Step 2).

Step 1: Regulatory Surplus

Project proponents must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the *Sustainable Development Verified Impact Standard.*

Step 2: Positive List

For projects that restore and increase the area of tidal wetlands, the applicability conditions of this methodology represent the positive list. The project must demonstrate that it meets all of the applicability conditions listed in Section 4 above, and in so doing, it is deemed as complying with the positive list. The positive list was established under VCS Methodology VM0007 using the activity penetration option. Projects which meet the applicability conditions above, which are in line with the applicability conditions for Wetland Restoration and Conservation projects within VM0007, are deemed additional. Justification for the activity method is provided in Appendix A to VMD0052 of VM0007.

8 QUANTIFICATION OF SUSTAINABLE DEVELOPMENT IMPACTS

Project proponents shall quantify the flood impacts to people and property from coastal storm events using either the scenario method or the deemed estimate methods described below. Both methods are based on an Avoided Damages (also known as Expected Damage Function) approach. This approach is widely used in engineering and risk analyses and the advancement of this approach for coastal habitats was reviewed with the World Bank (World Bank, 2016). The approach has been applied regionally and globally for coral reefs (Beck et al., 2018; Storlazzi et al., 2019; Reguero et al., 2020), mangroves (Menendez et al., 2019, 2020; Narayan et al., 2019, World Bank, 2019) and salt marshes (Narayan et al., 2017).

If using the deemed estimate approach, the quantification of baseline and project impacts is not necessary (go to section 8.3). If using the scenario method, proceed to Baseline Impacts (section 8.1).

8.1 Baseline Impacts

If using the scenario method, the flooding impacts in the baseline shall be estimated by performing the following steps:

1. Characterize offshore dynamics by defining the total water levels for storm events associated to specific probabilities
2. Assess nearshore hydrodynamics and onshore flooding in the baseline scenario.
3. Assess flood impacts for the baseline scenario.

For each step, general equations are provided that have been applied in regional and global models for the assessment of the flood reduction benefits of tidal marsh and mangrove habitats globally (e.g. Narayan et al., 2017; Menendez et al., 2020). However, various models (including those reviewed in World Bank 2016 and others) may be used to perform each step so long as they meet the following requirements:

1. Models shall be publicly available, though not necessarily free of charge, from a reputable and recognized source (e.g., the model developer's website).

2. Model parameters shall be determined based upon studies by appropriately qualified experts that identify the parameters as important drivers of the model output variable(s).
3. Models shall have been appropriately reviewed, tested and validated (e.g., ground-truthed using empirical data or results compared against results of similar models) by a recognized, competent organization, or an appropriate peer review group.
4. All plausible sources of model uncertainty, such as structural uncertainty or parameter uncertainty, shall be assessed using recognized statistical approaches.
5. Models shall have comprehensive and appropriate criteria for estimating uncertainty, and the model shall be calibrated by parameters to be appropriate for the given location.
6. Models shall apply conservative factors to discount for model uncertainty (in accordance with the most current criteria set out in the *SD VISta Standard, v1.0*), and shall use conservative assumptions and parameters that are likely to underestimate, rather than overestimate, the SD VISta assets.

8.1.1 Step 1: Characterize Total Water Levels for Storm Events

The process of estimating coastal flooding and flood impacts requires an assessment of winds, waves, mean sea level, tides, and storm surge that are expected to cause coastal flooding at the shoreline (Losada et al 2013). These conditions can be assessed statistically through extreme value analysis to determine storm conditions, i.e., conditions associated with certain probability of occurrence. These probabilities should be assessed for four return periods, 1 in 10 year (10% chance of occurrence in a given year), 1 in 25 year (4% chance of occurrence in a given year), 1 in 50 year (2% chance of occurrence in a given year) and 1 in 100 year (1% chance of occurrence in a given year). The outputs from this step are offshore storm parameters and the corresponding total water levels that can be used in the models described in Steps 2 and 3.

Models selected shall estimate the total water level due to offshore storm conditions, η by adding the contributions from mean sea-level, astronomical tide, storm surge and wave-driven flooding (Losada et al 2013):

$$\eta = MSL + AT + SS + Ru \quad (1)$$

Where, MSL is the mean sea level at the project site; AT is the astronomical tide, generally the peak tide within the storm event; SS is the storm surge associated with a storm event for a given return period; and R is the contribution of waves from runup and setup.

8.1.2 Step 2: Characterize Baseline Nearshore Dynamics and Onshore Flood Extents

The next step is to estimate the onshore flood extents and depths resulting from the η, total water levels at the shoreline, due to offshore storms. To define the project impact area, project proponents should assume an impact area boundary that extends on either side of the project along the coastline to a width equal to the project. The inland boundary of the project impact area will be defined by the 10-meter elevation contour which is assumed to be an elevation above which coastal flood impacts will not occur.

In general, the onshore flood depths in the project impact area in the baseline scenario are obtained as a function of the total water level, ground elevation and friction due to any vegetated land-cover that exists in the baseline scenario at the end of the baseline period.

$$F_{baseline} = f(\eta, z_{baseline}, n_{baseline}) \quad (2)$$

where, $z_{baseline}$ is the ground elevation in the baseline scenario within the project impact area, $n_{baseline}$ is the friction due to vegetated land-cover in the baseline scenario within the project impact area at the end of the baseline period ($A_{baseline,\ t=10}$). The outputs from this step are maps of flood extents and depths for the baseline scenario associated with storms of certain occurrence probabilities.

The project proponent shall use Manning's friction coefficients to determine the friction of land cover within the project impact area. Manning friction coefficients (Manning's n) relate the type of land-cover including vegetation to the resistance that it offers to flow through the floodplain (Arcement & Schneider, 1989). These friction coefficients vary by the type of land cover (Bunya et al., 2010). The proponent should pick Manning's friction coefficient values suitable to the coastal wetland types within the project area (Table 3). These friction coefficients represent an acceptable range of values selected by the project proponent. Coefficients selected for this methodology should fall within this range such that they are internally consistent with the friction coefficients of other land-cover types within the project impact area.

Table 3 Manning's Friction Coefficient

Classification	Wetland Description	Class	Manning's n
NLCD	Woody Wetland	91	0.140
	Herbaceous Wetland	92	0.035
	Open Water	11	0.020
MS-GAP	Intermediate Marsh	2	0.050
	Brackish Marsh	3	0.045
	Saline Marsh	4	0.035
	Wetland forest - deciduous	5	0.140
	Wetland forest - evergreen	6	0.160
	Water	23	0.020 – 0.045
LA-GAP	Estuarine emergent	7	0.050
	Estuarine woody	8	0.060
	Wetland	71	0.045
	Estuarine Water	4	0.025

Table 3: Manning's friction coefficient values for tidal wetland land cover types under three different land cover classifications: National Land Cover Database; Mississippi Gap Analysis Project (MS-GAP); Louisiana Gap Analysis Project (LA-GAP). (Adapted from Bunya et al., 2010).

To identify the extent of coastal habitats within the project impact area, project proponents can use global or regional tidal wetland distribution datasets (e.g., Global Mangrove Watch for mangroves, UNEP-WCMC for mangroves and coral reefs, Florida Wildlife Commission for all coastal habitats in the state of Florida, etc.). Land-cover data may be obtained from regional datasets such as the NLCD database for the USA and should be adjusted to reflect the projected baseline land cover in the project impact area at the end of the baseline period as further described in section 6 (Baseline Scenario).

8.1.3 Step 3: Assess Flood Impacts

To estimate flood impacts to people for the baseline scenario, the proponent will estimate the total number of people within the project impact area where baseline flood depths are greater than 0.5 m. To estimate property damages in the baseline scenario (optional) the proponent will estimate the total value of properties where baseline flood depths are greater than 0.5 m. The proponent should apply this step for each of the selected storm return periods to calculate annual expected damage values in the baseline scenario (i.e., the expected number of people flooded annually under the baseline scenario). The output from this step is the annual expected damage in terms of the number of people flooded or the value of property damaged in the baseline scenario.

The people affected (damaged) by flooding, D_{people} is the number of people that live within zones of the project impact area where flood depths are greater than 0.5 m:

$$D_{people-baseline} = \sum pop_{F-baseline} \quad (3)$$

where, $pop_{F-baseline}$ is the number of people living within zones of the project impact areas where flood depths are greater than 0.5 m in the baseline scenario. Similarly, the property value damaged by flooding is a function of the flood depth greater than 0.5 m and the total property value in the baseline scenario:

$$D_{property-baseline} = f(\sum property_{F-baseline} \ , F_{baseline}, \ d_F) \quad (4)$$

Where $property_{F-baseline}$ is the property value at a location in the baseline scenario, $F_{baseline}$ is the flood depth for the baseline scenario at a location, and d_F is the % damage to that value for a given flood depth. The proponent should identify and obtain the most recent and highest resolution population or property asset dataset available for their project impact area. Where possible, the proponent should refine their estimates of property damages using data on the vulnerabilities of different property types to different severities (i.e. depths) of flooding, where flood depths are greater than 0.5 m. In the absence of better local data, proponents will use standard functions developed by the European Joint Research Centre that describe how floods of different heights can impact property values in different regions of the world (Huizinga et al, 2017), or other functions that have been developed for the project impact area that have been peer reviewed, and that have criteria for estimating uncertainty.

Finally, annual flood damages to people and property for the baseline scenario are calculated by integrating the damages from each event with the occurrence probability of that event using a trapezoidal integration formula as in (Olsen et al 2015):

$$EAD_{people-baseline} = \frac{1}{2}\sum_1^n\left(\frac{1}{T_i} - \frac{1}{T_{i+1}}\right)(D_{i.people-baseline} + D_{i+1.people-baseline}) \quad (5)$$

and

$$EAD_{property-baseline} = \frac{1}{2}\sum_1^n\left(\frac{1}{T_i} - \frac{1}{T_{i+1}}\right)(D_{i.property-baseline} + D_{i+1.property-baseline}) \quad (6)$$

Where, i is the storm event, from 1 to n, where n is the total number of events assessed, T_i is the return period of storm event i, expressed in years, and D_i is the damage caused by event i, expressed as number of people flooded or value of property damaged.

8.2 Project Impacts

If using the scenario approach, the flooding impacts in the project scenario shall be estimated by performing the following steps. As noted below, the steps follow those described in section 8.1 and parameters that are applicable to be baseline scenario should be substituted with those that are applicable to the project scenario.

8.2.1 **Step 1:** Characterize Offshore Dynamics and Total Water Levels for Projected Storm Events

In this step total water levels for the storm events shall be estimated as described in Step 1 in Section 8.1.1 and using equation (1).

8.2.2 Step 2: Characterize Project Effects on Nearshore Hydrodynamics and Onshore Flood Extents

In this step, the proponent assesses changes to total water levels for projected storm events and onshore flood extents within the project impact area. By increasing the extent of vegetation and potentially the land elevation nearshore, a project that restores or protects tidal marshes or mangroves is expected to increase flood resistance, reduce water levels landward, or upland of the project and thereby reduce inland flooding.

For each selected storm event, the models used in Step 2 (Section 8.1.2) are modified for estimating the effects on flooding by vegetated extent in the project scenario. These effects are estimated over the project impact area, and at the end of the baseline period. In this step the methodology assumes that vegetated extent in the project area is fully protected (in the case of protection projects) or fully restored (in the case of restoration projects). Actual areas restored or protected are monitored and net benefits are scaled accordingly in section 8.3.

The outputs from this step will be flood extent maps incorporating the vegetated area impacted by the project for each projected storm event.

In general, the modified onshore flood extent for the project scenario is derived similarly as for the p baseline scenario (in section 8.1.2), with the only difference being a change in elevation and vegetative friction within the project impact area.

$$F_{project} = f(\eta, z_{project}, n_{project,}) \qquad (7)$$

Where, $z_{project}$ is the ground elevation in the project scenario, $n_{project}$ is the friction due to vegetated land-cover in the project impact area in the fully restored/protected project scenario at the end of the baseline period ($A_{project\text{-}E,\ t=10}$).

8.2.3 Step 3: Assess Flood Impacts

In this step, the proponent estimates the number of people flooded and value of property damaged in the project scenario. This step is identical to Step 3 of the baseline scenario

(Section 8.1.1), except that the proponent will use the flood extents generated for the project scenario as inputs. For implementation details see Step 3 in Section 8.1.1.

In general, the people affected by flooding greater than 0.5 m in the project scenario is given by:

$$D_{people-project} = \sum pop_{F-project} \quad (8)$$

Where, $pop_{F-project}$ is the number of people within the flood extent for the project scenario.

The value of property damaged by flooding in the project scenario is:

$$D_{property-project} = f(\sum property_{F-project}, F_{project}, d_F) \quad (9)$$

Where, $property_{F-project}$ is the property value within the flood extent for the project scenario, and $F_{project}$ is the onshore flood depths in the project scenario and d_F is the percentage of value damaged as a function of flood depth.

These event-specific flood impacts are then used to estimate annual flood damages. Identical to the baseline scenario, annual flood damages to people and property for the project scenario are calculated by summing the damages from each event with the occurrence probability of that event:

$$EAD_{people-project} = \frac{1}{2}\sum_{1}^{n}(\frac{1}{T_i} - \frac{1}{T_{i+1}})(D_{i.people-project} + D_{i+1.people-project}) \quad (10)$$

And

$$EAD_{property-project} = \frac{1}{2}\sum_{1}^{n}(\frac{1}{T_i} - \frac{1}{T_{i+1}})(D_{i.property-project} + D_{i+1.property-project}) \quad (11)$$

Where, i is the storm event, from 1 to n, where n is the total number of events assessed, T_i is the return period of storm event i, expressed in years, and D_i is the damage caused by event i, expressed as number of people flooded or value of property damaged. Here the proponent will apply this methodology for 10, 25, 50 and 100 year return period events,

8.3 Net Coastal Resilience Project Impacts

In this final step, the proponent will assess the coastal resilience benefits of the project in terms of reductions in the number of people impacted by flooding and/or reductions in the total property value damaged due to flooding within the project impact area.

8.3.1 Scenario Method

If using the scenario approach, the project benefit is calculated as the difference in the number of people impacted by flooding and/or the difference in property damages between baseline and project scenarios. These benefits are expressed in annual terms.

In general, these project benefits are first assessed for floods of specific return periods as:

$$B_{people} = D_{people(baseline)} - D_{people(project)} \quad (12)$$

and

$$B_{property} = D_{property(baseline)} - D_{property(project)} \quad (13)$$

The expected annual benefits, (*EAB*), from the project activity are then estimated for people and property as

$$EAB_{people} = EAD_{people-baseline} - EAD_{people-project} \quad (14)$$

and

$$EAB_{property} = EAD_{property-baseline} - EAD_{property-project} \quad (15)$$

Project benefits are then converted to a benefits per hectare of tidal wetland extent to allow scaling of benefits due to changing tidal wetland extents,

$$EAB_{perHa-people} = EAB_{people}/A_{project-E(t=10)} \quad (16)$$

And

$$EAB_{perHa-property} = EAB_{property}/A_{project-E(t=10)} \quad (17)$$

Where $A_{project-E}$ is the estimated area of vegetated extent of mangroves or tidal marshes in the project impact area in the project scenario, and t=10 is the end of the baseline period.

The net change in vegetated area due to the project is calculated for protection projects as:

$$A_{net-protection} = [(A_{Baseline(t=0)} - A_{Baseline(t=T)}) - (A_{Project(t=0)} - A_{Project(t=T)})] \quad (18)$$

And for restoration projects as:

$$A_{net-restoration} = [(A_{Project-A(t=T)} - A_{Project-A(t=0)}) - (A_{Baseline(t=T)} - A_{Baseline(t=0)})]$$

(19)

Where, $A_{Project\text{-}A}$ is the actual area of vegetated extent of mangroves or tidal marshes in the project impact area; $A_{baseline}$ is the area of vegetated extent of mangroves or tidal marshes in the project impact area, t=0 is to the start of the baseline period and t=T is the year when the net project benefit is calculated.

Net project benefits to people and property in the project impact area are then calculated for protection projects as

$$EAB_{project-people-protection} = EAB_{perHa-people} * \ A_{net-protection}$$

(20)

$$EAB_{project-property-protection} = EAB_{perHa-property} * \ A_{net-protection}$$

(21)

And for restoration projects as:

$$EAB_{project-people-restoration} = EAB_{perHa-people} * \ A_{net-restoration}$$

(22)

$$EAB_{project-property-restoration} = EAB_{perHa-property} * A_{net-restoration}$$

(23)

8.3.2 Deemed Estimate Method for Estimating Project Benefits for Mangrove Projects

For mangrove protection projects, project proponents may use a deemed estimate approach based on freely available datasets (https://osf.io/ecs4p/) from a peer-reviewed, global study of mangrove resilience benefits (Menendez et al., 2020). This dataset provides estimates of annual number of people and value ($) of property protected per hectare for points every 20-km across the 700,000 km of coastal study units for mangrove habitats globally. The approach calculates mangrove benefits to inland populations and properties based on an assumption of total loss of mangroves at the location.

The approaches in Menendez et al. (2020) are the same as outlined herein (section 8.1.1, 8.1.2) to provide estimates of the flood risk reduction benefits of mangroves. They couple spatially explicit 2-D hydrodynamic analyses with people and property values to provide probabilistic valuations of the flood reduction benefits of mangroves. Benefits are quantified by estimating the difference in flood damages between two scenarios “with mangroves” (current extent of mangroves) and “without mangroves”. For the two scenarios, the extent and height of inland flooding are estimated for 4 storm return periods (i.e. 1 in 10-, 25-, 50- and 100-year) to estimate the annual expected benefit (i.e., the probability of expected damages in any year across the full spectrum of storms). Flood depths were modeled every 1 km (for the 4 storm return periods) and downscaled to estimate flood extents and depth every 30 m. Ultimately these spatially explicit differences in flood impacts were summarized in 20-km coastal study units for the 4 storm return periods and as the annual expected benefit (avoided flood impacts) provided by mangroves in that unit. These annual avoided impacts are then divided by the extent of mangroves in the study area to provide a single value of benefits/ha.

Project proponents using the deemed estimate approach can use the online dataset to identify the annual resilience benefits per ha of mangrove within their ~20-km coastal sections. This value identifies the annual number of people or amount of property per hectare of mangrove with flood reduction benefits. Project benefits can be estimated by multiplying this per hectare annual resilience benefit by the net increase in mangrove area relative to the baseline scenario (number of hectares of mangroves protected or restored since the project start date relative to the baseline scenario). The net expected annual benefits to people and property from the project using the deemed estimated approach are:

$$EAB_{people-deemed} = A_{net-protection/restoration} * EAB_{perHa-people-deemed} \quad (24)$$

And

$$EAB_{property-deemed} = A_{net-protection/restoration} * EAB_{perHa-property-deemed} \quad (25)$$

Where, $EAB_{perHa-deemed}$ refers to the net people or property benefits per hectare of mangroves for the datapoint nearest to the project impact area.

9 MONITORING

9.1 Data and Parameters Available at Validation

The following data and parameters will be determined or be available at validation and remain fixed throughout the project crediting period.

Data / Parameter	η
Data unit	Meters
Description	The total water level at the shoreline comprised the compounded effect of sea level, tide, storm surge and wave height components for a storm event of a certain recurrence probability
Equations	1
Source of data	Modeled or from peer reviewed literature
Value applied	N/A – varies by location
Justification of choice of data or description of measurement methods and procedures applied	Models must meet the requirements listed in section 8.1 Peer reviewed literature must be derived from datasets relevant to the project impact area
Purpose of Data	Calculation of baseline scenario impacts Calculation of project impacts
Comments	N/A

Data / Parameter	MSL
Data unit	Meters
Description	Mean sea level for the project location
Equations	1
Source of data	Modeled or from peer reviewed literature
Value applied	N/A – varies by location

Justification of choice of data or description of measurement methods and procedures applied	Models must meet the requirements listed in section 8.1 Peer reviewed literature must be derived from datasets relevant to the project impact area
Purpose of Data	Calculation of baseline scenario impacts Calculation of project impacts
Comments	Required model parameter for estimating total water level for the baseline and project scenarios if using the scenario method

Data / Parameter	AT
Data unit	Meters
Description	Astronomical tide for the project location, generally the peak tide within the storm event
Equations	1
Source of data	Modeled or from peer reviewed literature
Value applied	N/A – varies by location and by time period and duration of considered storm event
Justification of choice of data or description of measurement methods and procedures applied	Models must meet the requirements listed in section 8.1 Peer reviewed literature must be derived from datasets relevant to the project impact area
Purpose of Data	Calculation of baseline scenario impacts Calculation of project impacts
Comments	Required model parameter for estimating total water level for the baseline and project scenarios if using the scenario method

Data / Parameter	SS
Data unit	Meters
Description	Storm surge associated with a storm event

Equations	1
Source of data	Modeled or from peer reviewed literature. Data and literature sources may include but are not limited to: i) historic observations of storm tracks (e.g. www.ibtracs.org; NOAA Hurricane Database or HURDAT, https://www.aoml.noaa.gov/hrd/hurdat/Data_Storm.html) ii) historic observations of total water levels associated with specific storm events (e.g. Global Extreme Sea Level Analysis, www.gesla.org) iii) numerical models of extreme total water levels (e.g. Vousdouskas et al., 2018, Muis et al., 2016), though these are generally only for specific recurrence probabilities such as the 1 in 100 year storm event.
Value applied	N/A – varies by location and by storm event
Justification of choice of data or description of measurement methods and procedures applied	Models must meet the requirements listed in section 8.1 Peer reviewed literature must be derived from datasets relevant to the project impact area
Purpose of Data	Calculation of baseline scenario impacts Calculation of project impacts
Comments	Required model parameter for estimating total water level for the baseline and project scenarios if using the scenario method

Data / Parameter	R
Data unit	Meters
Description	Wave runup, i.e. the increase in total water levels due to wave action
Equations	1
Source of data	Modeled or from peer reviewed literature. Sources may include but are not limited to formulae from peer-reviewed literature (e.g. see Stockdon et al., 2014 and FEMA, 2005 for a review of suitable numerical and parametric models)

Value applied	N/A – varies by location and by wave heights, water levels and shoreface characteristics at location
Justification of choice of data or description of measurement methods and procedures applied	Models must meet the requirements listed in section 8.1 Peer reviewed literature must be derived from datasets relevant to the project impact area
Purpose of Data	Calculation of baseline scenario impacts Calculation of project impacts
Comments	Required model parameter for estimating total water level for the baseline and project scenarios if using the scenario method

Data / Parameter	$F_{baseline}$
Data unit	Meters
Description	Onshore flood depth at any given location in the project impact area
Equations	2
Source of data	Modeled
Value applied	N/A – varies by location
Justification of choice of data or description of measurement methods and procedures applied	Models must meet the requirements listed in section 8.1 Peer reviewed literature must be derived from datasets relevant to the project impact area
Purpose of Data	Calculation of baseline scenario impacts Calculation of project impacts
Comments	The baseline flood depths at all locations within the project impact area will be used to prepare the flood maps for the baseline scenario

Data / Parameter	$z_{baseline}$

Data unit	Meters
Description	Ground elevation in the project impact area in the baseline scenario
Equations	2
Source of data	Project Impact Area; Global or regional datasets with at least 90m resolution for project impact area Project Area: Measurements from field surveys or aerial/satellite imagery of at least 10 m resolution within project area
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	Datasets should be from closest date prior to the project start date
Purpose of Data	Calculation of baseline impacts
Comments	Required model parameter for estimating flood depth for the baseline scenario if using the scenario method

Data / Parameter	$n_{baseline}$
Data unit	$sm^{-1/3}$
Description	Coefficient of friction of all land-cover types, including vegetated habitats in the project impact area
Equations	2
Source of data	Peer reviewed literature (e.g. see Bunya et al., 2010)
Value applied	Varies by habitat and by land cover
Justification of choice of data or description of measurement methods and procedures applied	The land cover classification chosen for assigning parameter values should match, as closely as possible, the actual land cover at that location
Purpose of Data	Calculation of baseline impacts

Comments	Required model parameter for estimating flood depth for the baseline scenario if using the scenario method Coefficients should be internally consistent with the friction coefficients of other land-cover types used within the project impact area.

Data / Parameter:	$A_{Baseline}$
Data unit:	Hectares
Description:	Vegetated extent of all habitats in the project impact area in the baseline scenario
Equations	2, 18, 19
Source of data:	Spatially explicit map of baseline land use at the end of the baseline period prepared following the procedures, and from the sources of data, described in VM0033 for restoration projects and in modules BL-UP and BL-PL of VM0007 for protection projects, or those approved by Verra or by the host country that are applicable to the project activity.
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	Baseline land use maps at the end of the baseline period will be used to estimate flood extent in the baseline scenario during the baseline period and will be reassessed at least every 10 years. Procedures to estimate impact for years within the baseline period are included in the calculation of annual net benefit.
Purpose of data:	Calculation of baseline impacts and expected annual benefits.
Comments:	Baseline vegetated extents are used to determine appropriate friction coefficients within the model for the baseline scenario, and in calculating expected annual benefits.

Data / Parameter:	$D_{people\text{-}baseline}$
Data unit:	Population

Description:	Number of people affected by flooding within the project impact area in the baseline scenario
Equations	3
Source of data:	Calculated
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of baseline impacts
Comments:	N/A

Data / Parameter:	$pop_{F\text{-}baseline}$
Data unit:	Population
Description:	Number of people in locations where flood depth is at least 0.5 m
Equations	3
Source of data:	From peer-reviewed literature or global or regional datasets of at least 10 km resolution
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of baseline impacts
Comments:	Required model parameter for estimating flood impacts for the baseline scenario if using the scenario method.

Data / Parameter:	$D_{property\text{-}baseline}$
Data unit:	US$ or equivalent

Description:	Total property value affected by flooding within the project impact area in the baseline scenario where flood depth is at least 0.5 m
Equations	4
Source of data:	Calculated
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of baseline impacts
Comments:	Required model parameter for estimating flood impacts for the baseline scenario if using the scenario method

Data / Parameter:	$property_{F\text{-}baseline}$
Data unit:	US$ or equivalent
Description:	Property value damaged by flooding in locations where flood depth is at least 0.5 m
Equations	4
Source of data:	From peer-reviewed literature or global or regional datasets of at least 10 km resolution
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of baseline impacts
Comments:	Required model parameter for estimating flood impacts for the baseline scenario if using the scenario method

Data / Parameter:	d_F

Data unit:	%
Description:	Percentage of property value damaged by a given flood depth
Equations	4
Source of data:	Local or regional data from specific storm events or standard functions such as JRC (2017) for different regions or FEMA for the USA.
Value applied	Varies by location and property types
Justification of choice of data or description of measurement methods and procedures applied	Choice of damage functions must be justified using local or regional datasets or peer-reviewed literature
Purpose of data:	Calculation of baseline impacts
Comments:	Required model parameter for estimating flood impacts for the baseline scenario if using the scenario method

Data / Parameter:	$EAD_{people\text{-}baseline}$
Data unit:	Population
Description:	Annual number of people flooded for baseline scenario
Equations	5
Source of data:	Calculated
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of baseline impacts
Comments:	N/A

Data / Parameter:	$EAD_{property\text{-}baseline}$
Data unit:	US$ or equivalent

Description:	Annual property damages due to flooding for baseline scenario
Equations	5
Source of data:	Calculated
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of baseline impacts
Comments:	N/A

Data / Parameter:	n
Data unit:	number
Description:	Total number of storm events
Equations	5,6,10,11
Source of data:	Determined by proponent
Value applied	At least 4 (See Section 8.1.1 for guidance)
Justification of choice of data or description of measurement methods and procedures applied	Models must meet the requirements listed in section 8.1
Purpose of data:	Calculation of baseline impacts Calculation of project impacts
Comments:	N/A

Data / Parameter:	T
Data unit:	Years

Description:	Return period (inverse of recurrence probability) of a storm event
Equations	5,6,10,11
Source of data:	Determined by proponent
Value applied	Varies by storm event from 10 to 500 (See Section 8.1.1 for guidance)
Justification of choice of data or description of measurement methods and procedures applied	Models must meet the requirements listed in section 8.1
Purpose of data:	Calculation of baseline impacts Calculation of project impacts
Comments:	N/A
Data / Parameter	$\mathrm{F}_{project}$
Data unit	Meters
Description	Onshore flood depth at any given location in the project impact area for the project scenario
Equations	7
Source of data	Modeled
Value applied	N/A – varies by location
Justification of choice of data or description of measurement methods and procedures applied	Models must meet the requirements listed in section 8.1 Peer reviewed literature must be derived from datasets relevant to the project impact area
Purpose of Data	Calculation of project impacts
Comments	The project flood depths at all locations within the project impact area will be used to prepare the flood maps for the project scenario

Data / Parameter	$z_{project}$
Data unit	Meters
Description	Ground elevation in project impact area in the project scenario
Equations	7
Source of data	Project Impact Area; Global or regional datasets with at least 90m resolution for project impact area Project Area: Measurements from field surveys or aerial/satellite imagery of at least 10 m resolution within project area
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	Datasets should be from closest date prior to the project start date
Purpose of Data	Calculation of project impacts
Comments	Required model parameter for estimating flood depth for the project scenario if using the scenario method Conservatively uses ground elevation at the start of the baseline period.

Data / Parameter	$n_{project}$
Data unit	$sm^{-1/3}$
Description	Coefficient of friction of all land-cover types, including vegetated habitats in the project impact area for the project scenario
Equations	7
Source of data	Peer reviewed literature (e.g. see Bunya et al., 2010)
Value applied	Varies by habitat and by land cover

Justification of choice of data or description of measurement methods and procedures applied	The land cover classification chosen for assigning parameter values should match, as closely as possible, the actual land cover at that location
Purpose of Data	Calculation of project impacts
Comments	Required model parameter for estimating flood depth for the project scenario if using the scenario method Coefficients should be internally consistent with the friction coefficients of other land-cover types used within the project impact area and selected in the baseline scenario.

Data / Parameter:	$A_{Project\text{-}E}$
Data unit:	Hectares
Description:	Expected vegetated extent of all habitats in the project impact area in the project scenario
Equations	7, 16, 17, and 18
Source of data:	Spatially explicit map of land use in the project scenario at the end of the baseline period, assuming full restoration/protection of the project area.
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of project impacts and expected annual benefits
Comments:	Project vegetated extents are used to determine appropriate friction coefficients within the model for the project scenario and to calculate expected annual benefits.

Data / Parameter:	$D_{people\text{-}project}$
Data unit:	Population
Description:	Number of people affected by flooding within the project impact area in the project scenario
Equations	8
Source of data:	Calculated
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of project impacts
Comments:	N/A

Data / Parameter:	$pop_{F\text{-}project}$
Data unit:	Population
Description:	Number of people in locations where flood depth is at least 0.5 m in the project scenario
Equations	8
Source of data:	From peer-reviewed literature or global or regional datasets of at least 10 km resolution
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of project impacts

Comments:	Required model parameter for estimating flood impacts for the project scenario if using the scenario method.

Data / Parameter:	$D_{property\text{-}project}$
Data unit:	US$ or equivalent
Description:	Total property value affected by flooding within the project impact area in the project scenario
Equations	9
Source of data:	Global or regional datasets of at least 1 km resolution; Depth-damage functions from local or regional data or standard functions such as JRC (2017) for different regions or FEMA for the USA.
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	Models must meet the requirements listed in section 8.1. If depth-damage functions are used to refine property damage estimates during model calibration or validation, the choice of these functions must be justified using local or regional datasets or peer-reviewed literature
Purpose of data:	Calculation of baseline impacts
Comments:	Required model parameter for estimating flood impacts for the project scenario if using the scenario method

Data / Parameter:	$property_{F\text{-}project}$
Data unit:	US$ or equivalent
Description:	Property value damaged by flooding in locations where flood depth is at least 0.5 m in the project scenario
Equations	9

Source of data:	From peer-reviewed literature or global or regional datasets of at least 10 km resolution
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of project impacts
Comments:	Required model parameter for estimating flood impacts for the project scenario if using the scenario method

Data / Parameter:	$EAD_{people\text{-}project}$
Data unit:	Population
Description:	Annual number of people flooded for project scenario
Equations	10
Source of data:	Calculated
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of project impacts
Comments:	N/A

Data / Parameter:	$EAD_{property\text{-}project}$
Data unit:	US$ or equivalent
Description:	Annual property damages due to flooding for project scenario
Equations	11

Source of data:	Calculated
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of project impacts
Comments:	N/A

Data / Parameter:	B_{people}
Data unit:	Population
Description:	People benefiting due to the project for a given storm event
Equations	12
Source of data:	Calculated
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of net benefits
Comments:	N/A

Data / Parameter:	$B_{property}$
Data unit:	US$
Description:	Property value benefits (i.e. property value damage avoided) by the project for a given storm event

Equations	13
Source of data:	Calculated
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of net benefits
Comments:	N/A

Data / Parameter:	EAB_{people}
Data unit:	Population
Description:	Annual people project benefits
Equations	14,16
Source of data:	Calculated
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of net benefits
Comments:	N/A

Data / Parameter:	$EAB_{property}$
Data unit:	US$ (or equivalent)
Description:	Annual property project benefits
Equations	15,17

Source of data:	Calculated
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of net benefits
Comments:	N/A

Data / Parameter:	$EAB_{perHa\text{-}people}$
Data unit:	Population/Ha
Description:	Annual people project benefits per hectare
Equations	16
Source of data:	Calculated
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of net benefits
Comments:	N/A

Data / Parameter:	$EAB_{perHa\text{-}property}$
Data unit:	US$ (or equivalent)/Ha
Description:	Annual property project benefits per hectare
Equations	17
Source of data:	Calculated

Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of net benefits
Comments:	N/A

Data / Parameter:	$A_{project-E}$
Data unit:	Ha
Description:	Vegetated area within the project impact area in the project scenario
Equations	16, 17 18
Source of data:	Estimated based on existing vegetated cover in the project impact area and assuming project area is fully restored/protected
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of net benefits
Comments:	N/A

Data / Parameter:	$A_{net-conservation}$
Data unit:	Ha
Description:	Net change in vegetated area due to a conservation project
Equations	18

Source of data:	Measured
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	Vegetated extent measured using field surveys or aerial/satellite imagery
Purpose of data:	Calculation of net benefits
Comments:	N/A

Data / Parameter:	$A_{net\text{-}restoration}$
Data unit:	Ha
Description:	Net change in vegetated area due to a restoration project
Equations	19
Source of data:	Measured
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	Vegetated extent measured using field surveys or aerial/satellite imagery
Purpose of data:	Calculation of net benefits
Comments:	N/A

Data / Parameter:	$EAB_{project\text{-}people\text{-}conservation}$
Data unit:	US$ (or equivalent)
Description:	Annual people project benefits for a conservation project
Equations	20
Source of data:	Calculated

Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of net benefits
Comments:	N/A

Data / Parameter:	$EAB_{project\text{-}property\text{-}conservation}$
Data unit:	US$ (or equivalent)
Description:	Annual property project benefits for a conservation project
Equations	21
Source of data:	Calculated
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of net benefits
Comments:	N/A

Data / Parameter:	$EAB_{project\text{-}people\text{-}restoration}$
Data unit:	US$ (or equivalent)
Description:	Annual people project benefits for a restoration project
Equations	22
Source of data:	Calculated
Value applied	Varies by location

Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of net benefits
Comments:	N/A

Data / Parameter:	$EAB_{project\text{-}property\text{-}restoration}$
Data unit:	US$ (or equivalent)
Description:	Annual property project benefits for a restoration project
Equations	23
Source of data:	Calculated
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data:	Calculation of net benefits
Comments:	N/A

Data / Parameter:	$EAB_{people\text{-}deemed}$
Data unit:	Population
Description:	Annual people project benefits
Equations	24
Source of data:	Menendez et al., 2020
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	Global, peer-reviewed and validated dataset for mangrove habitats

Purpose of data:	Calculation of net benefits using the deemed estimate approach
Comments:	Expected to vary over time

Data / Parameter:	$EAB_{perHa\text{-}people\text{-}deemed}$
Data unit:	Population/Ha
Description:	Annual people project benefits per hectare
Equations	24
Source of data:	Menendez et al., 2020
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	Global, peer-reviewed and validated dataset for mangrove habitats
Purpose of data:	Calculation of net benefits using the deemed estimate approach
Comments:	N/A

Data / Parameter:	$EAB_{property\text{-}deemed}$
Data unit:	US$
Description:	Annual property project benefits
Equations	24
Source of data:	Menendez et al., 2020
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	Global, peer-reviewed and validated dataset for mangrove habitats
Purpose of data:	Calculation of net benefits using the deemed estimate approach
Comments:	N/A

Data / Parameter:	$EAB_{perHa\text{-}property\text{-}deemed}$
Data unit:	US$ (or equivalent)/Ha
Description:	Annual property project benefits per hectare
Equations	25
Source of data:	Menendez et al., 2020
Value applied	Varies by location
Justification of choice of data or description of measurement methods and procedures applied	Global, peer-reviewed and validated dataset for mangrove habitats
Purpose of data:	Calculation of net benefits using the deemed estimate approach
Comments:	N/A

9.2 Data and Parameters Monitored

The following data and parameters will be monitored during the project crediting period.

Data / Parameter:	Vegetated Extent in Project, $A_{Project\text{-}A}$
Data unit:	Hectares
Description:	Vegetated extent in the project area
Equations	19
Source of data:	Field surveys, aerial imagery (drones, LiDAR, etc) or satellite imagery for larger projects
Description of measurement methods and procedures to be applied:	The proponent will measure vegetated extents within the project site every year after project completion to monitor any reductions in these extents that could affect project impacts.
Frequency of monitoring/recording:	At least every 5 years; and 1 month after a major storm event within 50 km of the project site

QA/QC procedures to be applied:	All field measurements of vegetated extents will be validated using imagery-based data, and vice-versa. If using imagery, data resolution should not be less than 100 m.
Purpose of data:	Indicate one of the following: Calculation of project effects
Calculation method:	N/A
Comments:	N/A

9.3 Description of the Monitoring Plan

9.3.1 General

The main objective of project monitoring is to reliably quantify changes in flood impacts and coastal resilience benefits in the project scenario during the project crediting period, prior to each verification, with the following main tasks:

- Monitor change in vegetated extent of project
- Assess whether re-evaluation of project impacts is necessary

The monitoring plan must contain at least the following information:

- A description of each monitoring task to be undertaken
- Parameters to be measured or modeled
- Data to be collected and data collection techniques
- Frequency of monitoring
- Quality assurance and quality control (QA/QC) procedures
- Data archiving procedures
- Roles, responsibilities and capacity of monitoring team and management

Where the scenario method is applied, the project monitoring plan will identify the model(s) selected initially and document that the model(s) meet the requirements described in section 8.1.

9.3.2 Managing data quality and uncertainty

Quality management procedures are required for the management of data and information, including the assessment of uncertainty relevant to the project and baseline scenarios. As far as practical, uncertainties related to the quantification of flood impacts and coastal resilience benefits due to the project should be reduced.

To help reduce uncertainties in the accounting of flood reduction benefits, this methodology uses data and methods from NOAA, USGS, the World Bank and peer-reviewed literature. The key data in these analyses are on storm characteristics, bathymetry, habitats, topography and assets (people and property). Whenever possible project proponents should seek high resolution data on these parameters. In the absence of these, the project proponent must identify key parameters that would significantly influence the accuracy of estimates. Local values that are specific to the project circumstances must then be obtained for these key parameters, whenever possible. These values should be based on:

- Data from well-referenced peer-reviewed literature or other well-established published sources[27];
- In the absence of the above sources of information, expert opinion may be used to assist with data selection. Experts will often provide a range of data, as well as a most probable value for the data. The rationale for selecting a particular data value must be described in the project description.

In choosing key parameters, or making important assumptions based on information that is not specific to the project circumstances, such as in use of default data, the project proponent must select values that will lead to an accurate estimation of coastal resilience benefits, taking into account uncertainties.

If uncertainty is significant, the project proponent must choose data such that it indisputably tends to under-estimate, rather than over-estimate, net coastal resilience project benefits.

When using models, calibration and validation of the model is a requirement and minimizes model uncertainty.

To ensure that resilience benefits are estimated in a way that is accurate, verifiable, transparent, and consistent across measurement periods, the project proponent must establish and document clear standard operating procedures and procedures for ensuring data quality. At a minimum, these procedures must include:

- Comprehensive documentation of all field and satellite measurements carried out in the project area. This document must be detailed enough to allow replication in the event of staff turnover between monitoring periods.
- Training procedures for all persons involved in field measurement or data analysis. The scope and date of all training must be documented.
- A protocol for assessing the accuracy of satellite-based or aerial (i.e. LiDAR) measurements in case using remote-sensing tools and a plan for correcting the data if errors are discovered.
- Protocols for assessing data for outliers, transcription errors, and consistency across measurement periods.
- Data sheets must be safely archived for the life of the project. Data stored in electronic formats must be backed up.

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